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Technical Report UMTRI-93-31 November, 1993

Examination of a Videotape-Based Method to Evaluate the Usability of Route Guidance and Traffic Information Systems

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Transportation Research Institute

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Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.

4. Title and Subtitle **EXAMINATION OF A VIDEOTAPE-BASED METHOD TO EVALUATE THE USABILITY OF ROUTE GUIDANCE AND TRAFFIC INFORMATION SYSTEMS**	5. Report Date November, 1993 6. Performing Organization Code account 080066
7. Author(s) Paul Green, Eileen Hoekstra, Marie Williams, Cathy Wen, and Kellie George	8. Performing Organization Report No. UMTRI-93-31
9. Performing Organization Name and Address The University of Michigan Transportation Research Institute 2901 Baxter Rd, Ann Arbor, Michigan 48109-2150	10. Work Unit no. (TRAIS) 11. Contract or Grant No. DTFH61-89-C-00044
12. Sponsoring Agency Name and Address U.S. Dept. of Transportation, Federal Highway Admin. 400 7th Street, SW Washington, D.C. 20590 USA	13. Type of Report and Period Covered final, 9/91- 11/93 14. Sponsoring Agency Code

15. Supplementary Notes

This research was funded jointly by the Federal Highway Administration and the National Highway Traffic Safety Administration. The Contracting Officer's Technical Representative (COTR) was Nazemeh Sobhi (HSR-30).

16. Abstract

Forty-eight drivers, while seated in a mockup of a car, watched a videotape of a driver's eye view of a 25-minute trip. Simultaneously, they received route guidance and traffic information in one of the four formats: visual, visual with landmarks, auditory, or auditory with landmarks. Drivers pressed buttons when they could see the intersections in the videotaped scene referred to by the route guidance system. They also stepped on the brake pedal when a car immediately in front of them braked. In addition, subjects rated the effect that the reported traffic problems would have on their travel.

Following the test session, subjects completed questionnaires concerning the ease of use and usefulness of the route guidance system. They also indicated their preferences for all four systems and rated the difficulty of performing driving tasks. Differences in task difficulty due to interface design were small and not correlated with the results from a subsequent on-the-road experiment. Glance data in the laboratory were not correlated with glance data collected on-road for the same roads. These results, along with problems in recovering the data, suggest that the videotape method may not be a good approach for evaluating the usability of route guidance driver interfaces.

17. Key Words	18. Distribution Statement
IVHS, driving, human factors, ergonomics, safety, route guidance, navigation, driver interfaces, human engineering	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of pages	22. Price
none	none	91	

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in²	square inches	645.2	square millimeters	mm²
ft²	square feet	0.093	square meters	m²
yd²	square yards	0.836	square meters	m²
ac	acres	0.405	hectares	ha
mi²	square miles	2.59	square kilometers	km²
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	ml
gal	gallons	3.785	liters	l
ft³	cubic feet	0.028	cubic meters	m³
yd³	cubic yards	0.765	cubic meters	m³
NOTE: Volumes greater than 1000 l shall be shown in m³.				
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celcius temperature	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	l
fl	foot-Lamberts	3.426	candela/m²	cd/m²
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
psi	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm²	square millimeters	0.0016	square inches	in²
m²	square meters	10.764	square feet	ft²
m²	square meters	1.195	square yards	ac
ha	hectares	2.47	acres	mi²
km²	square kilometers	0.386	square miles	
		VOLUME		
ml	milliliters	0.034	fluid ounces	fl oz
l	liters	0.264	gallons	gal
m³	cubic meters	35.71	cubic feet	ft³
m³	cubic meters	1.307	cubic yards	yd³
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg	megagrams	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m²	candela/m²	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	psi

* SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.

(Revised August 1992)

PREFACE

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

The driver interface project had three objectives:

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

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

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

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

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

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

This report describes driver performance and behavior (including eye fixation data) while using simulated route guidance and traffic information systems in a laboratory. Detailed descriptions of the route guidance and traffic information system driver interfaces are also included.

TABLE OF CONTENTS

LIST OF FIGURES

Figure **Page**

LIST OF TABLES

INTRODUCTION

As required by the project contract, this experiment examined the effects of combining two of the five systems that served as the focus of the project was a whole. Route guidance and traffic information were chosen for this investigation as two that could likely be combined by those manufacturing the hardware. Combinations of the other three with each other (e.g., a car phone with vehicle monitoring system, or vehicle monitoring with a road hazard warning system) are very unlikely. The display device requirements for the pair selected are similar, though the display may be shared by other systems. Further, one information infrastructure could be used to assemble and disseminate both route guidance and traffic information. By design, the route guidance system computes the location and direction of the vehicle, even when it is not presenting route guidance instructions. A traffic information system could be merged into the route guidance system, and could provide unprompted information about traffic problems ahead.

This report examines a new method for evaluating the usability of those two systems. It also provides initial data for a protocol in which drivers rated the safety and usability of various aspects of candidate route guidance and traffic information systems. Initially, this report was intended to provide driver performance data to identify the value of landmarks for route guidance and a desired presentation modality (visual versus auditory). Due to hardware and software problems, some of the driver performance data was not recovered.

Previous Research on Navigation/Route Guidance

Driver interfaces for route guidance and traffic information systems have been examined in several experiments described in the literature. (See references 22, 23, 24, 25, and 26). The research on route guidance systems has been summarized in two reviews completed as a part of this research program. One review of the literature pertains to U.S. research on these systems, while another contains additional information on research conducted elsewhere.[3,17] From the studies summarized in those reviews, one cannot conclude whether the navigation display should be visual, auditory, or both. This issue, as well as many others relating to the details of navigation display design, are yet to be conclusively resolved.

To further the development of route guidance displays, several experiments were conducted as part of this project.[8,9] In the earlier phases of the development of the navigation system, a single driver or small groups of drivers were shown drawings of navigation displays and asked to explain them. That effort led to the development of several design guidelines, as well as the initial interface concept.

Next, an experiment involving 3 groups of 20 drivers was conducted at a local driver licensing office to explore the perspective in which intersections should be presented in a visual-based system (plan, perspective, or aerial view). Participants were shown drawings of intersections and expressway entrances and exits, with colored arrows as turn instructions, and were asked to explain what was shown. Each group of drivers saw one-third of the view-intersection combinations. Differences in the number of errors were slight because the task was very easy. Drivers' preferences, however, favored the plan and aerial views over the perspective view.

In a subsequent response-time experiment, 12 drivers were presented with slides of 15 intersections, projected on a wall in front of a vehicle mock-up. The intersection slides were photographed from the driver's point of view. At the same time, slides of a route guidance display were shown on either an instrument panel (IP) display or on a simulated head-up display (HUD). Drivers responded by pressing one of two buttons, indicating whether the intersection slides were "the same" or "different" from the navigation display. Displays could show any one of three views of the intersection, as in the previous experiment (plan, aerial, perspective). Two formats were used to represent roads: solid or outline. Approximately 1,000 button press responses were obtained from each driver.

Response times to plan and aerial displays were significantly less than those to perspective displays, and slightly less for the HUD versus the IP location. Response times were also slightly less for solid than for outline displays. In addition, both the error data and driver preference ratings of displays led to the same conclusions. Because of ease in implementation, and since performance differences were slight, solid plan displays in the IP location were chosen for further evaluation.

Issues to Be Investigated

Despite the considerable amount of research conducted to date, several questions regarding the basic design remained unanswered. Also yet to be considered was the relationship between laboratory and on-road experiments. As a result, an experiment was conducted that considered the following issues:

- How does navigation performance with a voice (auditory) route guidance system compare with an alternative visually-based interface? Does the presence or absence of landmarks (traffic lights, stop signs, etc.) influence navigation performance?

- How often in each portion of a trip do drivers look at visually based route guidance displays? How many times do drivers look at traffic information displays to read them?

  The longer the time the driver spends looking away from the road, the more likely he or she will be involved in an accident. Safe and easy-to-use route guidance and traffic information systems should require only a few fixations and those fixations should be brief.

- Which versions do drivers prefer, and how acceptable and safe do drivers consider them?

- What kinds of problems are there in using somewhat passive viewing in a laboratory of videotaped road scenes to examine navigation problems?

METHOD

Summary of the Method

In this experiment drivers seated in a vehicle mockup watched a videotape of a short trip taken from the driver's perspective. Synchronized to the videotape were simulated navigation and traffic information displays. Four interface designs were examined: two instrument panel display implementations (with and without landmarks) showing upcoming intersections and turn arrows, and two auditory implementations (with and without landmarks). When drivers could see a decision point on the videotape, to which they had been referred by the route guidance system, drivers pressed a key to indicate which way they would go. The associated performance measures, the predecision point time and distance (from an intersection or exit), were thought to be indicators of interface usability. The tenet is that the farther in advance of a maneuver drivers knew what to do, the more likely the maneuver could be planned and executed safely.

Interleaved with use of the route guidance system was the presentation of traffic information in the same modality as the route guidance information. In response to traffic information, drivers rated the effect the presented information would have on their travel.

While using both systems, driver eye fixations (to assess attentional demands) were recorded, as well as driver responses to the random braking of a lead vehicle on the videotape. (The test subject was asked to step on the brake pedal.) The lead vehicle braking was included to maintain driver attention to the videotape. After the tape ended, drivers rated the safety and usability of a lengthy list of interface features and responded to an extensive list of questions.

Test Activities and Their Sequence

Subjects were contacted by phone and scheduled for a 1 1/2 hour time period. When they arrived at UMTRI, the purpose of the experiment was explained. Participants then read and signed a consent form, completed a biographical form, and were given a vision test.

In the laboratory, the participant adjusted the car buck seat and the experimenter then pointed out the video equipment. A brief introduction followed, including information about the features of the route guidance and traffic information system. The participant was told that with a real navigation system, the driver would be required to enter the desired destination. In response, the system would provide the driver with the best route to the destination along with appropriate traffic information concerning problems along the route. Participants were told they would watch a videotape of a 25-minute trip from Taylor to Canton, Michigan. The videotape was taken from a fixed camera mounted along the vehicle centerline near the inside rearview mirror. The monitor showing the playback was set up directly in front of the driver's side of the buck at a visual angle comparable to normal driving conditions. The image presented was similar to what a driver would see if he or she were actually driving the route. While watching the road scene, subjects received route guidance and traffic information from the display in the center console. This protocol is similar to one used by Fraser, Davis, Hawken, Tollyfield, Neave, and Sievey.[27]

Subjects were instructed to use the response box to indicate which turn or maneuver to make at all intersections or expressway exits on the videotape, based on the information given by the route guidance system. As soon as they were able to see a cue on the videotape (e.g., the actual intersection, a sign, a traffic light), drivers pressed a button to indicated if they would "turn or bear left" (the left key), "continue or go straight" (the middle key), or "turn or bear right" (the right key). Drivers did not have to wait until they were at the intersection. Rather, they indicated the direction as soon as they spotted the location ahead. This required the driver to constantly monitor both the road scene and the in-vehicle route guidance display.

Subjects were also told to watch for the brake lights of any car immediately in front of them in the same lane. If they saw the car's brake lights go on, they were instructed to step on the brake pedal as soon as possible, and to keep the brake depressed for as long as the car in front of them was using its brakes. This vigilance task was intended to simulate the attentional demands of on-the-road driving.

In addition to the route guidance information, subjects also received traffic information reports. Four were presented during the 25-minute route, temporarily replacing the route guidance screen in the visual modality conditions. Subjects were told that these reports provided detailed information describing accidents, construction sites, or other traffic problems. Before a traffic information screen appeared, two beeps sounded. Prior to testing, along with the practice route guidance video and instruction, a sample traffic information report was presented and explained. Participants were asked to rate the effect that the incident described by the traffic report would have on travel through that area of traffic. The effect rating could be thought of in terms of any measure they wished to use (such as delaying their arrival or inconvenience). A 7-point rating scale was used, where 1 meant "no effect" and 7 meant an "extreme effect." The experimenter prompted the subjects to give their rating aloud.

At the conclusion of the test session, subjects completed two questionnaires. The first concerned ratings of the usefulness and perceived safety of the route guidance system. The second questionnaire concerned ratings of the difficulty of performing normal tasks associated with driving a car. Drivers also rated the difficulty of performing tasks associated with the route guidance and traffic information systems, and the amount they would be willing to pay for such a system. (Copies of the questionnaires are in the appendix.)

Subsequently, while seated in the buck, the three other formats for presenting route guidance information were demonstrated for one and one half minutes each. (Each participant was tested on only one of the four candidate formats) The four possible route guidance formats consisted of two visual (with and without landmarks) and two auditory (with and without landmarks). Their order was counterbalanced across age and sex. (Subjects did not see a sample of the system that they had just used during their test session.) Subjects were instructed to watch (or to listen to) the demonstration while simultaneously watching a videotape of a corresponding road segment. (The brake pedal and response keys were not used.) After viewing all systems, subjects indicated their preferences by ranking the four route guidance formats from best to worst.

Finally, subjects were paid $15 for their time.

Test Equipment and Materials

The arrangement of the equipment and model numbers are shown in figure 1. Drivers sat in a 1985 Chrysler Laser A-to-B-pillar buck with steering wheel and brake pedal. A 13-inch Macintosh monitor with a black foam-core cover and frame was mounted in the center of the console. An 11.3 cm high by 14.5 cm wide (4 1/2 by 5 3/4 in) cut-out in the foam-core board allowed drivers to see the central portion of the screen, which displayed a 10 cm high by 14.3 cm wide (4 by 5 5/8 in) diagonal display. Shown on this simulated 17.5 cm (7 in) diagonal display were visual route guidance instructions and traffic information screens. The visual route guidance and auditory route guidance interfaces were programmed in SuperCard running on a Macintosh Quadra 700. Auditory route guidance and traffic information instructions were recorded in a female voice on the same Macintosh.

A 25-minute, videotaped test route was displayed on a 33-cm (13-inch) Commodore color video monitor positioned in the front of the driver about 30 cm (1 foot) forward of the base of the windshield. (For eye-to-monitor distances, see figure 1.) The videotape of the route was taken in the daytime in August of 1992. The NEC PC-VCR used to present the road scene was controlled by the Macintosh computer.

Participants' response times to the route guidance system were recorded using a custom three-key response box resting on a custom-made stand. Brake pedal responses were also collected by having the computer monitor switches attached to the brake pedal assembly. Behind the monitor, aimed toward the driver's face, was a low-light level, black and white camera to record eye glances to the route guidance and traffic information screens. In addition, a color video camera was aimed at the Macintosh monitor to record the navigation screens shown to the driver. A color special effects generator was used to create a split screen image of the participant's face, the road scene, and route guidance screens. These images were viewed on two black and white monitors and one color monitor. The final combined video image was videotaped for each subject.

Copies of the experimental procedure, consent form, biographical form, and post-study questionnaires, are in the appendix.

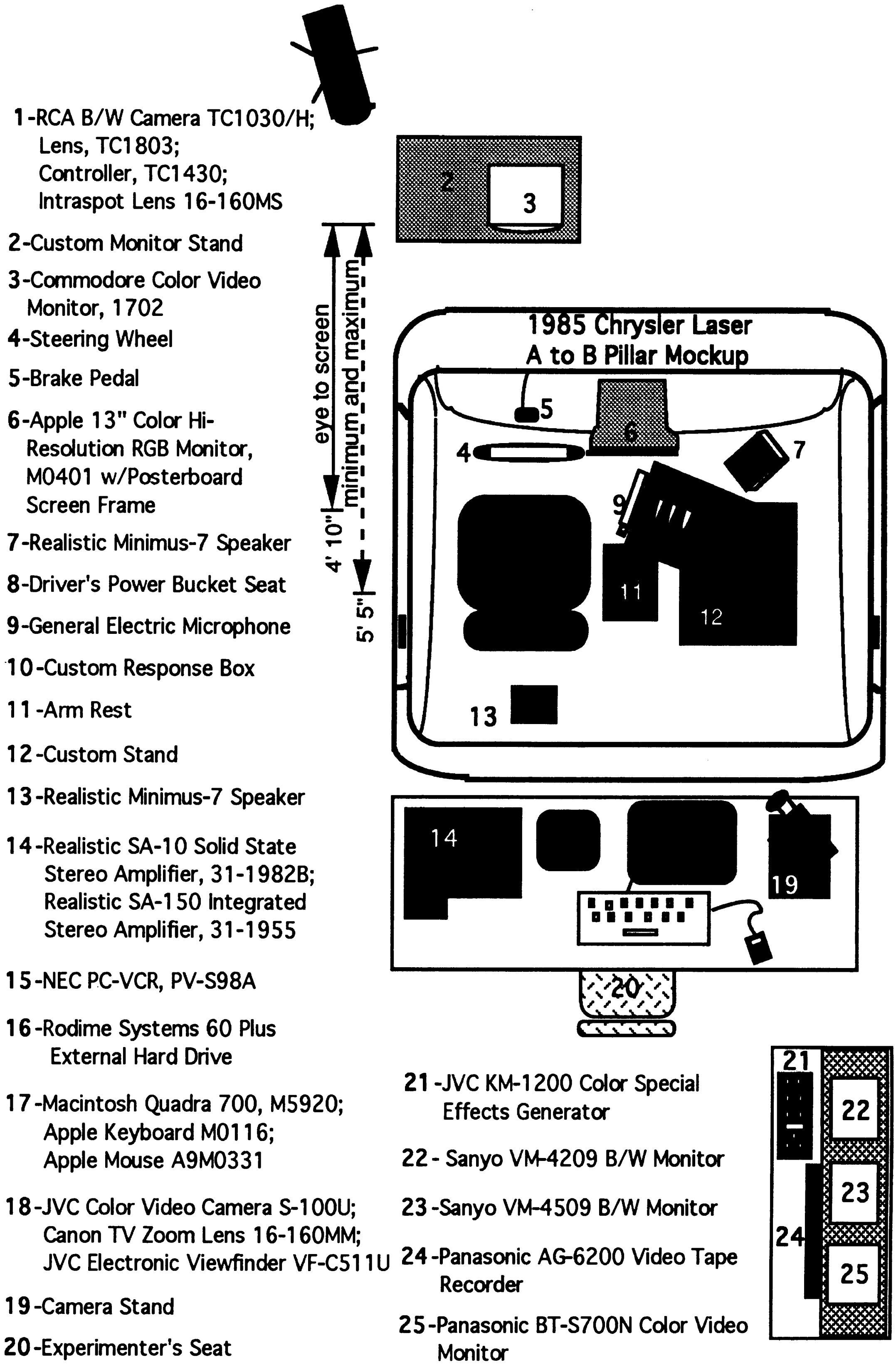


Figure 1. Laboratory equipment arrangement and model numbers.

The Videotaped Route

The test route videotape (figure 2) starts in a subdivision in Taylor, Michigan where the streets are in an orthogonal pattern. There were four residential streets (speed limit 25 mi/h) and the turns were simple lefts and rights. Some intersections had stop signs that served as landmarks in some of the route guidance interfaces. The videotape showed entering the commercial section of the route by making a right turn at a T-intersection onto Telegraph Road (US-24, 45 mi/h limit), a divided nonlimited access highway. Within a mile, a ramp was taken to Ecorse Road (45 mi/h). Next, the videotape showed driving on Ecorse for 1 1/2 mi and taking the entrance to I-94 west (55 mi/h speed limit). Then I-94 was traveled for 6 mi to I-275 north. I-275 was taken until Ecorse Road. The scene showed traveling on Ecorse Road 1/2 mile to Hannan Road and turning north for 2 mi where it turned onto Michigan Ave (US-12), which required a Michigan left turn. (A Michigan left turn is a right turn followed by a U-turn, to make a left.) The video scene showed reentering I-275 north (within 1/2 mi), going 2 1/2 mi to the Ford Road exit. The route ended after 1/2 mile on Ford Road.

It is important to note that drivers watched the videotape of the route, as if it was their forward scene while driving with the route guidance and traffic information system. Although the scene and the information systems were synchronized, drivers' use of the mockup's steering wheel or brake had no effect on the scene from the videotape.

