PB86-226206

MOTORIST DIRECTION-FINDING AIDS: RECOVERY FROM FREEWAY EXITING ERRORS

U.S. Department of Transportation

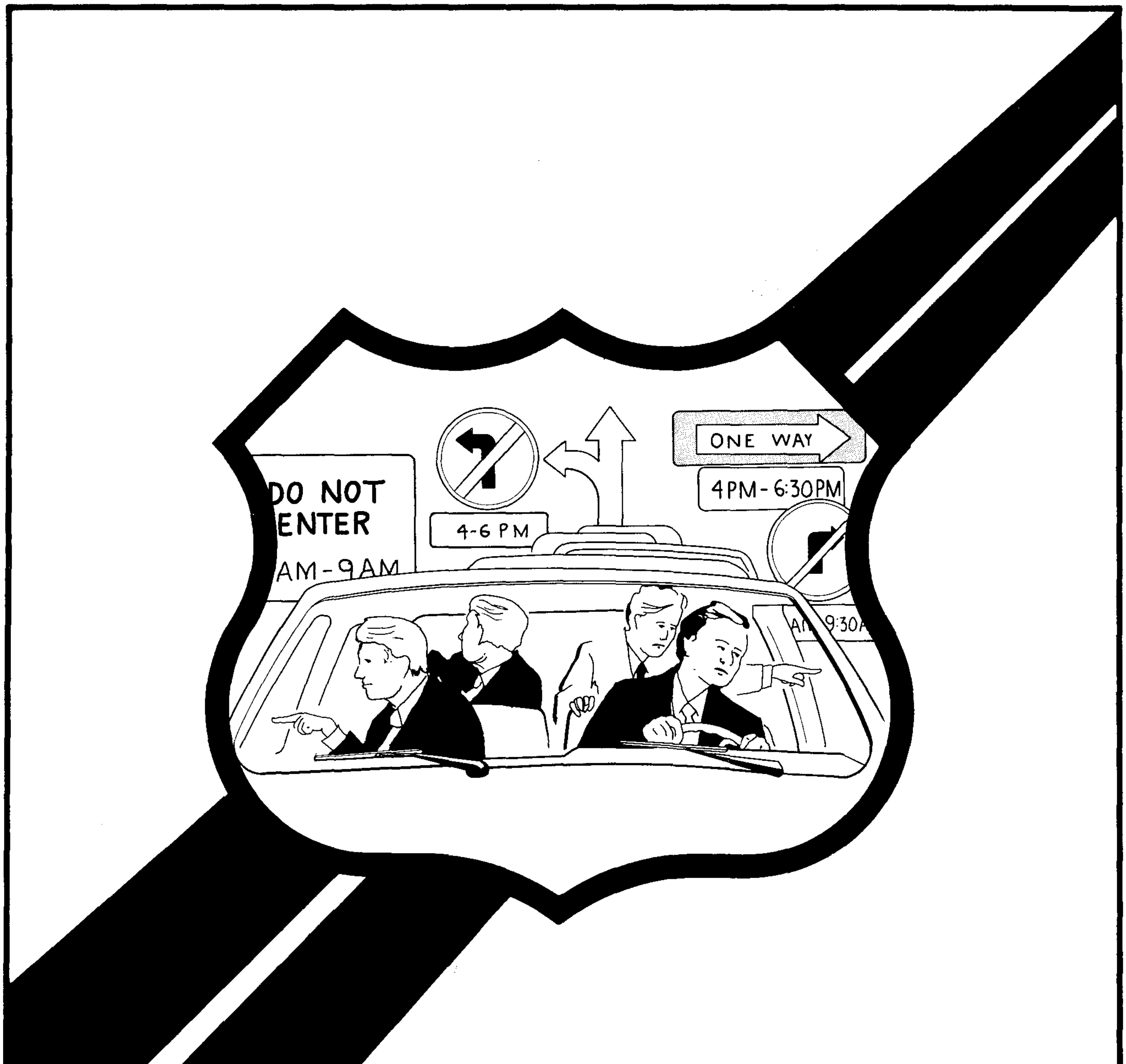
Federal Highway Administration

Research, Development, and Technology

Turner-Fairbank Highway Research Center
6300 Georgetown Pike
McLean, Virginia 22101

Report No.
FHWA/RD-82/098

Final Report
December 1984



FOREWORD

The work prepared herein was conducted as an in-house study by the Systems Technology Division, Office of Safety and Traffic Operations Research and Development. The study was initiated as part of Federally Coordinated Project 2N, "Motorist Information System." The findings of this study will be of interest to researchers and persons concerned with efficient motorist direction-finding, energy conservation and highway safety.

The report is being distributed on a limited basis to selected researchers, technical specialists, and the National Technical Information Service.

Stanley R. Byington, Director
Office of Safety and Traffic
Operations R&D

NOTICE

This document is disseminated under the sponsorship of the Department of Transportation in the interest of information exchange. The United States Government assumes no liability for its contents thereof.

The contents of this report reflect the views of the contractor, who is responsible for the accuracy of the data presented herein. The contents do not necessarily reflect the official policy of the Department of Transportation.

This report does not constitute a standard, specification, or regulation.

The United States Government does not endorse products or manufacturers. Trademarks or manufacturers' names appear herein only because they are considered essential to the object of this document.

Technical Report Documentation Page

1. Report No. FHWA/RD-82/098	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Motorist Direction Finding Aids: Recovery From Freeway Exiting Errors		5. Report Date December 1984
		6. Performing Organization Code
		8. Performing Organization Report No.
7. Author(s) Truman M. Mast and William Lareau, Jr.		
9. Performing Organization Name and Address Department of Transportation Federal Highway Administration HSR-10 Washington, D.C. 20590		10. Work Unit No. (TRAIS) 22N2-072
		11. Contract or Grant No. Staff Study
12. Sponsoring Agency Name and Address Department of Transportation Federal Highway Administration HSR-10 Washington, D.C. 20590		13. Type of Report and Period Covered Final Report
		14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

Two controlled field experiments were conducted to investigate driver direction-finding performance following a missed exit error on a freeway. A total of 118 male and female subjects was observed as they attempted to navigate to a pre-assigned destination after an induced error. The effectiveness of road maps, an interactive phone information center, and a schematic map generated by a simulated computerized information center were studied.

Unaided subjects were observed to have considerable difficulty in recovering from the missed exit error. Use of road maps increased route-finding efficiency. However, a significant proportion of the subjects could not or would not use available maps. The more sophisticated navigational aids were the most effective in improving direction-finding performance. Subjects using the schematic map from the computerized information center performed the best.

A severe motorist direction-finding problem exists and additional studies are required to identify practical solutions that can be implemented on a wide scale. It is also concluded that improved motorist direction-finding is a major means to conserve fuel.

17. Key Words Motorist direction-finding, energy conservation, highway navigation, highway information, computerized highway information	18. Distribution Statement No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161

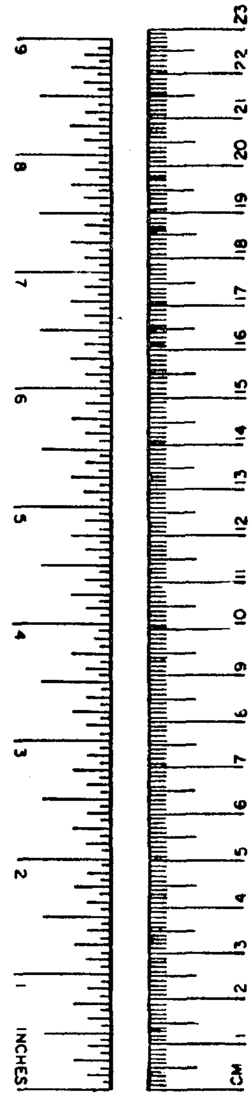
19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	57	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

METRIC CONVERSION FACTORS

APPROXIMATE CONVERSIONS FROM METRIC MEASURES

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
	LENGTH			
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.6	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



APPROXIMATE CONVERSIONS FROM METRIC MEASURES

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	8.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	36	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F

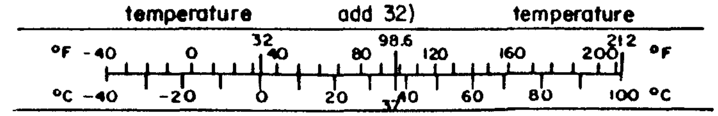


TABLE OF CONTENTS

Table of Contents (continued)

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

Improvements in motorist direction-finding performance could reduce unnecessary travel, provide an important savings of fuel, increase highway safety, and decrease the physical deterioration of the system. There could also be benefits associated with reductions in traffic congestion, air pollution, and driver frustration. The potential economic gain and energy conservation is significant. It has been estimated an annual savings of over 15 billion miles and 4 billion gallons of gasoline could be achieved through better driver route-selection and route-following performance. There is evidence substantial safety benefits could be achieved by giving motorists improved ways to solve their route-following problems. Lost and confused motorists cause accidents by slowing, stopping or backing up at decision points, reading maps under dangerous conditions, and driving erratically. Unnecessary travel also causes greater wear on the highway system. Truckers traveling into unfamiliar areas have similar route-following problems as automobile drivers. Additional truck traffic is associated with greater highway maintenance and rehabilitation requirements, increased accident severity, more energy waste, increased air pollution, and worsened traffic congestion. Finally, route-finding problems top the list of motorist complaints to the American Automobile Association (AAA) and traffic engineers. Ameliorating these problems would reduce driver frustration which results from their inconvenience and lost time.

Objective and Scope

The present study examined driver efficiency in route-following under different types of direction-finding aids. The purpose was to gain an understanding of motorist direction-finding problems and to propose some potential solutions. To accomplish this, two experiments were conducted to investigate driver performance following a missed freeway exit navigational error. In both experiments subjects were forced to miss a critical freeway exit in a real driving situation while enroute to a predetermined destination. Their driving performance was observed as they attempted to correct the "error" and continue to the destination.

Experiment I

In Experiment I, the performance of subjects in a map group were compared to those in a control group who received no navigational assistance. Data were collected on variables that included number of choice point errors, number of miles, and length of time to recover from the error and reach the destination. The results indicated that map usage facilitated driver recovery from the error in that map users committed significantly fewer choice point errors (4.1 vs. 14.5), drove fewer miles in excess of the optimum correction route (6.4 vs. 19.3 mi), and took less time (11 vs 28 min) to reach their destination. Although map usage enhances the ability of many drivers to recover lost routes, there is a significant proportion of the driving population (35-40 percent) who cannot or will not use road maps. Moreover, the map users in this study used on the average twice the optimum recovery distance in correcting for the error.

Experiment II

The purpose of Experiment II was to examine the effects of three types of navigational aids on driver route recovery behavior. The aids were a road map, a telephone information system, and a computerized roadside information system. Four independent groups, each consisting of 24 subjects, were used in this experiment. One group served as the control, being given no navigational aid. The other three groups were given direction-finding assistance in the form of detailed area road map, information via a roadside telephone, and a simulated computer drawn strip map which was disseminated at a roadside information center. The results demonstrated that the direction-finding aids reduced the number of choice point errors, number of miles, and driving time to correct for the navigational error. Generally, means for these measures were largest for the control group and fell in decreasing order through map to phone to computer group. For example, the average recovery mileage (over the optimum recover distance) for the control, map, phone, and computer groups were, respectively, 7, 5, 1.5, and 0.8 mi.

The results of this study are consistent with prior research that indicates a significant motorist direction-finding problem exists. Moreover, the findings suggest that alternative types of navigational aids can significantly increase motorist direction-finding efficiency. The opportunity clearly exists to reduce the highway costs and energy waste associated with poor motorist navigation performance. However, the missed freeway exit situation and the aids tested in this study represent only one portion of the driver navigation problem. Other possible aids are discussed in the report including in-vehicle audio signing and telecommunication systems. It is apparent additional research is needed to fully understand and define the magnitude of the motorist direction-finding problem so that realistic solutions can be identified and developed.

Chapter I. Introduction

The reliance of the United States and most other western nations on imported oil has led to intensified efforts to encourage fuel conservation. The automobile-highway transportation system is vital to our present standard of living and will continue as the main personal transportation system for the forseeable future. Given the large number of automobiles in use, the existing extensive highway system, the nature of urban "sprawl," and the central position which automotive and related industries hold in our overall industrial community, major fuel shortages will cause serious social and economic upheaval. Clearly, conservation efforts must at present involve more efficient use of trucks, automobiles, and buses. Emphasis on car and van pooling and the expansion of mass transit facilities represent recent attempts to improve overall system efficiency. There are, however, other less obvious areas in which comparatively minor system modifications might result in considerable fuel savings. One such area involves the improvement of driver navigational performance. Included in this category are those activities which relate to the driver's ability to plan and execute a trip from point of origin to destination.

Navigational Performance

In 1972 the results of a study concerned with the navigational problems of urban motorists was reported by King and Lunenfeld (10). In this study a series of 114 case studies in urban guidance were made in 31 different urban areas. Out of a total of 959 individual direction-finding problems identified, more than half of these involved difficulties in navigating urban arterials or city streets. Other problem categories included navigating freeways, finding freeways, unavailable or inadequate maps, and problems connected with an understanding of urban geography. A nationwide distribution of a questionnaire on user-perceived guidance problems and information needs also yielded insight on motorist trip-making and trip-planning behavior in urban areas. The extent of the urban navigational problem was indicated by the fact that more than half of all respondents reported feeling lost at some stage of their most recent trip into unfamiliar urban areas. Of the seven problem types that were rated highest in severity by the questionnaire respondents, four dealt with arterial navigation, two with road maps, and one with freeway or expressway navigation. Synthesis of all the data obtained in the case studies and in the nationwide survey showed that the major and most frequently encountered problems in urban guidance fell into five distinct categories: (1) trip planning and trip plan execution, (2) getting on and off freeways and expressways, (3) navigating the conventional road network, (4) system forgiveness (i.e., recovery from being lost), and (5) system implementation (e.g., sign size, legibility, and maintenance).

A 1960 California study (19) found that 58 percent of respondents to a survey indicated that they started for an unfamilar destination without advance preparation. Over 15 percent explicitly stated that this was their customary behavior. Interviews of motorists at freeway on-ramps showed that 17 percent were taking indirect routes and that 15 percent were taking routes that would not have permitted them to reach their destination without extreme route changes. At exit ramps, 17 percent were found to be taking indirect routes and 5 percent were taking routes which would create considerable difficulty in reaching their stated destination. Another survey, conducted at a California State Fair, found that of respondents making a trip of 500 miles or more for the first time, over 51 percent reported that they thought they had been on a wrong road at least once. Of these, 34 percent had, in reality, been on at least one wrong road.

