Advanced Traveler Information Systems and Commercial Vehicle Operations Components of the Intelligent Transportation Systems: On-Road Evaluation of ATIS Messages

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FOREWORD

This report is one of a series of reports produced as part of a contract designed to develop precise, detailed human factors design guidelines for Advanced Traveler Information Systems (ATIS) and Commercial Vehicle Operations (CVO). During the analytic phase of the project, research issues were identified and rated by 8 human factors experts along 14 separate criteria. The goal of the experimental phase was to examine the highest rated research issues that can be addressed within the scope of the project. The 14 experiments produced in that phase reflect the results of those ratings.

This report documents a study that was performed to determine how ATIS information, primarily In-Vehicle Signing and Information Systems (ISIS) and In-Vehicle Safety Advisory and Warning Systems (IVSAWS), influences driver behavior. The objective was to develop design guidelines to define the amount and format of information that can safely be displayed in an ATIS.

Copies of this report can be obtained through the Research and Technology Report Center, 9701 Philadelphia Court, Unit Q, Lanham, Maryland 20706, telephone: (301) 577-0818, fax: (301) 577- 1421, or the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, Virginia 22161, telephone: (703) 605-6000, fax: (703) 605-6900.

Michael F. Trentacoste
Director, Office of Safety
Research and Development

NOTICE

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16. Abstract

This report describes the results of an on-road study that examined how Advanced Traveler Information Systems (ATIS) information influences driver behavior. The objective of the study was to develop ATIS design guidelines, primarily for In-Vehicle Signing Information Systems (ISIS) and In-Vehicle Safety Advisory and Warning Systems (IVSAWS), to define the amount and format of information that can safely be displayed in an ATIS. A general issue facing ATIS designers is to determine how much information can safely be presented in an ATIS. This study investigated rates of one, two, or three message presentations per minute. No effects of information density were observed on driving performance. Another general issue that faces ATIS designers is how message potency (i .e. message style and display modality) affects driving safety and compliance with ATIS messages. Message potency is shown to have an important effect on both compliance and driving safety, confirming previous findings on how particular ATIS design characteristics can undermine driving safety by fostering an over-reliance on ATIS information. Also investigated in this study was whether advance notification messages that warn drivers of upcoming route guidance instructions are helpful. The results show that the drivers make use of advance notification messages to prepare for upcoming turns.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	**ha**
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3

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

Symbol	When You Know	Multiply By	To Find	Symbol
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celcius temperature	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.71	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

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

(Revised September 1993)

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LIST OF ABBREVIATIONS

ATIS	Advanced Traveler Information Systems
BMDP	Bio-Medical Data Processing
CVO	Commercial Vehicle Operations
GPS	Global Positioning System
HFTC	Human Factors Transportation Center
IRANS	In-Vehicle Routing and Navigation Systems
ISIS	In-Vehicle Signing and Information Systems
IVSAWS	In-Vehicle Safety Advisory and Warning Systems
km	kilometer
mi/h	miles per hour
NTIS	National Technical Information Service
SD	standard deviation
STWA	steering wheel angle
VCR	video cassette recorder

EXECUTIVE SUMMARY

Advanced Traveler Information Systems (ATIS) are being designed and implemented that provide drivers with a wealth of real-time information, including In-Vehicle Routing and Navigation Systems (IRANS), In-Vehicle Signing and Information Systems (ISIS), In-Vehicle Safety Advisory and Warning Systems (IVSAWS), as well as general service information and vehicle monitoring information. Although these systems are already in wide use, little is known about drivers' ability to use and process this information in a real driving environment. Further, there is a lack of research examining ISIS and IVSAWS; most of the ATIS research to date has concentrated on IRANS. Since ISIS and IVSAWS have important but quite different functions than IRANS, this lack of testing constitutes a major ATIS research gap.

The goal of this study was to determine how ATIS information, primarily ISIS and IVSAWS, influences driver behavior. It was our intent to develop design guidelines to define the amount and format of information that can safely be displayed in an ATIS. To accomplish this an on-road study, taking into account driver characteristics and roadway environment characteristics, was conducted.

Information density (i.e., the number of messages presented per minute) and message potency (i.e., the modality and style of message presentation) were the two ATIS design issues considered. The questions addressed in the study were:

! *Does message potency affect compliance rates to navigation, ISIS, and IVSAWS messages?* Message potency is defined as a combination of message style and presentation modality. A notification message advises drivers of a roadway condition (e.g., Icy Road Ahead) while a command message tells drivers to perform a specific action (e.g., Slow Down). In this experiment high message potency uses a command style presented in the auditory modality; low message potency uses a notification style presented visually.

! *Are advance notification messages* (e.g., Prepare to turn left on 15th Avenue North East) *that warn drivers of upcoming route guidance instructions* (e.g., Turn left on 15th Avenue North East) *helpful?*

! *Do traffic density and roadway demands affect driver's ability to utilize ATIS information?*

Twenty-four subjects were asked to drive in Seattle in an instrumented vehicle equipped with a prototype ATIS. A "Wizard of Oz" methodology was used whereby ATIS messages presented to the driver were controlled by an experimenter in the back seat of the vehicle. Five types of messages (navigation, ISIS, IVSAWS, general/service and vehicle monitoring) were presented throughout the 30-mile drive.

Data examined included compliance to messages, and driver performance data such as message-initiation latency (indicating readiness to receive a message), average deviation of the steering wheel angle (STWA), number of large steering wheel reversals, and standard deviation (SD) of velocity. Velocity and steering wheel measurements were calculated for 5-second windows before and after message onset.

As expected, drivers who received advanced notification of a turn were prepared to turn sooner (indicated by turn signal activation) after the onset of the actual navigation message than those who did not receive advance notification. This suggests that the advance notification messages were used by drivers to help them prepare for upcoming turns.

Compliance was much higher to auditory/command messages than to visual/notification messages. In fact, auditory/command messages were so powerful that the drivers tended to “automatically” follow them without much independent verification of the immediate appropriateness of the message. For example, drivers receiving these messages tended to change lanes abruptly as instructed, without carefully checking that such maneuvers were safe. ATIS designers should be aware that the power of auditory/command messages carries an attendant risk, so this message format should be reserved only for urgent messages of high priority.

Message-initiation latency did not differ as a function of information density. Contrary to our expectations, presenting two or even three messages within 1 minute did not appear to be too many, at least to the extent that it affected the drivers’ readiness to receive a new message. Also, no significant differences were found in SD of velocity as information density increased. This suggests that presenting three messages within a 1-minute period does not draw attention away from the primary task of driving any more than one message per minute does, at least for the short messages investigated in this study.

The number of large steering wheel reversals in the “before message” window did not differ significantly from those recorded in the “during message” window. This suggests that the presentation of ATIS messages did not increase attentional or workload demand, at least to the extent that would be reflected in an increase in the number of large steering wheel reversals.

INTRODUCTION

Advanced Traveler Information Systems (ATIS) are being designed and implemented that provide drivers with a wealth of real-time information, including In-Vehicle Routing and Navigation Systems (IRANS), In-Vehicle Signing and Information Systems (ISIS), In-Vehicle Safety Advisory and Warning Systems (IVSAWS), as well as general service information and vehicle monitoring information. Although these systems are already in wide use, little is known about drivers' ability to use and process this information in a real driving environment. Further, there is a lack of research examining ISIS and IVSAWS; most of the ATIS research to date has concentrated on IRANS. Since ISIS and IVSAWS have important but quite different functions than IRANS, this lack of testing constitutes a major ATIS research gap.

The goal of this study was to determine how ATIS information, primarily ISIS and IVSAWS, influences driver behavior. It was our intent to develop design guidelines to define the amount and format of information that can safely be displayed in an ATIS. To do this, an on-road study, taking into account driver characteristics and roadway environment characteristics, was conducted.

ATIS DISPLAY CHARACTERISTICS

Two design issues considered in this study were information density (i.e., the number of messages per minute) and message potency (i.e., modality and style of message presentation).

Information Density

With the amount of information available to drivers growing rapidly, an issue of great importance to ATIS designers is how much information can be safely presented to a driver without creating a safety hazard or negatively affecting driving performance. Hanowski et al. (1997) examined the issue of display density, which was defined as the amount of information (i.e., text messages, symbols, and icons) displayed on the screen at any given time. In their on-road test, drivers received IRANS, ISIS, and IVSAWS information via the ATIS. The ATIS also warned drivers of planned external events (such as one-lane tunnel and disabled vehicle ahead). Three levels of information density were examined: none, low, and high. In the low-density condition, two to three ISIS and IVSAWS items were displayed, and in the high-density condition, six to seven ISIS, IVSAWS, and IRANS items were displayed. Driving performance and compliance to the IVIS messages were measured. Hanowski et al. concluded that there were no differences between the low- and high-density condition for time to respond to events. This suggested that the extra information in the high-density condition did not reduce the time required to obtain relevant information from the display and respond appropriately.