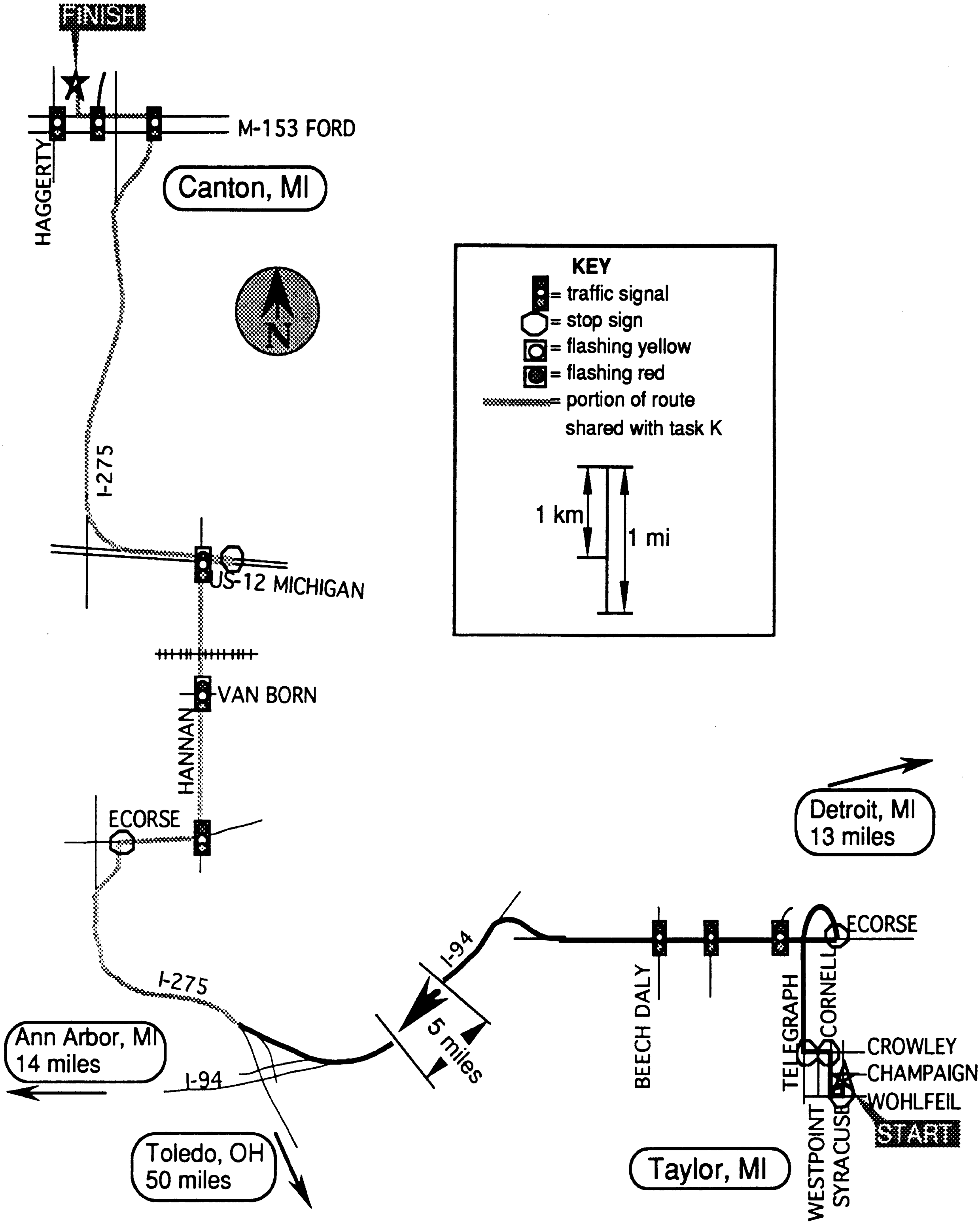


Figure 2. Test route.

Route Guidance System Interfaces

Four different route guidance interfaces were tested: visual with and without landmarks, and auditory with and without landmarks. Landmarks consisted of traffic control devices (stop signs and traffic signals) and other items typically shown on a map (overpasses and underpasses). Synchronized with the viewed video scene, the route guidance instructions were displayed and updated by the Macintosh. The visual route guidance interface provided instructions for each major intersection, whether the driver was to continue straight, turn, or complete a more complex maneuver. The auditory interface provided instructions on the next maneuver and the distance to it. The auditory interface did not contain instructions for intersections where the driver was to continue straight. The visual and auditory interfaces were not information-content equivalents because of practical design constraints, with the visual interface presenting more information. Furthermore, the auditory interface provided information only when a new instruction was to be presented to the driver.

Before the actual route video was shown, drivers were shown a short practice video of a different road segment than that to be shown in the test trial, along with the appropriate route guidance instructions for the interface type (auditory or visual) they were to see later. The practice route contained 1 turn and 6 major intersections, while the actual route contained 13 turns and 10 major intersections.

The interface for the basic visual (without landmarks) route guidance system is shown in figure 3. The display presented the geometry of the next intersection along with an indicator of the distance to that intersection, and, if that intersection was not a turn, the distance and road at which the next turn occurred. The present location was shown at the bottom of the screen. Distances to turns were updated each tenth of a mile. After a passing decision point or completing a maneuver (e.g., a turn), the screen was updated to show the next decision point. The countdown bars estimated the time to reach the maneuver point in 20-second increments. The complete set of screens for the test and practice conditions (in fact, for all four implementations) appear in the appendix. The development of that set of screens, made necessary by this experiment, was an important step in the evolution of the route guidance system developed for this project.

The visual-with-landmarks interface was identical to the interface just described, except for the addition of simple landmarks. The traffic control landmarks (signs and signals) were placed in the middle of the intersection they controlled, since the exact arrangement of the devices on the road can vary greatly by intersection. The predominate traffic signal arrangement in Southeastern Michigan is vertical, so that arrangement was chosen for this study. The full set of screens for both the practice and test conditions are in the appendix.

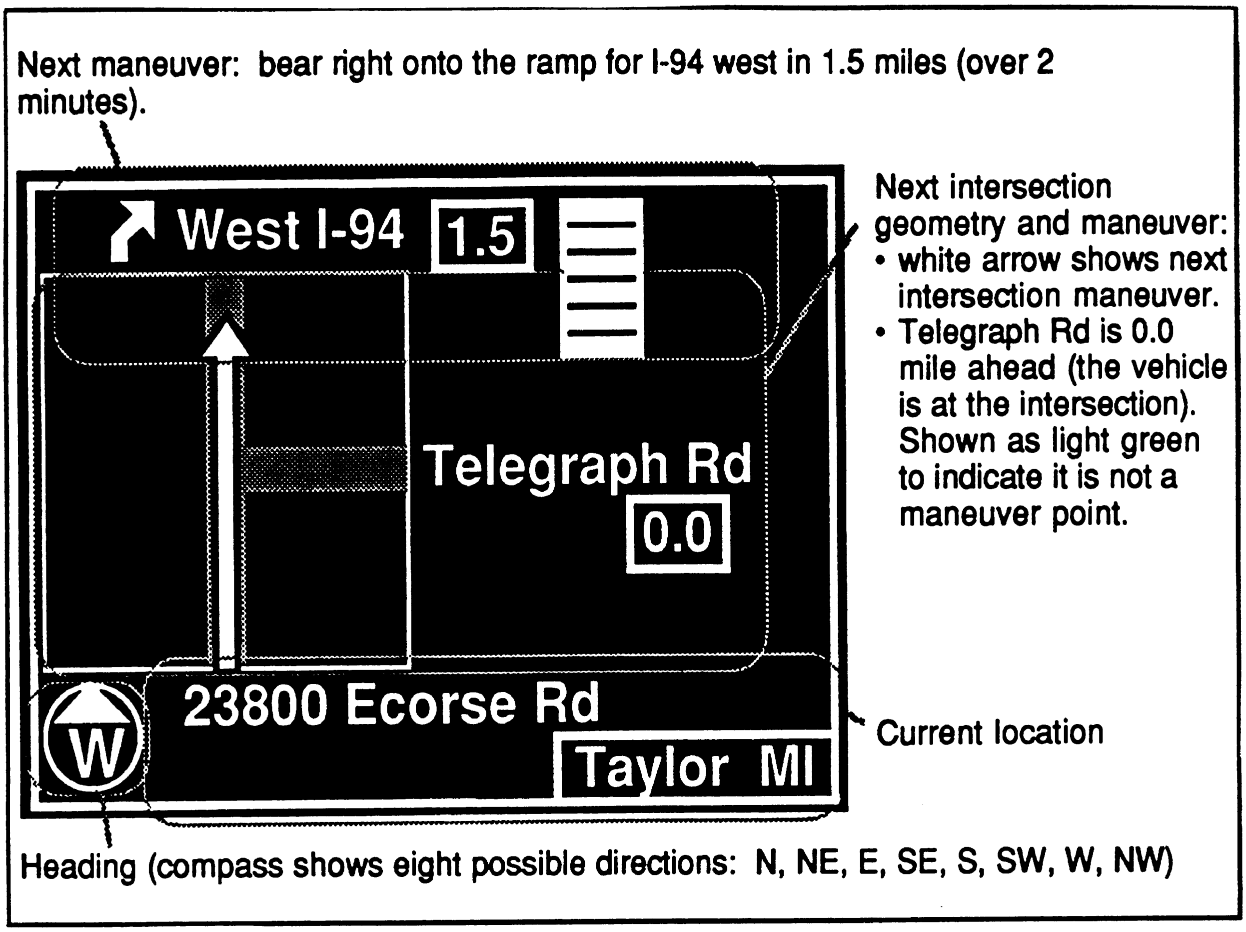


Figure 3. Basic visual (without landmarks) route guidance system screen.

The auditory route guidance system gave the driver turn instructions at three different times: just after a maneuver, a set distance from the maneuver, and just before the maneuver. The first message contained the distance, location, and maneuver description. (For example, "In 1 point 7 miles at Green Road turn left.") The second message was the same as the first but always occurred 1 mile away from the maneuver point on surface streets and 2 miles away on the expressway. (For example, "In 1 mile, at Green Road, turn left.") The third message, which contained only the location and the maneuver description, was completed 15 seconds before the maneuver on surface streets and 30 seconds before on the expressway. (For example, "At Green Road, turn left.") If, just after a turn, the next maneuver was closer than the distance specified by the second message, then the first two messages would be combined, and only two messages would be presented for that maneuver. The complete set of messages appears in the appendix, except for the practice message, which were just described.

The auditory-with-landmarks interface was identical to that just described, except for the addition of landmarks. The landmark set used for the auditory was identical to that used for the landmark version of the visual interface. The landmark description, when appropriate, was inserted in the second and third instructions for a given maneuver.

For the example Green Road turn given in the previous section, the equivalent sequence when landmarks are provided would be:

- "In 1 point 7 miles at Green Road turn left."
- "In 1 mile at the 5th traffic light at Green Road turn left."
- "At the traffic light, at Green Road, turn left."

Underlining has been added to emphasize the differences from the no landmark implementation. As with the other implementations, the complete set of messages appears in the appendix.

Traffic Information System Interfaces

There was some difficulty in determining the most realistic, real-world application involving integrated use of the route guidance and traffic information systems. Presumably a route guidance system, of the type prototyped here, would be intended for a noncommuter; that is, someone who lacks detailed knowledge of the route. This category of drivers may have limited use for the traffic data that an integrated navigation/traffic information system would utilize to compute the most efficient route. However, in the case of a midroute diversion, traffic information might be necessary to maintain driver confidence in changes in route recommendations. On the other hand, the commuting driver may find turn information at the detailed level of the prototype system used in this study less useful, but detailed in-vehicle information about traffic problems more useful.

Just as there were four different interfaces tested for route guidance or navigation systems (visual and auditory, with and without landmarks), traffic information systems were presented with different interfaces: visual text, visual graphics, and auditory. The display modes for traffic information (visual and auditory) were matched to the mode of the route guidance system for each condition. The subjects who saw the visual route guidance interface without landmarks were shown the map-based format of the visual traffic information system. The visual route guidance interface with landmarks was paired with the text-based format of the traffic information system. Both versions of the auditory route guidance system presented the same auditory traffic information messages.

The visual traffic information screens used in this study were the same as those used in earlier work associated with this project.[10] Two formats of visual traffic information screens were used: text-based format with simple icons representing lane status, and a graphic, map-based format (containing the same information as the text format except for the lane status). The map-based format contains more precise information about the location of the traffic back-up than does the text-based format. Figures 4 and 5 show practice text and graphic traffic information screens. The auditory messages were verbal equivalents of the text-based visual screens. (For example, "Traffic Information for I-94 West, construction, from Exit 194 I-275 to Exit 187 Rawsonville Road. Right lane closed, speed is 45 miles per hour.")

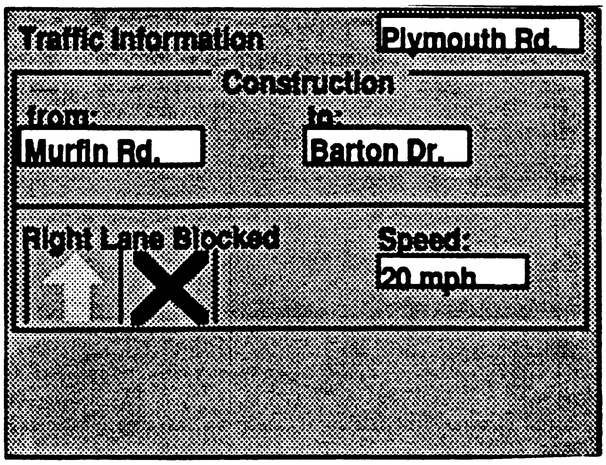


Figure 4. Practice text-based traffic information screen.

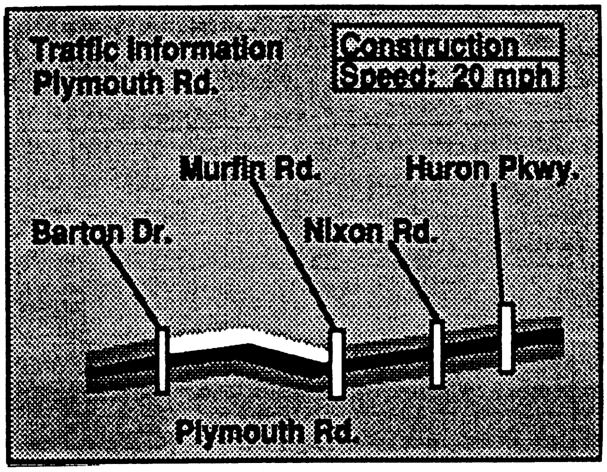


Figure 5. Practice graphic-based traffic information screen.

To evaluate usability for both types of drivers, four traffic problems were designed. The traffic problem descriptions were designed around the available test route video and described a range of traffic problem types and severity. Since subject testing involved ranking perceived severity, a range of traffic problems was needed to spread out the rankings and to keep subjects interested in reading the screen.

The first traffic information report, an accident 12 miles ahead, was presented on the I-94 expressway. This was a commuter message, as the navigation system's route does not travel this stretch of expressway and thus a noncommuter, only interested in the selected route, would not likely be attentive to neighboring traffic information. The second message was presented 1 1/2 miles ahead of a construction zone. (This described an actual construction zone recorded on the video scene.) This message could be categorized as a realistic implementation of the system, as it is feasible to inform all drivers of these types of hazards, ones that are to be found on their route. Subjects also may have believed the system is informing them of the construction to allow the option of diversion, since their route involved an exit to another expressway just inside the construction zone. The third message was also a realistic one. It informed the driver of a serious accident 3 miles ahead and, at the next exit, the navigation system instructs the driver to get off the expressway. The route then paralleled the expressway for 2 miles and then reenters the expressway, thus diverting around the imaginary problem. The fourth traffic information message was the other commuter type, which provided peripheral information as it describes a construction zone 5 miles beyond the exit the navigation system instructed the driver to take.

Drivers were given one practice traffic information screen or message during the practice route guidance segment. This gave the subjects a chance to familiarize themselves with the format and to practice using the ranking scale. For further details on the appearance of visually-based traffic information screens and the verbiage used for the auditory format, readers are referred to the appendix.

Test Participants

Forty-eight drivers (24 men and 24 women), recruited from previous unrelated studies, participated in this experiment. The subjects were separated into two age groups, younger (18 to 30 years, mean = 23) and older (60 or over, mean = 69). The range of participants' corrected visual acuity was 20/13 to 20/100, as measured by the experimenter. Groups of 12 drivers, with an equal number of men and women at each age level, were randomly assigned to one of the following route guidance conditions: visual with landmarks, visual without landmarks, auditory with landmarks, or auditory without landmarks.

The majority of participants (32 of 48) stated that they were "neutral" to "moderately unfamiliar" with the Canton, Romulus, and Taylor, Michigan area where the experiment was conducted. Drivers reported they drove from 0 to 30,000 miles per year, with a mean of 12,300 miles. (One older participant had not driven a car in the previous year.) None of the subjects had previously driven a car with a navigation system. Most (44 of 48 subjects) reported being either "very comfortable" or "moderately comfortable" using maps. The mean number of times that participants reported having used a map within the last six months was approximately seven. Participants, on average, stated that they relied on traffic information reports to get to a destination about once per week.

RESULTS

In this experiment the objective dependent measures of interest were brake actuation times (indicators of attentional demands of the in-vehicle information presented), the frequency of glances to the in-vehicle displays (another measure of attentional demand), and the predecision point time and distance (how far in advance of an intersection or exit the driver knew what to do). Because of hardware and software problems, the predecision data were not analyzed. For selected subjects, fixation durations were also examined.

Also analyzed in considerable detail were ratings of the safety and ease of use of the alternative displays, as well as driver willingness to pay for them.

Brake Actuation Responses

To examine the effects of navigation system use on primary task performance, the brake response times and percentage of missed brake applications were examined. Since the time base that the computer was using to present navigation information and the VCR playback control were slightly different, the exact time of each brake application relative to when each brake light actuation occurred could not be determined. However, since the VCR (under computer control) and navigation program started at the same time, they shared a common origin. Differences between the two were due to a start up delay and to tape playback speed. The playback speed error was corrected by generating a linear regression equation comparing the time in the program when brake lights appeared to the time when the brake was applied. The intercept is the tape start up delay plus driver response time. The data were adjusted to zero the delay and assume a minimum response time of 500 milliseconds. The slope represents the difference due to tape playback speed, which the equation was used to correct.

In the ANOVA of response times, there were no times for the auditory-no landmark combination because of a software problem during data collection. Also, the data from eight other drivers were deleted after data inspection revealed that the brake pedal switch had functioned intermittently. In that ANOVA, there was no effect of driver sex ($p = 0.09$), driver age ($p = 0.41$), or landmark versus no landmark ($p = 0.57$). (The landmark versus no landmark comparison was computable for only the visual interface because of missing data.) There was a significant difference due to display modality ($p = 0.04$) with auditory interfaces being associated with brake response times approximately 500 milliseconds faster (for overall mean response times of approximately two seconds).

Also examined was the percentage of missed brake applications, averaging about 14 percent. There were no differences due to driver sex ($p = 0.87$), visual versus auditory format ($p = 0.17$), or landmarks versus no landmarks ($p = 0.54$). There was, however, a difference due to driver age ($p = 0.01$), with younger drivers missing fewer applications (10 percent) than older drivers (17 percent).

Thus, the brakelight response data favor use of auditory route guidance, and suggest that the presence or absence of landmarks has no detectable effect on secondary task performance (such as brake application).

Frequency of Glances to the In-Vehicle Display

Glances to a navigation system with an instrument panel display (with landmarks) were examined for 12 drivers, 6 younger and 6 older. Similar interfaces were evaluated in subsequent on-the-road experiments.[15,16] The purpose of the analysis described here was to explore the collected data for insights on glance behavior, to use glances at the display as an indication of attentional demand, and also to pursue a potential rapid analysis process. Since there was no guidance display for the auditory version, eye glances for that condition were not examined. Within this report, a glance sequence is defined as a series of fixations to a particular screen. Since the analysis presented here was done viewing videotapes of subjects taken from an external camera, it was not possible to distinguish the individual fixations that made up each glance to the navigation and traffic information displays. For example, if the driver looked at one corner of the display and then looked at another, these individual eye movements (fixations) were indistinguishable to the analyst, and the group of fixations were considered the same glance.