The above earlier findings are substantiated by motorist interview data reported by Cross and McGrath in 1975 (2). In response to an inquiry as to why they had looked at a map, 16 percent of 1,284 map users checked the reason: "To find your way back to the correct route after getting lost." Of the 1,305 interviewees who had traveled on unfamiliar roads prior to being questioned, almost 70 percent admitted to having doubts about their route orientation at least once. Questioning motorists (N = 1,492) about their freeway/toll road/interstate highway experiences, Cross and McGrath also found that: 13.6 percent missed a planned by-pass route, 16.4 percent had trouble finding an entrance ramp, 15.4 percent took a wrong entrance (on the correct freeway) without realizing it, 10.1 percent traveled some distance on the wrong freeway without realizing it, 13.1 percent became confused or bewildered at an interchange, 15.2 percent felt they were lost or on the wrong road but were not sure, and 16.9 percent made a wrong turn at an interchange. Other problems were also cited.

Findings such as these and the continuous concern for signing efficacy lead to the question, "How efficient are drivers in using available system information and their own knowledge to get where they want to go?" While some data concerning driver reactions to particular signing configurations and traffic situaions are available (e.g., 9), analysis of overall driver navigational performance, particularly in unfamiliar situations, is lacking. A lost or unfamiliar driver attempting to make route corrections, sometimes at high speed, presents an obvious safety hazard. As King and Lunenfeld state, "It is logical to assume that without improvement in the system, the trend of rising traffic fatalities will continue, and the number of drivers lost, confused, and otherwise irritated will increase."

The timeliness of investigating this problem is reflected by their additional comment, "The intrusion of directional information on the senses of a driver who should be more concerned with vehicle, road, and traffic information is a problem that to date seems to have been ignored in the field of highway research" (11). Equally as critical is the investigation of the dynamics and behavior of lost drivers with emphasis on reducing the number of drivers who get lost and efficiently redirecting those who are.

There is no comprehensive quantitative data available as yet on the added fuel that lost drivers consume in attempting to correct navigational errors. A study by Gordon and Woods (7), however, provides some interesting insights. They found, in local wayfinding in residential areas, that unfamiliar drivers took twice as long, went only two-thirds as fast, and traveled 50 percent further than subjects who were given detailed enroute instructions. The unfamiliar drivers were found in 95 percent of the cases to adopt a strategy of getting as close as possible to the destination, asking for directions (generally at gas stations), and then repeating the process as often as necessary. Clearly, this strategy would result in greater fuel use and time lost if used on major freeways and expressways because of the greater travel distances required to find an information source.

Unquestionably, driver navigation problems constitute an important source of energy waste and operational inefficiency in the highway transportation system. For example, drivers are not required to demonstrate map-reading ability for licensing; consequently, all types of inefficient navigational practices are employed in lieu of this basic skill. It is estimated that even a modest improvement in motorist navigation performance would result in a considerable savings of automobile fuel. According to the estimates for total vehicle-kilometers given in the statistical abstracts published by the U.S. Department of Commerce, non-commercial motor vehicles traveled about 1.5 trillion mi. during 1979. The potential economic gain that might be derived from improvements in highwayway navigation would appear to be truly significant when one considers the magnitude of this volume of travel. As a speculative example, suppose it was possible to improve navigational efficiency by 1 percent--that is, through better pre-trip planning and/or better route-finding performance, motorists were able to save an average of 1 mi. of unnecessary travel in every 100 mi. traveled. That result would translate to an annual savings of well over 15 billion unnecessary miles of travel.

A British report indicates a considerable savings in mileage and fuel consumption is actually realizable. On the basis of a comprehensive study, which included controlled experimentation, it was concluded at least 4 percent of all British route mileage travelled was wasted. Applying the findings of a recoverable 4 percent to the estimated 1.5 trillion vehicle miles of American vehicular travel, and assuming a fuel usage of 15 miles per gallon, yields a potential savings of 4 billion gallons per year.

There is evidence substantial safety benefits will be achieved by giving motorists improved ways to solve their route-following problems. Lost and confused motorists cause accidents by slowing, stopping or backing up at decision points, reading maps under dangerous conditions, and driving erratically. A review of multidisciplinary accident investigation reports found erratic driving behavior and consequent accidents occurred with high frequency at major route decision points. A second hazard associated with driver route-following problems showed up in the occurrence of accidents in urban areas involving motorists either looking for streets or specific addresses, and as a result, not attending to the task of driving.

No known data exists on the extent truck drivers are having problems navigating the highway system. However, truckers travelling into unfamiliar areas would be expected to have the same problems as automobile drivers. Some unknown proportion of trucks routinely travel unfamiliar routes, e.g., large furniture moving vans, independent operators, delivery and service vehicles. When trucks are compared to automobiles on the basis of wasted mileage, excess travel by trucks has a much more profound impact on the highway system. Additional truck traffic is associated with increased accident severity, greater wear and tear on the highway system, more energy waste, increased air pollution, and worsened traffic congestion. The economic burden associated with excessive wear and tear on the highway facility due to trucker direction-finding problems is of particular concern. It is clear that truck traffic generates greater maintenance, resurfacing and rehabilitation requirements than automobiles.

Aside from issues of fuel conservation, system efficiency, safety, traffic management problems, and increased highway maintenance costs, lost drivers undoubtedly contribute to air and noise pollution. Pollution in urban areas is currently a major ecologicalsocial problem. Coincidentally, these same urban areas, with their complex highway systems, heavy traffic, high driver-decision loads, and large numbers of unfamiliar drivers, provide the "easiest" opportunities to get lost (McNees and Hutchingson) (12).

All available evidence points to the existence of a large but as yet unspecified lost driver problem. Average drivers continually, routinely, and habitually either get "lost" or confused or pursue direction-finding strategies which increase the opportunities to do so.

Objective and Scope

The present study examined driver efficiency in route following under different types of direction-finding aids. The purpose was to gain an understanding of motorist direction-finding problems and to propose some potential solutions.

Two experiments were conducted to investigate driver performance following a missed freeway exit navigational error. Both experiments were controlled field investigations conducted on public roads and highways with paid volunteer subjects. Subjects were given predriving instructions to a specific fixed destination. Enroute to the destination they were forced to "miss" a turn at a critical exit ramp. The subjects' driving behavior was observed as they attempted to correct the "error." The first experiment presented this treatment to two groups. One, a control group, received no navigational assistance. The second, a map group, was permitted to consult a typical gas station type road map. Overall driver performance (distance traveled, routes taken, etc.) was recorded. The second experiment used the same test route and vehicle, but employed different test subjects and expanded the scope of the investigation. A control group and three navigational aid groups were tested. The navigational aids consisted of a detailed area map, a simulated interactive telephone information system, and a simulated computerized roadside information system.

In the next chapter, the general methodology common to both experiments will be described. In subsequent chapters, the specific methodology and results of each of the two experiments will be followed by a discussion of its findings. A final consolidated discussion will deal with the overall findings and implications of both experiments.

Chapter II. General Methodology

There was some commonality between the methodologies of experiment I and experiment II. Both experiments used the same test route and experimental vehicle as well as the same exit ramp for the induced navigational error and the same target destination. In order to facilitate the presentation of the research approach used in the two experiments, the general methodology common to both experiments I and II will be presented in this chapter.

General Test Route Area

The field testing was conducted on portions of Interstate 495 (I-495), sections of the George Washington Memorial Parkway (GWP) in Virginia and Maryland, and neighboring streets in suburban Washington, D.C. Figure 1 presents the general test route area. A small number of subjects navigated beyond the areas illustrated in this figure, using various other interchanges on I-495 and I-270 to change direction.

General Procedure

Subjects in both experiments were told that they were to drive from the Fairbank Highway Research Station (FHRS), Langley, Virginia, to the Parkway lot of the Lock 10 picnic area (hereafter referred to as Lock 10) on the C&O Canal. Verbal instructions were given as the experimenter pointed out the optimum route to Lock 10 on a large wall map. Upon reaching the critical freeway exit to Lock 10, subjects were not permitted to exit, thereby "inducing" an error. Subjects were then told to drive to the original destination, Lock 10. The optimum correction route was the shortest route from the "error" point to Lock 10. Therefore, both experiments utilized the same general test route area, optimum route, and optimum correction route.

Optimum Route

All subjects were told that they would be given all necessary route instructions to get them to the northbound lanes of I-495 from the FHRS. They were told that they would then have to drive from that point to the Lock 10 parking lot by using the directions they had been given earlier. After the point labeled "start" in figure 1, the optimum route required the subject to drive approximately 0.9 mi to exit 15 and turn right. The "heavy" arrows in figure 2 illustrate this route. Following the exit from I-495, a right turn at the fork would take the subject onto the GWP in Maryland, heading east. The Lock 10 parking lot was then in sight and signed for on the right side of the road.

Optimum Correction Route

The "induced" error was given all subjects. After "missing" the exit 15 turn, the optimum correction route involved traveling north on I-495 approximately 1.64 mi to exit 16 and using this interchange to return to I-495 going southbound. The heavy arrows in figure 3 show this route. As there is no eastbound exit to the GWP from I-495 at exit 15, it is essential to exit westbound and use the naval Ship Research and Development Center (NSRDC) overpass to reach the GWP eastbound, and continue to Lock 10. This optimum correction route, from the

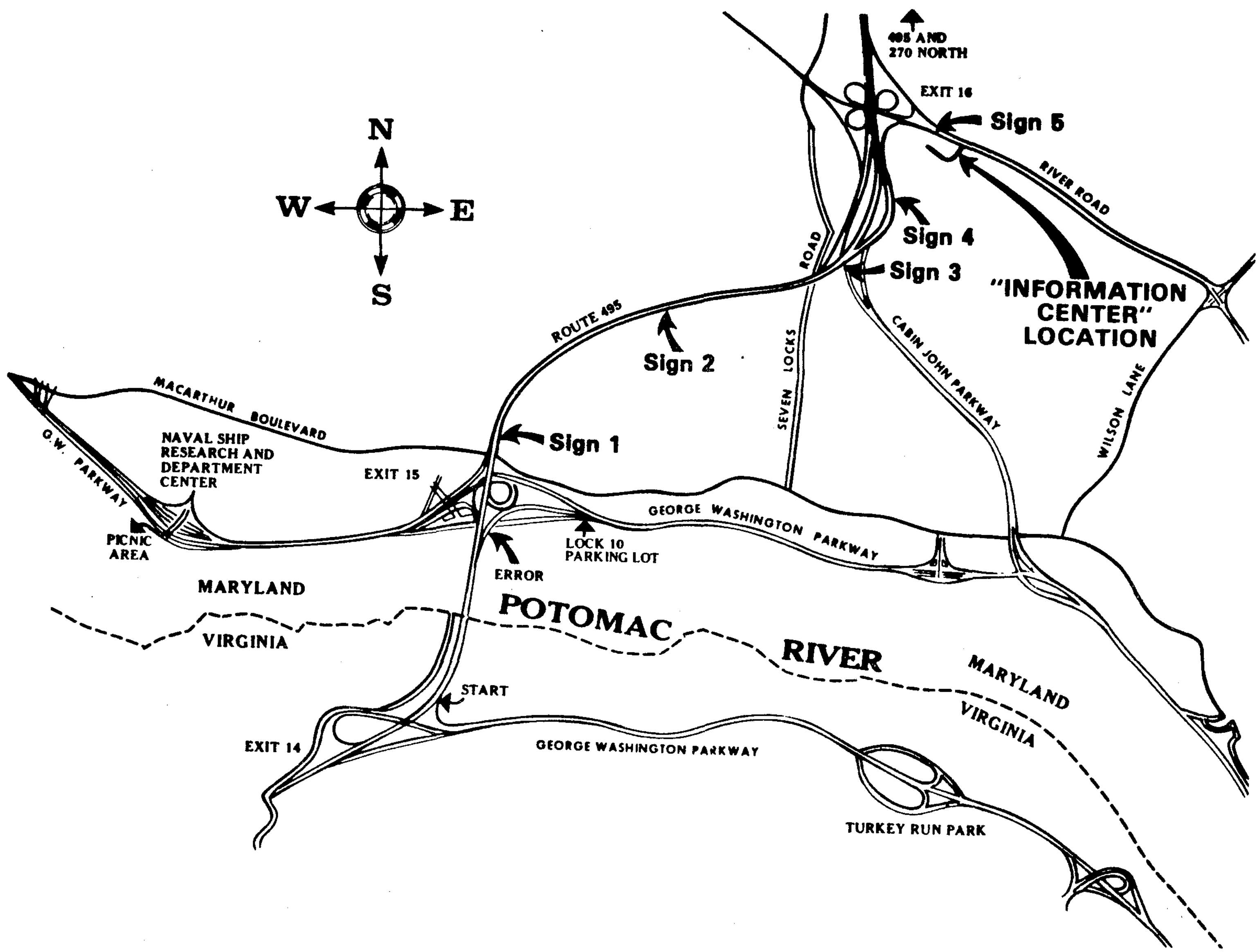


Figure 1. General test route area.