Another related issue that an ATIS designer must be concerned with is how much information, or how many messages, can be presented to a driver in a given period of time. This study will examine the ability of drivers to obtain and comply with one, two, and three messages within a time period of 1 minute.

Message Potency

Lee et al. (1996) defined message style on a dimension of directiveness. They suggest that at one extreme, messages advise or notify drivers of a roadway condition (e.g., Icy Road Ahead) and at the other extreme, messages command drivers to take a specific action in response to a condition (e.g., Slow Down). In their low-fidelity simulator study, subjects received command or notification style ISIS and IVSAWS messages in either the auditory or visual modality. Lee et al.'s results showed that, while sensory modality was unimportant, message style had powerful effects on driver behavior as it influenced both compliance to ATIS messages and driver safety. Specifically, ATIS messages presented in a command style produced higher levels of compliance than messages presented in a notification style. It was suggested that command messages should be reserved for safety-critical situations, particularly where redundant information is not available in the external environment. Less critical messages should use a notification style and be paired with redundant roadway information. Lee et al. acknowledged that because their study was conducted in a low-fidelity simulator, the limited field of view, low resolution of images, and novelty of the ATIS messages limit the generalizability of their results. The current study intended to replicate the findings of Lee et al. (1996) in a setting that allowed for a greater degree of realism. It was hypothesized that in a real-world driving scenario, where drivers are aware of the rules of the road and where there are real consequences to one's actions, compliance to unnecessary or incorrect ATIS commands would be reduced.

DRIVER CHARACTERISTICS

Driver characteristics such as age, gender, and driving experience are known to have an influence on driving behavior. For instance, average travel speed, tendency to follow closely, and the number of severe crash involvements vary with respect to age and gender (Evans, 1991). It is quite possible that these driver characteristics also influence how a driver interacts with an ATIS; hence, such characteristics must be identified so that an ATIS can either be designed for the worst case user or allow drivera to optimize their own display features.

Studies examining the design features of an ATIS have often included young drivers (usually 18 to 25 years) and older drivers (often 65 years and older) (e.g., Lee et al., 1996; Pauzie, Martin-Lamellet, and Trauchessec, 1991; Dingus, Antin, Hulse, and Wierwille, 1989, Hanowski et al., 1997). Pauzie et al. and Dingus et al. reported that older drivers spend significantly more time looking at navigation displays than younger drivers. In Hanowski et al.'s field study, older drivers were slower to respond to external events, but both younger and older drivers realized benefits of an in-vehicle system. Very few studies, if any, have examined the needs of middle-age drivers. This is of concern because it is the middle-age group (age 26-45) that is most likely to purchase and use a commercial ATIS compared with young and older drivers. In general, the middle-age group possesses more years of driving experience than the younger age group and, as a result, driver age is confounded with driving experience.

ROADWAY CHARACTERISTICS

It is also important to examine driver interaction with an ATIS within the context of real-world traffic demands. For example, the manner in which a driver obtains, processes, and complies to a message may depend on whether they are in low- or high-traffic density. The same must be considered for roadway demands, defined as the number of traffic devices per mile, including traffic signals and stop signs. The development of design guidelines in isolation of these very important real-world variables may lead to an unsafe ATIS design.

OBJECTIVES AND HYPOTHESES OF THIS STUDY

This study was designed to answer three research questions intended to provide information for the development of ATIS design guidelines. The three questions were:

1) Does message potency affect compliance rates to navigation, ISIS, and IVSAWS messages?

2) Are advance notification messages that warn drivers of upcoming route guidance instructions helpful?

3) Do traffic density and roadway demands affect drivers' ability to utilize ATIS information?

METHOD

SUBJECTS

Twenty-four subjects between the ages of 18 and 45 were recruited from the University of Washington. Two age groups of subjects were recruited: younger drivers between the ages of 18 and 25 (M = 19 years) and middle-age drivers between the ages of 26 and 45 (M = 34 years). All drivers had a valid driver's license and drove at least two times a week within the Seattle area. Drivers were paid $10.00 per hour for 2.5 to 3 hours of their time.

APPARATUS

Participants drove an instrumented 1994 Saturn Station Wagon that was equipped with a prototype ATIS. A Wizard of Oz methodology was used whereby ATIS messages presented to the driver were controlled by an experimenter in the back seat of the vehicle. Four video cameras and an eye tracker were used to record driver behavior.

Instrumented Vehicle

The Battelle Human Factors Transportation Center's (HFTC) instrumented vehicle is a 1994 Saturn Station Wagon (figure 1). The vehicle has been modified to include the instrumentation suite described below.

As a safety measure, a secondary braking control system was installed. This system was intended for use by the experimenter sitting in the front passenger seat in the event of an impending collision.

The vehicle provided a means of collecting and recording data based on driving performance using sensors and an analog to digital interface to record and store performance data in the form required for analyses. All of the instrumentation was powered by a 12 Volt DC to 110 Volt AC inverter. The inverter was capable of delivering 750 Watts of power to the instrumentation. The instrumented vehicle allows for storage of data at a rate of 20 Hertz, or one sample every 0.05 seconds. The data were synchronized and time stamped to an accuracy of +/- 0.05 seconds. Each data point was written to file as a string for ease of analysis.

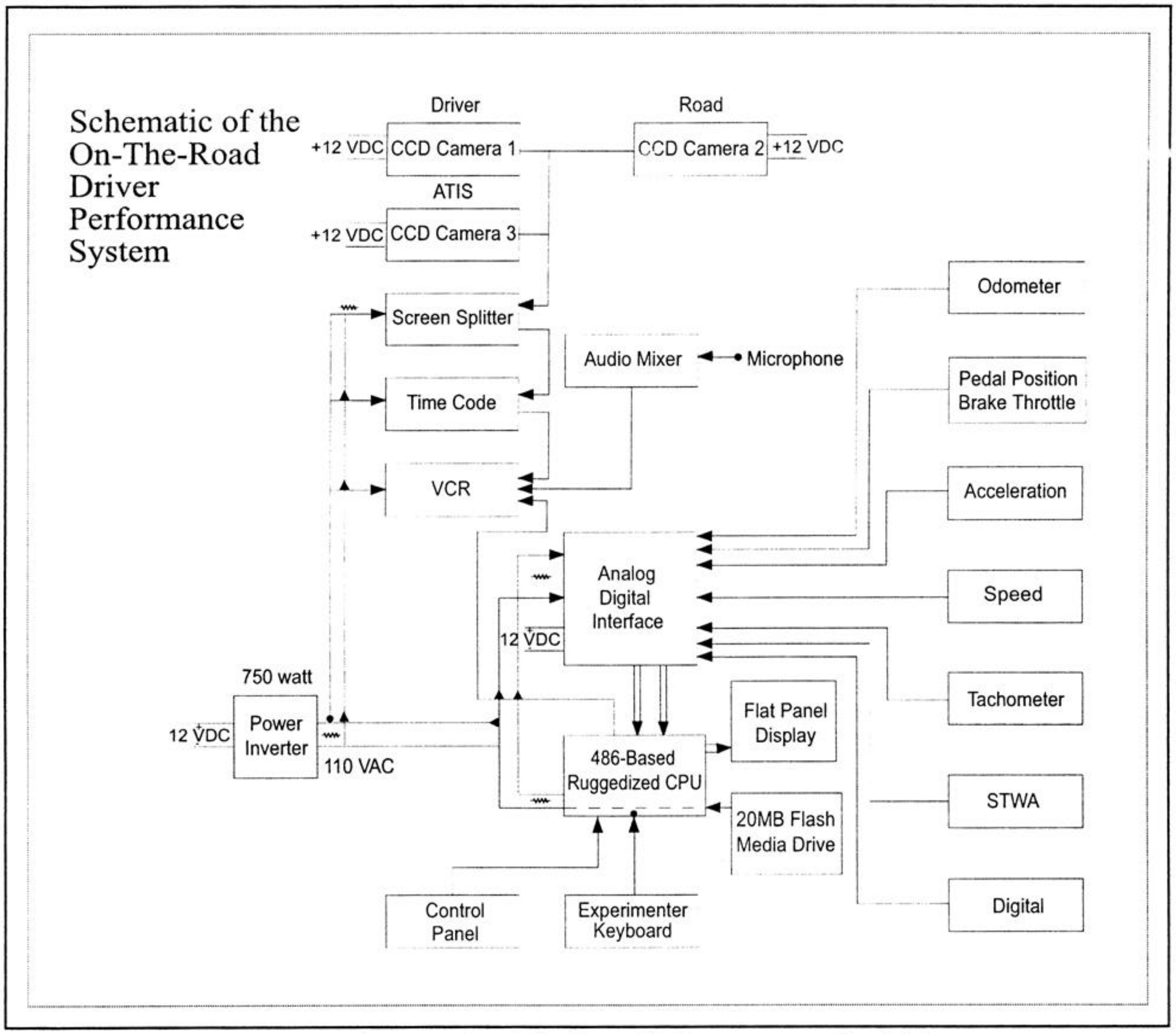

Figure 1. Schematic of the Battelle instrumented vehicle.