Because of its importance, the coding method is described in detail. Using a split screen videotape image, which showed the participant's face, the road scene, and the navigation system, glance data were analyzed manually. A custom time study program, written in BASIC, was used to log glances to the IP display and other events.[28] Events of interest included eye glances, the start and end of turns, etc. Videotapes of each driver were played back at normal speed. When the experimenter observed an event of interest, she pressed a key on the computer keyboard, which recorded the key pressed and the time (to the nearest second). Codes and associated events are shown in table 1. Break points for directional changes (lane changes, turns) occurred when a vehicle started or returned to driving straight down a road, as shown by the camera's forward scene. Since events were sequential, the completion of one driving maneuver (e.g., turning) was the beginning of the next (driving straight). Figure 6 shows how a hypothetical road segment would be coded.

Since the purpose of the tape was to examine generally where drivers looked, and to examine the merits of the videotape method as a substitute for on-road testing, only a portion of the 25-minute trip for each participant was examined. That portion, from I-275 north to the end of the trip (the last 13 minutes of the trip), would be selected for testing in a later on-road study. Data from the future experiment will be compared to the present one.[15]

Table 1. Codes used in eye glance analysis.

Code	Event	Comment
g	Glance	To IP display on center console, press once per glance.
b	Beep	Alerting tone produced by the traffic information system.
e	Exit	Press once at start of expressway entrance or exit ramp, once at end.
m	System malfunction	Press once at start, once at end.
o	Off route	Press once at start, once at end.
c	Change lanes	Press once at start, once at end.
r	Right turn	Press once at start, once at end.
l	Left turn	Press once at start, once at end.

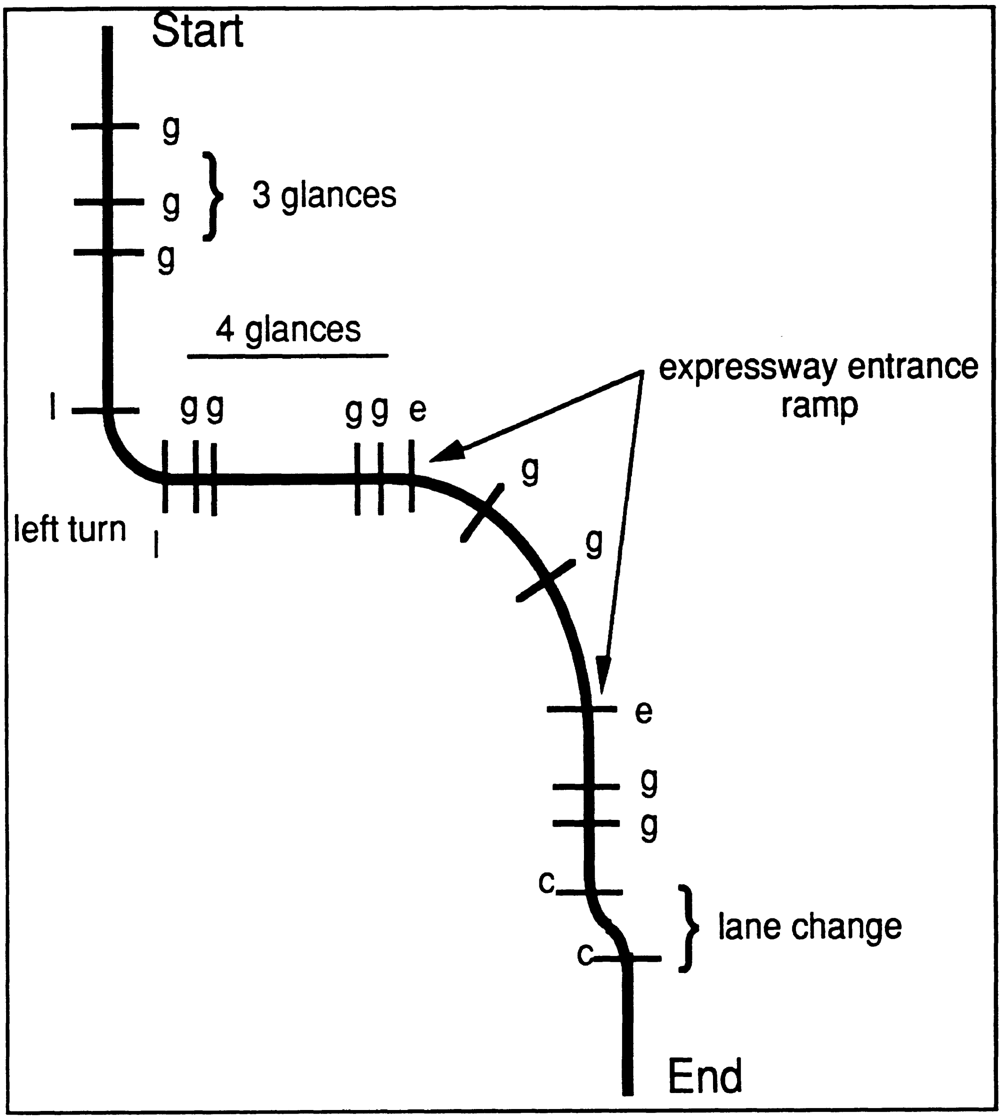


Figure 6. Coding of hypothetical road segment.

The IP display served a dual purpose in this experiment. It presented navigation information a majority of the time, but switched to presenting traffic information when needed. Although glances to the traffic information screen were included in the total number of glances to the guidance screens, traffic information appeared only once (for 15 s) during the partial trip. Therefore, the small number of additional glances did not affect the data. Table 2 shows the duration for each segment.

Table 2. Duration and length of each road segment.

Location (Belleville to Canton, MI)	Duration (s)	Approximate Length mi (km)
I-275 North*	90.0	1.6 (2.6)
Exit ramp: I - 275	34.3	0.4 (0.6)
Ecorse Rd to Hannan Rd	87.6	0.6 (1.0)
Hannan Rd to Michigan Ave	222.3	2.0 (3.2)
Michigan Ave to Michigan Ave	30.3	N/A**
Michigan Ave	62.3	0.6 (1.0)
Entrance ramp: I - 275	37.8	0.4 (0.6)
I-275 North*	136.6	2.4 (3.9)
Exit ramp: I - 275	29.8	0.3 (0.5)
Ford Rd to Destination	30.4	0.1 (0.2)
Total	761.4	8.4 (13.5)

*Traffic information screen appeared.
**The Michigan Ave to Michigan Ave segment (a Michigan left-turn) was too short to approximate its length. Much of the time on the segment was spent waiting for traffic to clear.

To gain additional understanding of the driver glance behavior, trip segments were classified into four road types:

- Suburban.
- Ramps.
- Expressway.
- City/business.

Small town main roads were included in the suburban road type category. They included one or more traffic lights or stop signs and were an average of 154 s in duration. Ramps (mean duration = 34 s) included both expressway entrances and exits. Expressway segments (mean = 113 s), all involving limited-access roads, did not include interchanges. A city/business segment was a main road that was more heavily traveled than a suburban road. It typically included two or more traffic lights or complex intersections, and had a mean duration of 46 s. (An example of a complex intersection is a Michigan left-turn; a right turn is required before a u-turn is made.) Table 3 lists the road segments examined.

Table 3. Segments classified according to road type.

Road segment (Belleville to Canton, MI)	Road type
I-275 north	Expressway
Exit ramp: I - 275	Ramp
Ecorse Rd to Hannan Rd	Suburban
Hannan Rd to Michigan Ave	Suburban
Michigan Ave to Michigan Ave	City / business
Michigan Ave	City / business
Entrance ramp: I - 275	Ramp
I-275 north	Expressway
Exit ramp: I - 275	Ramp
Ford Rd to destination	City / business

Note: The first city/business segment (Michigan Ave to Michigan Ave) was not included in the analysis, because it was extremely short.

Two people reduced the glance data to verify that the eye glances were coded in a consistent manner. In addition, each videotape was viewed multiple times by the analysts. Though the glances recorded by one person may not have been the identical glances recorded by the other, the number of glances logged by each person was comparable. For example, Analyst A observed 91 glances to the navigation system for subject 5, while Analyst B observed 95 glances. The difference in total glances for each subject, between analysts, was fewer than five. For each driver, the data from the analyst thought to best represent the glance pattern for that driver was used in subsequent statistical analyses. The general pattern of glances was for drivers to look at the navigation display just after turns, and, to some extent, just before turns, with periodic glances throughout the trip.

Table 4 shows the total number of glances for all drivers for each road segment. Older subjects glanced at the navigation display, on average, 88 times throughout the partial trip, with a range from 70 to 153 glances. Younger subjects glanced an average of 100 times during the partial trip, 12 more times than the older subjects. The number of glances for the younger subjects ranged from 92 to 126.

Table 4. Total number of glances for each road segment.

Location	Total number of glances for each segment	
	Younger Drivers (n=6)	**Older Drivers (n=6)**
I-275 north from I-94	70	65
Exit ramp: I - 275	18	14
Ecorse Rd to Hannan Rd	56	37
Hannan Rd to Michigan Ave	172	135
Michigan Ave to Michigan Ave	18	16
Michigan Ave	50	51
Entrance ramp: I - 275	15	23
I-275 North	135	123
Exit ramp: I - 275	17	20
Ford Rd to Destination	46	42
Total number of glances for partial trip	**597**	**526**

To compute glance statistics, the mean trip time was calculated separately for older and younger subjects. Using this mean, each subject's trip time was normalized, allowing for comparison. The partial trip length was then divided into 10 segments. A road segment was defined as the time between any of the four major maneuvers: right turn, left turn, change lanes, expressway entrance/exit. The mean segment time was calculated for each of the 10 segments, and the segments were normalized for each subject according to the mean segment time.

The mean frequency of glances to the IP display per minute (defined as total glances / (number of subjects * road segment time)), is shown in table 5, for each road segment. The average frequency of glances for younger subjects was 7.5 glances per minute, while older subjects glanced at an average rate of 7.1 times per minute. Younger subjects' glance frequencies ranged from 4.0 to 14.8 glances per minute. Older subjects had a similar range of frequencies, from 4.1 to 14.1 glances per minute.

Histograms were developed for older and younger subjects for each road category. Logically, it was thought that each trip segment should be partitioned into sections during which different glance behavior might be expected, the beginning, the middle, and the end. However, splitting each segment into thirds made the beginning and ending portions too long, so trip segments were partitioned into fifths. Finer partitioning did not leave enough glances in each cell for between cell comparisons of glance distributions.

Table 5. Mean frequency of glances per road segment.

Road segment	Mean frequency of glances (per minute) Younger drivers (n=6)	Older drivers (n=6)
I-275 north from I-94	7.8	7.2
Exit ramp: I - 275	5.3	4.1
Ecorse Rd to Hannan Rd	6.4	4.2
Hannan Rd to Michigan Ave	7.7	6.1
Michigan Ave to Michigan Ave	5.9	5.3
Michigan Ave	8.0	8.2
Entrance ramp: I - 275	4.0	6.0
I-275 North	9.8	9.1
Exit ramp: I - 275	5.8	6.6
Ford Rd to Destination	14.8	14.1
Mean frequency (per minute)	**7.5**	**7.1**

The glance frequency data were examined using analysis of variance (ANOVA). The model included three main effects (driver age, road type, and segment fifths), and two interactions (road type by segment fifth, and age by road type). Age by segment fifths, although initially included in the model, was not significant and so was pooled into the error of the model, to increase model accuracy. While not significant, the age by road type interaction ($p = 0.27$) was left in the model because it was considered to be an important term. Of the main effects, road type ($p = 0.0001$) and segment fifth were highly significant ($p = 0.0003$); age was not ($p = 0.25$). Segment fifths may have been significant because the navigation display was updated immediately after each turn, leading to more glances in the first fifth of each segment. A Scheffe's post-hoc test, used for pairwise comparison of segment fifths, revealed that the first segment fifth differed significantly with segment fifths 3, 4, and 5. It also revealed that both ramps and suburban roads differed from expressway and city/business segments.

Detailed glance data are provided here to facilitate comparison with similar data collected in subsequent on-the-road experiments.[15,16] Figure 7 shows the glance frequencies to the IP display for suburban roads. The pattern for younger and older subjects was nearly identical, with glances occurring the most during the first fifth of a road segment. Drivers continued to glance at approximately a constant rate throughout the rest of the segment, with a small increase in frequency during the fourth segment.

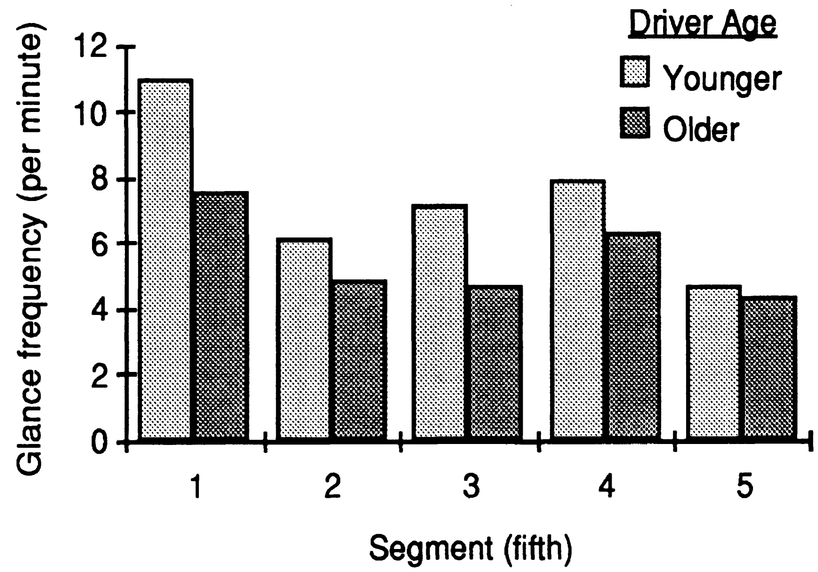


Figure 7. Frequency of glances to in-vehicle displays for suburban roads.

Figure 8 shows the glance data for expressway entrances and exits. The glance pattern for ramps was, again, similar for younger and older subjects. The total number of glances that occurred while entering (or exiting) the expressway was small. Younger subjects glanced the most during the fourth segment, while older subjects glanced the most during segment fifths 3 and 4 of the ramps. This difference is reflected in the road type by age interaction described earlier.

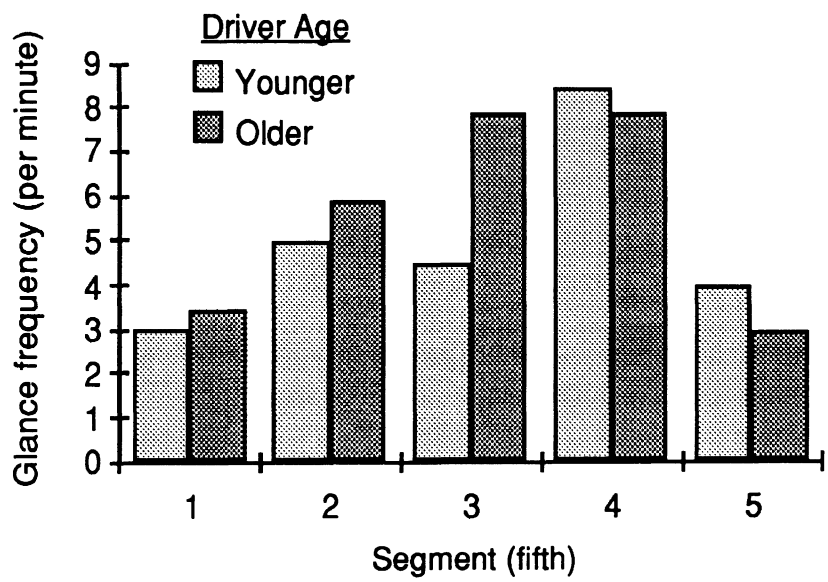


Figure 8. Frequency of glances to the in-vehicle display for ramps.

Both younger and older drivers glanced the most during the first segment of the expressway. (See figure 9.) During the second and third segment, older drivers tended to glance at the display at a constant rate. Their frequency was also constant for segment fifths 4 and 5. Younger drivers glanced at a constant rate during the final four segment fifths of the expressway.

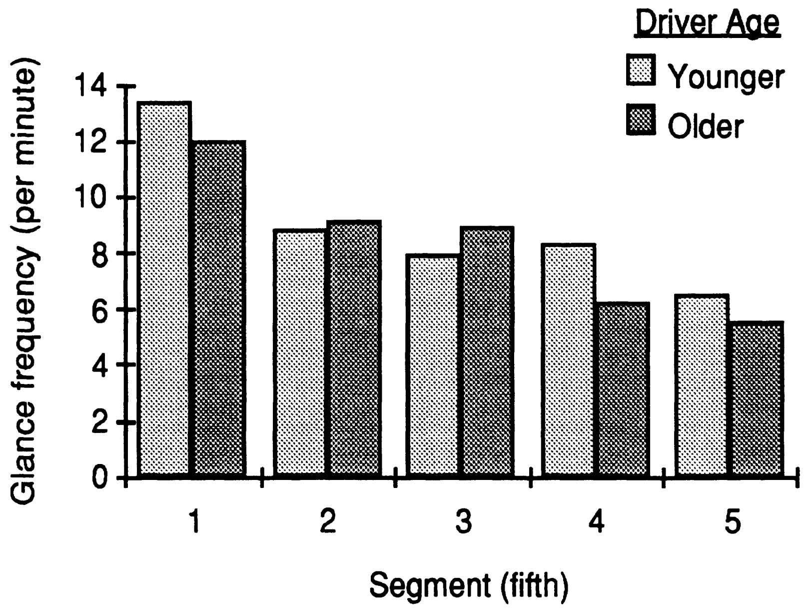


Figure 9. Frequency of glances to the in-vehicle display for expressways.

While driving on city/business roads, younger subjects glanced at the navigation display the most during the first segment. (See figure 10.) While older subjects also glanced at a high rate during the first segment, they glanced the most during the second segment.

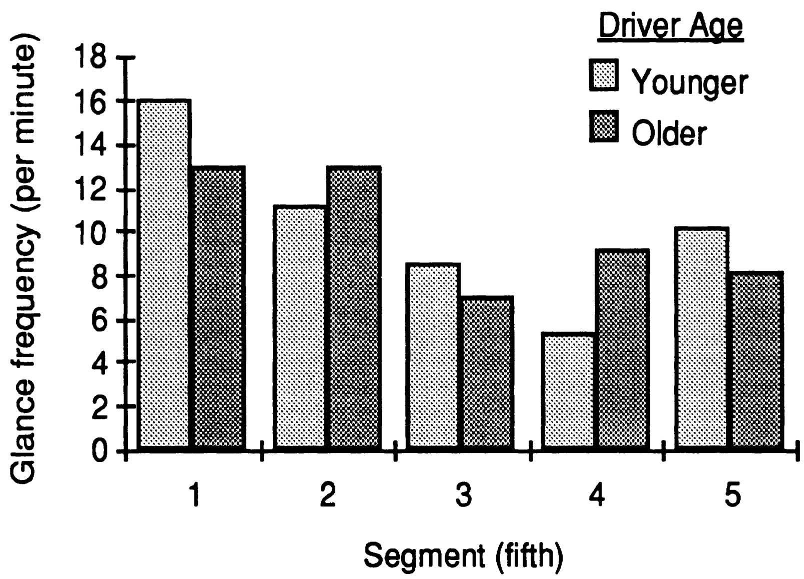


Figure 10. Frequency of glances the in-vehicle display on city/business roads.

With the exception of ramp road types, both older and younger subjects glanced most at the navigation display at the beginning of a segment. Furthermore, the pattern of glancing frequency was similar for older and younger subjects, except for a few minor differences.