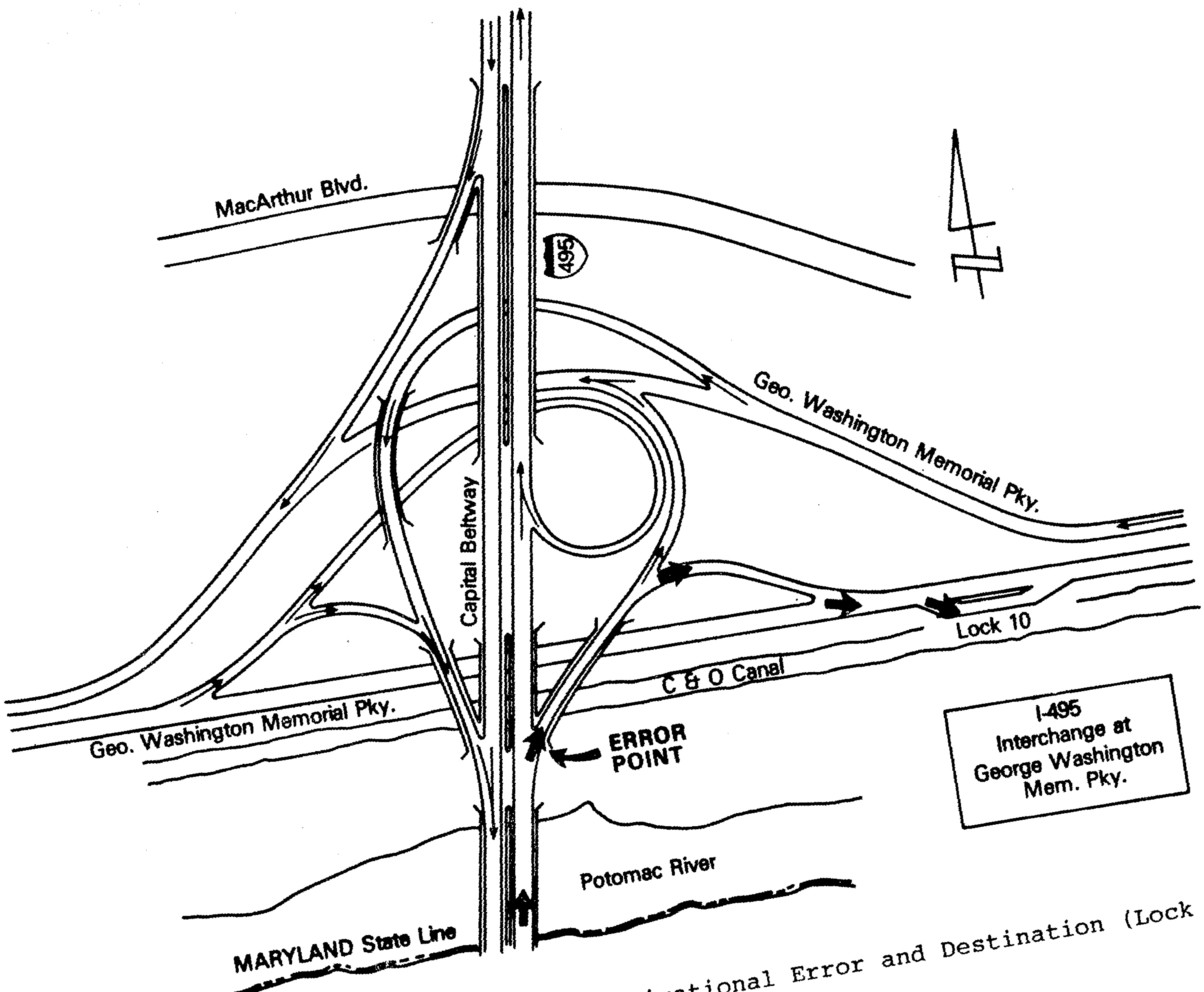


Figure 2. Exit 15 Showing Location of Navigational Error and Destination (Lock 10).

"error" point at exit 15 to Lock 10, was 6.83 mi. Experimental procedures in experiment II required that subjects in all but the control group first be directed to eastbound River Road and the "Information Center" location (see figure 3) before attempting to navigate to Lock 10. The optimum correction distance for these groups was 7.34 mi.

Data Recording

As the subject attempted to drive to the Lock 10 parking lot, the experimenter monitored the vehicle's instrumentation and kept a written log describing the subject's route and the decision points through which he/she passed. Readings from the distance recording device were noted in the log at each decision point. Also, at each decision point, a special event marker was entered on the digital and the analog recording tapes. Cross comparison of the log and the magnetic tapes made it possible to precisely locate the exact route location to which a given portion of the magnetic tapes referred.

Apparatus

Instrumented Vehicle

The field experimentation in this study was conducted in the Federal Highway Administration's instrumented 1970 Chrysler test vehicle. In-vehicle instrumentation provided for both the presentation of simulated signing information (used in experiment II and for the storage of a wide array of subject and vehicle responses on magnetic tape. The In-Vehicle Sign Simulation (ISS) technique is discussed in detail in Mast et al. (13). Basically, the ISS technique permits the presentation of highway information to the subject and allows the measurement of his/her responses as he/she drives on existing highway configurations. Presentation of highway information to the subject may be either visual, with slides, or aurally, with taped messages.

Sign Presentation and Subject Response Equipment (used only in experiment II)

Road signs were simulated by the projection of 35mm color slides onto a 10 by 3.5 in Ektalite screen mounted inside the windshield to the left of a center hung rearview mirror. The projector (Kodak Ektagraph AF-2) was mounted behind and to the right of the driver. Slide projection was controlled by the experimenter, and slide termination was controlled by the subject.

The subject's termination of a projected slide was initiated by his/her pressing of a pressure-sensitive tube located around the inside circumference of the steering wheel.

Distance Measurement and Recording Equipment

A Zeronics 220 device measured the distance traversed by the vehicle. Data were sampled and recorded once each second. A Cipher 9-track digital tape recorder was used to store information concerning vehicle performance parameters, slide presentation and response data, and experimenter-initiated event codes. These data were sampled and recorded once each second.

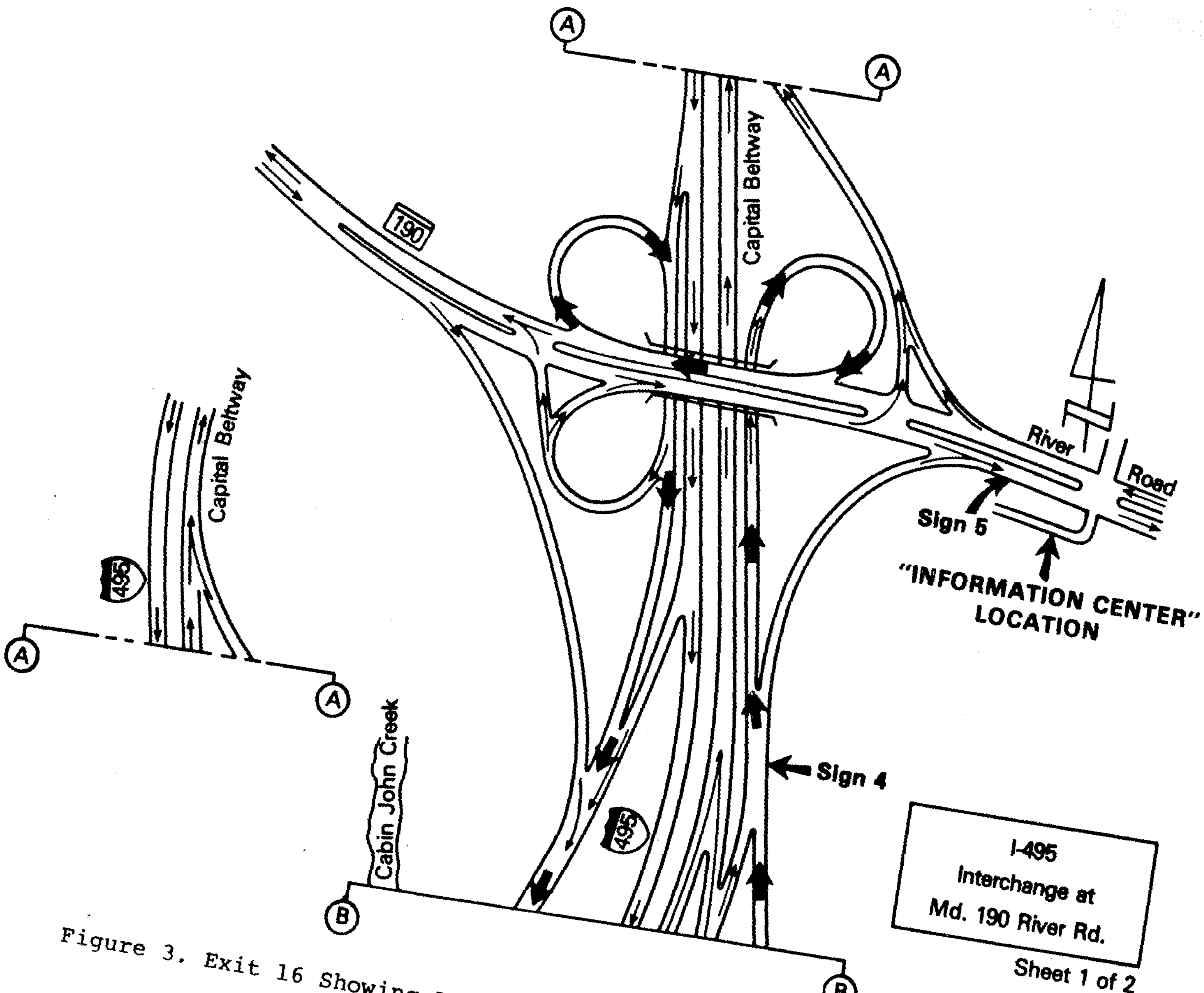


Figure 3. Exit 16 Showing Location of Information Center.

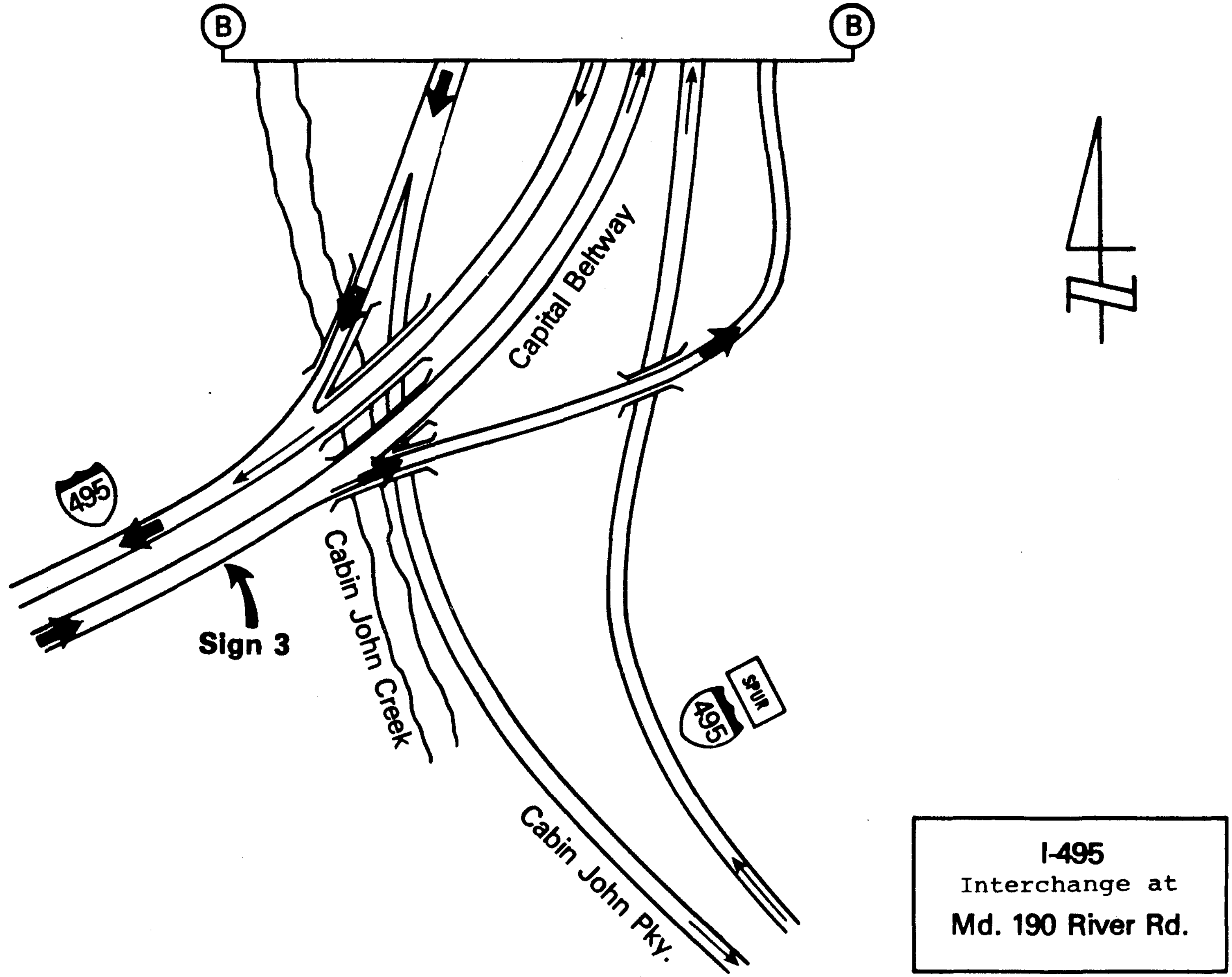


Figure 3. Exit 16. (continued)

All monitoring and recording instrumentation was located in the left back seat area and was not visible from the driver's seat. The experimenter sat in the right back seat area. Presentation of slides and recording onto the magnetic tape of special event codes were controlled by means of a hand-held remote control.

Chapter III. Experiment I

Objective

The purpose of this experiment was to examine driver behavior following a missed exit type navigational error on an urban freeway. The study was also intended to provide data on the effectiveness of map use as it pertains to recovery from freeway navigational errors.

Subjects

The subjects were 22 paid male and female volunteers who responded to notices placed at colleges in the Washington, D.C., area or who were contacted from files of subjects who had participated in previous unrelated research. Subjects were randomly assigned to either the experimental (map available) group or the control (no map available) group. Table 1 (columns 1-4) presents mean and standard deviation data on subject variables such as age and driving experience for both groups and the total sample. Also shown in this table are the results of t-tests on the mean difference exhibited between the two groups for the subject variables. Nonsignificant t-test values for all the subject variables demonstrate that the random assignment procedures were effective; i.e., experimental and control groups did not differ with respect to sample selection criteria.

Experimental Design

A two independent groups design was used, thereby permitting t-test comparisons between groups on variables of interest. The independent variable in this study was availability versus nonavailability of a standard gas station road map during the driver's attempt to correct the induced navigational error. The control group did not have the map available. The experimental group was permitted, upon request, to view the map as needed during recovery attempts. The dependent variables under investigation, and their operational definitions, were as follows:

Subject Variables

1. Age - Chronological age at last birthday.

2. Education - Total number of academic school years completed; e.g., high school = 12, college graduate = 16.

3. Driving Experience - Total number of years (to the closest year) in which valid driving license had been held.

4. Average Yearly Mileage - Average yearly mileage driven, in thousands, over the last 2 years.

Table 1. Means, standard deviations, and t-tests between variables for control and experimental groups.