Data Collection Computer

The data collection computer is a ruggedized chassis from Industrial Computer Source using a passive backplane 486-equivalent board, with 4MB of RAM, a 20 Megabyte Flash Memory Card, an Electroluminescent Display, and a compact 102-key keyboard. The flash memory card was chosen as a means of data storage for its inherent benefits over a standard hard drive. These benefits include the ability to perform under adverse conditions, the lack of mechanical movements, and the ease of downloading collected data. Each day, the driving performance data were compressed using the PKZIP utilities and stored to floppy disk. This system provides reliable data collection under all possible roadway conditions. The analog to digital system used was the IO Teck Daq Book 100 with 16 analog input channels and 24 digital input channels along with 3 digital counters.

Performance Data

The performance data were collected using an analog to digital interface. The analog data included STWA, accelerator position, brake position, speedometer, odometer, tachometer, and longitudinal acceleration readings. Digital inputs stored were turn signals, headlight settings, and windshield wiper settings. The STWA was recorded via a potentiometer attached to the steering column. The steering column was modified to include a gear track so as to turn the potentiometer as the wheel was turned. This potentiometer was a high precision potentiometer produced by Maurey. The output signal of the potentiometer was then connected to the analog to digital interface for direct input into the data stream. The accelerator and brake pedals were equipped with linear slide potentiometers. The outputs of the two sensors were attached in the same fashion as the STWA potentiometer. The odometer data set was created using a digital counter in the data acquisition system to produce reliable distance values in 0.01-mile increments. The speedometer and tachometer readings were created using a frequency to voltage conversion. An accelerometer was mounted in the trunk of the vehicle to measure longitudinal accelerations. Turn signal, headlight, windshield wiper settings, and experimenter input were directly wired to the digital input portion of the data collection system.

Video System

Cameras were mounted with driver, roadway, and ATIS display orientations. The driver camera was mounted so as to provide a clear view of the subject's face and eyes. The camera was focused and centered for each individual subject to ensure proper framing. The roadway camera provided both road condition and lane deviation data. This camera utilized a wide angle lens to provide a full field of view across the entire lane of travel. The final camera was aimed at the in-vehicle display to provide a method of knowing when images were present on the display. The three video input signals were combined using a screen splitter. This signal was then passed through a Time Code Generator to stamp the signal with the current time. The video signals were recorded using a S-VHS video cassette recorder (VCR).

Experimenter Control Panel

The experimenter was provided with a control panel that was used to log portions of the drive where the driver had gone off route.

Eye Tracking Equipment

A helmet-mounted ASL 4000 Eye Tracker was used to record eye position. The helmet consisted of a glass visor that was lowered in place in front of the driver's eyes, and a scene camera mounted to the left-hand side of the helmet recorded the environment as the driver saw it with a set of cross hairs marking what the drivers' eyes were focused on. This equipment posed logistical problems for several reasons. Many subjects bumped the equipment on the vehicle's side or roof and thus negated the calibration. Also, the drivers tended to use either peripheral vision or look out of the corner of their eye to view the ATIS, and in doing so, their eyelashes tended to occlude the pupil and cornea.

ATIS

The ATIS had two components. The first was a Retki Land Navigation System, a Global Positioning System (GPS), which operated on an IBM ThinkPad. Drivers viewed a map of Seattle as shown in figure 2. It was scaled such that the entire route, which was shown by a thick black line, filled the entire screen. Control inputs were not necessary to zoom or pan the display. This system used a global positioning satellite link to determine the current location of the vehicle. A red star marked the location when the vehicle was stationary, and a black arrow showed both the location and the direction when the car was moving.

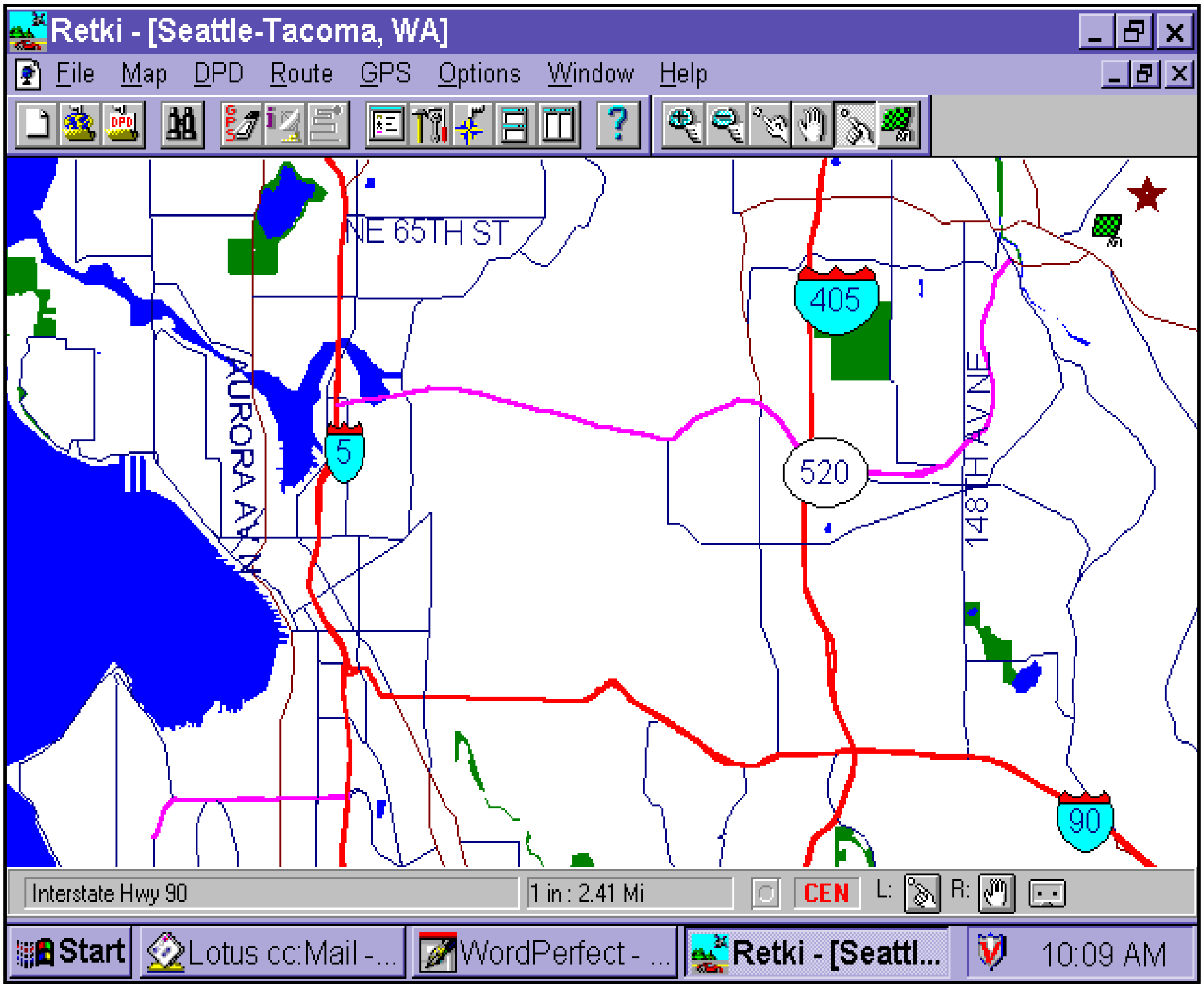

Figure 2. The Retki land navigation system.

The second component was a ruggedized 486 computer responsible for presenting both visual and auditory messages to the drivers. Visual messages were presented on a 5 × 7 inch screen mounted to the dashboard to the right of the steering wheel. The average viewing distance was 22 inches. The screen presented amber text messages on a black background. Auditory messages were presented via two speakers behind the subject. Subjects were led to believe that message presentation was driven by the Retki system (see experimental protocol, appendix D), and that the

GPS system kept track of their position, compared it to a data base, and presented messages only when relevant . In actuality, messages were cued by the backseat experimenter by the press of the space bar, and key strokes were used to advance to the next segment of messages or replay a message if necessary. To maximize experimental control, all drivers received all messages at the same point along the roadway. As a consequence, some drivers received messages that were not relevant for their situation. For example, some drivers were told to slow down even if they were driving below the new posted speed limit.