The glance frequency data were compared to data collected in a later experiment using similar route guidance and other displays on the road.[15] Seven segments were identical and, therefore, analyzed identically (I-275 exit ramp, Ecorse Road to Hannan Road, Hannan Road to Michigan Avenue, Michigan Avenue, I-275 entrance ramp, I-275 north, and the I-275 exit ramp). An ANOVA of those data showed there were no differences in glance frequency (6.5 per minute) due to testing location (laboratory videotape versus on-the-road) ($p = 0.98$). Driver age ($p = 0.81$) and the age by testing location interaction ($p = 0.38$) were also not significant. While the sample is not large--12 drivers in this laboratory experiment, and 8 in the subsequent on-the-road experiment, with approximately 10 minutes of data per driver--the level of agreement is quite high. However, when examined by road segment and driver age combination, there was no agreement between the two data sets (r = -0.21). Figure 11 shows that relationship.

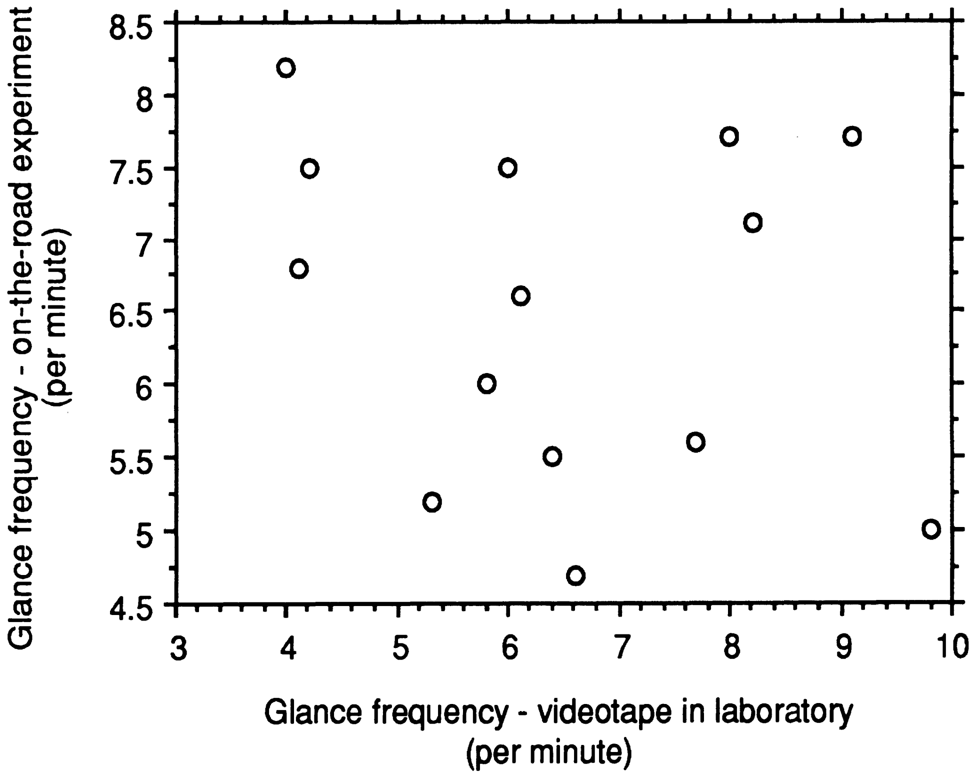


Figure 11. Glance frequencies to the IP display, in-the-aboratory versus on-the-road experiments.

Note: The data are means by road segment and driver age.

So, in summary, the glance frequency data show that drivers look at the route guidance display approximately seven times per minute (or once every 8.5 seconds). Given the large number of turns on the test trip, these values seem reasonable. There were significant differences due to road type and the portion segment examined (more fixations immediately after a turn), but not due to driver age. There was no correlation between the fixation frequency in the laboratory and fixation frequency on the road for the same road segment.

Detailed Examination of Glance Duration

The glance behavior of six drivers who used the visual route guidance system was examined in detail. This analysis was conducted to provide additional insights into the experiment and values for parameters that might be included in future calibration of the integrated driver model developed as part of this research program.[19,20]

These six subjects varied in terms of their age, sex, and the route guidance condition they experienced (e.g., younger versus older, male versus female, visual with landmarks versus visual without landmarks). Because glances to the IP display were of main concern, only duration and number of glances to this display were tallied. Additionally, two of the six subjects were analyzed in fine detail. Their glances were classified into five categories: display, road, three (response) keys, blink, or other.

By playing the videotapes in slow, single frame modes (1 frame = 1/30 s), glance durations could be determined by counting the number of video frames in which the glance location remained unchanged. The "other" category represented the transitions of the eye between categories. This frame-by-frame analysis was much more time consuming than the rapid analysis procedure described earlier.

The distributions for all subjects appear log normal and are shown in the appendix. Glance durations were converted into log (time) and an ANOVA was performed, with glance duration as the dependent variable. Because many of the results from the ANOVA are based on data from one subject per condition and the differences are between subjects, the outcome of the statistical analysis should be viewed as illustrative rather than conclusive. The results may reflect individual differences, not differences due to conditions.

The data show that there was a significant gender effect ($p = 0.029$), but there were no significant main effects of age or landmark condition. Another model showed a significant landmark by subject interaction ($p = 0.019$), indicating that landmarks may have an effect on how long drivers look at the system display. This effect can be seen in table 6. Conditions with landmarks and older males showed slightly higher times than conditions without landmarks and younger females. The range in means across all factors is only 0.07 s, not very much.

Table 6. Durations of eye glances to the IP display, by factors (landmark, driver age, and driver sex).

	Landmarks	Without landmarks	Younger	Older	Female	Male
Mean (s)	0.98	1.02	0.97	1.01	0.96	1.03
Standard deviation (s)	0.71	0.73	0.66	0.74	0.71	0.73
Duration (%)	14.8	14.5	12.1	17.2	12.9	6.4

Detailed analysis of road fixation duration for two subjects showed log normal distributions. The older male had a mean of 0.57 s with a standard deviation of 0.44 s, while the younger female had a much larger mean (3.44 s) and was much more variable (standard deviation of 2.63 s). The distribution for the younger female appeared bimodal, representing a mixture of short fixations to inside the vehicle and longer fixations to the road. The data for the detailed analysis are given in tables 7 and 8.

Table 7. Detailed eye fixation data for an older male using the visual with landmarks interface.

	Road	Display	Three keys	Blink	Other
Mean (s)	0.57	1.05	0.41	0.22	0.27
Standard deviation (s)	0.44	0.72	0.18	0.08	0.18
Fixations (%)	37.3	9.4	1.7	35.5	16.1
Duration (%)	48.5	22.2	1.6	17.9	9.9

Table 8. Detailed eye fixation data for a younger female using the visual with landmarks interface.

	Road	Display	Three keys	Blink	Other
Mean (s)	3.44	0.70	0.13	0.18	0.15
Standard deviation (s)	2.63	0.33	0.00	0.12	0.07
Fixations (%)	33.0	17.4	0.1	31.6	17.9
Duration (%)	84.7	9.1	0.00	4.3	2.0

The older male's glances were shorter and more numerous; he had almost three times as many glances as the younger female. While the percentage of glances to the road were similar (37.3 percent for the older male and 33.0 percent for the younger female), there was a large difference between the percent durations for these two subjects. The older male spent less than half the time watching the road, while the younger female kept her eyes on the road almost 85 percent of the time. The display is responsible for diverting some of the male's attention, but other factors also played a role. About 30 percent of the older males' fixation duration was accounted for in the three keys, blinking, and "other" categories.

The limited glance duration data examined indicate glance durations to the in-vehicle display were approximately 1.0 seconds, with a standard deviation of slightly less than 0.75 seconds. Other measures, such as the mean glance time to the road, the percentage of fixations to the display, etc., varied widely between individuals. While the data are quite limited, the fixation frequency data described in the previous section, and the fixation duration data described here, suggest that the interface design developed does not require an excessive attentional demand. However, the lack of correlation between the laboratory and on-the-road evaluations is a disappointment.

Task Difficulty, Safety, and Utility Ratings

The purpose of this evaluation was to explore the use of subject ratings of the simulator trial for subsequent on-the-road experiments, and to see if differences exist in subject ratings due to landmarks, or visual versus auditory presentation.

The mean task difficulty ranking of common tasks done while driving ranged from 2.3 (talking with people in the car) to 7.5 (reading a map). The mean difficulty ratings for all subjects are shown in Table 9. Most of these driving tasks were rated more difficult to do while driving than other tasks associated with the route guidance and traffic information systems.

Table 9. Mean difficulty rating for performing various tasks while driving.

Task Difficulty Statement Not at all Difficult 1 --------> 10 Extremely difficult	**Overall mean**
Talking with other people in the car.	**2.3**
Adjusting the fan speed on the car heater or air conditioner.	**2.9**
Changing stations on the car radio using presets.	**4.0**
Drinking a beverage.	**4.0**
Changing a tape cassette in a car stereo.	**4.3**
Looking at street numbers to locate an address.	**6.0**
Reading a map.	**7.5**

(n=48)

The mean ratings for the common driving tasks are similar ($r = 0.99$, p , 0.0001) to those obtained by Kames, where people rated the difficulty of 14 tasks on a 1 to 10 scale (10 being the most difficult).[29] Selected questions and ratings from that study for the five task in common are shown in table 10. In both studies, reading a map was rated as the most difficult of all tasks.

Table 10. Selected mean difficulty ratings for common driving tasks from Kames .

Common driving task 1----------->10 Most difficult	**Mean rating**
Conversing with other people in the vehicle.	**1.3**
Adjusting a car heater or air conditioner.	**2.2**
Tuning a car radio.	**2.8**
Drinking coffee or other beverage.	**3.5**
Reading a map.	**7.9**

The mean difficulty ratings for various tasks associated with the route guidance system are shown in Table 11. For all the following questions, participants rated the systems they had used for the 25-minute route. For all participants, the responses ranged from 1.8 (hearing the traffic information alert tone) to 3.5 (reading the traffic information report).

Table 11. Mean difficulty ratings for performing various tasks associated with the route guidance system while driving.

	RG user group (n = 12, for each group)				
Route Guidance (RG) Task Difficulty Statement Not at all Difficult 1 ---> 10 Extremely difficult	**Vis w/ Land**	**Vis no Land**	**Aud w/ Land**	**Aud no Land**	**over all**
Determining the next maneuver from the RG system.	3.3	2.4	3.3	1.9	**2.7**
Looking for the next turn indicated by the RG system.	2.8	2.3	3.8	2.8	**2.9**
Looking at the RG screen to see it update.	2.9	3.2	n/a	n/a	**3.1**
Reading, or listening to, the information on the RG system.	4.1	3.8	2.8	2.4	**3.3**
Remembering the next maneuver you should make after hearing it from the RG system.	n/a	n/a	4.6	2.8	**3.7**
Mean by RG user group	**3.3**	**2.9**	**3.6**	**2.5**	**3.1**

Ratings of difficulty for the traffic information tasks were analyzed for main effects of system. These means are shown in table 12. The reader is reminded that while there were four different route guidance systems (varied by mode and presence of landmarks), the primary variation of traffic information interfaces was in modality (visual versus auditory).

Before analyzing for main effects of modality, the ratings for "reading the traffic information report" were combined with "listening to the traffic information report," as both questions related to acquiring information from that system. A statistically significant difference was found for modality (auditory or visual), with $p = 0.003$. Overall, the auditory users rated listening to the traffic information as easier (mean = 2.7) than the visual users rated reading the information (mean = 4.4).

Table 12. Mean difficulty ratings for performing various tasks associated with the traffic information system while driving.

Traffic Information (TI) **Task Difficulty Statement** Not at all Difficult 1 ---> 10 Extremely difficult	**TI user group** (n = 24, for each group) **Visual***	 **Auditory**	 **Overall**
Hearing the TI alert tone.	1.9	1.8	**1.8**
Listening to the TI report.**	n/a	2.7	**2.7**
Reading the TI report.**	4.4	n/a	**4.4**
Mean by RG user group	**3.1**	**2.2**	**2.7**

*includes both visual systems
**significant difference due to TI user group

With regard to safety issues for using the route guidance and traffic information systems, there were statistically significant differences in level of agreement to the statements due to route guidance user group, as measured by an ANOVA. Interestingly, all participants on average "slightly agreed" (overall mean = 2.2) that it was safe for themselves to use their respective system while driving (with no system differences). There were, however, significant differences in their attitudes toward other people (passengers and inexperienced drivers) using their system. See table 13.

Table 13. Level of agreement for safety issues for the use of the route guidance and traffic information systems.

Safety Issue Strongly agree 1 -------->5 Strongly disagree	**RG user group** (n = 12, for each group) **Vis w/ Land**	 **Vis no Land**	 **Aud w/ Land**	 **Aud no Land**	 **over all**
It is safe for a passenger to use this system while I drive.**	1.4	1.1	2.0	2.1	**1.6**
It is safe for me to drive while using this system.	2.6	2.5	2.2	1.5	**2.2**
It is safe for inexperienced drivers to use this system while driving.**	3.8	3.8	2.6	2.0	**3.0**
Mean by RG user group	**2.6**	**2.5**	**2.3**	**1.9**	**2.3**

**significant difference due to RG user group

There was a significant difference due to route guidance system for the ratings of allowing a passenger to use the system ($p = 0.02$) while the participant drove. The visual system users agreed more strongly (mean = 1.3) than did the auditory users (mean = 2.1) that it would be safe for passengers to use the system while they drove, although there were no pairwise, user group differences. Assessing the safety of inexperienced drivers using their respective system, there was a significant difference due to system ($p = 0.0005$). In this case, visual route guidance users were less positive about novice drivers using their system (mean = 3.8), than were the auditory users (mean = 2.3). In addition, significant pairwise differences exist between the auditory without landmarks and visual without landmark conditions ($p = 0.007$), and between the auditory without landmark and visual with landmark conditions ($p = 0.004$).

ANOVAs computed for each of the utility statements showed the main effects of user group were not statistically significant different at the $p < 0.05$ level. The means for each question are shown in table 14.

Table 14. Utility of the route guidance systems.

	RG user group (n = 12, for each group)				
Utility Issue Strongly agree 1 ------->5 Strongly disagree	**Vis w/ Land**	**Vis no Land**	**Aud w/ Land**	**Aud no Land**	**over all**
I would likely use this system when driving in unfamiliar areas.	1.3	1.7	1.8	1.3	**1.5**
The route guidance information provided by this system is useful.	1.8	1.8	1.8	1.5	**1.8**
The traffic information provided by this system is useful.	2.4	1.8	2.0	1.8	**2.0**
I would use this system if I were in a hurry.	1.9	2.0	2.4	1.8	**2.0**
I would rather use a route guidance system similar to this one than use a standard paper route map to find my way.	1.8	2.3	2.5	2.3	**2.2**
I would likely use this system for my daily travel.	3.3	2.7	2.9	2.8	**2.9**
Mean by RG user group	**2.1**	**2.1**	**2.2**	**1.9**	**2.1**

Route Guidance System Usability Rankings

Participants were also asked to rank the four systems, in terms of their preference, from best (1) to worst (4). (As a reminder, after the 25-minute use of one route guidance system, they were briefly shown the other three other candidate interfaces.) Mean rankings of all systems are shown in table 15. An ANOVA revealed no significant differences in rankings based on whether the subject used the system or just watched a demonstration of it (p = 0.66).

Table 15. Mean preference ranking for each route guidance system.

	Mean Rank Best 1 -----> 4 Worst			
RG System User Group (n = 12 for each group)	**Vis w/ Land**	**Vis no Land**	**Aud w/ Land**	**Aud no Land**
Visual with landmarks	1.7	3.4	1.9	3.0
Visual without landmarks	2.1	3.1	1.8	3.0
Auditory with landmarks	1.8	3.0	2.3	2.8
Auditory without landmarks	2.6	3.5	1.3	2.7
Mean Rank of System	**2.0**	**3.3**	**1.8**	**2.9**

Note: Shaded areas present mean rankings for the system used.

These data indicate that the most important aspect of the interface (in terms of usability rankings) was if the interface used landmarks (mean rank = 1.9) or did not (mean rank = 3.1). A difference due to modality (auditory = 2.4, visual = 2.7) was also evident. In an ANOVA, both differences were statistically significant ($p < 0.0001$ and $p < 0.04$ respectively).

Traffic Information Screen Ratings

Table 16 presents the mean ratings of each traffic information screen presented to each of the four test groups while watching the videotape. Ratings (1 = no effect, 7 = extreme effect) relate to driver responses to the traffic information if they were driving through the problem reported. In an ANOVA of the traffic information screen ratings, there were significant differences between screens (p = 0.014), which was due to the problem (an overturned gasoline truck) having a larger impact. The modality of the traffic information report (visual versus auditory), had no significant effect on its rated impact ($p = 0.68$). In contrast, based on the preference ratings, listening to traffic information (with the auditory system) was not as difficult as reading the traffic information (with the visual system).

Table 16. Ratings of the effect of traffic problems.

Mode (system)	Traffic Information Problem 1 Accident	 2 Construction	 3 Accident	 4 Construction	Mean
Visual Landmarks	4.7	3.0	4.8	2.9	4.0
Visual No Land.	5.0	3.3	5.3	3.0	
Auditory Landmarks	5.1	3.2	6.2	2.7	4.3
Auditory No Land.	4.4	3.6	6.2	2.7	
Mean	**4.8**	**3.3**	**5.6**	**2.8**	

Comparison of Laboratory and On-the-Road Preference Ratings

Correlations of mean responses in responding to various questions were obtained for the visual with landmarks and auditory with landmarks interfaces examined in a subsequent on-the-road experiment.[15] Mean responses were used in the computations because the same subjects were not examined in both experiments. There were some differences in the location of the visual display (in the center of the console in the laboratory experiment; on top of it in the on-the-road experiment). The rules and language for presenting the auditory route guidance instructions were not identical, but contained a similar structure. It was discovered upon running initial on-road subjects that the rules used in the laboratory were insufficient to guide drivers successfully.[15]

Six difficulty ratings were common to both experiments:

- Determining the next maneuver from the route guidance system.
- Looking for the next turn indicated by the route guidance system.
- Looking at the route guidance screen to see it update.
- Reading the information of the route guidance screen.
- Hearing the traffic information alert tone.
- Reading the traffic information report.

Correlations of the means of the visual system users from both studies, as well as the means from the auditory system users from both studies, were not statistically significant ($p = 0.53$ and $p = 0.75$, respectively). In addition, there was no significance when an aggregate of the visual and auditory mean ratings of the laboratory study were compared with aggregate data from the on-the-road experiment ($p = 0.41$). These results suggest that difficulty ratings of specific tasks related to using the route guidance and traffic information systems on the road can not be predicted from watching a videotape in the lab, when done in the manner of this experiment.

Similar analysis was done over the following utility questions:

- I would likely use this system when driving in unfamiliar areas.

- The route guidance information provided by this system is useful.
- The traffic information provided by this system is useful.
- I would use this system if I were in a hurry.
- I would rather use a route guidance system similar to this one than use a standard paper route map to find my way.
- I would likely use this system for my daily travel.

When the visual system users' mean responses from both studies were compared, and when both auditory users' responses were compared, there was no significant correlation (with $p = 0.17$ and $p = 0.12$, respectively). Aggregates of the visual and auditory means from both experiments also were not significantly correlated ($p = 0.17$).

Three safety issues were examined for significant correlation. These issues, dealing with the perceived safety of various system users, were:

- It is safe for a passenger to use this system while I drive.
- It is safe for me to drive while using this system.
- It is safe for an inexperienced driver to use this system.

In this case, there was a correlation of the mean responses in the laboratory and those obtained on the road for both the visual system (r = 0.98) and the auditory system groups (r = 0.69), though these correlations were based on only three pairs of points. When the data were aggregates across modality, the correlation of the ratings was significant (r = 0.89, $p = 0.02$).

Willingness to Pay

Participants were asked how much they would be willing to pay for the system they had used in the 25-minute trial. (Participants had not been shown the brief demonstrations of each of the remaining three systems yet.) Table 17 presents the mean prices stated by each user group, for their respective system. An ANOVA revealed no statistically significant differences due to system group, at the $p < 0.05$ level.

Table 17. Mean price that participants would be willing to pay for the system they used.