GROUPS		SUBJECT VARIABLES				DRIVER PERFORMANCE VARIABLES			
		1. Age (years)	2. Education (years)	3. Driving Experience (years)	4. Ave. Yearly Mileage (thousands)	5. Choice Point Errors	6. Worsening Errors	7. Miles to Correct	8. Seconds to Correct
Control Group (No Map) N=11	Mean	24.6	15.1	6.9	11.1	14.0	3.9	20.0	1,744.6
	S.D.	5.7	2.7	5.5	5.9	13.9	2.9	16.1	1,112.3
Experimental Grp. (Map Available) N=11	Mean	24.7	14.6	8.1	10.6	8.5	2.4	10.3	1,187.5
	S.D.	5.9	1.9	5.4	8.1	12.9	1.6	11.3	856.2
t diff.		-0.07	0.54	-0.51	0.20	0.97	1.56	1.66	1.32

Driver Performance Variables

5. Total Choice Point Errors - Total number of times the driver made a route choice that was not the optimum alternative available at that time. Going straight through an intersection when a left turn should have been made was scored as a choice point error.

6. Total Worsening Errors - Total number of times that the driver made a route change that further complicated his recovery problem. This type of error was a subcategory of total choice point errors.

7. Miles to Correct - This was computed in one of two ways: (1) If the subject was able to reach the destination within 3,000 seconds (50 min), number of miles to correct was calculated as the distance from the "start" point to the destination minus 6.83 mi; (2) If the subject had not reached the destination within 3,000 seconds, the distance was calculated as the mileage traveled in those 3,000 seconds minus 6.83 mi plus the additional distance required to travel from the ending point to the destination along the shortest available route. These procedures resulted in a true "zero" distance scale; i.e., subjects that corrected along the optimum correction route received a score of zero.

8. Time to Correct - This measure was computed in one of two ways as was "Miles to Correct": (1) If the subject reached the destination within 3,000 seconds, "Time to Correct" was defined as the number of seconds used from "start" to destination less the number of seconds required to correct along the optimum route at posted speed limits; (2) If the destination was not reached in 3,000 seconds, this score was computed by adding to 3,000 seconds the time required to travel from the driver's ending point to the destination along the optimum route at posted speeds minus the optimum correction time.

For Map Group Only

9. Total Number of Map Stops - Total number of times that a driver stopped the vehicle and requested the road map.

10. Total Map Study Time - Total number of seconds that a driver viewed the road map over all map stops.

Procedure

All scheduling, interviews, testing, experimentation, and scoring were conducted by the same individual. Upon arrival for testing, each subject was interviewed and pertinent biographic data was recorded. Drivers' licenses were checked for validity. The subject was then randomly assigned to one of the two experimental groups and shown a large map of the Washington D.C. metropolitan area. Instructions were given as to the optimum route to Lock 10.

Subjects in the control group were told that they would not have a map to study once they began driving. Subjects in the experimental group were told that they would have the opportunity to look at a map once they began driving.

All the subjects were then taken to the experimental vehicle and instructed as to control locations. Seat and mirror adjustments were made. All subjects were required to use seat belts. At all times during the experimentation, the experimenter was located in the back seat. Subjects were instructed to obey all traffic regulations and posted speeds and to obey any commands given by the experimenter if they could be safely executed.

All subjects were required to drive the vehicle around the research facility road to allow them to familiarize themselves with its controls and to allow the experimenter to make a determination as to whether the subject could safely operate the vehicle on the highway. Two subjects were dropped from the study at this point and their data discarded. The subjects were then directed onto the GWP to the beginning of the test route (marked "start" in Figure 1).

As the vehicle approached the exit 15 turn (marked "error" in Figure 1), all subjects were told not to exit. After passing the turnoff, all subjects were told to attempt to return to Lock 10 by any safe and legal means possible. Subjects in the experimental group were reminded that a map was available.

Subjects were timed and their distance traveled-mileage measured by onboard equipment. Number and times of map study stops were hand tallied and timed by the experimenter. Routes taken and locations of stops, special events, etc., were hand scored by the experimenter on maps of the area.

Subjects were allowed a maximum of 50 minutes (3,000 seconds) to correct the "error." After either 50 minutes or arrival at the Lock 10 parking lot, subjects were directed back to the Fairbank Highway Research Station. Subjects were debriefed by means of a structured interview, paid for their participation, and released.

Results

Of the 22 subjects participating in the experiment, 17 located the Lock 10 parking lot within the criterion time and 5 did not. Of the five who did not reach the destination within 3,000 seconds four were in the no-map-available (control) group. Table 1 presents means and standard deviations for both groups and the total sample, as well as t-test comparisons between groups for the variables under study. There were large but statistically nonsignificant differences between groups on choice point errors, worsening errors, miles to correct, and time to correct (columns 5-8). Those in the no-map-available group used on the average 94 percent more miles and 47 percent more time to reach the destination. The extremely large standard deviations for driving performance variables precluded finding significant t-test values. Applications of the median test, a non-parametric measure useful in controlling extreme scores, and Winsorized t-tests (also designed to deal with extreme scores) failed to produce significant differences between the groups on any of the driver performance variables. Inspection of the data revealed that the failure to find statistical differences was partly attributable to four subjects in the map-available group who did not use the map. These subjects, in effect, did not receive the experimental treatment.

In order to make comparisons between map users and map nonusers, the data were regrouped on the basis of actual map usage by the subjects. Table 2 presents means, standard deviations, and t-test values for map users versus map nonusers. While differences between the two groups on subject variables (columns 1-4) are no larger than those of Table 1 (map availability data), differences on the driving performance variables were much larger. Map users made less than a third of the choice point errors made by map nonusers (column 5); 42 percent less worsening errors (column 6); drove an average of 12.9 mi less; and took an average of 1061.4 fewer seconds. As Table 2 shows, the difference between groups for miles to correct (column 7) attained significance at the 0.05 level.

To gain further understanding of the subject variables important to efficient navigational error recovery behavior, the data were regrouped and analyzed on the basis of driver success in reaching the destination. Table 3 presents means, standard deviations, and t-test differences between subjects who reached the destination within 3,000 seconds and those who did not. As might be expected, these two groups differed greatly and significantly on the driving performance variables. Subjects who did not find the Lock 10 parking lot in 3,000 seconds, compared to those who did, made almost six times more choice point errors, three times more worsening errors, drove an average of 30 mi more, and took an average of 2,404.6 seconds (40+ minutes) longer. All of these differences attained significance at the 0.01 level. As to subject variables, those who reached the destination also had significantly more education (column 2). There were also large but nonsignificant differences on average yearly mileage driven (column 4).

Intercorrelations were computed to determine if there were any significant relationships between the subject and performance variables in the study. Table 4 presents the intercorrelations between all the experimental variables. Age and driving experience correlated highly, as might be expected. Aside from this single correlation, age, driving experience, and average yearly mileage driven demonstrated no other significant correlations with any other variables. As might be expected, choice point errors and worsening errors correlated highly with each other. They also demonstrated similar high, significant correlations with years of education, mileage to correct, time to correct, and with success in reaching the destination. As number of errors of either type increased, mileage and time to correct increased and education, and probability of reaching the destination decreased. Miles to correct and time to correct correlated highly $r = 0.97$, and demonstrated relationships with other variables similar to those of both choice point errors and worsening errors. That is, as miles and time to correct increased, education and probability of reaching the destination decreased, while choice point and worsening errors increased. As mentioned in the discussion of the other variables, reaching the destination correlated significantly with education ($r = 0.53$), choice point errors ($r = -0.82$), worsening errors ($r = -0.80$), miles to correct ($r = - 0.90$), and time to correct ($r = - 0.85$).

Table 2. Means, standard deviations, and t-tests between variables for map users and non-map users.

GROUPS		SUBJECT VARIABLES				DRIVER PERFORMANCE VARIABLES			
		1. Age (years)	2. Education (years)	3. Driving Experience (years)	4. Ave. Yearly Mileage (thousands)	5. Choice Point Errors	6. Worsening Errors	7. Miles to Correct	8. Seconds to Correct
Map Non-Users	Mean	25.5	14.9	7.9	10.5	14.5	3.6	19.3	1,697.3
N = 15	S.D.	6.1	2.6	5.9	6.3	15.2	2.8	15.7	1,115.9
Map Users	Mean	22.9	14.7	6.6	11.6	4.1	2.1	6.4	635.9
N = 7	S.D.	4.4	1.6	4.2	8.5	2.7	0.9	5.0	492.2
t diff.		1.01	0.14	0.55	-0.33	1.78	1.36	2.11*	1.63

* Significant at the 0.05 level ($p<0.05$)

Table 3. Means, standard deviations, and t-tests between variables for drivers who did and did not reach the destination in 3,000 seconds.

GROUPS		SUBJECT VARIABLES				DRIVER PERFORMANCE VARIABLES			
		1. Age (years)	2. Education (years)	3. Driving Experience (years)	4. Ave. Yearly Mileage (thousands)	5. Choice Point Errors	6. Worsening Errors	7. Miles to Correct	8. Seconds to Correct
Did Not Reach Destination in 3,000 seconds	Mean	25.0	12.6	7.6	6.8	31.0	6.6	38.7	3,415.0
N = 5	S.D.	7.6	1.3	7.0	3.8	14.7	1.3	6.4	305.5
Reached Destination in 3,000 seconds	Mean	24.5	15.5	7.5	12.0	5.4	2.1	8.3	1,010.4
N = 17	S.D.	5.3	2.2	5.0	7.2	4.9	1.5	6.4	586.9
t diff.		0.16	-2.80*	0.05	-1.59	6.38**	6.01**	9.23**	7.57**

* Significant at the 0.05 level ($p<0.05$)

** Significant at the 0.01 level ($p<0.01$)

Of the 11 subjects in the map-available group, only 7 used the map during their test run. Of the seven map users, four exited from I-495 at exit 16 and immediately consulted the map before proceeding further. Of these four, three returned to I-495 southbound and one attempted to correct by proceeding down River Road and using Wilson Lane (see figure 1). Of the other three who later used the map, one missed the exit 16 interchange completely and proceeded to the next exit, and two used the exit 16 interchange to proceed Southbound on I-495 without consulting the map. All three of the drivers who did not consult the map at the first opportunity failed to use the map until they had returned to exit 15 and had exited onto the GWP in Maryland. All of the map users eventually reached the Lock 10 parking lot within the time limit of 3,000 seconds. The seven map users made a total of 10 map stops, resulting in a mean of 1.4 stops per person per trip and an average time per stop of 118.2 seconds or almost 2 minutes.

There was large variation in the performance of the non-map users. Two subjects returned to the destination along the optimum correction route, while two others left I-495 at exit 16 along River Road and continued eastbound until the time expired. Two other subjects in the non-map-user group had near optimum correction routes in that they U-turned at the intersection of MacArthur Boulevard and the GWP rather than at the NSRDC overpass. Within the remaining nine non-map users, an interesting dichotomy presented itself. Four of the subjects traveled almost exclusively on main highways (I-495, GWP, or Cabin John Parkway), choosing to make route changes or correction attempts by using highway interchanges. The remaining five subjects demonstrated considerable "neighborhood" street involvement (McArthur Boulevard, River Road, and adjoining streets). Three of these subjects were among those that could not reach the Lock 10 parking lot within 3,000 seconds. While it is difficult to quantify these results, there seemed to be a tendency among these subjects to traverse repeatedly the same route or to continue along an incorrect route. For example, the latter would drive off into the country where the roads become increasingly more narrow and rural for several miles before making a U-turn. When the two subjects who exited at River Road and continued east until the time limit expired are added to this group of "perseverers," they comprise a large portion of the non-map users (7 of 15 non-map users) and account for all five of the subjects that did not reach the Lock 10 parking lot.

In applied situations, male-female performance differentials are sometimes encountered. Between-sex t-tests on all subject and performance variables were therefore conducted. No significant differences were found (alpha = 0.05). Such findings might appear to be at odds with the "popular" male conception of poor female route navigation skills. The sample used in this study possessed a "restricted range" on several characteristics in that the entire sample was younger and more highly educated than the general public. Because of the younger average sample age, between sex differences in driving experience were small. Thus, any sex differential, if it does exist, would not have had time to manifest itself. The results of this study would seem to argue against any sex performance differences among younger, more highly educated males and females on route recovery performance.

Table 4. Intercorrelation matrix of experimental variables.

VARIABLES	Age (years)	Education (years)	Driving Experience (years)	Ave. Yearly Mileage (thousands)	Choice Point Errors	Worsening Errors	Miles to Correct	Seconds to Correct	Reached Destination 1=yes,2=no
Reached Destination (1=yes, 2=no)*	-0.04	0.53	-0.01	0.33	-0.82	-0.80	-0.90	-0.85	1.00
Seconds to Correct	0.08	-0.57	0.02	-0.19	0.88	-0.92	0.97	1.00	
Miles to Correct	0.11	-0.55	0.03	-0.22	0.91	0.93	1.00		
worsening Errors	0.14	-0.48	-0.22	-0.04	0.86	1.00			
Choice Point Errors	0.07	-0.55	-0.08	-0.23	1.00				
Ave. Yearly Mileage	0.01	0.04	-0.09	1.00					
Driving Experience	0.89	0.05	1.00						
Education	0.18	1.00							
Age	1.00								

═══ Significant at the 0.05 level ($p<0.05$)
─── Significant at the 0.01 level ($p<0.01$)

* All correlations with "Reached Destination" are point-biserial correlation coefficients.

Discussion

The introductory section of this report presented data which suggest that a considerable "lost driver" problem might exist. The present preliminary findings support such a hypothesis. Over 22 percent (5 of 22) of the sample could not find the destination within the criterion time of 50 minutes. Given a recovery problem that seemed, intuitively, rather straightforward, many "lost" subjects consistently demonstrated, by virtue of their meandering routes, that they generally had no conception of where they were, vis-a-vis the geographical location of the destination. Results of the debriefing interview demonstrated that this was not the result of confusion on the subject's part as to what he was supposed to do.

The statement of one of the subjects who had turned onto River Road east from exit 16 is illustrative. After traveling east away from the Beltway until the criterion time was reached, he was asked what his route correction strategy had been. He replied, "I'm looking for the Beltway (I-495)." Such a lack of directional sense is staggering in its implications concerning the magnitude of the lost driver problem in the general motoring public. The magnitude of the problem may be larger than what had been previously supposed.

The sample used in this study had considerably more education (mean = 14.8 years, none less than 12) than does the general public. Given the high negative correlation of education with all of the driver performance measures, one would expect to find, using the same route and a more representative sample (i.e., less well-educated), an even higher proportion of drivers getting lost. The "lost" subjects in this study used an average of 38.7 mi to correct, almost six times the optimum correction distance. It is unknown what the totals would have been if the subjects had been allowed to continue to attempt to find the destination beyond the 50-minute time limit. If extrapolation of the present experimental results to the behavior of the general public is approximately valid in describing driver performance when lost, the magnitude of fuel waste, increased air pollution, and traffic congestion must be considerable.