ATIS Messages

Five types of messages (navigation, ISIS, IVSAWS, general/service, and vehicle monitoring) were presented throughout the 30-mile drive. Most messages were preceded by an auditory tone cued by the backseat experimenter. This indicated to the driver that the system had information for them. Subjects were required to press a button mounted on the dash to hear/see the message. If drivers did not press the button within 10 seconds, the message was automatically played. All visual messages remained on the screen for 5 seconds. Two types of message potency were presented: auditory/command and visual/notification. As defined in Lee et al. (1996), auditory/command messages presented the message as an order (i.e., Slow Down) whereas visual/notification messages presented information that required the driver to process the information and then make a decision to respond (i.e., Speed Limit 40 mi/h). A complete list of ATIS messages presented in this experiment is provided in appendix A.

<u>Navigation</u>

Navigation or route guidance information was presented to all drivers following the preferred maximum distance recommendations provided by Ross, Vaughan, and Nicolle. (1997). Specifically, message timing was calculated using the following equation: distance to turn = (Speed × 2.222) + 37.144. As the equation was calculated using the speed limit (in km), all subjects received the message at the same position along the road regardless of their actual velocity. Six navigation messages were used for experimental purposes; three were auditory/ command and three were visual/notification. A visual/notification and an auditory/command message for navigation are displayed in figures 3 and 4.

Figure 3. Visual/Notification for Navigation message.

"TURN LEFT ON
15TH AVENUE, NORTH EAST."

Figure 4. Auditory/Command for Navigation message.

In addition, half of the drivers also received advance notification of turns that were always auditory and not preceded by a tone. An example of these messages is "Prepare to turn left on 15th Avenue North East." The presentation of these messages followed guidelines suggested by Green, Williams, Hoekstra, George, and Wen (1993), which suggested that advance notification messages be presented about 1 mile in advance of a turn on city streets and 2 miles from the exit on a freeway. Where conflicts occurred in downtown and residential areas (e.g., the distance to the turn was shorter than the time guideline), the advance warning was presented approximately one block before the regular navigation messages.

<u>ISIS</u>

Regulatory information about roadway characteristics, such as changes in speed limits, crosswalks, and sharp turns, was presented via text or auditory messages inside the vehicle. Drivers received six ISIS messages: three auditory/command and three visual/notification. Figures 5 and 6 display ISIS messages presented in visual/notification and auditory/command styles.

Figure 5. Visual/Notification for ISIS message.

**"SLOW DOWN,
CROSSWALK AHEAD."**

Figure 6. Auditory/Command for ISIS message.

<u>IVSAWS</u>

Information about roadway hazards, accidents, and traffic congestion was presented to the driver in the vehicle. Six IVSAWS messages were presented: three auditory/command and three visual/notification. A visual/notification and an auditory/command message displaying IVSAWS information can be seen in figures 7 and 8.

Figure 7. Visual/Notification for IVSAWS message.

**"CHANGE LANES,
SLOW VEHICLE AHEAD."**

Figure 8. Auditory/Command for IVSAWS message.

General/Service

General information about services and activities within the Seattle area, such as hotels and tourist attractions, was provided. These messages were only presented in the visual/notification style. Figure 9 shows a general/service message presented in the study.

Figure 9. Visual/Notification for general/service message.

Vehicle Monitoring

In an effort to integrate all computerized systems in the vehicle, the ATIS also presented messages about the status of the vehicle such as windshield wiper fluid or fuel levels. These messages were only presented in the visual/notification style. Figure 10 shows the vehicle monitoring message presented in the study.

Figure 10. Visual/Notification for Vehicle Monitoring message.

EXPERIMENTAL DESIGN

Independent Variables

Table 1 summarizes the independent variables of interest in the present study. There were six between subject variables (age, gender, traffic density, advance notification, order of information density, and order of message potency) and five within-subjects variables (road demand, information density, message potency, message window, and message type).

Table 1. Independent variables.

Variable	Type	Levels
Age	Between	Young (18-26) Middle (26-45)
Gender	Between	Female Male
Traffic Density	Between	Rush hour (4:00 to 6:00 p.m.)[1] Non-rush hour (7:00 to 9:00 p.m.)
Advance Notification of Turn	Between	No Yes
Order of Information Density	Between	Low, medium, high, high, medium, low Medium, high, low, low, high, medium High, low, medium, medium, low, high
Order of Message Potency	Between	Auditory/Command, Visual/Notification Visual/Notification, Auditory/Command
Road Demands	Within	Low (0.19 traffic devices / mile) Medium (3.4 traffic devices / mile) High (6.8 traffic devices / mile)
Information Density	Within	Low (1 message / 60 seconds) Medium (2 messages / 60 seconds) High (3 messages / 60 seconds)
Message Potency	Within	1 = Visual/Notification 2 = Auditory/Command
Message Window	Within	Before (5 seconds before message) During (5 seconds during message) After (5 seconds after message clears)
Message Type	Within	Navigation ISIS IVSAWS General/Service Vehicle Monitoring

The 30-mile route (shown in figure 2) was divided into three roughly equal segments of road based on road demands (number of traffic devices per mile). Within each segment of road demand, drivers received six "action" messages that required them to turn (navigation), slow down (ISIS), or change lanes (IVSAWS). These action messages were presented at specific

[1]Subjects were tested during the months of December and January, in Seattle, WA. Due to the northern latitude of Seattle and the lengthy training and eye-tacker calibration, the actual data collection for rush hour drivers started after the sun set. In other words, rush hour drivers were tested in dark, as were non-rush hour drivers.

locations on the roadway; all subjects received the action messages in the same order. The order of information density was assigned by Latin square, such that for each action message, one-third of the subjects received low (no additional messages), medium (one additional messages), or high (two additional messages) information density. The additional messages were either general/service or vehicle monitoring messages. The message potency of the action messages was counter-balanced, such that for every action message, half of the drivers received a visual/notification message, and half received the same message in auditory/command style.

Table 2 shows the six experimental orders that were created by three orders of information density and two orders of message potency. Table 2 was replicated twice as a between subjects variable. One group received advance notification messages and one did not.

Table 2. Six experimental orders.

Experi-mental Order	Road Demand																	
	Low						Medium						High					
	Action Message Type						Action Message Type						Action Message Type					
	ISIS	IVSAWS	IVSAWS	NAV	ISIS	NAV	ISIS	IVSAWS	NAV	ISIS	NAV	IVSAWS	NAV	ISIS	ISIS	IVSAWS	NAV	IVSAWS
1	Lv	Ma	Hv	Ha	Mv	La	Lv	Ma	Hv	Ha	Mv	La	Lv	Ma	Hv	Ha	Mv	La
2	La	Mv	Ha	Hv	Ma	Lv	La	Mv	Ha	Hv	Ma	Lv	La	Mv	Ha	Hv	Ma	Lv
3	Mv	Ha	Lv	La	Hv	Ma	Mv	Ha	Lv	La	Hv	Ma	Mv	Ha	Lv	La	Hv	Ma
4	Ma	Hv	La	Lv	Ha	Mv	Ma	Hv	La	Lv	Ha	Mv	Ma	Hv	La	Lv	Ha	Mv
5	Hv	La	Mv	Ma	Lv	Ha	Hv	La	Mv	Ma	Lv	Ha	Hv	La	Mv	Ma	Lv	Ha
6	Ha	Lv	Ma	Mv	La	Hv	Ha	Lv	Ma	Mv	La	Hv	Ha	Lv	Ma	Mv	La	Hv

Information Density: L = 1/min., M = 2/min., H = 3/min.
Message Potency: v = Visual/Notification, a = Auditory/Command

Dependent Variables

Four types of dependent measures were collected: 1) driving performance data, 2) compliance to messages, 3) eye position data, and 4) driver preference data. The objective dependent variables are summarized in table 3.

Table 3. Objective dependent variables.

Type	Dependent Variable
Driving Performance Data	SD of velocity Average deviation of STWA SD of STWA Number of steering wheel reversals greater than 6 degrees
Compliance	Compliance to message (binary) Time to turn signal activation (for IVSAWS messages only)

<u>Performance Data</u>

Of particular interest in performance data are measures of steering wheel movements and velocity SDs.

Research has shown that changes in driver steering behavior occur when driver attention changes (Wierwille and Gutman, 1978). In normal, low-attention circumstances, drivers make continuous, smaller steering corrections to make up for roadway variance and driving conditions. These corrections are typically within the range of 2 to 6 degrees. As attention is drawn away from the task of driving, the frequency of steering corrections tends to decrease. Since the small centering corrections decrease, the vehicle tends to drift farther from the lane center, and a larger steering input is required to correct the position. These larger steering inputs generally exceed 6 degrees and are referred to as large steering reversals. Since small corrections decrease and large corrections increase, an increase in the steering wheel position variance indicates high attention or workload requirements and a reduction in driving performance. In this study, a number of measures, including the number of steering reversals, the duration of each steering reversal, and the rate of reversals, were examined.