RG System User Group (n=12 for each group)	**Mean Price Willing to Pay ($)**
Visual with landmarks	404
Visual without landmarks	468
Auditory with landmarks	384
Auditory without landmarks	573
Overall Mean	**458**

CONCLUSIONS

This experiment was designed to answer four questions:

- How does navigation performance with a voice (auditory) route guidance system compare with an alternative visually-based interface? Does the presence or absence of landmarks (traffic lights, stop signs, etc.) influence navigation performance?
- How often in each portion of a trip do drivers look at visually-based route guidance displays? How many times do drivers look at traffic information displays to read them?
- Which versions do drivers prefer, and how acceptable and safe do drivers consider them?
- What kinds of problems are there in using somewhat passive viewing in a laboratory of videotaped road scenes to examine navigation problems?

Based on performance, should route guidance interfaces be visual or auditory, and should landmarks be provided?

The primary performance measure was the decision lead time/distance, how far in advance of turn points drivers were able to identify where a maneuver was needed and which maneuver should occur. Because of hardware and software problems, navigation performance data using the four systems of interest could not be recovered.

Secondary measures relating to braking were recovered. The auditory interfaces had response times that were 500 ms less, suggesting that auditory interfaces demanded less attention. That difference was statistically and practically significant. There were no significant differences in the number of missed brake applications due to the modality (visual versus auditory) of the route guidance interface. In contrast, there were no differences in response time or the number of misses due to landmarks. This suggests there is no penalty for providing the additional information associated with landmarks. This is supported by the detailed eye fixation analysis of six drivers. For them, fixation durations actually were 40 msec less when landmarks were present (where the mean fixation duration was approximately 1 second). This difference was neither statistically or practically significant.

How often and for how long do drivers look at visually-based route guidance displays?

Route guidance displays were examined approximately 7 times per minute or once every 8.5 seconds. How frequently drivers looked depended on the type of road and the portion of the segment of the road, with drivers looking more at the display shortly after a turn was completed. This was primarily because complete information was available on the next turn immediately after a turn was completed. Also, there were several turns in quick succession on the road, something for which drivers had to check.

Fixation durations to the display, based on a very limited sample, had a mean of approximately 1.0 seconds with a standard deviation of 0.75 seconds. Glance durations followed a log-normal distribution.

While it provided less information in that it did not examine fixation duration, the rapid analysis procedure to examine fixation frequency was considerably less tedious than the manual frame-by-frame analysis procedure. It also proved to be extremely reliable. When an eye mark recorder with computer output is not available, this procedure is recommended for the reduction of data.

Which versions of the interface do drivers prefer and how acceptable and safe do drivers consider them?

In regard to completing specific tasks (determining the next maneuver from the route guidance system, remembering the next maneuver after hearing it, etc.), route guidance interfaces had a mean rating of approximately 3 on a 1 to 10 scale (not difficult at all to extremely difficult). This value corresponds to the rated difficulty of tuning a radio. To put these numbers in context, the ratings for other (common) driving tasks from this experiment were highly correlated with those reported by Kames.[29] With regard to interface attributes, visual route guidance interfaces were rated equally as difficult to use as auditory interfaces (both 3.1). Interfaces without landmarks were rated as slightly easier to use than those with landmarks (3.5 versus 2.7). For traffic information, the auditory interface had a lower difficulty rating (2.2) than the visual interface (3.1).

To provide another perspective, issues regarding safety (it is safe for a passenger/myself/inexperienced driver to use this system) were rated on a different scale (1 = strongly agree, 5 = strongly disagree). Participants were slightly more likely to agree with that statement for auditory systems (2.1) than for visual interfaces (2.6), and for interfaces without landmarks (2.2) than with them (2.5). One interpretation of the task difficulty and safety ratings is that drivers base their responses primarily on the extent to which retrieving route guidance information interferes with the primary driving task. Since the interfaces with landmarks provide more information, they were rated as more difficult to use.

From the perspective of utility (use when driving in unfamiliar areas, use if in a hurry, etc.), there were basically no differences between systems (where the range was 1.9 to 2.2 on a 1 to 5 scale). For the traffic information interfaces, there were no differences between the visual and auditory designs in terms of their effect on driving. In contrast to the task difficulty and safety ratings, the utility ratings take into account the benefits of landmarks, a characteristic that balances out the cost of using them. (It takes additional time to read or to listen to the display).

This cost/benefit tradeoff is also reflected in the preference rankings of interfaces were best (1) to worst (4). Drivers strongly preferred to have landmarks (with = 1.9, without = 3.1), and somewhat preferred auditory interfaces (auditory = 2.4, visual = 2.7). Drivers were willing to pay about $458 for these systems (range = $384 to $573). The authors cannot explain the variation in the willingness to pay data.

While the willingness to pay responses were based on limited simulated experience in using the route guidance and traffic information systems, there is some concern about the manner in which the question was posed. In brief, for many consumers, real purchases are discretionary; they are made from a budget. Usually buying one object means something else is not purchased. An alternative way to pose this question to reflect consumer behavior would be to ask what they might trade to acquire a driver information system.

Thus, in terms of safety and accomplishing specific tasks, drivers rated the auditory interfaces and those without landmarks as easier and safer to use than the others. Those ratings may fail to consider the entire driving task. If landmarks are not provided, then the driver needs to search more for street signs, which may detract from driving safely. A suggestion of this occurs in the utility ratings, which are approximately equal for all interfaces. An even stronger indication comes from subsequent on-the-road testing on parts of the same route. That was not true of the safety questions, where there was some level of agreement.

When participants were asked what they preferred, they strongly favored interfaces with landmarks over those without, and somewhat preferred visual over auditory. To the authors, these results suggest that route guidance interfaces with landmarks should be implemented, but further testing is required to consider the differences between visual and auditory formats. Task difficulty and the utility questions from that experiment were not correlated with the results of the laboratory experiment described in this report.

What kinds of problems are there in using videotaped road scenes to examine navigation problems?

There were significant problems in carrying out this experiment. Motion sickness when watching the videotape forced the experimenters to display the road scene image on a video monitor instead of projecting it onto a large screen. This reduced the fidelity of the experiment. This problem may be overcome by using a gyro-stabilized camera mount and having the camera lead through turns just as a person turns their head when driving. That is, after looking both ways to check for traffic, the driver looks towards the street they are turning to and keeps their head turned in that direction once the turn is initiated. However, it is more probable that the lack of proprioceptive cues that would be expected with lateral g-loads of a turn are the cause of the symptoms, and a high-fidelity motion-base simulation is beyond the scope of the researchers. Problems may be resolved by adaptation to the simulation, as the motion sickness symptoms generally extinguish after time.

A second problem with the videotape method is image resolution. When a single video image is used for the forward scene (the central 30 to 90 degrees), resolution is generally too low to present highway signs at the same resolution as they appear in the real world. While this can be overcome by using high resolution video systems and covering the forward scene with multiple channels, the increase in resolution required is considerable. Most driving simulators face a similar problem, which limits their utility. The Highway Simulator (HYSIM) at FHWA superimposes 35 mm slides of signs on the road scene to overcome this problem.

As implemented in this experiment, there were problems in coordinating the videotape playback with presentation of the navigation information. Potential solutions include placing Society of Motion Picture and Television Engineers (SMPTE) time code on the videotape, or playing back Motion Picture Experts Group (MPEG) compressed road scene in real time from a hard disk. The MPEG technology was not readily available when this experiment was conducted.

The final problem with the experiment was the nature of the primary task, stepping on the brake when the vehicle ahead braked. As only one lead vehicle (driven by a researcher) appeared on the videotape, test participants were able to anticipate turns from that vehicle's maneuvers. Multiple vehicles should have been used and that vehicle should not have given early cues of turns. This would have made the primary task less of a car-following task.

Even if these problems were overcome, for what kinds of research questions is it appropriate to use the videotape approach? While the sample sizes were small, agreement was not good enough among responses to questions regarding the difficulty of completing tasks (obtaining traffic information) in the laboratory and on the road, to allow for selection of display formats (visual or auditory) or interface features (with or without landmarks).

Viewing of the video scene is an extremely boring task for participants. Contrary to the interest in the in-vehicle system and the task in the on-the-road experiments, the participants in the laboratory seemed ready to fall asleep. Perhaps a secondary tracking task added to the video image would increase interest. Or perhaps the sense of responsibility and repercussion of driver error is so reduced in the simulation compared to road trials, that data comparison is not warranted.

Unfortunately, the predecision time and distance data were not analyzed for the laboratory experiment, so the general agreement with on-the-road data is uncertain. For matching road segments, the glance frequencies to the in-vehicle displays were the same in both experiments. However, when partitioned by age group (younger, older) and road segment, there was no correlation between the two data sets.

Data that did correlate quite well were the mean willingness to pay results, with means of approximately $500 in the laboratory and on the road.

To the authors, these results suggest that videotape simulations of the type explored here have limited use in examining task difficulty and driver performance. Different results might have been obtained had larger samples been used or had the differences among interfaces been more pronounced. As suggested by the on-the-road data collected subsequently, it is believed that the four interfaces tested were all reasonably well designed. It could be that these experiments are therefore trying to measure what might be considered "noise" in the data, and hence no correlation should be expected. The only data to show a strong connection (and then based only on the means) were regarding the willingness to pay. This suggests that videotape-based methods might be appropriate for marketing studies.

In summary, based on the limited data collected, videotape experiments can be used to make only general judgments about the difficulty of various tasks, but are not sufficiently precise to distinguish among alternative interface designs. While sample sizes may provide the accuracy desired, substantially larger sizes are not likely to be used, given normal funding and schedule constraints. In terms of performance and behavior, again the mean levels for the one measure examined (glance frequency) gave roughly similar values in the two settings, but there was no correlation when the data were partitioned more finely. At the present time, videotape-based experiments seem to have limited utility for assessing driver performance and judgments, though they may be useful for giving drivers impressions of systems for making willingness-to-pay decisions. As the technology for conducting experiments of this type is refined, the utility of videotape methods should be reexamined.

APPENDIX A - AUDITORY ROUTE GUIDANCE AND TRAFFIC INFORMATION PARTICIPANT CONSENT FORM

We are working on a system to present drivers with auditory route guidance and traffic information that might be in cars of the future. A well designed system can be used easily, so people can concentrate on driving. Responses from typical drivers, such as you, will help identify the best way to show this information.

While sitting in a car mock-up, you will see ahead of you, on a monitor, a videotape of a predetermined route you will pretend to be driving along. At various times, you will be given auditory instructions about route guidance and traffic information. Based on the information you receive, you will indicate (by pressing a button) what turns or maneuvers to make when you identify them from the video of the route.

During the study, you will be videotaped. The experiment should take about 1 1/2 hour, for which you will be paid $15.00. If you have any problems or discomfort while completing this experiment, you can withdraw at any time. You will be paid regardless.

I have read and understand the information above.

______________________________	____________________
Print your name	Date
______________________________	____________________
Sign your name	Witness (experimenter)

APPENDIX B - VISUAL ROUTE GUIDANCE AND TRAFFIC INFORMATION PARTICIPANT CONSENT FORM

We are working on a system to show drivers route guidance and traffic information that might be in cars of the future. A well designed system can be used at a glance, so people can concentrate on driving. Responses from typical drivers, such as you, will help identify the best way to show this information.

While sitting in a car mock-up, you will see ahead of you, on a monitor, a videotape of a predetermined route you will pretend to be driving along. Inside the car, you will be presented with route guidance and traffic information on another monitor. Based on the information you receive, you will indicate (by pressing a button) what turns or maneuvers to make as soon as you see them on the video of the route.

During the study, you will be videotaped. The experiment should take about 1 1/2 hour, for which you will be paid $15.00. If you have any problems or discomfort while completing this experiment, you can withdraw at any time. You will be paid regardless.

I have read and understand the information above.

Print your name	Date
Sign your name	Witness (experimenter)

APPENDIX C - AUDITORY ROUTE GUIDANCE SYSTEM SUBJECT INSTRUCTIONS

This appendix contains the experimental procedure used for this study. Instructions to the experimenter were shown in *italics* and suggested dialogue was shown in **UPPERCASE BOLD.**

Before subject arrives:
Check schedule to determine subject name, number and designated system order (according to counterbalanced ordering).

Laboratory Activities (if first subject of the day)
VCR setup, Mac, monitor, cameras, cables OK

Set up Titmus vision tester in the laboratory. Have ready a consent form, biographical form, task difficulty form, safety/rating questions, master data collection form, payment forms (University employee or non-U employee), and $15.00 cash (if subject is not a University employee).

Also have a VCR tape labeled with subject name and number, and disk to back up data right away. Fill in as much information on the bio form as possible.

Turn on the Rodime, Mac, both Realistics, and PC-VCR. Put the Practice tape in the PC-VCR. Click on Aldus SuperCard. Double click on the pre-determined system practice. Select Set-Up, let the PC-VCR run and stop.

Turn on the 2 cameras (remove lens caps). Turn on Video recording equipment, both power strips. Press 1A, 2B, eff, then Take on the JVC Special Effects. Make sure video split screen is on.

When Subject Arrives
Hi, are you _________ (use subject's name)**? I'm** _________ (experimenter's name). **Thanks for coming, let's go down to the conference room so we can begin.**

Take subject down to conference room and be seated.

As I mentioned earlier, this study will take about 1 1/2 hours to complete, and you'll be paid $15.00. It involves a simulated trip in Southeastern Michigan.

The purpose of this experiment is to determine the best way to present drivers with route guidance and traffic information in cars of the future. Since people such as yourself will be driving while obtaining that information, the system must be easy to use and not distract drivers from watching the road. Therefore, your opinion is important.

Before we start, there is some paperwork to complete. First you need to read and sign this official consent form, which basically repeats in writing what I just said. I also want to mention that if you feel

uncomfortable at any time in the experiment, you should let me know and we can stop.

Have participant read and sign the consent form.

Also, we need to know a little more about you.

Go through bio form with subject and fill in the appropriate answers.

Now we can check your vision.

Turn on both eye switches on the vision tester, slide 1. Adjust the height of the vision tester for the subject. Make sure subject wears any vision correction.

Can you see in the first diamond, that the top circle is complete but the other three (on the right, left, and bottom) are incomplete? Can you tell me which circle is complete in the second diamond? The third?...

Prompt the subject until s/he has missed two in a row. Record the last number answered correctly on the bottom of the bio form, and note if corrective lenses are worn. Take subject to laboratory.

Now that that is complete, please sit in the driver's seat of the car. Are you comfortable? Would you like the seat moved at all? *(Show subject where seat controls are and steering wheel adjustment is)* **To help us keep track of what happens in this experiment, we are videotaping all the sessions. There is a camera in front of you (*point to it*) and one behind you (*point to it*).**

Explain systems to subject:

Like I said before, the purpose of this study is to determine the best way to present route guidance and traffic information to drivers. Route guidance information tells you how to get to a certain destination. In systems of this type, the computer would know where you are. You would tell it where you want to go, either a street address, an intersection, or the name of a place, such as Detroit Metro Airport. It will figure out the best way to get you there, and as you drive, tell you where to turn. It could do this using auditory instructions, such as the one you'll be using. The computer will also monitor traffic, and will tell you about any problems that occur.

This experiment concerns a hypothetical 25-minute trip from Taylor to a business in Canton, Michigan. Don't worry if you don't know the area, the computer will tell you how get to the destination by indicating when and where you should turn. In actuality, this route may not be the fastest way. It was chosen to help test the design.

The monitor straight ahead is the screen you will be watching. It will show you a videotape of the route you are driving during your trip. Watch it as if it were the road. As you are driving, when any car directly in front of you brakes, you should also brake. So when their brake lights go on, step on the brakes as quickly as possible. Then, when the brake lights go off, take your foot off the brake. The car will brake at regular times (stoplights and intersections). Also, the car in front may brake unexpectedly to make sure you are paying attention to the road. You should also brake at those times.

Now I'm going to give you an example of an Auditory Route Guidance Instruction that you will hear to give you a sense of what to expect. It will tell you where to go at expressway exits and major intersections along the route which you'll be watching on the monitor ahead of you. You will hear these instructions given by a human voice. This is what it sounds like: *Press Practice Nav button.*

It tells you what to do at a certain cross street and how far you are from it. Once you are close to the street, in this case, Green Rd., the system will repeat the guidance instructions. So you actually get route guidance information twice. One to prepare for the maneuver and once again right before the maneuver. Would you like to hear the guidance information again?

Do you see the white keys to the right? You'll be using those keys to indicate what turn or maneuver you'll be making at an exit or intersection. The left key means turn or bear left, the middle key means go straight, and the right key means turn or bear right. You will be resting your fingers on the keys throughout the "trip," so you can move the board that the keys are on to a comfortable position.

As soon as you can see, on the videotape, the actual location, sign, traffic light, or some other clue that you have reached the exit or intersection that you are supposed to do something at -- press the button indicating what the auditory route guidance system tells you to do, either turn or bear left, go straight, turn or bear right. You can think of it as an "I See It" Button. You may not always see a sign so you may have to use other clues, like distance. When you actually see the place on the videotape press a key.

For example, with this audio instruction, you know a mile ahead of time that you'll be turning left at Green Rd. So you're waiting until you see Green Rd. to press a button. Which button would you press when you can see Green Rd.? *Subject should answer "Left Key, go left." If not, explain procedure again.*

You also will be going through other intersections where you will not have to make a turn, and will not hear any audio instructions that tell you to go straight through the traffic light. However, anytime you pass

through an intersection with a traffic light, or pass an exit ramp on the expressway, you should also press the appropriate key for what to do at that intersection -- whether you hear an instruction or not. Is that clear?

Sometimes instead of route guidance, you will hear about traffic information reports describing an accident, construction site, or some other traffic problem. You will hear two beeps before you receive this message. This is what a traffic information report will sound like:
Press Practice Traf Button.

After this message is heard, I will ask you to rate the <u>effect</u> that incident would have on your travel, <u>if</u> you were to drive through that area. This effect could be in terms of delaying your arrival, inconvenience, or any other measures you wish to use. You will rate the effect it would have on your travel schedule using a scale of 1 to 7, with 1 having almost no effect, and 7 having an extreme effect on your travel. A traffic rating scale is posted ahead of you for reference. I'll ask you to tell me your rating and you just answer out loud.

Do you have any questions?
Are you ready to go through a practice?

In general just watch the videotape, and when the car ahead brakes, step on the brake. When the route guidance system tells you where to turn, or go straight, and you can actually see that place on the videotape (not when it gives you the instruction) press the go left, go straight, or go right keys. Finally, when you get a traffic information message, I'll ask you to rate the effect you think it would have on your travel. (Also, I want to remind you to keep your hand on the keys throughout the experiment, so you can respond as quickly as possible.)

Run through the practice stack. <u>Remind subjects to brake and use the directional keys</u> if they forget to do it twice.

*<u>*Check Data</u> after practice session. Quit out of SuperCard when subject is done.*

Do you have any questions before we begin the study?

Change the videotape to Final Tape, and record session on video cameras. Select the pre-determined system. Set-Up, type name and number. Start!

<u>After the subject views the videotape and data has been collected.</u>

OK, we're done with that part. You can get out of the car for now and stretch if you'd like. There is another activity to complete in the car after this. First, I'd like you to read these questionnaires and respond to

a few statements about the system you just used. *Give subject both questionnaires, and seat them at desk in the front of the lab.*

Quit out of SuperCard. Put the Practice tape back in the PC-VCR. When subject is done, ask them to sit in car again.

What you just saw was the __________ system. Now I'm going to demonstrate 3 other systems that present route guidance information. At the end, I'll ask you to compare all 4 systems. You do not need to brake or press the keys for any of this, just watch it. This first system is _______. *(Click on the first pre-determined preference system.) Continue to do the same for the other 2 systems. Quit out of Aldus.*

FOR VISUAL SYSTEM EXPLANATION:

This is a visual route guidance system. Instead of *hearing* traffic information, you will *see* Route Guidance on a map on the monitor in the car.

Click on "Show Graphic w/Land" or "Show Graphic NO Land" button, then do Command 2. Explain Screen:

This is an example of a Route Guidance screen you will see. Throughout the trip, this route guidance system would also tell you where to go at expressway exits and major intersections. However, it would present the information visually, using a map on the computer monitor, not by a voice over a speaker.