These results suggest that map use effectively reduces the number of driver errors and consequently provides considerable savings in both distance and time necessary to correct the missed exit error. Map use attenuated the remaining lost period as all subjects who used the map were able to eventually recover and find the destination within the criterion time. Map use resulted in a statistically significant savings of 12.9 mi per subject. Given the high intercorrelations between all of the driver performance variables (average magnitude of intercorrelation = 0.91), it is reasonable to assume that a larger sample would have reduced the effects of the large variabilities encountered and resulted in significant differences for the other driving performance variables. The findings strongly suggest that the use of maps can lead to quicker navigational error recovery, thus reducing fuel waste, air pollution, and traffic congestion.

Unfortunately, as effective as map usage has shown it can be to route correction, drivers cannot be forced to utilize them even if they are present. Four of the 11 subjects in the map-available group did not consult the map, even though they had been strongly urged to do so. Undoubtedly, some of the non-user map-available subjects did not consult the map because they "knew" how to recover and/or thought they did. Nevertheless, the earlier quoted subject who continued on River Road for the entire session was in the map-available group, but never looked at the map. When these non-user subjects, some of whom had great difficulty in reaching the destination, were questioned as to why they did not consult the map, they generally replied either that they could not read a map or that it would only confuse them further. Additionally, several subjects in the non-map-available group volunteered that they could not read maps and therefore would not use them if given the opportunity.

Data gathered by Cross and McGrath (2) confirm this conclusion. They found that between 30 and 40 percent of all the respondents obtained road maps principally from oil companies while enroute. The finding that 25 percent of 1,770 respondents planned all or part of their trip after leaving home obviates the need for road maps. Indeed, it was found that highway road maps were the main source of both pre-trip planning information (55 percent of all aids) and enroute guidance (42 percent of all aids). Nevertheless, only 1,284 (61 percent) of the 2,099 motorists who responded to this question affirmed that they consulted a road map at least once. Thus, almost 40 percent did not use road maps at all. This substantiates the findings of the present study (4 of 11, or 36 percent, did not use maps that were available).

It is apparent, then, that attempts to eliminate or reduce the lost driver problem cannot rely solely on making adequate maps available. Alternative approaches should be developed and evaluated.

Off-road information centers or travelers aid centers located in the vicinity of urban interchanges that present complex navigational problems to motorists may be a partial solution for drivers who will not or cannot use maps. The education level intercorrelation data suggest that route recovery navigation is particularly difficult for individuals with minimal cognitive skills. Years of education reflect an individual's level of cognitive functioning and his general knowledge.

Summary and Conclusions (Experiment I)

Data were obtained on the effects of road map usage and the ability of drivers to recover from a freeway navigational error. Twenty-two subjects were tested in an instrumented vehicle in a real-world driving situation where they were confronted with a "missed exit" problem. Data were collected on variables that included number of miles and length of time for subjects to recover from the induced error and reach a preassigned destination. The results indicated that map usage facilitated driver recovery from the error in that map users committed significantly fewer choice point errors (4.1 vs. 14.5), drove fewer miles (6.4 vs. 19.3 mi), and took less time (635.9 vs. 1,697.3 sec) to reach their destination. Intercorrelations computed between driver performance variables and subject variables suggested that route recovery navigation is particularly difficult for individuals with minimal cognitive skills. Although map usage enhances the ability of many drivers to recover lost routes, there is a significant proportion of the driving population who cannot or will not use road maps. Aside from the highway safety considerations, the lost motorist adds to the problems of air and noise pollution, wasted fuel consumption, traffic management problems, and increased highway maintenance costs. It is concluded that the magnitude of the lost motorist problem warrants the search for additional aids to assist motorists in coping with route navigation problems in urban areas.

Chapter IV. Experiment II

Objective

The purpose of this experiment was to examine the effects of three types of navigational aids on driver route recovery behavior. The aids were an area map, a telephone information system, and computerized roadside information system.

Subjects

Subjects were recruited from posted notices placed in public areas in and around the Washington, D.C., metropolitan area. Subjects were males and females between 18 and 65 years of age, free from serious visual defects, and in possession of a valid driving license for at least the 2 consecutive years prior to volunteering. One hundred twenty-five subjects were paid $15 each for their participation in this study. Equipment failures, sudden rainstorms during field testing, and screening procedures to eliminate poor drivers reduced the number of usable subjects to 96. All data for dropped subjects were discarded for the purposes of this study.

Experimental Design

Four independent groups, each consisting of 24 randomly assigned subjects, were used in this experiment. Each subject was field tested once under one of the four treatment groups. One group served as the control, being given no navigational aid, while the other three groups were given direction finding assistance in the form of a detailed map, information via the telephone, and a simulated computer drawn map. Thus, the basic design was that of a four group, one-way analysis of variance (ANOVA).

Procedure

Individual subjects met the experimenter at the Fairbank Highway Research Station (FHRS) located in Langley, Virginia. The subject was taken to a large wall map of the Washington, D.C., metropolitan area and its surrounding suburbs. He/she was told that he/she would have to drive the instrumented vehicle to the parking lot of a place known as Lock 10 of the C&O canal (hereafter referred to as Lock 10). The experimenter pointed out the shortest, most direct route to Lock 10, adding that he/she would receive necessary instruction to get onto the northbound lanes of I-495. Figure 2 demonstrates this route. The subject was told to study the map to "get his/her bearings" and was then taken to the instrumented vehicle.

Field testing was conducted only on clear or partly cloudy days and on dry streets. In the event of sudden rainstorms or traffic jams created by accidents, testing was terminated and the data discarded.

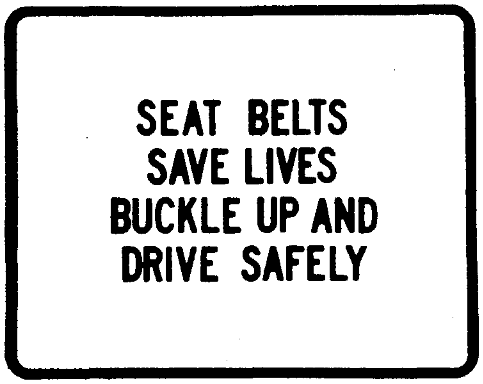
After the subject was seated in the vehicle, permitted to adjust the seat, told to fasten the lap and shoulder harnesses, and asked to adjust the mirrors if necessary, instructions were given as to the location and operation of vehicle controls. A sample slide not used in the study was presented and the subject was shown how to operate the response mechanism. After the experimenter adjusted the experimental instrumentation, he directed the subject to drive the vehicle around the FHRS circular driveway (0.34 mi) in order to familiarize himself/herself with the vehicle's handling characteristics. It was at this time that the experimenter made a subjective assessment of the subject's driving skills. Six subjects were dropped from the study at this point because of poor driving performance and their data discarded.

A subject who demonstrated adequate driving skills was then directed to the GWP in Virginia heading west and from there to the entrance to I-495 northbound. Upon passing the point marked "start" on Figure 1, the experimenter pointed out the clearly visible upcoming right-hand turn at exit 15 and asked if the subject recalled that the turn was part of the best route to Lock 10. Just prior to reaching the turn marked "error" in Figure 1, the error was "induced." After "missing" the turn, the subject was instructed to assume that he/she had "really wanted" to turn at exit 15 but that he/she had been daydreaming and missed the turn. Subjects in the control group were told to try to get back to Lock 10 by any legal and safe means available. Subjects in the map group were told that there was a road map available for them to view and that the experimenter was going to direct them to the first "legal and safe" area where a motorist who wanted to look at a map could do so. Subjects in the phone and computer map groups were told that they would be shown a series of signs on the in-vehicle display that would direct them to an information center where they would receive navigational assistance.

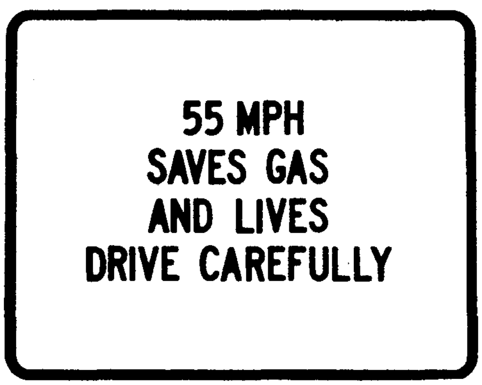
Between exits 15 and 16, signs were presented to all subjects at three predetermined locations (see Figure 1). An additional two signs were presented to subjects in the map, phone, and computer navigational aid groups who traveled the path leading to River Road eastbound and the information center location (sign locations four and five in Figures 1 and 3).

Subjects in the control and map groups viewed the series of signs displayed in Figure 4. Subjects in the phone and computer map groups viewed the signs presented in Figure 5.

Upon arrival at the information center location (see Figure 3), the subject was instructed to pull over to a predetermined spot on the side of the road and to put the vehicle's transmission in "park" while allowing the engine to run in order to provide power for the instrumentation. Different procedures were then followed for the map, phone, and computer aid groups. The control group was not directed to the information center because for them it did not "exist".

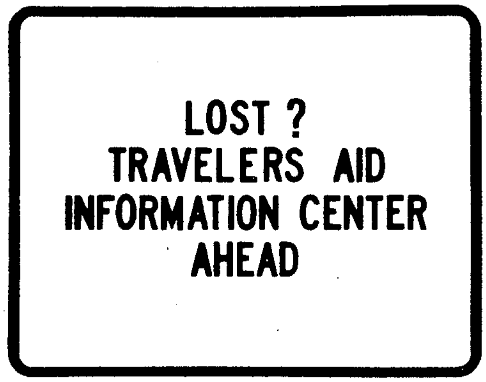


Shown at sign locations one, three, and five (fig. 1)

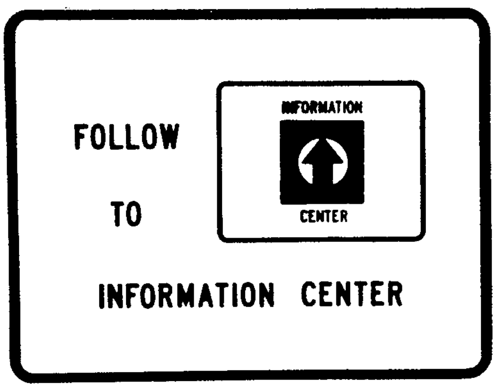


Shown at sign locations two and four (fig. 1)

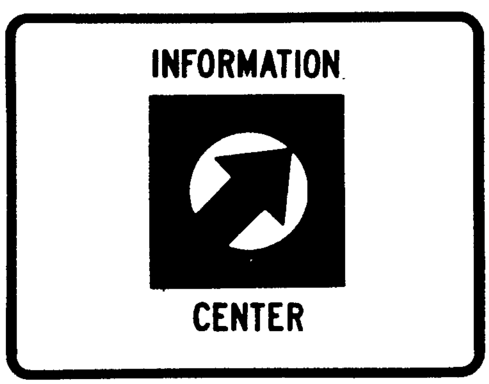
Figure 4. Signs shown to subjects in the control and map groups (locations keyed to figure 1).



Shown at sign location one (fig. 1)



Shown at sign location two (fig. 1)



Shown at sign locations three, four, and five (fig. 1)

Figure 5. Signs shown to subjects in the phone and computer map groups (locations keyed to figure 1).

Map Group

The subject was handed a large, detailed map of the Washington, D.C., metropolitan area and surrounding suburbs. He/she was told to view the map for as long as he/she liked. Subjects who said they would prefer not to look at the map were requested to look it over for the sake of the study. The subject was told that he/she could view the map as many times as he/she wished while trying to get to Lock 10, with the only restriction being that he/she locate a "safe and legal" area in which to do so. When he/she wanted to view the map, he/she was told that he/she should indicate to the experimenter the area where he/she would like to pull over. If the experimenter gave his approval of the area's safety, he would tell the subject that he/she could pull over. With the vehicle in "park," the experimenter would then give the map to the subject. At the completion of the map viewing, the subject returned it to the experimenter.

Phone Group

The subject was instructed to assume that he/she had arrived at an unstaffed information center which possessed a phone which would connect him/her with a highway information specialist. He/she was also told to assume that there was a large map attached to the wall next to the phone at the center. The subject was handed the same large map used by the map group and told to assume that the map had an arrow pointing to the information center location which was labeled "YOU ARE HERE." The experimenter indicated where the arrow would be pointing if it was on the map.

The experimenter then got out of the vehicle and unlocked a private phone installed next to the car on the driver's side. An experimenter at the FHRS was called and the phone handed to the subject. The experimenter was prepared to play the role of a knowledgeable highway information specialist. He had driven the test route, had available a map identical to the subjects, and possessed photographs of all key decision points and their signing.

The same experimenter was used for all subjects. He was instructed to give all subjects route information to return them to Lock 10 via I-495. If the subject then requested information on alternative routes, such as River Road east to Wilson Lane, etc., the information specialist was to comply after pointing out that the I-495 route was the shortest and most direct. Subjects were not permitted to "take notes" or write anything down on scratch pads. This was done for control purposes and to simulate what was thought would be the typical user behavior.

Computer Group

The subject was told to assume that he/she had arrived at an unstaffed information center which possessed a large wall map of the Washington, D.C., area. He/she was told to assume that the map had a "YOU ARE HERE" arrow pointing to the information center location. The experimenter then handed the subject the same map used by the map and phone groups and pointed out the center's location. The subject was told to further assume that the map displayed codes at numerous key intersections along with directions that informed motorists that by entering the code of a given intersection they would receive a set of printed instructions directing them to that intersection. The subject was told to assume that he/she had entered the code located at the entrance of the Lock 10 parking lot and had received a set of instructions. The experimenter then handed the subject a 8.5- by 14-in sheet which contained printed instructions and a diagram directing the subject to Lock 10 via the I-495 route (see Figure 6). The subject was told that he/she could view both the map and the printed instructions for as long as necessary but that, after leaving the information center, he/she would have only the sheet of printed instructions. The subject was told that he/she could view the computer printout sheet as he/she attempted to navigate to Lock 10 but to exercise extreme caution in doing so.

Upon reaching Lock 10 the subject was told that the experiment was over. The experimenter took the wheel and drove back to FHRS and the subject was debriefed, paid, and released. Experimentation was also terminated for those subjects who were not able to locate Lock 10 within 50 minutes after passing the "error" point. Subjects in all groups were encouraged to "stick with it" and "try a little longer" if they voiced despair or said that they wanted to give up. Only in two cases did the experimenter permit subjects to quit before the time limit when he did not think they were hopelessly lost. In these cases the subject's emotional state was such that the experimenter made the subjective judgment that it would be unsafe to continue with the test. These subjects' data were discarded.