Vehicle speed, like lane position, can be considered a vehicle state that has to be held constant in most circumstances. Therefore, for the same reasons described above for steering wheel reversals, variations in velocity are used to evaluate performance. According to Monty (1984), drivers are required to make continuous adjustments in pedal displacement to maintain correct speed. When driver attention is drawn away from the driving task, there is a tendency to maintain the foot in the same position. When drivers realize they are going (generally) too slow, the accelerator is depressed to a greater degree than is normal for a continuous adjustment. Research has found velocity maintenance to be a sensitive measure to changes in the amount of attention demands by secondary driving tasks (Monty, 1984).

<u>Compliance</u>

A binary variable was created to reflect compliance to messages. Objective data, such as turn signal activation and velocity changes, were recorded to produce this measure. Also the experimenter completed a checklist and noted if the driver complied with each message. The objective measures were compared with the experimenter's check list. This was important because some subjects did not activate the turn signal when turning or changing lanes. For navigation and IVSAWS messages, where it was possible for the experimenter to determine if the action was carried out with complete accuracy, the subjective measure was used if the objective and subjective measures did not agree.

For IVSAWS messages, time to turn signal activation was another measure of compliance. This was recorded as the time from message onset to the time of turn signal activation.

Eye Position Data

The eye tracker recorded three measures: 1) percent of time focused on target, 2) number of glances to target, and 3) duration of glances. Two “targets” were created in the initial calibration process: the ATIS and the windshield. Given the problems associated with eye tracker use inside the vehicle, and the resulting missing data, these data could not be reliably analyzed. It is estimated that approximately 33 percent of the 24 drivers had missing data because of equipment failures or because the subject disrupted the calibration by knocking the equipment by moving or during a shoulder check. This was to be expected in an on-road driving situation. For the remaining drivers the data revealed that drivers did not look directly at the ATIS display; rather they used peripheral vision, or looked out of the corner of their eye to read the display. As a result the data were not usable for our purposes.

Driver Preference Data

A driver preference questionnaire was administered to solicit drivers’ subjective opinion of the prototype ATIS. Questions were asked about both the ATIS messages and the GPS tracking system. Also included in the questionnaire were questions regarding drivers’ level of comfort with computers and experience driving in Seattle. The questions asked and drivers’ responses can be found in appendix B.

PROCEDURE

Pre-Experiment Screening

Drivers were screened for experiment eligibility using the Subject Selection Phone Questionnaire to ensure that all were licensed drivers between the ages of 18 and 45, and that all drove at least two times a week in the Seattle area. Eligible drivers also completed the Driver Demographics Phone Questionnaire. Both questionnaires are provided in appendix C.

Introduction and Training

The Experimenter Protocol is presented in appendix D. Subjects were welcomed to Battelle, were provided a brief description of the purpose of the research project, and were asked to complete and sign the Research Participation Consent Form (appendix E). Subjects were then escorted to the test vehicle, where they were encouraged to adjust the seat and mirrors so they were comfortable. A quick overview of the vehicle’s displays and controls was conducted before drivers tested the vehicle in the Battelle parking lot. If the driver was comfortable and experimenters were confident in the driver’s ability, drivers were taken into the surrounding residential community for a longer test drive.

ATIS Alone (Stationary)

Next, the two components of the ATIS were introduced to the subjects. It was explained that even though each component had its own display, they work hand in hand to provide relevant information to the driver. The first component of the ATIS, the vehicle tracking system (the Retki System), was shown and the vehicle's current position, marked by a red star, was pointed out to the driver. Drivers were told that the star moves along as the vehicle moves and tracks their position throughout the drive. Drivers were also shown the thick black line that marked the driving route. Finally, drivers were told that, for safety reasons, they can only look at the display when the car is stopped or traveling below 5 mi/h. When traveling over 5 mi/h, a blank safety screen covered the map. They were encouraged to monitor the status of their trip when stopped at a traffic light or when in traffic. The second component of the ATIS, which presents the auditory and visual messages, was then introduced. The auditory tone was played, and drivers were told that this is their cue that the system has a message for them. They were instructed to press the red button mounted on the dash as soon as they are ready to receive the message. It was emphasized that subjects should press the button only when safe to do so, and if they did not press the button, the message will automatically be presented after 10 seconds. Examples of both auditory/command and visual/notification messages were presented for navigation, ISIS, and IVSAWS messages, as well as visual general/service and vehicle monitoring messages.

ATIS (Driving)

Once drivers understood all practice ATIS messages, they were led on a short (5-minute) practice route throughout a neighboring residential community. The ATIS provided all route guidance instructions, as well as ISIS messages where relevant. At the end, drivers were guided to the Battelle parking garage.

Eye Tracker Setup

Once in the parking garage, drivers were shown the eye-tracker helmet, and told that it was equipped with a specially coated lens designed to record where they were looking as they drove. They were told that the helmet must fit snugly and the straps must be adjusted tightly so that it does not slip during the drive. Once in a comfortable position, the eye tracker was calibrated.

On-Road Instructions to Subjects

Once the recording equipment and eye tracker were set-up, drivers were asked to exit the parking garage. They were told that once they left the garage, the ATIS would provide all the information they needed, and the experimenters would not be able to answer any questions. They were told to use the system only to augment their driving but not to rely on it as their sole source of information. They were encouraged to drive as they normally would if they had rented a vehicle and were following directions provided by an in-vehicle ATIS.

Two experimenters accompanied the subject in the car. One operated a secondary emergency brake, similar to what is used in driver education vehicles. The second experimenter, seated in the back, had control over the 486 computer and cued messages by pressing the space bar at pre-determined locations along the route. If drivers got off the route, the safety braker informed the driver that: “It seems as if the GPS system has lost us temporarily,” and guided the driver back on route.

Post-Experiment

Drivers were asked their opinion of the system, and where appropriate, were prompted for more information or to expand on their thoughts. Then they completed a questionnaire (appendix B). At the end, the driver was debriefed, and any questions were answered.

RESULTS

Three types of data were examined: (1) driver performance, (2) compliance to messages, and (3) driver preference. The data analyses were prepared using the Bio-Medical Data Processing (BMDP) version 7.0 statistical software package. Complete analysis of variance tables can be seen in appendix F. Prior to conducting the analyses, the data were subjected to an extensive data checking and screening process to verify the accuracy of the vehicle instrumentation. For the compliance data, performance data such as turn signal activation, and changes in velocity, brake position, throttle position, and STWA were examined to determine if the action suggested by the ATIS was carried out.

DATA FILTERING

The performance data, particularly the velocity and STWA data, exhibited very infrequent unnatural spikes and unrealistic values. The spikes in the velocity data were attributed to random system noise. Typically they lasted for only a single record and each subject had less than 20 records across the entire 60-minute drive that needed to be filtered. These records were filtered and replaced with the mean of the previous and following velocity values.

The steering wheel sensor is a continuous one turn potentiometer with a useful range of 570 degrees (285 to each side of center). This type of potentiometer allows great precision particularly with wheel movements of 3 to 5 degrees. As a consequence of this fine degree of accuracy, when the steering wheel turns beyond the useful range, the data become unreliable as the device "wraps around" to the other end of the range. The device then takes up to 500 ms to begin producing reliable data after a wrap around. Rather than sacrificing valid data in the 3 to 5 degree range, the wrap-around data were processed to remove data points that were beyond the useful range. Specifically, any time a STWA was greater than 285 or less than 285 degrees, the value and all values recorded within half a second of it were filtered out before means were calculated.

DRIVER PERFORMANCE DATA

Message-Initiation Latency

The time taken to press the message button in response to the auditory tone was recorded as an indication of a subject's state of readiness to receive a message. Long button press latencies would suggest that the driver was occupied with demands of the driving task and chose to delay the presentation of the ATIS message. Figure 11 shows the effect of road demand, age, and traffic density on message-initiation latencies. Our hypothesis that latencies would be longer for middle-age drivers was not supported. Latencies for middle-aged drivers were longer only in non-rush hour conditions; however, the difference was not statistically significant, $F(1, 16) = 2.83$, $p>.05$.

As can be seen in figure 12, message-initiation latency did not differ as a function of information density. It was expected that presenting multiple messages within 1 minute might exceed drivers' ability to process information, resulting in longer button press latencies. Contrary to our hypothesis, presenting two or even three messages within 1 minute did not appear to be too many, at least to the extent that it affected their “state of readiness” to receive a new message, $F(2,32) = 0.16$, $p>.05$. This is an important result for ATIS designers.