Can you see the "hand" (mouse) on the screen. I'll explain the screen from the bottom, up.

Explain the information on route guidance card:

1. Compass (direction traveling)
2. Current town
3. Current block address
4. Next major intersection (in green) and distance in miles to it
5. Within map, white arrows tell you what to do at next intersection (with or without Landmarks)
6. White arrow above map tells you the next turn or maneuver and distance to that point
7. Countdown blocks = 20 seconds (time to next maneuver)

With this system, as you continue along Plymouth Rd., you'll see other cross streets between Dixboro Rd and Green Rd because the route guidance system is constantly updating the roads you cross as you're driving along Plymouth Rd *(use mouse to show on route guidance screen)* **.**

Press Command 1 to return to Set-Up/Preference screen.

Also, for this part of the experiment, you don't have to press the keys or use the brake.

Demonstrate remaining systems.

All right, four systems were presented to you: There were 2 visual (with and without landmarks) and 2 auditory (with and without landmarks). Can you please rank the 4 systems in order of preference (in terms of ease of use), from 1st to 4th? *Record subject responses on collection sheet.*

OK, we're all done here. You can get out of the car now. We just need to finish up the paperwork for your payment and we'll be finished.

At the table in the front of the lab, give participant the appropriate payment form. Show them the parts to fill out.

Make sure paperwork is filled out properly, and pay the subject (if not university employee). Otherwise tell participant that the amount will be on their next paycheck. Thank the participant and walk them back out to the third floor elevator of UMTRI.

<u>After Subject has left:</u>

Clear the fields on the Mac.

Copy the data for that session off the Hard Drive, onto a floppy that is labeled with that subject's number. Change subject name and number on the Mac, for the next subject.

If another subject will be run that day, do steps up to Set-Up on Mac.

If the last subject of the day, shut down Mac and other equipment.

APPENDIX D - VISUAL ROUTE GUIDANCE SYSTEM SUBJECT INSTRUCTIONS

Before subject arrives:
Check schedule to determine subject name, number and designated system order (according to counterbalanced ordering.)

Laboratory Activities (if first subject of the day)
VCR setup, Mac, monitor, cables OK

Set up Titmus vision tester in the laboratory. Have ready a consent form, biographical form, ranking preference, cost, safety/rating questions, travel effect form, and payment forms (University employee or non-U employee), and $15.00 cash (if subject is not a University employee).

Also have a VCR tape labeled with subject number and disks to copy data off right away. Fill in as much information on the bio form as possible.

Turn on the Rodime, Mac and then Realistic. Put the Practice tape in the PC-VCR. Find Aldus SuperCard. Double click on the pre-determined system practice. Select Set-Up, let the PC-VCR run and stop.

Turn on the 2 cameras (remove lens caps). Turn on Video recording equipment (VCR, both cameras, audio recorder).

When Subject Arrives

Hi, are you __________ (use subject's name)**? I'm** __________ (experimenter's name). **Thanks for coming, let's go down to the conference room so we can begin.**

Take subject down to conference room and be seated.

As I mentioned earlier, this study will take about 1 1/2 hours to complete, and you'll be paid $15.00. It involves a simulated trip in Southeastern Michigan.

The purpose of this experiment is to determine the best way to present drivers with route guidance and traffic information in cars of the future. Since people such as yourself will be driving while obtaining that information, the system must be easy to use and not distract drivers from watching the road. Therefore, your opinion is important.

Before we start, there is some paperwork to complete. First you need to read and sign this official consent form, which basically repeats in writing what I just said. I also want to mention that if you feel uncomfortable at any time in the experiment, you should let me know and we can stop.

Have participant read and sign the consent form.

Also, we need to know a little more about you.

Go through bio form with subject and fill in the appropriate answers.

Now we can check your vision.

Turn on both eye switches on the vision tester, slide 1. Adjust the height of the vision tester for the subject. Make sure subject wears any vision correction.

Can you see in the first diamond, that the top circle is complete but the other three (on the right, left, and bottom) are incomplete? Can you tell me which circle is complete in the second diamond? The third?...

Prompt the subject until s/he has missed two in a row. Record the last number answered correctly on the bottom of the bio form. Take subject to laboratory.

Now that that is complete, please sit in the driver's seat of the car. Are you comfortable? Would you like the seat moved at all? *(Show subject where seat controls are and steering wheel adjustment is)* **To help us keep track of what happens in this experiment, we are videotaping all the sessions. There is a camera in front of you (*point to it*) and one behind you (*point to it*).**

Explain systems to subject:

Like I said before, the purpose of this study is to determine the best way to present route guidance and traffic information to drivers. Route guidance information tells you how to get to a certain destination. In systems of this type, the computer would know where you are. You would tell it where you want to go, either a street address, an intersection, or the name of a place, such as Detroit Metro Airport. It will figure out the best way to get you there, and as you drive, tell you when to turn. It could do this using a map on a computer monitor, such as the one you'll be using. The computer will also monitor traffic, and will tell you about any problems that occur.

This experiment concerns a hypothetical 25-minute trip from Taylor to a business in Canton, Michigan. Don't worry if you don't know the area, the computer will tell you how get to the destination by indicating when and where you should turn. In actuality, this route may not be the fastest way. It was chosen to help test the design.

There are two monitors. The one straight ahead *(point to it)* **will show you a videotape of the route you are driving during your trip. As you are driving, when the car in front of you brakes, you should also brake. So when their brake lights go on, step on the brakes as quickly as possible. Then, when their brake lights go off, take your foot off the brake. To check that you are paying attention, sometimes that car will brake unexpectedly, so be ready.**

The other monitor is in the car.*(point to it).* **This is the route guidance system.**

Use "Command 3" to flip forward to route guidance card.

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

Can you see the "hand" (mouse) on the screen. I'll explain the screen from the bottom, up.

Explain the information on route guidance card:

1. Compass
2. Current town
3. Current block address
4. Next major intersection (in green) and distance in miles to it
5. Within map, white arrows tell you what to do at next intersection (with or without Landmarks)
6. White arrow above map tells you the next turn or maneuver and distance to that point
7. Countdown blocks = 20 seconds (time to next maneuver)

This system will guide you along the route which you'll be watching on the monitor ahead of you.

Do you see the white keys to the right? You'll be using those keys to indicate what turn or maneuver you'll be making at an exit or intersection. The left key means turn or bear left, the middle key means go straight, and the right key means turn or bear right.

As soon as you can see, on the videotape, the actual location, sign, traffic light, or some other clue that you have reached the exit or intersection that you are supposed to do something at -- press the button indicating what the route guidance system tells you to do, either turn or bear left, go straight, turn or bear right. *(point to the keys)*

For example, as you are driving along Plymouth Rd and on the videotape you see Dixboro Rd press the key that the route guidance system tell you to do at Dixboro Rd.

So, what would you do at this intersection (point with mouse)**?**

In this study, as you continue along Plymouth Rd., you'll see other cross streets between Dixboro Rd and Green Rd because the route guidance system is constantly updating the roads you cross as you're driving along Plymouth Rd *(use mouse to show on route guidance screen)* **As soon as you see those other cross streets on the videotape, I want you to press the white key corresponding to what the route guidance system tells you to do at that street. So at every cross street you see on the route guidance system you should indicate what the system tells you to do.**

You should keep your fingers on these keys throughout the experiment since we will be collecting your response time.

Sometimes instead of route guidance, you will briefly see traffic information describing an accident, construction site, or any other traffic problem.

Flip to traffic information screen. Explain information on it.

You will hear two beeps before that information appears on the screen.

Explain screen: **Yellow areas mean a moderate slowdown, and red areas mean a more severe slowdown.**

When this screen appears, I will ask you to tell me what effect that incident would have on your travel, if you were to drive through that area. This could be in terms of delaying your arrival, inconvenience, or any other measures you wish to use. After you read the traffic information message, please rate the effect it would have on your travel schedule plans using a scale of 1 to 7, with 1 having almost no effect, and 7 having an extreme effect. A traffic rating scale is posted ahead of you for reference. When the traffic information screen appears, I'll prompt you to tell me your rating and you just answer out loud.

Are you ready to go through a practice?

In general just watch the videotape, and when the car ahead brakes, step on the brake. When the route guidance system tells you where to turn, or go straight, and you can actually see that place on the videotape (not when it gives you the instruction on the screen) press the go left, go straight, or go right keys. Finally, when you get a traffic information message, I'll ask you to rate the effect you think it would have on your travel. (Also, you should keep your hand on the keys throughout the experiment.)

Run through the practice stack. Remind subjects to brake and use the directional keys if they forget to do it twice.

**Check Data after practice session. Quit out of SuperCard when subject is done.*

Do you have any questions before we begin the study?

Change the videotape to Final Tape, and record session on video cameras. Select the pre-determined system. Set-Up, type name and number. Start!

After the subject views the videotape and data has been collected.

OK, we're done with that part. You can get out of the car for now and stretch if you'd like. Now, I'd like you to read these questionnaires and respond to a few statements about the system you just used. *Give subject both questionnaires, and seat them at desk in the front of the lab.*

Quit out of SuperCard. Put the Practice tape in the PC-VCR. When subject is done, ask them to sit in car again.

What you just saw was the __________ system. Now I'm going to demonstrate 3 other systems that present route guidance information. At the end, you'll be asked to compare all 4 systems. (You do not need to brake or press the keys for this.) This first system is _______. *(Click on the first pre-determined preference system.) Continue to do the same for the other 2 systems. Quit out of Aldus.*

All right, four systems were presented to you: There were 2 visual (with and without landmarks) and 2 auditory (with and without landmarks). Can you please rank the 4 systems in order of preference (in terms of ease of use), from 1st to 4th? *Record subject responses on collection sheet.*

OK, we're all done here. You can get out of the car now. We just need to finish up the paperwork for your payment and we'll be finished.

At the table in the front of the lab, give participant the appropriate payment form . Show them the parts to fill out.

Make sure paperwork is filled out properly, and pay the subject (if not university employee). Otherwise tell participant that the amount will be on their next paycheck. Thank the participant and walk them back out to the third floor elevator of UMTRI.

After Subject has left:

Clear the fields on the Mac.

Copy the data for that session off the Hard Drive, onto a floppy that is labeled with that subject's number. Change subject name and number on the Mac, for the next subject.

If another subject will be run that day, do steps up to Set-Up on Mac.

If the last subject of the day, shut down Mac and other equipment.

APPENDIX E - BIOGRAPHICAL FORM

University of Michigan Transportation Research Institute
Human Factors Division

Subject: ______

Route Guidance & Traffic Information Biographical Form

Date: ______

Name: ______________________________

Male Female (circle one) Age: ____________

Occupation: ______________________

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

Other: ______________________________

(If retired or student, note it and your former occupation or major)

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

How comfortable are you using maps?

very comfortable | moderately comfortable | neutral | moderately uncomfortable | very uncomfortable

How many times in the last six months have you used a map?

0-2 times | 3-5 times | 6-8 times | 9-12 times | 13 + times

How familiar are you with the Canton, Romulus, and Taylor area?

very familiar | moderately familiar | neutral | moderately unfamiliar | very unfamiliar

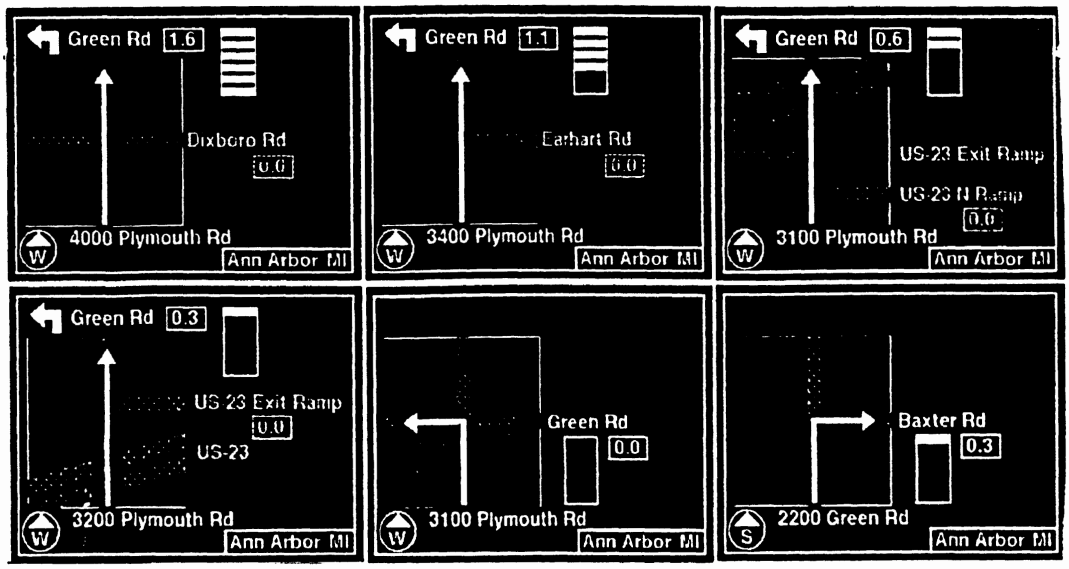
How many times per week do you rely on traffic information reports to get to a destination quickly and efficiently?

0-1 times | 2-3 times | 4-5 times | 6-7 times | 8 + times

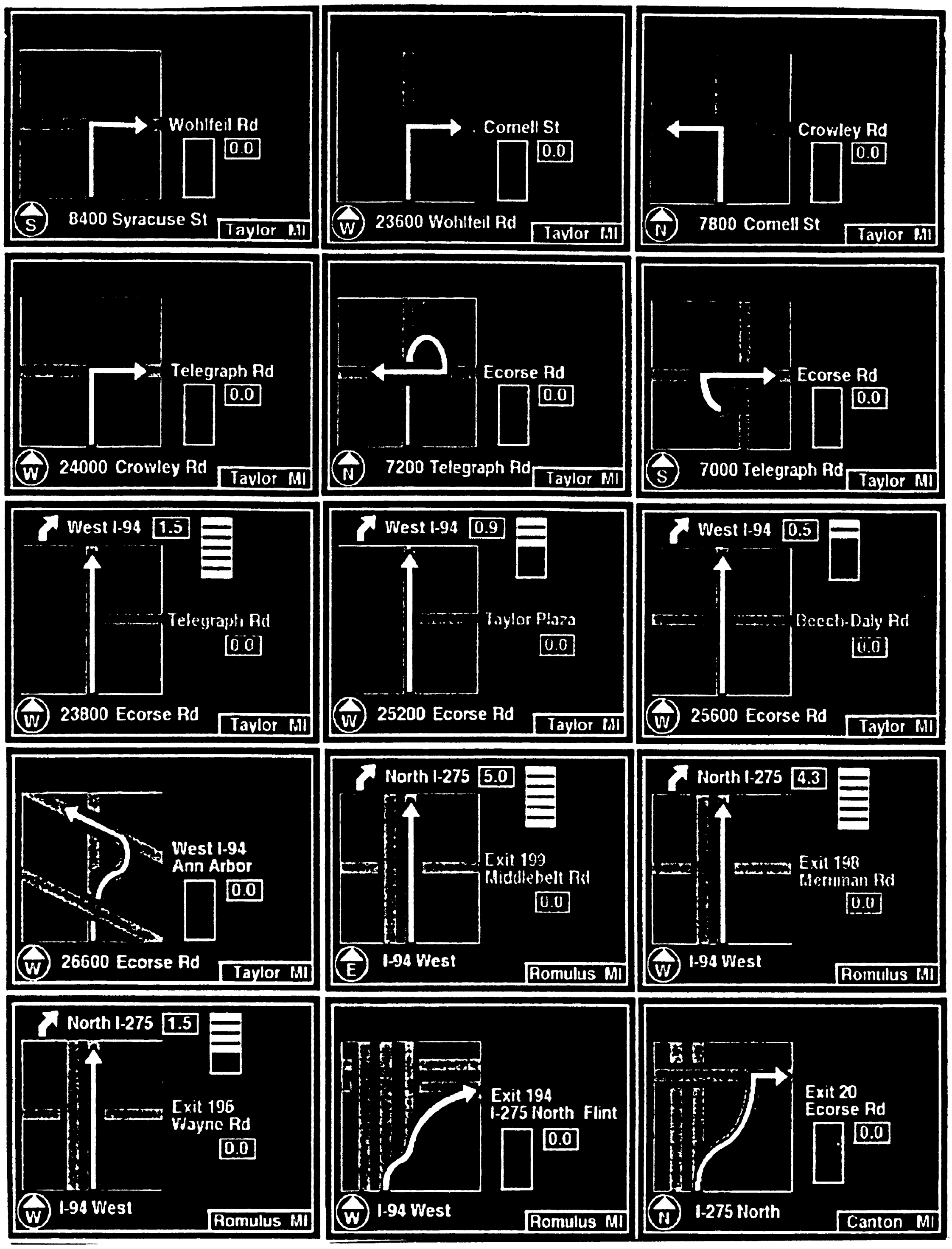
TITMUS VISION: (Landolt Rings)

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

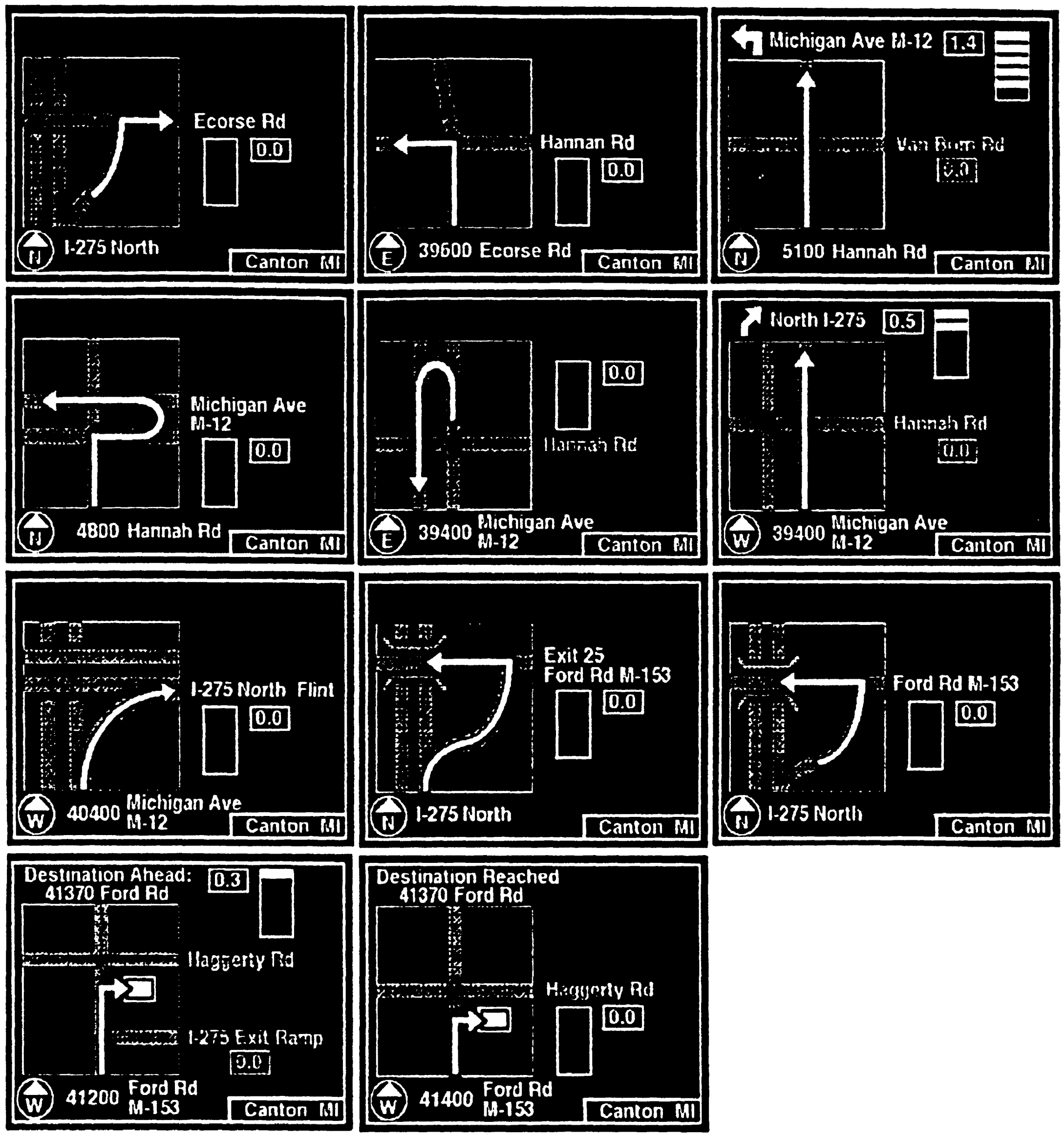
APPENDIX F - VISUAL ROUTE GUIDANCE SCREENS