Independent Variables:

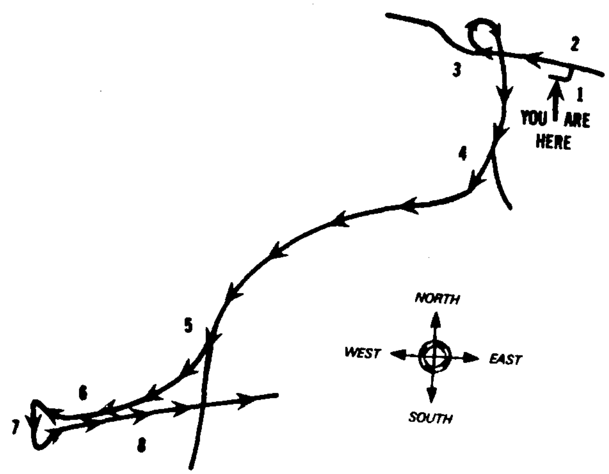
Navigational Aid

The four types of navigational aid and the means of assistance, in ascending order of amount of relevant, specific decisionmaking information, were: Control Group - No assistance was provided once the "error" point was passed; Map group - Subjects were given a road map; Phone Group - Subjects were allowed to view the same road map that was available to the map group and were also permitted two-way telephone interaction with an information specialist who provided infomation on sign content and extra road cues; Computer Map Group - subjects viewed the same map used by the map group and were provided with a labeled diagram (Fig.6) of the recovery route and detailed printed instructions concerning signing content at all key decision points.

Dependent Variables

The dependent variables served as measures of each subject's performance throughout the test drive. The following dependent variables were monitored and recorded throughout the field testing session.

Shown below is a schematic diagram to take you to or near your desired destination. The diagram is drawn proportionately so the lengths of the different parts of the route represent how far you have to drive. The numbered instructions to the right tell you what to do at the indicated places on the map below.



1. Return to the entrance of the information center.
2. Turn left (west) onto River Road.
3. Turn right at sign marked

   "495 Beltway
   Northern
   Virginia."

4. Take right fork at sign marked

   "495 Beltway
   Northern Virginia
   Fairfax."

5. Proceed on 495 to sign marked

   "Carderock
   Great Falls"

   and take the next right-hand turn.

6. Proceed west on the George Washington Parkway to the sign marked

   "Carderock
   Naval Ship Research
   and Development Center"

   and take the next right-hand turn.

7. Use the overpass to make a U-turn.
8. Proceed east on the George Washington Parkway, following signs marked

   "Glen Echo
   Washington."

Figure 6. Navigational aid presented to computer map group subjects.

Total Recovery Distance

The total number of miles required to reach the destination from the error point less the optimum recovery distance of 7.34 mi was obtained from distance records stored by on-board equipment. In those cases where experimentation was terminated before the destination was reached, total recovery distance was computed as the total extra optimum distance to the stopping point plus the number of miles that would be required to correct the error from that point as if the subject suddenly possessed perfect route knowledge. Since subjects in the control group were not required to travel to the information center location before attempting to reach the destination, their optimum correction distance was 0.51 mi less than for the navigational aid groups. In order to permit statistically unbiased mean comparisons, 0.51 mi was added to the total recovery mileage of all control subjects.

Total Recovery Errors

Each subject's route choice was scored at each decision point as to whether the route taken was the optimum choice available at that moment. The optimum choice was always defined as the route choice leading to the destination along the shortest route possible from that point. Recovery errors were further analyzed as to whether they represented omission or commission errors. Omission errors were defined as those errors where the subject did not make a route change that would have been optimum. Commission errors were defined as those errors created by the subjects deviating from what, at the moment, was the optimum route.

Total Error Cost

Error cost was calculated in an attempt to "weigh" the severity of various route errors. Starting at the location of each error, the recovery distance from that point was calculated using the assumption that after the error, the subject would then take the most optimum route available (i.e., the distance from after the error to the destination if no more errors were made). This was done for every error. Thus, by definition, errors committed closer to the destination would be less costly.

Total Recovery Trip Time

The duration in seconds of each recovery attempt less the optimum recovery time (set at 510 seconds) was recorded by onboard instrumentation from the error point to arrival at the destination. For those subjects who did not reach the destination, total recovery time was calculated as total seconds over optimum to that point plus the number of seconds required to continue to the destination along the optimum route at legal speeds. For the navigational aid groups, total recovery time was calculated as the total number of seconds from the error point to the destination including the number of seconds spent at the information center.

Total Recovery Driving Time

This was calculated as the total recovery trip time minus the duration of aid stops at the information center location (see Figure 3).

Total Information Stop Time

This was the time in seconds spent at the information center location (Figure 3).

Results

Overall Navigational Aid Groups' Performance

As was expected, the univariate ANOVA analyses demonstrated significant differences across the navigational aid groups. Significant differences were found for total recovery (TR) errors (Fig. 7), TR distance (Fig. 9), total error cost (Fig. 9), and TR trip time and TR driving time (Fig. 8). Generally, means were largest for the control group and fell in decreasing order through map to phone to computer group. There were only two exceptions to this pattern. TR trip time and information stop time were higher for the map and phone groups (Fig. 8). This was due to the long information stop time in these two groups. (Information stop time, $F = 5.32$, $p<.05$.) Perfect route recoveries ("1" = yes, "2" = no) were significantly different across the four groups ($X^2 = 17.93$, 3 df,$<.01$), with means increasing from the control through the computer groups.

Figure 8 presents total recovery trip time, driving time, and information stop time means. The TR driving time curve reflects the expected pattern found for TR errors and TR distance; that is, systematically decreasing means from control to computer group. TR trip times demonstrate a different pattern. TR trip times are greatest for the phone and map group in that order, with the control and computer groups showing the shortest TR trip times. The bottom curve in Figure 8 illuminates the cause of this phenomenon. Mean information stop times were 35 percent longer for the phone group subjects as for the subjects in the map group (433 seconds versus 318 seconds). Thus, while TR time was less for the phone subjects whose group means fell between the map and computer group means, the comparatively long information stop means for the phone subjects raised their TR trip time considerably. The comparatively very short information stop means (85.42 seconds) of the computer group, coupled with their much shorter TR driving time, insured that the computer group obtained by far the shortest TR trip time (366 seconds as opposed to 684 seconds for the control group).

Figure 9 presents curves detailing TR distance and error costs for the four navigational aid groups. The mean TR distances decreased dramatically over the first three groups, but there was little change from the phone to the computer group. Bonferonni test comparisons support this observation, in that pairwise comparisons were significant between the control group and both phone and computer groups and between the map and computer groups. The same Bonferonni test comparisons were significant for TR error cost, but as Figure 9 shows, the means decreased almost in a straight line from a high of 14.2 mi for the control group to 1.1 mi for the computer group.

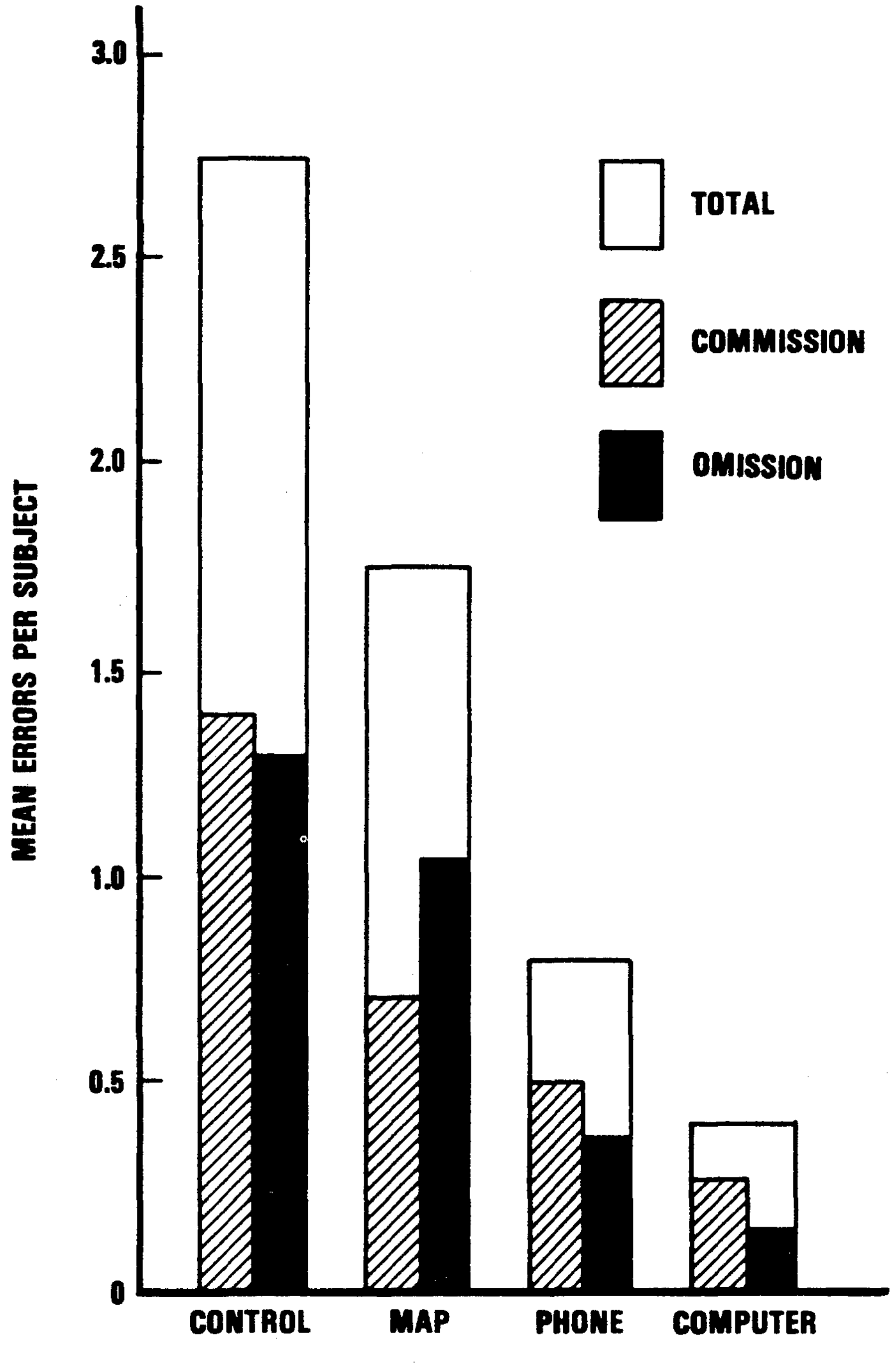


Figure 7: MEAN ERRORS PER SUBJECT FOR THE FOUR NAVIGATIONAL AID GROUPS.

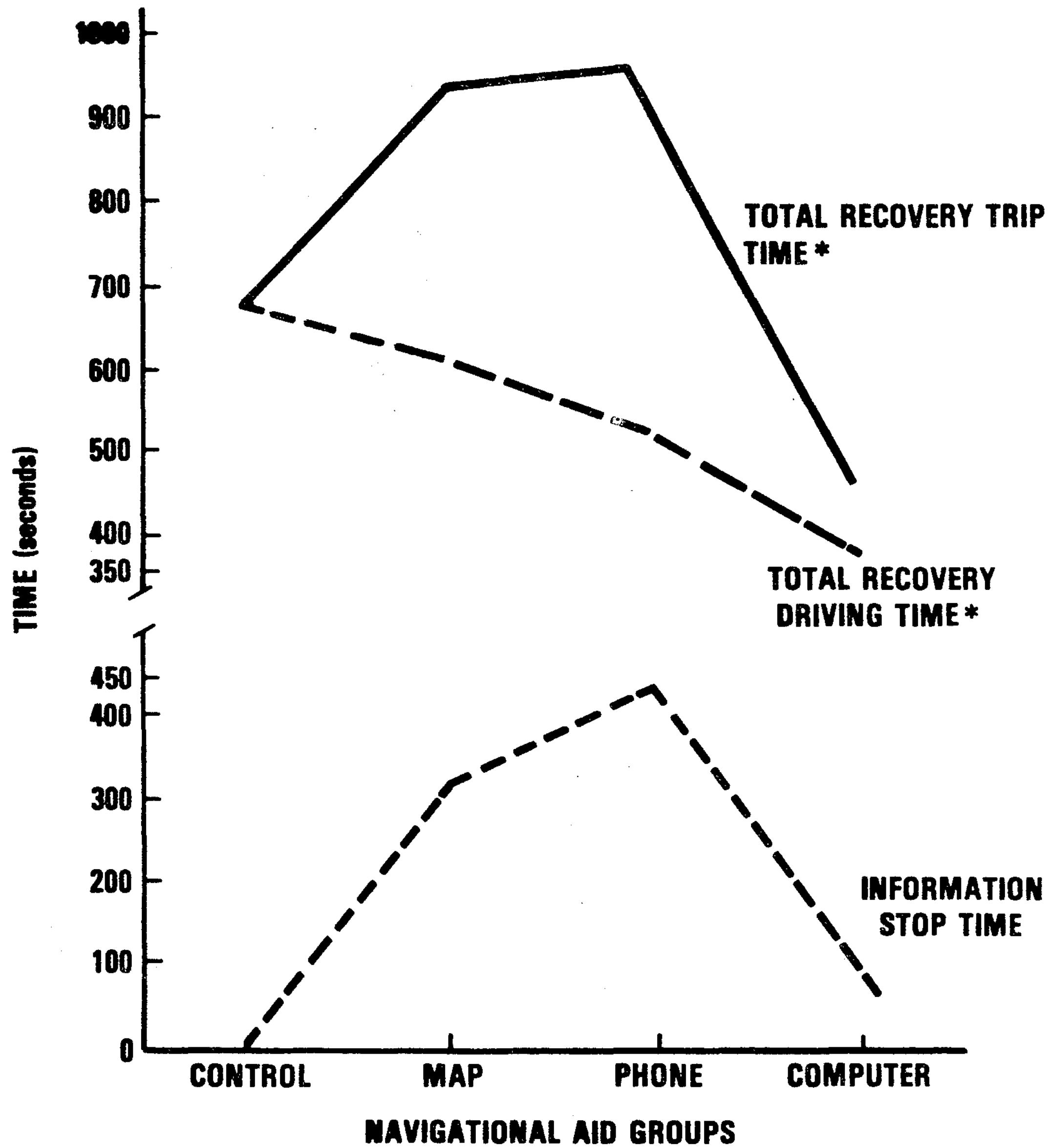


Figure 8: MEAN TOTAL RECOVERY TRIP TIME, DRIVING TIME, AND INFORMATION STOP TIME FOR THE FOUR NAVIGATIONAL AID GROUPS.