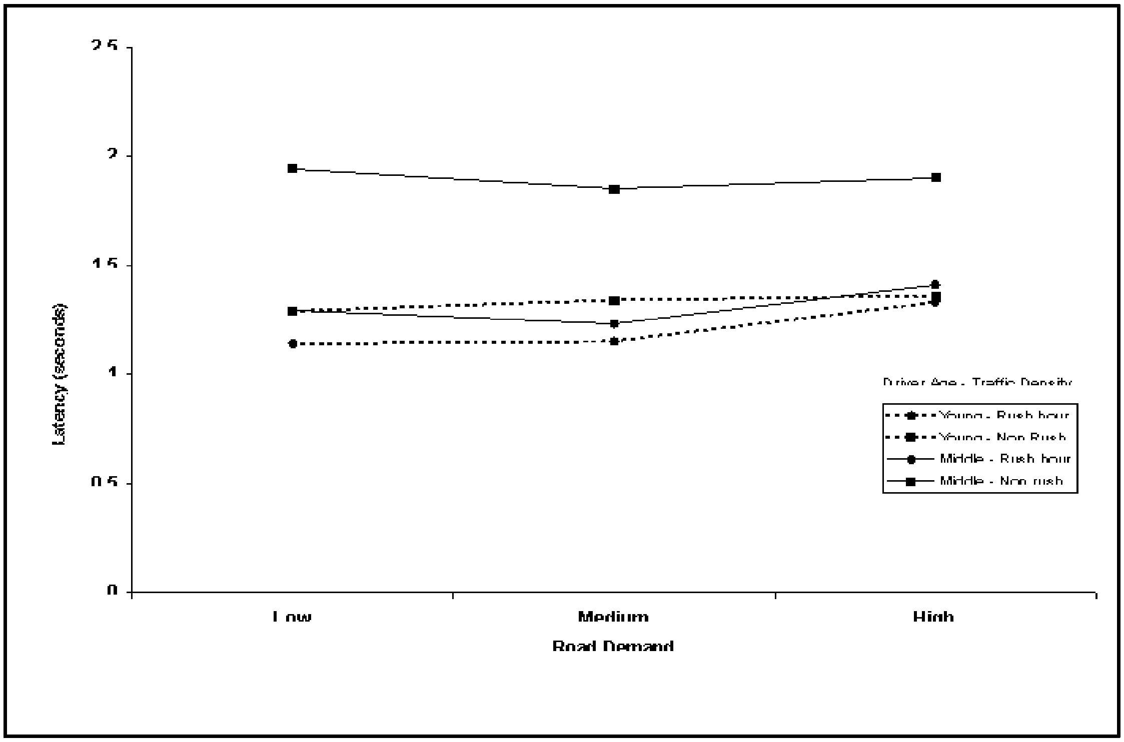

Figure 11. Message-initiation latency as a function of road demand, age, and traffic density.

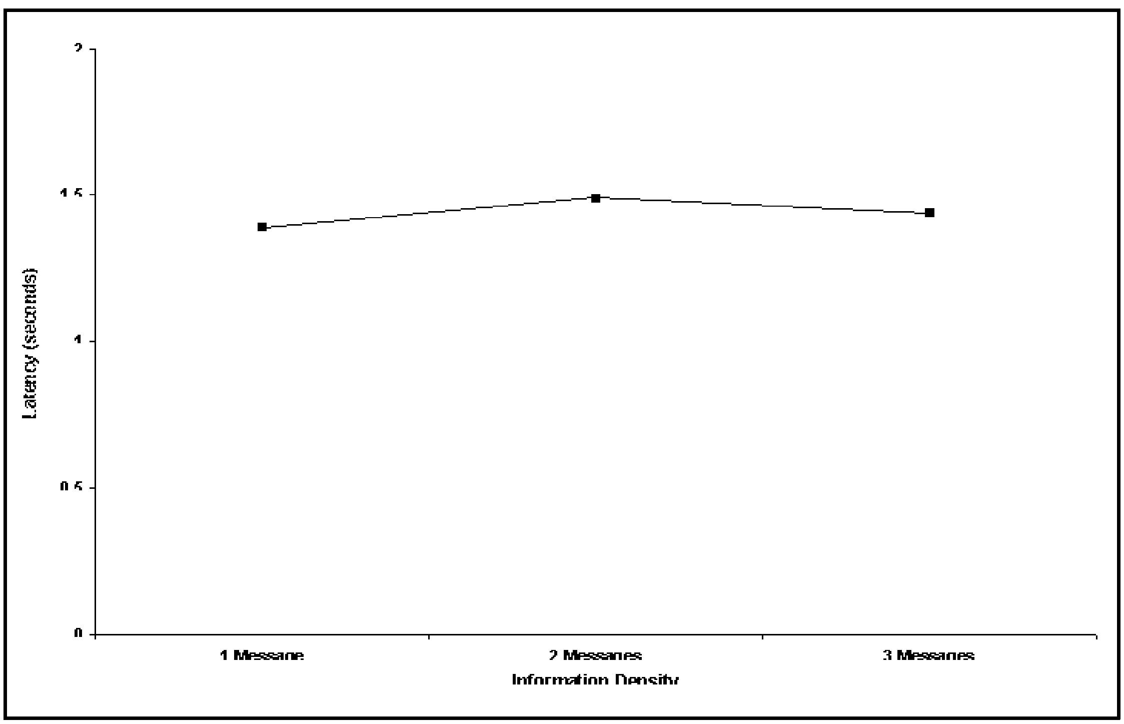

Figure 12. Message-initiation latency as a function of information density.

Average Deviation of the Steering Wheel Angle (STWA)

The average deviation of STWA is a measure of the variability of steering wheel movements. In these analyses, the steering wheel center position (0 degrees) was used as the reference value; thus the measure is the mean of the absolute deviations of STWAs. This was calculated for 5-second windows before and during message onset.

Figure 13 shows the effect of message potency and message window on the average deviation of the STWA. Each participant received 9 auditory/command messages and 27 visual/notification messages. The average deviation of STWA for the during message window was significantly lower than for the baseline measure (before message window) $F(1, 16) = 27.7$, $p<0.001$. This suggests that when attending to the message, STWA inputs were suppressed. Figure 13 also shows a significant main effect of message potency, $F(1,16) = 15.8$, $p<0.01$, with larger average deviations associated with visual/notification messages. Two possibilities may account for this finding: 1) auditory/command messages suppressed steering deviations because of their attention-getting properties (Sanders and McCormick, 1993), or 2) visual/notification messages caused larger deviations because drivers took their eyes off the road. A message window by message potency interaction was expected. Specifically, while no difference was expected between message potency levels before message presentation, lower average deviations were expected for auditory/command messages during message presentation. This was expected because the attention-getting properties of auditory messages are more likely to draw a driver's attention away from the task of driving, and therefore steering wheel movement would be suppressed. This hypothesized interaction was not substantiated, $F(1,16) = 0.18$, $p>.05$. Consistent with our expectations, data for the during message window showed smaller average deviations with auditory/command messages than with visual/notification messages. However, we are unable to explain why differences were obtained before the messages were presented. The absence of a message potency by message window interaction suggests that average deviations were not differentially affected by the onset of messages as a function of message potency.

Figure 14 shows the effect of road demand and information density on the average deviation of the STWA collapsed over message window. No main effects reached the .05 level of significance. The road demand by information density interaction, $F(4, 64) = 3.57$, $p<0.01$, is depicted in figure 14. Simple effect tests showed a significant difference among levels of information density in both the medium, $F(2,32) = 5.80$, $p<0.01$, and high, $F(2,32) = 4.33$, $p<0.05$, road demand conditions. Post-hoc Tukey tests revealed that the average deviation of STWA in the medium road demand condition was significantly higher, $p<0.05$, than in the low road demand conditions when one, two, and three messages per minute were presented. Also, average deviation was higher in the high road demand condition than the low road demand condition when two and three messages were presented per minute, $p<0.05$.