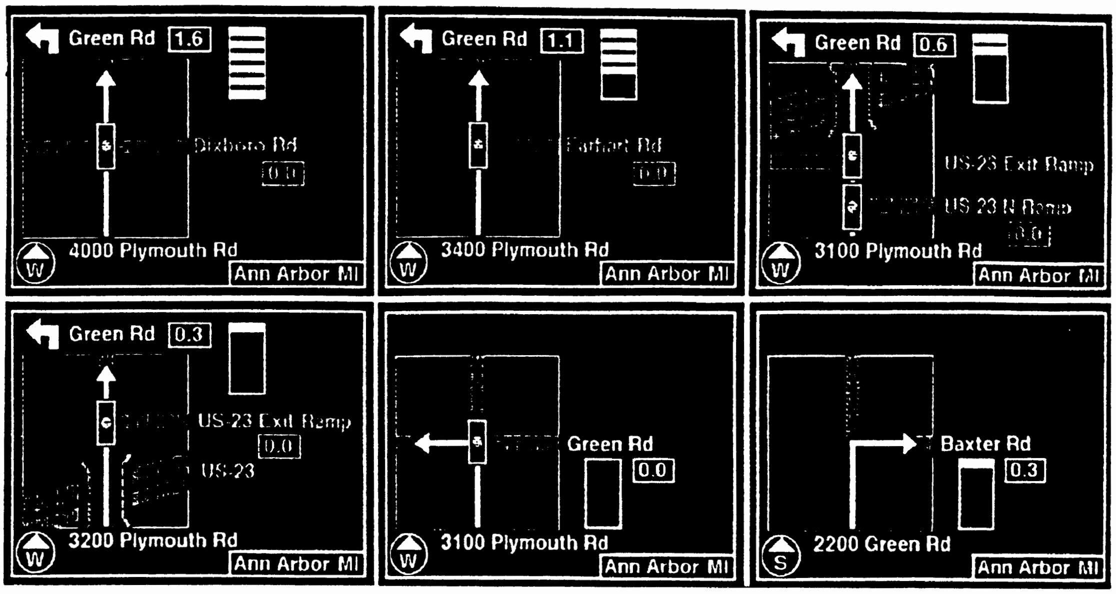
Basic visual route guidance (without landmarks) practice screens.



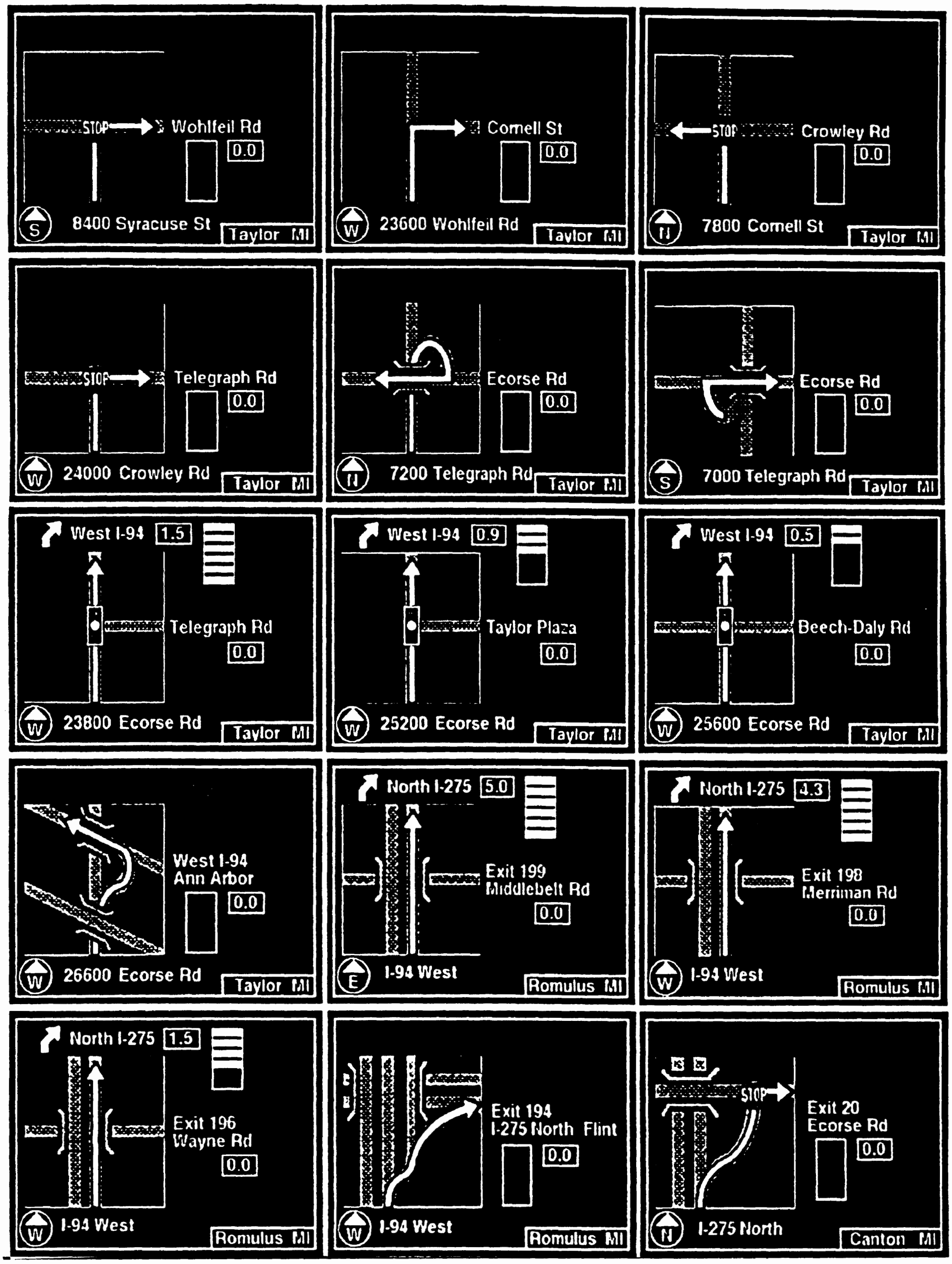
Basic visual (without landmarks) route guidance screens (shown from left to right, then top to bottom).



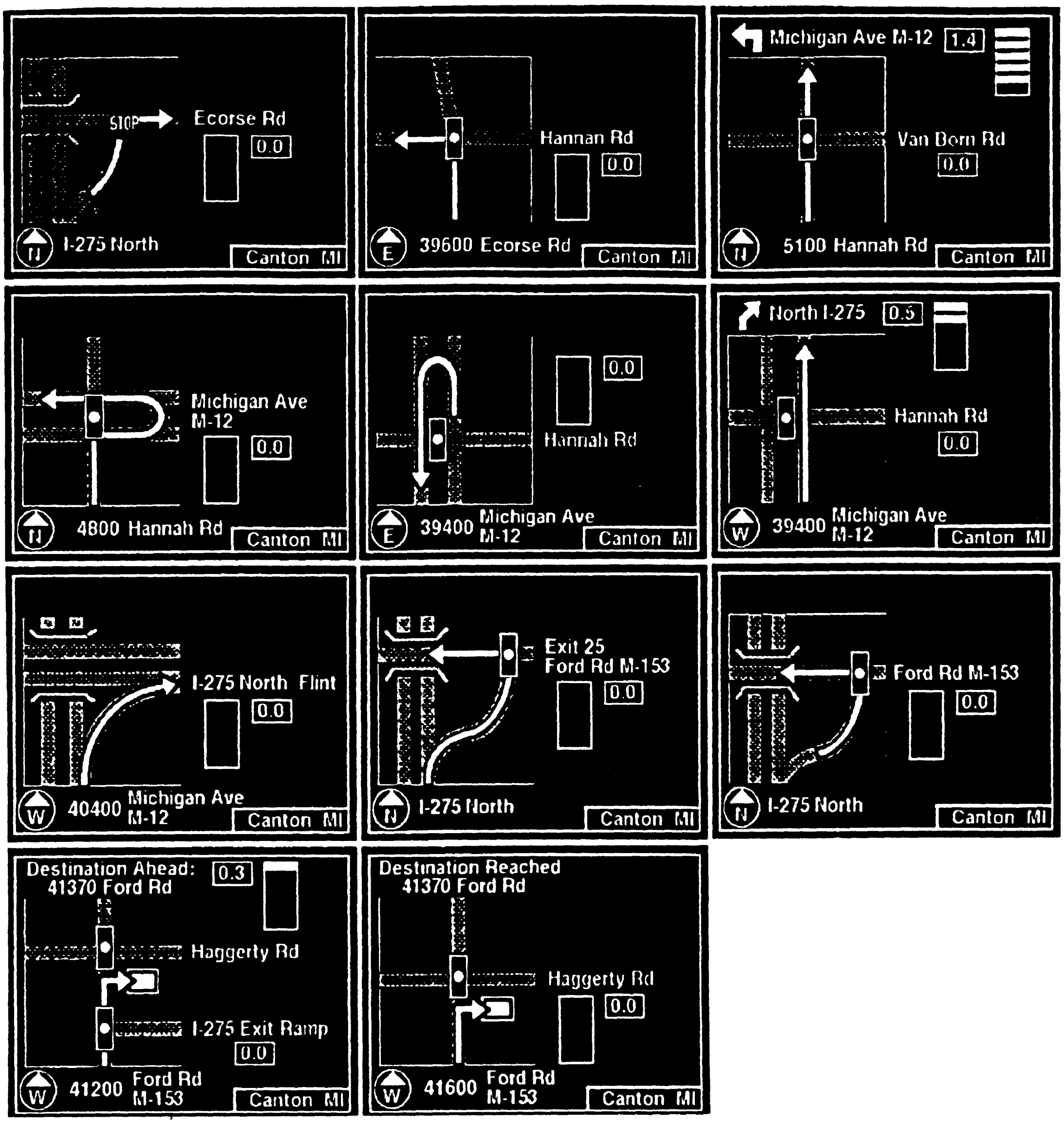
Basic visual (without landmarks) route guidance screens (from left to right, then top to bottom) (continued).



Landmark visual route guidance practice screens (shown left to right, then top to bottom).



Landmark visual route guidance screens (shown left to right, then top to bottom).



Landmark visual route guidance screens (shown left to right, then top to bottom) (continued).

Practice auditory route guidance instructions without landmarks.

In 1 point 7 miles at Green Road turn left.
In 1 mile, at Green Road, turn left.
At Green Road, turn left.

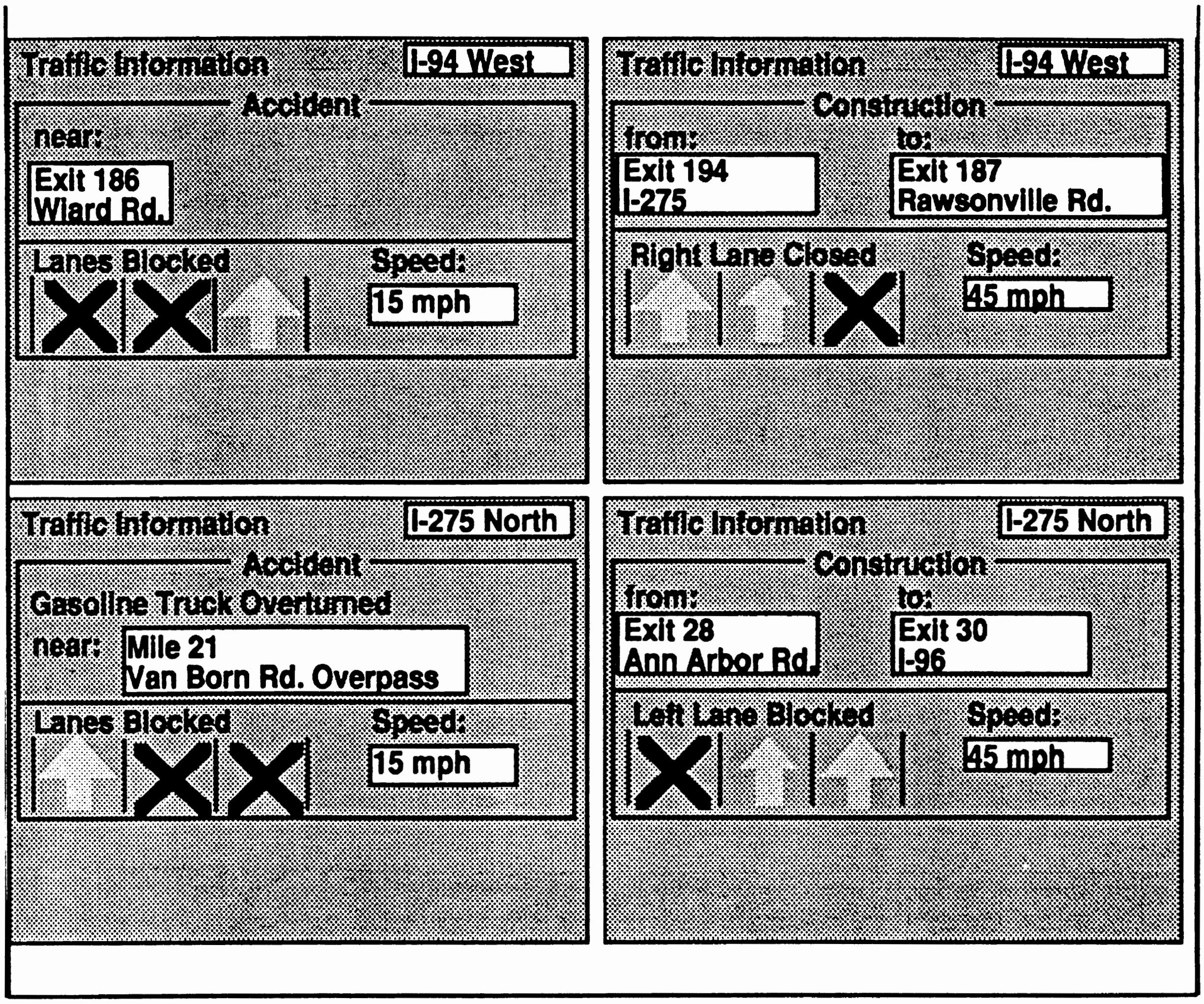
Auditory route guidance instructions without landmarks.

At Wohlfiel Road, turn right.
At Cornell Road, turn right.
At Crowley Road, turn left.
At Telegraph Road, turn right.
In point 3 mile, at west-bound Ecorse Road, enter.
At west-bound Ecorse Road, enter.
In 1 point 5 miles at I-94 West, enter.
In 1 mile, at I-94 West, enter.
At I-94 West, enter.
In 5 point 1 miles at Exit 194 I-275 North, exit.
In 2 miles at Exit 194 I-275 North, exit.
At Exit 194 I-275 North exit and then bear right.
In 2 miles at Exit 20 Ecorse Road, exit.
At Exit 20 Ecorse Road, exit and then turn right.
In point 8 mile, at Hannan Road, turn left.
At Hannan Road, turn left.
In 2 miles at Michigan Avenue, turn left.
In 1 mile, at Michigan Avenue, turn right and then make an immediate u-turn.
At Michigan Avenue, turn right and then make an immediate u-turn.
In point 5 mile at I-275 North, enter.
At I-275 North, enter.
In 3 miles at Exit 25, Ford Road, exit.
In 2 miles at Exit 25, Ford Road, exit.
At Exit 25, Ford Road, exit and then turn left.
Your destination is on the right.

Auditory route guidance instructions with landmarks.

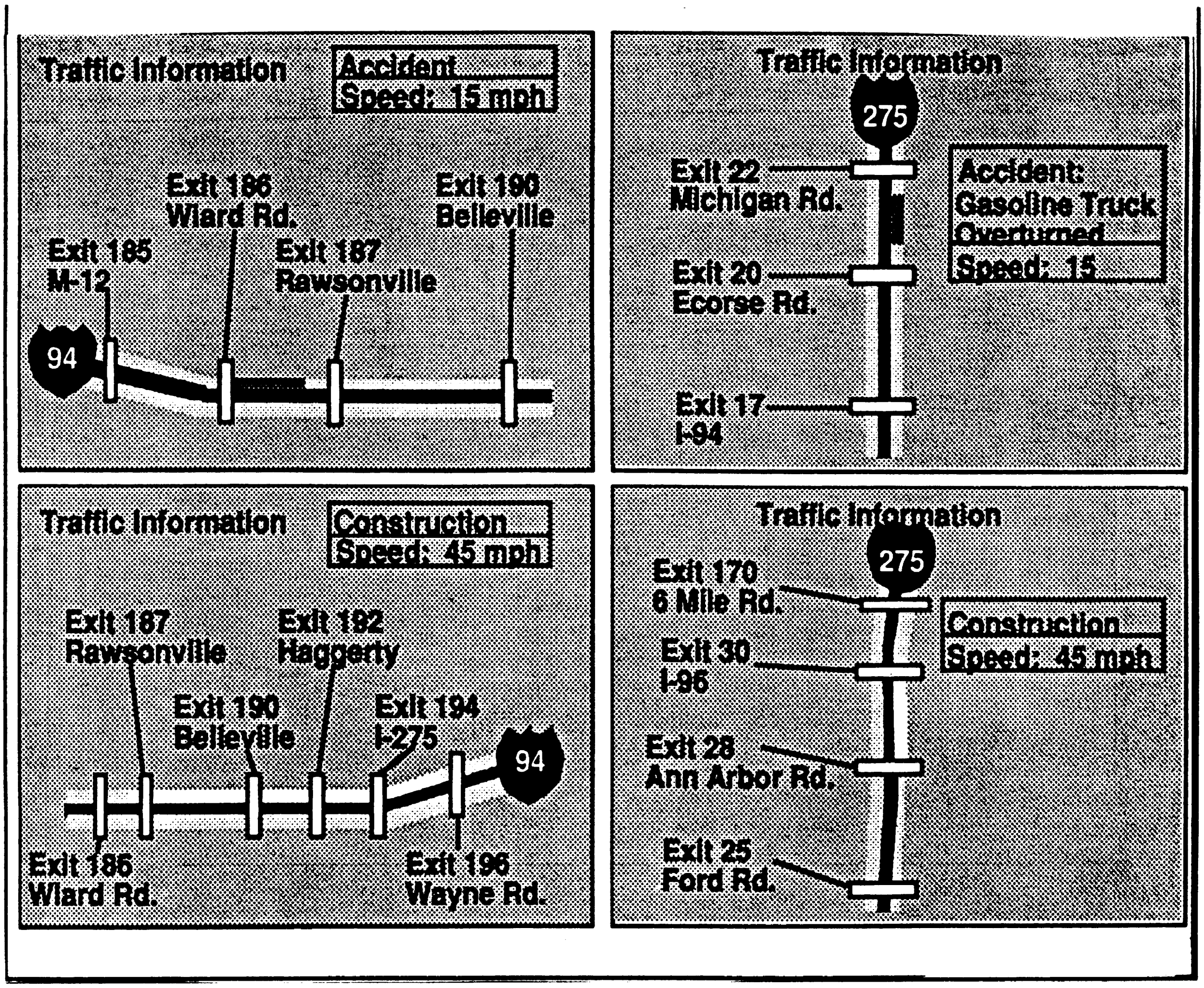
At the stop sign at Wohlfiel Road, turn right.
At Cornell Road, turn right.
At the stop sign at Crowley Road, turn left.
At the stop sign at Telegraph Road, turn right.
In point 3 mile after the overpass at west-bound Ecorse Road, enter.
At west-bound Ecorse Road, enter.
In 1 point 5 miles at I-94 West, enter.
In 1 mile, after the overpass, at I-94 West, enter.
After the overpass, at I-94 West, enter.
In 5 point 1 miles at Exit 194 I-275 North, exit.
In 2 miles at Exit 194 I-275 North, exit.
At Exit 194 I-275 North exit and then bear right.
In 2 miles at Exit 20 Ecorse Road, exit.
At Exit 20 Ecorse Road, exit and then turn right.
In point 8 mile, at the traffic light at Hannan Road, turn left.
At the traffic light at Hannan Road, turn left.
In 2 miles at Michigan Avenue, turn left.
In 1 mile at the traffic light at Michigan Avenue, turn right and then make an immediate u-turn.
In point 5 mile at I-275 North, enter.
At I-275 North, enter.
In 3 miles at Exit 25, Ford Road, exit.
In 2 miles at Exit 25, Ford Road, exit.
At Exit 25, Ford Road, exit and then turn left.
Your destination is on the right.