* LESS OPTIMUM RECOVERY TIME OF 510 SECONDS.

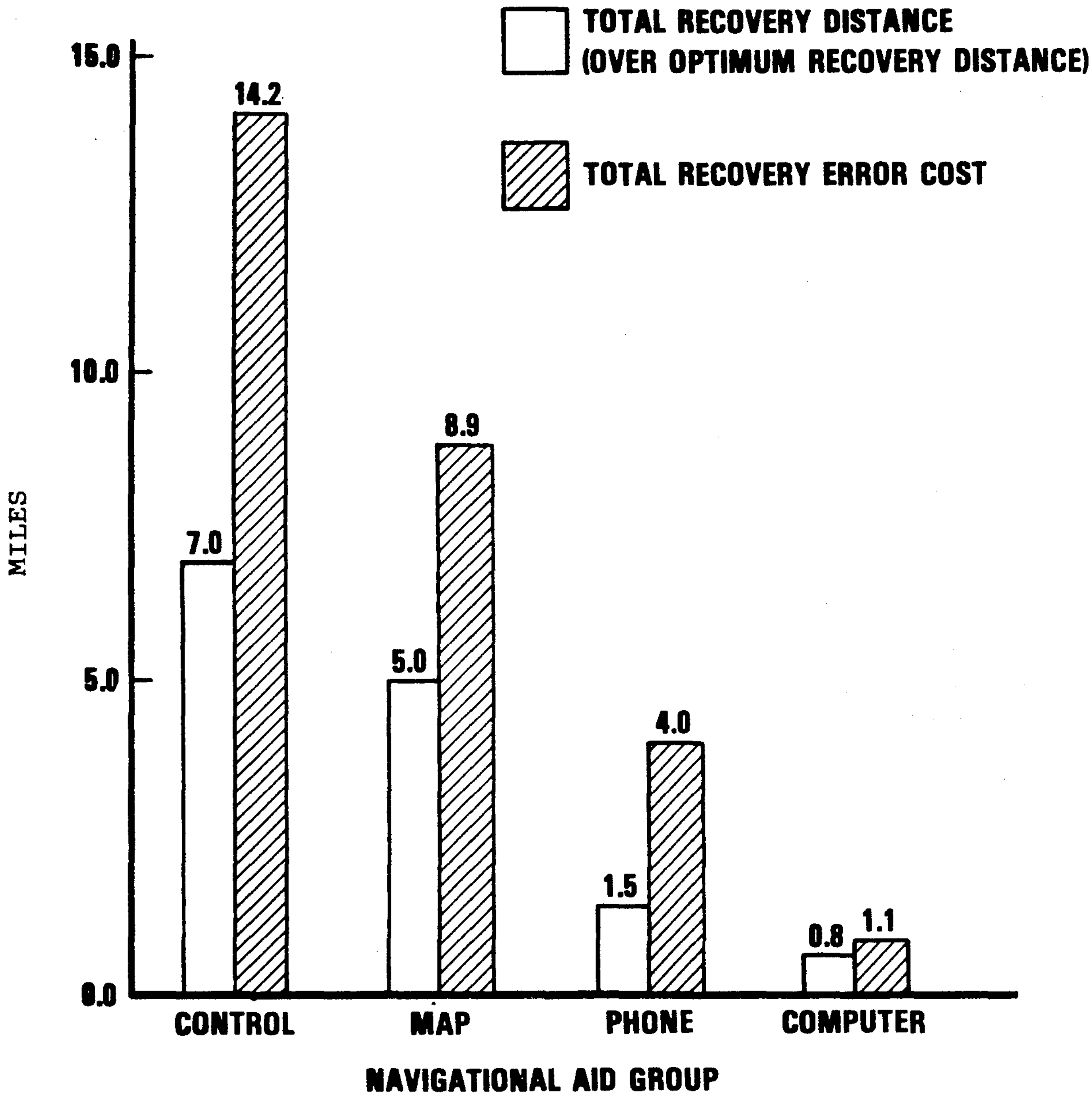


Figure 9: MEAN TOTAL RECOVERY DISTANCE AND ERROR COST FOR THE FOUR NAVIGATIONAL AID GROUPS.

Thus in terms of overall univariate analysis, the control group took longer (TR driving time), drove further (TR distance), and made more errors (and more costly ones) than the other groups. The map group's performance was better in all cases but inferior to the phone and computer groups. Overall, the computer group was consistently superior, using less time and distance and making significantly fewer errors.

As might be expected, there were high intercorrelations between several of the TR variables. Table 5 demonstrates that TR errors, error cost, and TR driving time and distance were all highly intercorrelated. While reinforcing the validity of anyone of these measures as a valid index of lost driver performance, it is clear (and it would seem intuitively obvious) that most of them are interrelated due to their separate relationships with TR distance. Obviously, as a driver travels further, a number of the other measures have ample opportunity to increase concomitantly. Thus, valid analyses of group differences on any of these measures must control for their relationship with distance.

Overall Route Errors

Figure 7 presents mean error rates per subject for the navigational aid groups. For each group, total commission and omission recovery errors are displayed. With only one exception, all types of error rates uniformly decrease across all four groups, from control to computer group with each group accumulating slightly more commission errors than omission errors. The exception to this trend was found in the map group's commission errors which were only slightly greater than those of the phone group.

Similar analyses of ommission and commission errors over the four groups yielded significant F's for navigational aid groups at better than the .01 level.

Bonferroni pairwise mean comparisons for TR errors affirmed that the control group accumulated significantly more errors than either the phone or computer groups. TR commission errors demonstrated only a significant pairwise comparison difference for the control versus computer means. TR omission errors pairwise comparisons found significant differences between the control and both the phone and computer groups and between the map and the computer groups.

Discussion

Overall Navigational Performance

The results demonstrate quite conclusively that route-specific navigational aids (as opposed to general highway signing) can dramatically reduce the distance and time required and errors associated with recovery from a freeway-missed exit error. Across the four groups, from control to computer, mean TR distance and driving time and errors per subjects progressively declined. The map and phone groups required (Fig. 9), respectively, 28 and 78 percent fewer miles to correct than the control group subjects. While the computer group's mean TR distance decreased only 0.7 mi from that of the phone group, savings in TR error cost were much larger. The TR error costs for control, map, and phone groups

Table 5. Intercorrelations of selected total recovery period variables pooled across the four navigational aid groups.

VARIABLES	TR Driving Time	TR Distance	Total Error Cost	TR Errors
Total Recovery (TR) Errors	0.60	0.85	0.93	1.00
Total Error Cost (Miles)	0.75	0.84	1.00	
Total Recovery Distance (Miles)	0.89	1.00		
Total Recovery Driving Time (sec)	1.00			

were, respectively 14.2, 8.9, and 4.0 mi. Figure 9 demonstrates that the control group's mean TR error cost continued to decline, to 1.1 mi, a further reduction of 72 percent from the phone group's error cost. Thus, while the computer's navigational aid did not markedly reduce mileage when compared to the phone group, it was considerably more effective in getting subjects closer to their destination.

Mean TR driving time follows the same general pattern as mean TR error costs; i.e., consistently decreasing mean over all four groups. Mean TR time, however, did not follow this continually decreasing pattern. Only the computer group had shorter mean trip times than the control group. Analysis of Figure 8 illuminates the cause of this anomaly. Both the map and phone groups required considerable time (respectively, 318 and 443 seconds) in which to complete their information stops. The mean computer group information stop was considerably lower (85 seconds). Thus, in terms of time-in-the-system, where information stop areas are considered part of the traffic network, only the computer group was able to complete its trip in less time than the control. Of course, in terms of overall system performance, it is probably more efficient (and safer) to have drivers stopped off the road at an information stop than it is to have them increasing traffic flows and making route errors throughout the system. Mean TR route errors of all types (Fig. 7) decreased steadily from the control to the computer group, as might be predicted from previous findings. Each group, with the exception of subjects in the map group, demonstrated a tendency to commit more commission errors than ommission errors. That is, subjects would more often "do something incorrect" than they would "not do something correct". In general terms, it might be concluded that most "lost" subjects would rather risk making incorrect route changes than continuing ahead on a possible incorrect route. Map group subjects showed the opposite tendency. They made more omission than commission errors, indicating that they seemed to have an inclination to follow a route longer without making changes.

There are several possible reasons for this reversal of error type in the map group. Perhaps subjects in the map group had less reason to fear "getting more lost". The phone and computer groups were provided with navigational aid that was directly and specifically related to the optimum correction route. As subjects in these groups traveled farther and farther from the areas mentioned in their instructions, the relevance of their information would rapidly decrease. Without any extra navigational aid, the control subjects faced an even more extreme situation; they could not afford to wander too far from the areas they had seen on the out-going trip. The map group, however, was provided with a take-along, widely relevant navigational aid. For those subjects who could use the map, route-specific navigational aid could be provided (by using the map) at any number of locations far from the correction route. Thus, map subjects may have been less concerned about leaving the immediate area of the correction route. They might therefore be willing to take a chance and continue along a given route longer before abandoning it. This would result in the fewer commission than omission errors demonstrated by map group subjects in Figure 7.

The findings regarding overall recovery strategies are in general agreement with data collected in experiment I. In experiment I it was found that 100 percent of all aided subjects (map users) eventually recovered. Ninety-four percent of the present study's aided subjects eventually recovered. Of the unaided subjects (non-map users) in experiment I, 26.7 percent managed to return to the GWP in Maryland and turn at exit 15 before commiting their first error. In the present study, 27.9 percent of the subjects in the control group got as far without error.

There were, however, some differences concerning recovery routes. None of the map users in experiment I attempted recovery along "neighborhood" streets such as Wilson Lane, etc. In the experiment II map group, 20 percent of the subjects attempted to reach Lock 10 by using either Wilson Lane or Seven Locks Road. This disparity is possibly attributable to the greatly increased detail of this study's map and the added and more accurate data it presented to the subjects. The more general information contained on "gas station" road maps (due to their larger scale) may have induced subjects in the earlier study to remain on main arteries that were displayed more accurately and graphically.

Given the single exception noted above, it appears that both studies showed fairly consistent subject behavior in a missed-exit recovery situation. This finding serves to reinforce belief in the validity of the general experimental procedure of both experiments and of this technique in general.

Chapter V. Potential Navigational Aids

British Studies

Driver responses in a missed exit freeway situation are representative, obviously, of only a small portion of the entire spectrum of driver navigational behavior. Other data, such as that presented in the introduction, however, indicate further that the average driver does have significant navigational difficulty. A recent British study (1) provides additional insights. Individual drivers attempted to navigate to an unfamiliar destination using urban and rural routes. One group of 48 subjects attempted to reach a destination in Chertsey approximately 25 km (15.5 mi) from the start point. Another group of 22 subjects attempted a trip to a destination in Bedford which was 10 km (6.2 mi) distant. The percentage additional distance over the optimum navigational route which was traveled is presented in Table 6. Adapted from Armstrong (1), the table presents the same data for Experiment II of the present study as well as data from several interview and survey studies also reported by Armstrong.

The present study's very large extra optimum travel distances are much greater than those of the other studies cited. This is in large part due to an artifact of the type of problem studied -- a missed freeway exit. An error on a controlled access highway commits the driver to freeway travel until the next choice point appears. The exits in this study were fairly close together. If they had been farther apart, as with most freeway exits, error distances would have been even greater. Armstrong's findings of 12.2 and 10.6 percent extra travel distance reflect driving where the driver was less restricted in making route corrections. Equally critical, Armstrong's subjects were notified of the destination 3 days prior to the testing session and were permitted to consult maps, etc. Map consultation by subjects in experiments I and II of this study considerably reduced error distances from that found in the control group. Armstrong stated that his error distances were significantly increased by near destination errors and that the enroute excess travel distance caused by navigational error was closer to the interview findings cited in Table 6. Nonetheless, these findings demonstrate that drivers who are on routine trips as well as drivers who are permitted to prepare 3-days in advance have been observed to drive significantly farther due to navigational errors. The present study's findings demonstrate that these routine navigational difficulties can become tremendously costly in specific everyday situations. Coupled with the survey findings discussed in the introduction, there can be little doubt that tremendous amounts of fuel are being used by drivers to correct navigational errors. The reduction of this waste presents a significant opportunity for energy savings.

Table 6. Extra-optimum travel observed in driver navigation studies.

Study		Average Excess Distance Per Trip (percent)	Methodology	Type Travel	Sample Size
Mast & Lareau (U.S.)	Group:		Direct Observation	recovery from navigational error-- missed freeway exit	96
	No aid	95.8			
	Map	68.6			
	Phone	21.0			
	Computer	11.0			
Gordon (7) & Wood (U.S.)	Bethesda Trip	55.0	Direct Observation	freeway to urban address	10
	Annandale Trip	39.0			10
Armstrong (British) (1)	Chertsey Trip	12.2	Direct Observation	cross country trip to unfamiliar destination	48
	Bedford TRip	10.6			22
Hull (3) (British)		6.5	Interview	shopping	1964
West Minister (15) (British)		5.5	Interview	general urban	122
East Midlands (16,18) (British)		6.6	Interview	inter urban	6221

There are many possible approaches which can be used to reduce the fuel waste attributable to navigational error. Some solutions which have been proposed involve extremely complex and, at least initially, costly systems. Others require less ambitious modifications or additions to the present highway environment. Subjects' responses to and performances with the navigational aids presented in the present study provide data on various aspects of the utility of commonly proposed solutions to the problem.

Road Maps

Better road maps are often proposed as a partial solution. The highly detailed used in experiment II reduced extra mileage to 68.6 percent over the optimum recovery distance compared to 95.8 percent for controls. Experiment I demonstrated that 36 percent of subjects who were permitted to use a map would not or could not utilize it. Thus, while better maps have been shown to reduce navigational error distances, the practical difficulties in obtaining them, and, ultimately, the proportion of persons who cannot use them optimally or at all, combine to reduce the potential impact of maps as a solution to the problem.

Highway Signing

Improvements in signs are often cited as a possible avenue to improved navigational efficiency. A number of factors limit the influence that signing modifications may be able to exert. The standard specifications for road sign designs are comprehensive. Significant increases in sign size would be expensive and would create aesthetic conflicts due to sign "clutter." There is also a limit on the amount of information a sign can present effectively and which the driver can process while the sign is in view. Even if sign content could be significantly increased, the plethora of local place names and alternative routes relevant to any destination would make a propitious choice of optimum sign content difficult. These difficulties demonstrate that dramatic increases in navigational efficiency will probably not be forthcoming from signing modifications.