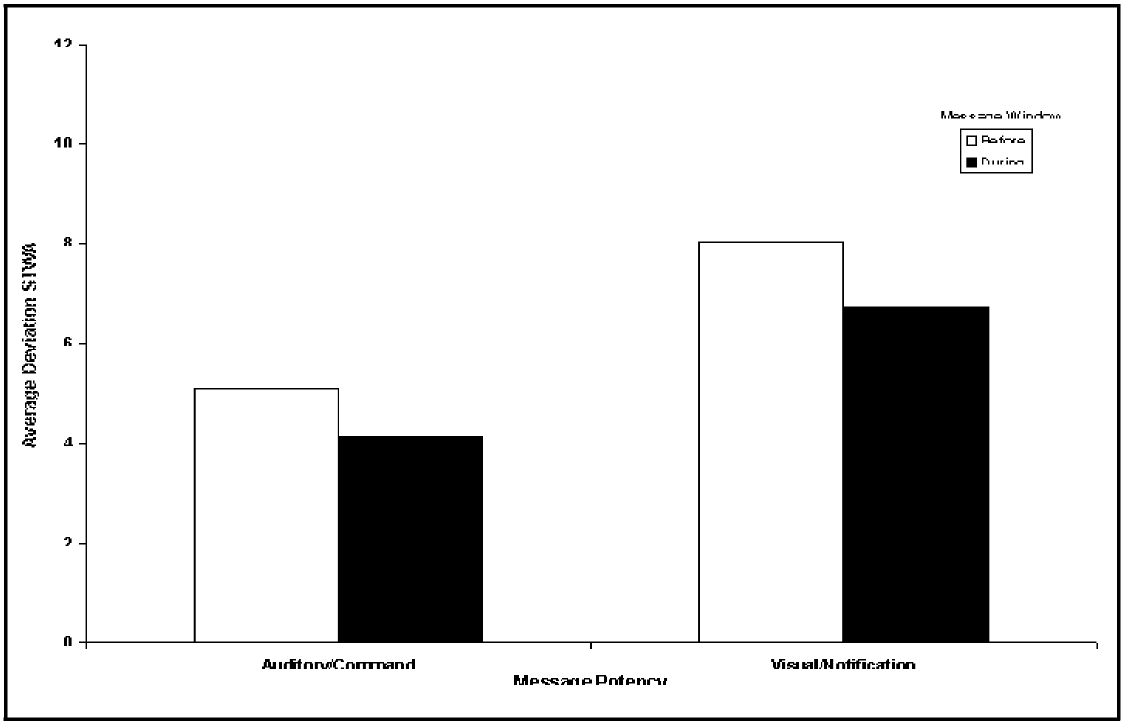

Figure 13. Average deviation of STWA as a function of message potency and message window.

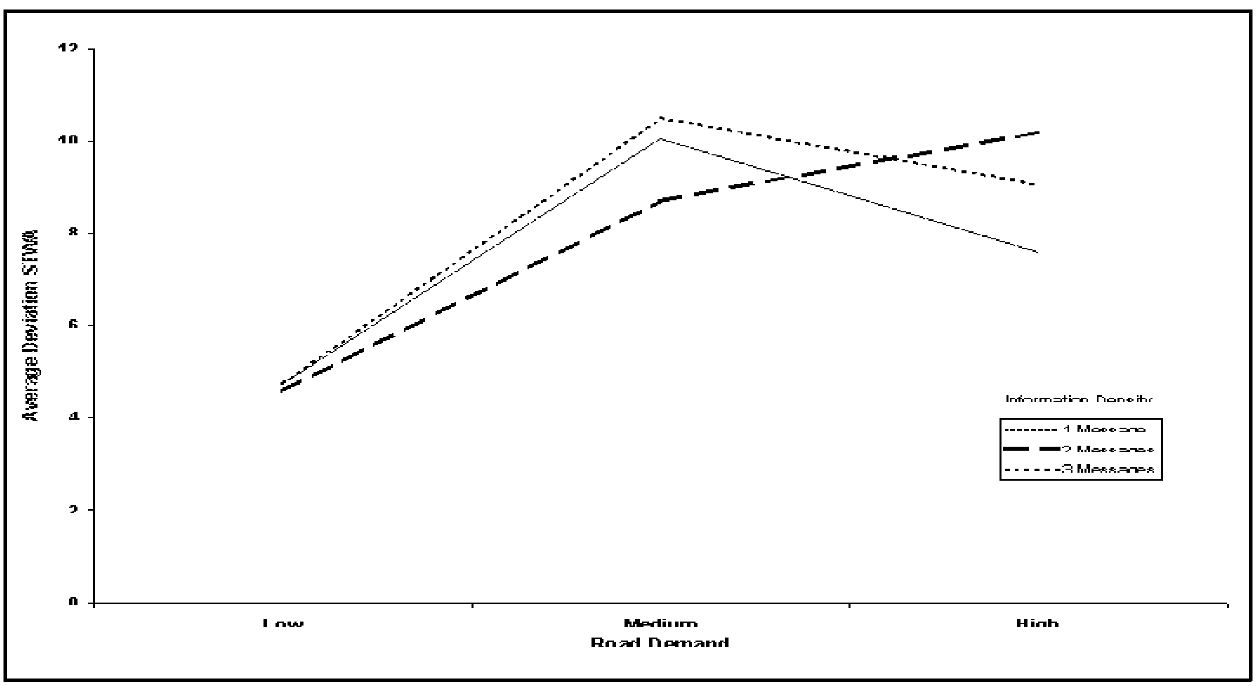

Figure 14. Average deviation of STWA as a function of road demand and information density.

Large Steering Wheel Reversals

Wierwille and Gutman (1978) suggested that as attention or workload demands increased, the frequency of steering corrections tends to decrease. Since the small centering corrections decrease, the vehicle tends to drift farther from the lane center, and a large steering input is required to correct the position. These large steering inputs tend to exceed 6 degrees and are referred to as large steering reversals.

Figure 15 illustrates the effect of road demands, traffic density, and message window on the number of large steering reversals made by drivers. As expected, the number of steering wheel reversals differed as a function of road demand, $F(2, 32) = 22.2$, $p<.001$. Post-hoc Tukey tests showed more large steering reversals associated with the medium road demand condition than with the low road demand condition, $p<.05$. Also, more large steering reversals were observed in the high road demand condition than the low road demand condition, $p<.05$. The number of large steering wheel reversals did not differ as a function of traffic density, $F(1,16) = 1.08$, $p>.05$. The number of large steering reversals in the before message window (M = .69) did not differ significantly from those recorded in the during message window (M = .64), $F(1,16) = 3.88$, $p>.05$. This suggests that the presentation of ATIS messages did not increase attentional or workload demands, at least to the extent that can be seen in an increase in large steering reversals. This is an important result for guideline designers. The three-way interaction of road demand, traffic density, and message window was not significant, $F(2,32) = 1.56$, $p>.05$.

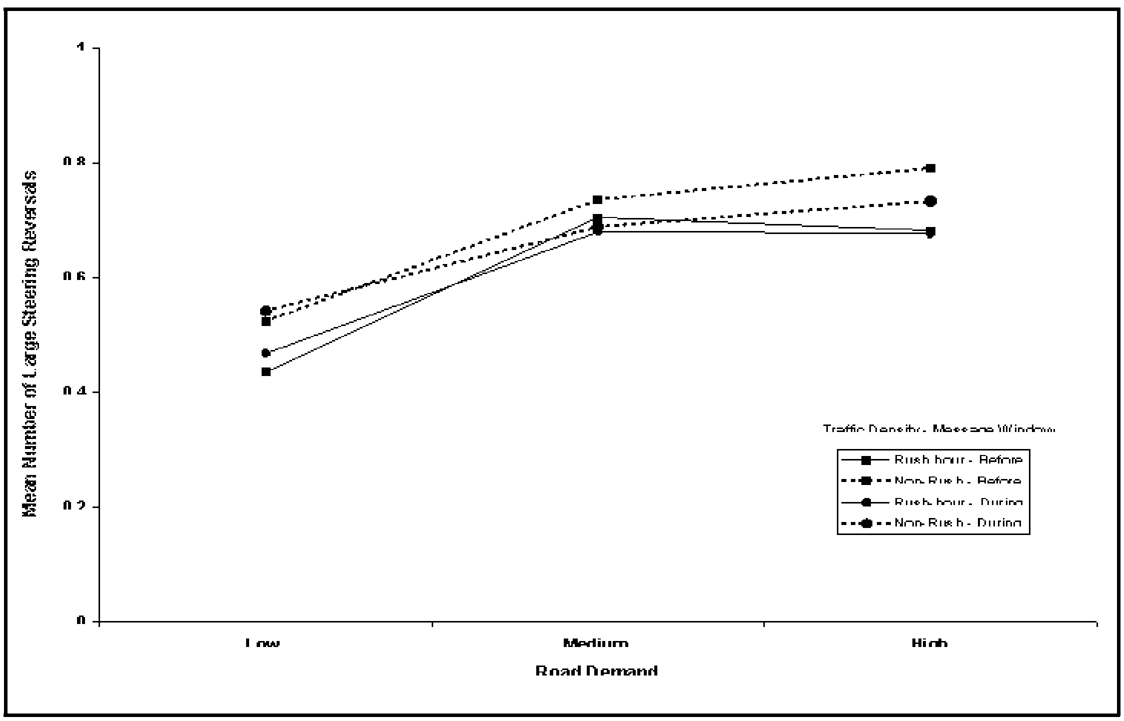

Figure 15. Number of large steering wheel reversals as a function of road demand, traffic density, and message window.