APPENDIX G - TRAFFIC INFORMATION SCREENS



Text traffic information screens.

Note: The graphic, map-based traffic information screens contain all the same information as the text-based screens, except for the lane blockages. Also, the map-based screen provides more references to problem location through additional street labels. A driver less familiar with the area may have more options for diversion with this format than he or she would with text-based information.



Graphic traffic information screens.

Note: The auditory version of the traffic information system contains exactly the information found in the text-based visual version, presented verbally.

Auditory traffic information messages.

Practice message
Traffic information, construction, on Plymouth Road from Murfin Road to Barton Drive. Right lane blocked, speed is 20 miles per hour.

Test route messages
Traffic Information for I-94 West, an accident, near Exit 186 Wiard Road,. Right lane blocked, speed is 15 miles per hour.
Traffic Information for I-94 West, construction, from Exit 194 I-275 to Exit 187 Rawsonville Road. Right lane closed, speed is 45 miles per hour.
Traffic Information for I-275 north, an accident, overturned gasoline truck, near mile 21 Van Born Road overpass. Right two lanes blocked, speed is 15 miles per hour.
Traffic Information, for I-275 north, construction, from Exit 28 Ann Arbor Road to Exit 30 I-96. Left lane blocked, speed is 45 miles per hour.

APPENDIX H - ROUTE GUIDANCE AND TRAFFIC INFORMATION POST-TEST QUESTIONNAIRE

Subject ______
Date ________

The route guidance information provided by this system is useful.

strongly agree	somewhat agree	neutral	somewhat disagree	strongly disagree

The traffic information provided by this system is useful.

strongly agree	somewhat agree	neutral	somewhat disagree	strongly disagree

I would likely use this system for my daily travel.

strongly agree	somewhat agree	neutral	somewhat disagree	strongly disagree

I would likely use this system when driving in unfamiliar areas.

strongly agree	somewhat agree	neutral	somewhat disagree	strongly disagree

I would use this system if I were in a hurry.

strongly agree	somewhat agree	neutral	somewhat disagree	strongly disagree

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

strongly agree	somewhat agree	neutral	somewhat disagree	strongly disagree

It is safe for me to use this system while driving.

strongly agree	somewhat agree	neutral	somewhat disagree	strongly disagree

It is safe for an inexperienced driver to use this system while driving.

strongly agree	somewhat agree	neutral	somewhat disagree	strongly disagree

It is safe for another passenger in the car to use this system while I drive.

strongly agree	somewhat agree	neutral	somewhat disagree	strongly disagree

How much would you pay for this system? $________________

APPENDIX G - AUDITORY ROUTE GUIDANCE DIFFICULTY QUESTIONS

This is a list of several tasks you may do while driving. I would like you to rate the difficulty of performing each task while driving. Please use a scale of 1 to 10 where 1 implies not at all difficult and 10 implies that it is extremely difficult to do while driving.

Not at all Difficult ... Extremely Difficult

|-------|-------|-------|------|-------|------|-------|-------|-------|

1 2 3 4 5 6 7 8 9 10

Tuning a car radio (NOT using presets)
1 2 3 4 5 6 7 8 9 10

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

Adjusting a car heater or air conditioner
1 2 3 4 5 6 7 8 9 10

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

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

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

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

Now I have a few more tasks for you to rate. These involve using the route guidance and traffic information system you just saw while actually driving. Again, please rate their difficulty from 1 to 10 with 10 being extremely difficult.

Hearing the traffic information alert tone
1 2 3 4 5 6 7 8 9 10

Reading/Listening to the information on the route guidance screen
1 2 3 4 5 6 7 8 9 10

Reading/Listening to the traffic information reports
1 2 3 4 5 6 7 8 9 10

Determining the next maneuver you should make from the route guidance system.
1 2 3 4 5 6 7 8 9 10

Looking for the next turn mentioned by the route guidance system
1 2 3 4 5 6 7 8 9 10

Looking at the route guidance system to see it update
1 2 3 4 5 6 7 8 9 10

APPENDIX I - VISUAL ROUTE GUIDANCE DIFFICULTY QUESTIONS

This is a list of several tasks you may do while driving. I would like you to rate the difficulty of performing each task while driving. Please use a scale of 1 to 10 where 1 implies not at all difficult and 10 implies that it is extremely difficult to do while driving.

Not at all Difficult — Extremely Difficult

|--------|--------|--------|-------|--------|-------|--------|--------|--------|

1 2 3 4 5 6 7 8 9 10

Tuning a car radio (NOT using presets)
1 2 3 4 5 6 7 8 9 10

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

Adjusting a car heater or air conditioner
1 2 3 4 5 6 7 8 9 10

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

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

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

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

Now I have a few more tasks for you to rate. These involve using the route guidance and traffic information system you just saw while actually driving. Again, please rate their difficulty from 1 to 10 with 10 being extremely difficult.

Hearing the traffic information alert tone
1 2 3 4 5 6 7 8 9 10

Reading the information on the route guidance screen
1 2 3 4 5 6 7 8 9 10

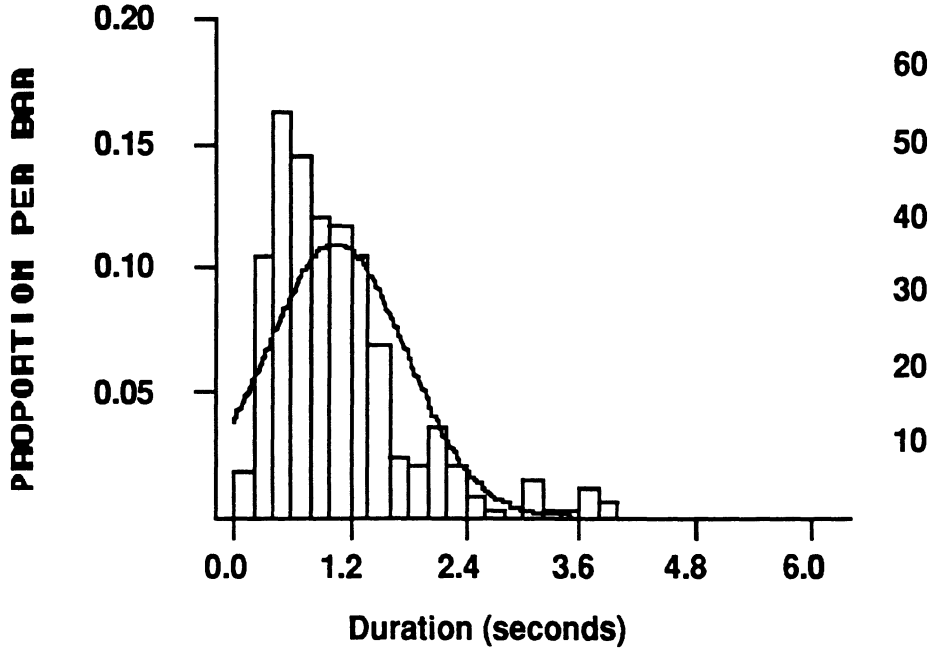
Reading the traffic information reports
1 2 3 4 5 6 7 8 9 10

Determining the next maneuver you should make from the route guidance system.
1 2 3 4 5 6 7 8 9 10

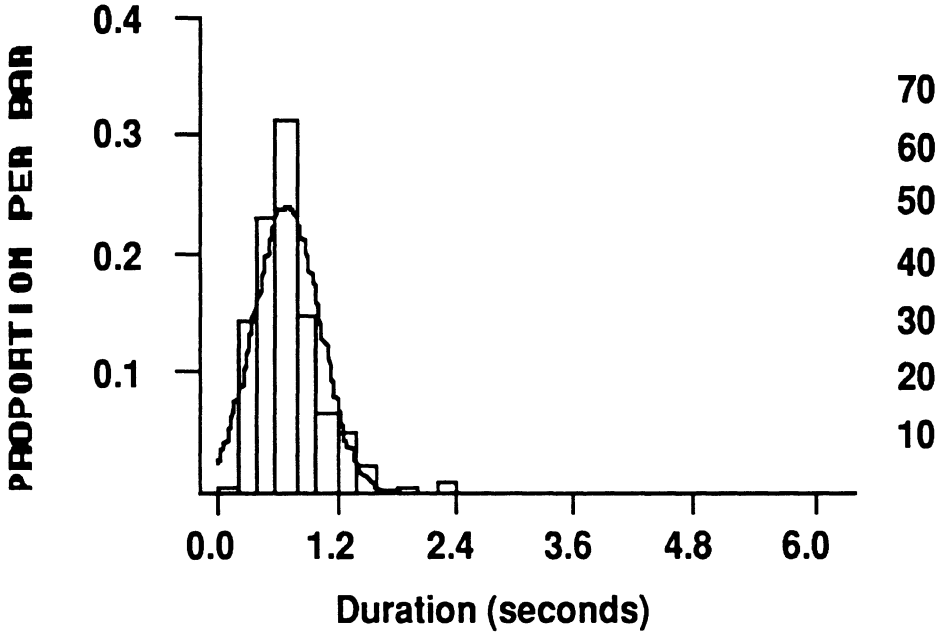
Looking for the next turn indicated by the route guidance system
1 2 3 4 5 6 7 8 9 10

Looking at the route guidance system to see it update
1 2 3 4 5 6 7 8 9 10

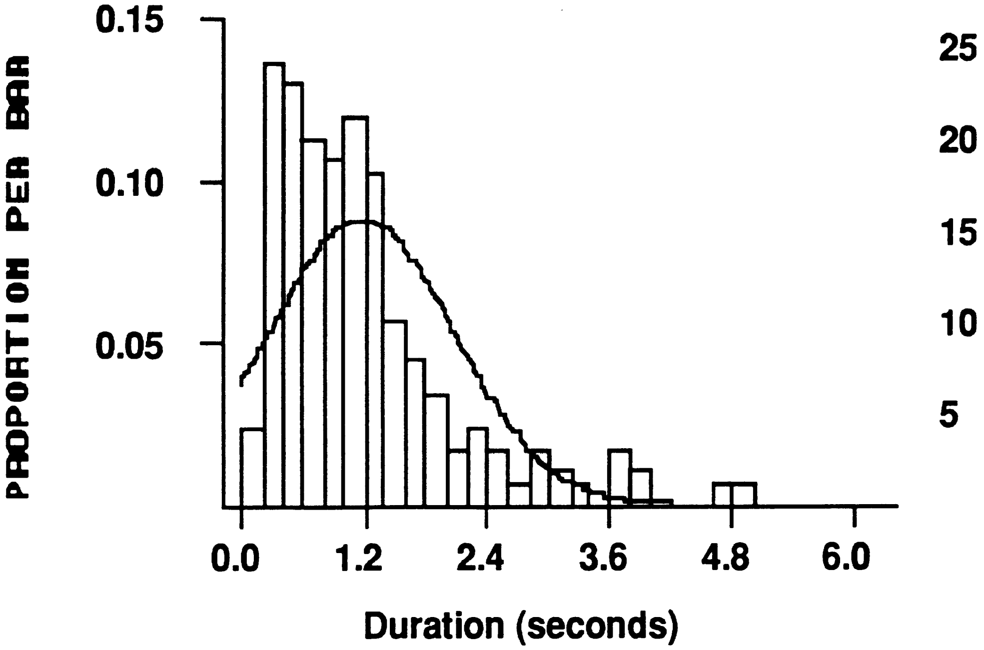
APPENDIX J - EYE FIXATION DISTRIBUTIONS TO ROUTE GUIDANCE DISPLAYS



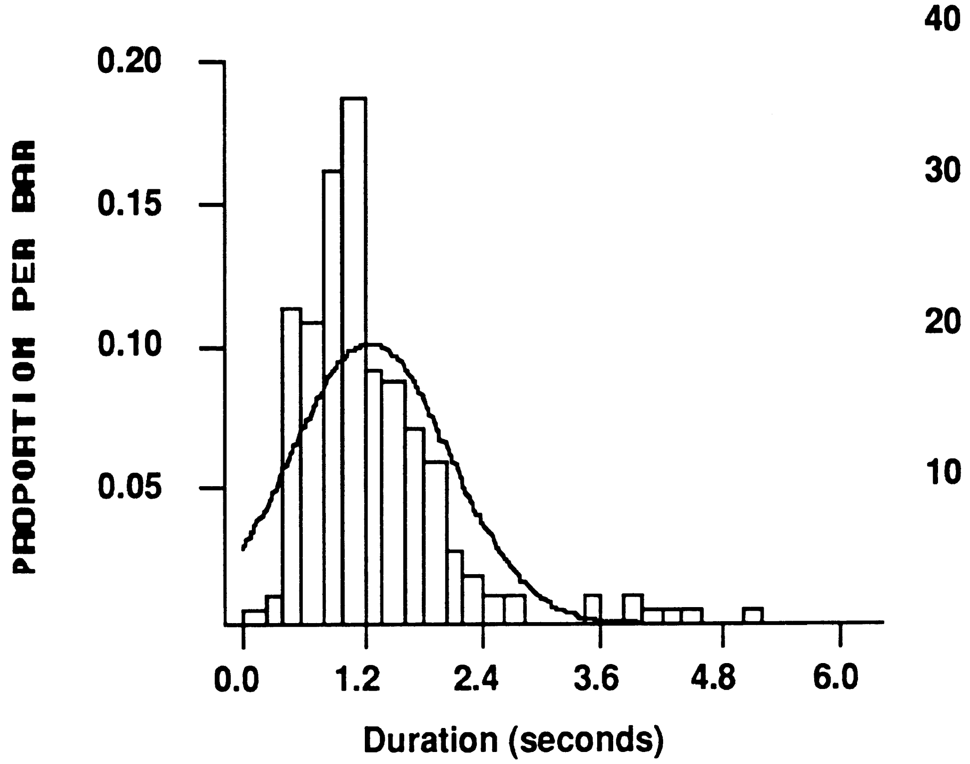
Eye fixation duration for visual route guidance interface with landmarks, older male
mean = 1.05 seconds, standard deviation = 0.72 seconds



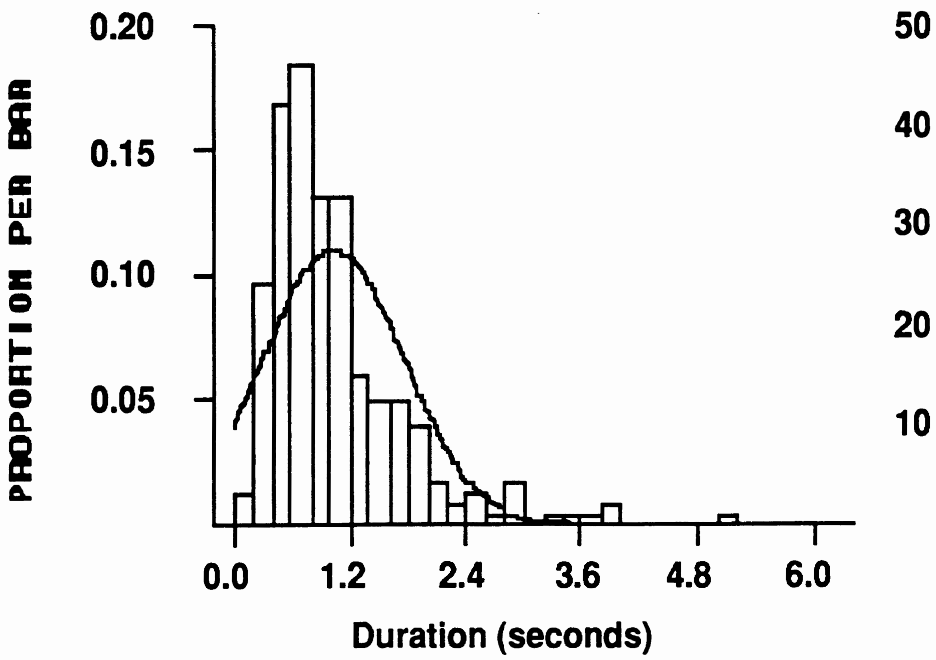
Eye fixation duration for visual route guidance interface with landmarks, younger female
mean = 0.70 seconds, standard deviation = 0.33 seconds



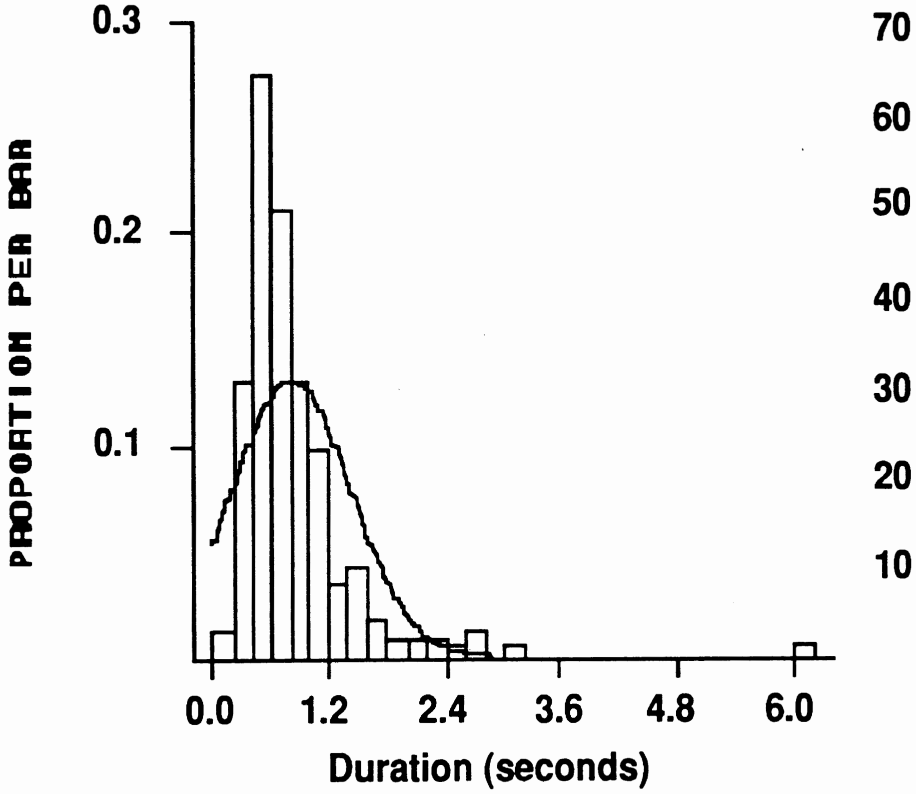
Eye fixation duration for visual route guidance interface with landmarks, older female
mean = 1.10 seconds, standard deviation = 0.93 seconds



Eye fixation duration for visual route guidance interface without landmarks, younger male
mean = 1.27 seconds, standard deviation = 0.79 seconds



Eye fixation duration for visual route guidance interface without landmarks, older female
mean = 1.03 seconds, standard deviation = 0.72 seconds



Eye fixation duration for visual route guidance interface without landmarks, older male
mean = 0.81 seconds, standard deviation = 0.61 seconds

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1 Green, P. (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.

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