Mourant and Rockwell (14) demonstrated that drivers in unfamiliar areas make wider and more frequent visual searches of their environment. The nature of eye movement changes, however, when driving demands are increased. Studies such as Fry's (4) and Gould and Schaffer's (8) demonstrate that a driver's focus of attention is dramatically reduced when sharp curves, road hazards, etc., are encountered. Eye movements in these situations are focused on road marking lines, barriers, and other vehicles in the immediate area. This "narrowing" of visual attention has obvious survival value in that it increases the probability that critical stimuli essential to short term vehicle control will be received. The converse side of this benefit, however, is that a narrow visual scan at or near a decision point will drastically reduce the probability that decision cues appropriate to the overall navigational task will be perceived. This is especially true in regard to the types of decision points encountered in this study. The largest part of navigational decision cues are displaced on high overhead signs. Increased vehicle control demands focus attention diametrically away from overhead areas to ground level cues. In this type of situation, the driver has to make a tradeoff between driving safely and attending to vehicle control or risk concentrating on navigational decision cues.

Call-In Information Center

Experiment II demonstrated that unstaffed off-road information centers may have a degree of utility in improving navigational efficiency. Manned information centers were not considered as a general solution as their high staffing costs (as well as security and training concerns) make them an unreasonable and too costly alternative for all but the most specialized purposes (as in national parks, near national monuments, etc.). Both the call-in and computerized information center dramatically reduced navigational errors and total recovery distance. Each approach has concomitant advantages and drawbacks. Although the call-in information centers would not be staffed in person, considerable personnel would be required to run the central information data bank for a metropolitan information system which would use a large number of peripheral roadside phones. There would be drastic fluctuations in load between peak summer vacation months and cold weather weekdays. Adequate employee training may be difficult and expensive. A number of other practical difficulties must also be surmounted. The average information stop time for the experiment II phone group was 433 seconds. Subjects were not permitted to write down information. More complex navigational problems would surely be presented to the information specialists. The presentation of correct routing information to drivers who would write down the instructions would take a great deal longer than the 433 seconds observed in experiment II. Only five or six motorists could conceivably fill the queue at one information center for an hour, assuming no "hold" time once the phone was available for use. Cognitively limited drivers may have difficulties presenting their informational need in an understandable manner and would "tie up" service lines even longer. Long "hold" times and inevitable occasional incorrect instructions would also lessen public confidence and use. The above considerations would demonstrate that the practical problems that such a system would encounter would be tremendous.

An alternative type call-in system may be feasible. The Federal Aviation Administration (FAA) is currently testing a computer-controlled voice-response system whereby pilots request weather information via the phone. The pilot interacts with an electronically-generated computer voice by pushing the telephone buttons in response to questions from the computer. FAA scientists point out that the only serious problems which they have encountered are those related to hourly weather updates and associated programming complexities.

Such difficulties would not be encountered in a basic driver navigational system as most of the data would be relatively static. The technology for such a system is currently available. The considerable staffing difficulties encountered in the operation of a human staffed phone system would be avoided. The format of the exchanges could be designed to reduce "on-the-line" phone time. There would also be no "hold" time as the computer could easily accommodate several phones at once in an interactive mode. There would, of course, be many practical problems such as user ability to interact with the system properly. Detailed cost-benefit analyses would have to examine the many possible configurations of such systems to determine their feasibility.

A recent feasibility study was undertaken to determine if the FAA type system could be adapted to provide motorists with directionfinding information (17). An experimental system was installed in the Washington D.C. area and tested with a limited sample of users. The system provided routing information between 45 travel points frequented by unfamiliar drivers. The system did not have a dynamic update capability. It was concluded from the study that an automated call-in system for providing motorists with advisory routing information is technically feasible. Such a system would require a dynamic update of information so that the most current and accurate routing information was available. This would require a procedure for entering current traffic reports into the system. To eliminate the need for a large computer storage system, the study concluded that routing information should be computed "on-line" rather than precomputing it and saving it in the data base. Before this type of system can be implemented, research and development is required to perfect the "on-line" computation of optimal routes and to human engineer the user interface with the system.

In-Vehicle Audio Signing

In-vehicle audio signing or Highway Advisory Radio (HAR) may be one possible alternative. In responding to the debriefing questions in Experiment I, a majority of subjects, 64 percent, indicated that they would prefer verbal instructions to more or better signs. Gatling (5) studied the effectiveness of in-vehicle audio signing in transmitting route guidance and amenities information to motorists. He found that navigational information is difficult to remember and that messages containing more than four units (e.g., take River Road west, then take I-495 south to George Washington Parkway and exit west contains four message units) resulted in high error rates. However, repetition of the message was found to increase retention. In another experiment, Gatling found that subjects were able to select pertinent information from a longer general message and that use of route numbers and specific distances decreased the total usable length of the message. A further study (16) found that subjects retained routing information more poorly after having to manually tune the radio in response to an alerting than subjects who automatically received radio messages without tuning. Thus, ideally, effective audio signing must utilize short messages, repeat them, and be presented without the driver having to manually tune his radio. Research will have to determine whether audio signing, given these restrictions, can be effective in redirecting drivers who fall prey to freeway navigational errors. The practical problems cited above, as well as the obvious expense, seem to limit in-vehicle auditory signing for freeway navigational problems to very specific and unusual areas of application.

An example of the special application of HAR would be in situations where time-of-day travel restrictions cause severe routing problems for the unfamiliar motorist. Even the best prepared tourist or "local stranger" often cannot obtain this kind of information. HAR could be used to give unfamiliar motorists alternate routing information in advance of locations where time-of-day restrictions affect large numbers of travelers. For instance, HAR could be used in advance of major urban bridge ramps that are closed during peak periods. An HAR message could advise unfamiliar motorists on alternate routes to the locations served by the bridge.

Computer Drawn Maps

The hard copy information disseminated by a computerized off-road information center simulated in experiment II appears to have a degree of utility in that it reduced total recovery mileage by half from that of the phone group. More importantly, in terms of queuing, it reduced interaction with the system for the mean 433 seconds of the phone group to a mean of only 85 seconds. The hard copy form of the instructions eliminated the need (or desire) to copy instructions. Although a map with push buttons was used as the interactive tool, it would be possible to provide additional visual aids at the computer location. Of course, many of the same user problems relevant to call-in centers also apply to computerized hard-copy centers. Further research will have to determine whether better information can be presented (and requested by users) in a manner sufficiently efficient to warrant the expenditure of developmental and installation funds.

Automatic Route Guidance

Automatic route guidance systems are the most ambitious navigational aid systems which have thus far been proposed. The Electronic Route Guidance System (ERGS) was proposed some years ago (20) but was never implemented in the U.S. Armstrong (1) calls for such a system as Britain's solution to navigational difficulties. Thus far, Japan's Comprehensive Automatic Control System (CACS) (21) and the German ALI - Destination Guidance System (22) are the only large scale systems in operation in which vehicle-computer communications provide the driver with routing and safety data. Systems such as ERGS and CACS are comprehensive, complex,.and expensive. It has yet to be demonstrated that the proportion of recoverable costs presently attributable to navigational problems are sufficiently large to ensure that such systems will be cost-effective.

In-Vehicle Telecommunications

The present and expected growth of mobile telephones offers the possibility for widespread existence of in-vehicle telephones. In-vehicular telephone access to a central navigation information center would bring detailed guidance instructions to the motorist as he was enroute to a destination. The motorist would not have to seek a roadside information station or telephone. He/she would have immediate access to navigational assistance the moment his/her route guidance problem developed. Moreover, the rapidly expanding telecommunications technology will make it possible for the motorist to obtain information in hard copy form over the telephone. Devices that attach to the telephone already exist whereby graphics and printed material can be transmitted via telephone lines. The availability of navigation instructions in hard copy form by means of an in-vehicle telephone would provide the benefits exhibited by the computer map group in experiment II. The hard copy, simplified map, eliminates the memory problem normally associated with receiving directions over the telephone. In addition, the in-vehicle telecommunication system could provide the motorist with information that could be updated on a real-time basis. Travel conditions as influenced by time of day and traffic accidents could be incorporated into the navigational information system.

Understanding the Problem

Effective and practical solutions to the motorist direction-finding problem will not be forthcoming until we fully understand the ramifications of the problem. The magnitude of the current fuel waste associated with "lost" and "disoriented" motorists must be accurately established. This will be difficult to do because we do not currently have enough exisitng data to break the problem down into its component parts and to assess the important determining factors. Moreover, this problem is insidious in that it is not intuitively possible to comprehend the magnitude of its impact. It is a very different kind of problem than the highway safety and traffic congestion issues that traffic engineers confront. Data on highway safety is collected and traffic congestion is directly observable. On the other hand, motorist route-finding problems do not show up in our data nor are they directly observed. A given highway interchange or street intersection might be perfectly safe and traffic congestion free but be a total disaster as far as motorist routefinding is concerned. The only way the problem becomes noticeable is through motorist complaints. And motorists do complain. Route-finding problems top the list of motorist complaints to AAA and city traffic engineers. If we are serious about reducing our dependency on foreign oil, and if we really believe that energy conservation is a national priority, then we must take immediate steps to understand and document the magnitude of waste associated with inefficient motorist direction-finding. Effective solutions cannot come about without this understanding.

Statement of Conclusions

The overall integrated results of this study's two experiments suggest a number of conclusions. They are:

- A significant "lost driver" problem exists; that is, navigational errors and attempts to recover from them result in a significant increase in the miles driven (and the fuel wasted) by many drivers.
- Use of road maps increases navigational efficiency and reduces navigational errors. Increases in map detail can increase navigational efficiency under some conditions.
- A significant proportion of the total driving population cannot and/or will not utilize present day road maps effectively.
- Unstaffed roadside information centers can increase navigational efficiency.
- Interactive telephone information centers connected to a centrally manned facility increase navigational efficiency but may present queuing problems at the information center.
- Computerized information centers which deliver hard-copy route information to drivers can be extremely effective in increasing navigational efficiency.
- The results of this study suggest alternative types of motorist navigational aid systems. It is clear that a motorist navigational problem exists and that significant savings can be realized by reducing that problem. However, it is equally clear that additional studies are essential to completely define the problem and to identify realistic solutions.

References

1. Armstrong, B. D., "The Need for Route Guidance," Transport and Road Research Laboratory," Digest SR 330, 1977.

2. Cross, K. D. and McGrath, J. J., "A Study of Trip Planning and Map Use by American Motorists." Final Report No. 170-1, West Virginia Department of Highways, Research Project No. 44, 1975.

3. Freeman Fox, Wilbur Smith and Associates, "Choice of Route by Car Driver." June 1971. (A report prepared for the Mathematical Advisory Unit, DOE.)

4. Fry, G. A., "The Use of Eyes in Steering a Car on Straight and Curved Roads," American Journal of Optometry, Vol. 45 (No. 6), 1968.

5. Gatling, F. P., "Auditory Message Studies for Route Diversion," Report No. FHWA-RD-75-73, Federal Highway Administration, Offices of Research and Development, Washington, D.C., 1975.

6. Gatling, F. P., "The Effect of Auditory and Visual Presentation of Navigational Messages on Message Retention," Report No. FHWA-76-94, Federal Highway Administration, Offices of Research and Development, Washington, D.C., 1976.

7. Gordon, Donald A. and Wood, Harold C., "How the Driver Finds His Way to an Unfamiliar Address." Public Roads, June 1970, pp. 44-47.

8. Gould, J. D. and Schaffer, A., "Eye-Movement Patterns During Visual Information Processing." Psychonomic Science, Vol. 2, 1965, pp. 187-202.

9. Johansson, G. and Ruhr, K., "Drivers and Road Signs, A Preliminary Investigation of the Capacity of Car Drivers to get Information from Road Signs," Ergonomics, Vol. 9, No. 1, January 1966.

10. King, G. F. and Lunenfeld, H. Urban Area Highway Guide Signing, Report No. 6566, AIL (a Division of Cutler-Hammer), Farmingdale, Long Island, New York, May 1972.

11. King, G. E. and Lunenfeld, H., Development of Information Requirements and Transmission Techniques for Highway Users, National Cooperative Highway Research Program Report 123, 1971, p. 312.

12. McNees, R. W. and Hutchingson, R. D., Questionnaire Survey of Motorist Route Selection Criteria, Vol. 5, "Human Factors Requirements for Real-Time Motorist Information Displays," Interim Report, September 1975.

13. Mast, T. M., Ballas, J. A., and Peters, J. F., "Instrumented Vehicle Research on Highway Information Systems," Public Roads, Vol. 40 (No. 2), 1976, pp. 53-59.

14. Mourant, R. R. and Rockwell, T. H., "Mapping Eye-Movement Patterns to the Visual Scene on Driving: An Exploratory Study," Journal of Human Factors, Vol. 12(1) 1970, pp. 81-87.

15. Orrom, H. and Wright, C. C., A New Technique for Traffic Studies. City of Westminster Transport Research Note, May 1976. (Paper given at the PTRC Summer Annual Meeting, University of Warwick, July 1976.)

16. Outram, V. E., Route Choice. Department of the Environment, MAU Note 256, March 1976.

17. Parikh, B. and Pollock, R., Motorist Call-in System for Computerized Routing Information, Input Output Computer Servics, Inc., Federal Highway Administration, Report No. FHWA/RD-81/100, 1981.

18. PTRC (UK) LTD., Inter-Ruban Route Choice Study. (A report prepared for the Mathematical Advisory Unit, DOE.)

19. Schoppert, D. W., Moskowitz, K., Hulbert, S. F., and Burg, A., "Some Principles of Freeway-Directional Signing Based on Motorists Experience," HRB Bulletin 224, 1960, pp. 30-87.

20. Stephens, B. W., Rosen, D. A., Mammano, F. J., and Gibbs, W. L., "Third Generation Destination Signing: An Electronic Route Guidance System." Highway Research Record 265, Washington, 1968 (Highway Research Board, National Research Council, USA).

21. Yumoto, N., Hirokasu, I., Tsutomu, T., and Masauru, N. Outline of the CACS Pilot Test System. Paper presented at the 58th Annual Meeting of the Transportation Research Board, Washington, D.C., January, 1979.

22. "ALI - Destination Guidance System," Blaupunkt Technical Brochure, Blaupunkt, Hildesheim, West Germany, 1978.

☆U.S. GOVERNMENT PRINTING OFFICE: 1985-461-816/10318