The effect of message potency on large steering reversals produced an interesting result. Here, the number of large steering reversals for the before and during message windows were reported. Note that the mean for auditory/command messages consisted of nine messages, whereas the mean for the visual/notification messages consisted of 27 messages. Figure 16 shows that visual/notification messages produced fewer large steering wheel reversals than auditory/ command messages, $F(1,16) = 4.53$, $p<0.05$. Presumably this occurred because with the auditory/command messages there was higher compliance—particularly to IVSAWS messages that necessitated large steering reversals. The main effect of window was not significant, $F(1,16) = 3.88$, $p>.05$, nor was the message potency × message window interaction, $F(1,16) = 0.28$, $p>.05$.

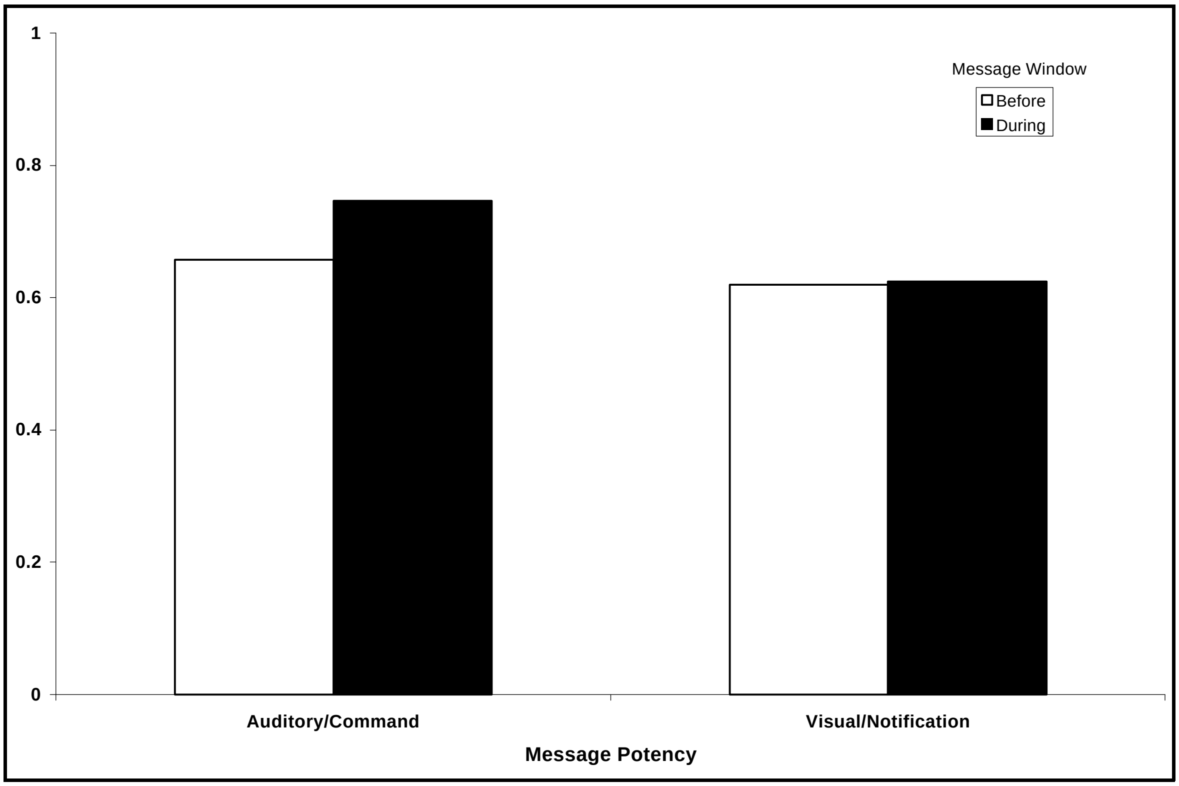

Figure 16. Number of large steering reversals as a function of message potency.

Standard Deviation (SD) of Velocity

Figures 17 and 18 illustrate the effect of road demand, traffic density, and message window on the SD of velocity. There was a main effect of road demand, $F(2,32) = 37.3$, $p<0.001$. Post-hoc Tukey tests revealed that SD of velocity associated with low road demands was significantly lower than with medium road demands, $p<0.05$, and with high road demands, $p<0.05$. Also, SD of velocity associated with medium road demands was significantly lower than with high road demands, $p<0.05$. This was expected because more stops and velocity changes are required as road demands (i.e., the number of traffic control devices per mile), increase. Also as expected, the SD of velocity is greater for rush-hour conditions, which by nature have more "stop and go" traffic than non-rush hour conditions, $F(1,16) = 8.86$, $p<0.01$.

A main effect of message window was predicted. Monty (1984) suggested that when a driver is attending fully to the roadway, he/she is constantly making small adjustments to the accelerator to maintain the correct speed. However, when attention is distracted away from the driving task (as may be the case with the presentation of ATIS messages), velocity deviations are lowered, as there is a tendency for the driver to maintain the foot in the same position on the accelerator. This expected finding was not substantiated in the data. The data show a slight, but not significant, tendency for SD of velocity to be lower during message presentation than before message presentation, $F(1,16) = 0.12$, $p > .05$.

The message window by traffic density by road demand interaction was significant, $F(2,32) = 5.48$, $p < 0.01$. Simple effect tests showed that the road demand by traffic density interaction was significant only in the before message window, $F(2,32) = 4.78$, $p < 0.05$. Post-hoc tests revealed a significantly higher SD of velocity during rush hour than non-rush hour with low road demands, $t(23) = 3.55$, $p < 0.05$.

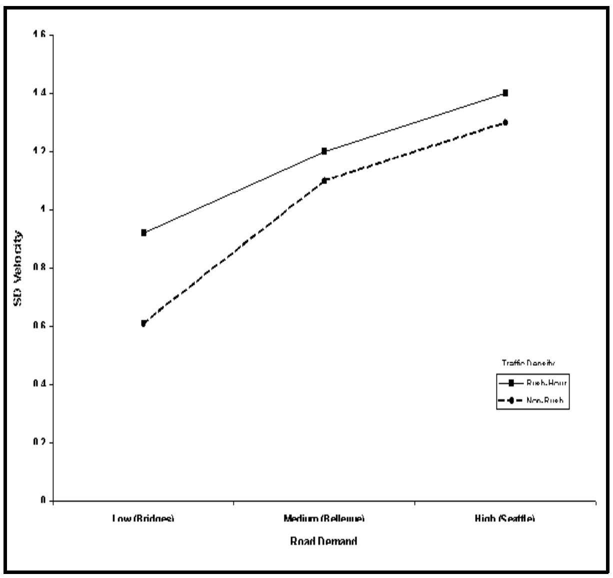

Figure 17. SD of velocity as a function of road demand and traffic density before message onset.

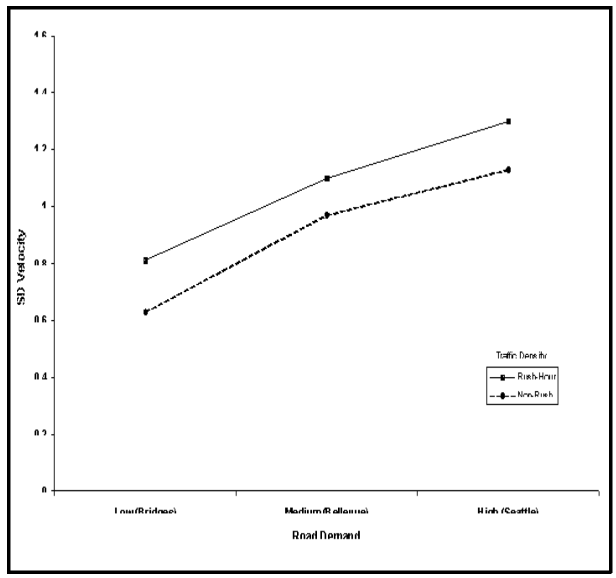

Figure 18. SD of velocity as a function of road demand and traffic density during message presentation.

SD of velocity does not differ as a function of information density. It was expected that presenting three messages per minute would draw more attention away from the driving task than two or one messages per minute. As a result, it was expected that SD of velocity would be lower as information density increased. This expected finding was not substantiated by the data. This would suggest that presenting three messages within a 1-minute period does not draw attention away from the primary task of driving any more than one message per minute does, $F(2,32) = 3.09$, $p = .059$. This has important implications for ATIS designers.

Figure 19 shows the effect of message potency and message window on SD of velocity. A message potency by message window interaction was expected. More specifically, no difference was expected before message onset; however, during message presentation it was expected that auditory/command messages would produce smaller velocity SDs. This was expected because the inherent attention-getting properties of auditory messages (Sanders and McCormick, 1993) would draw drivers' attention away from the driving task, and thus inputs to the accelerator would be suppressed.

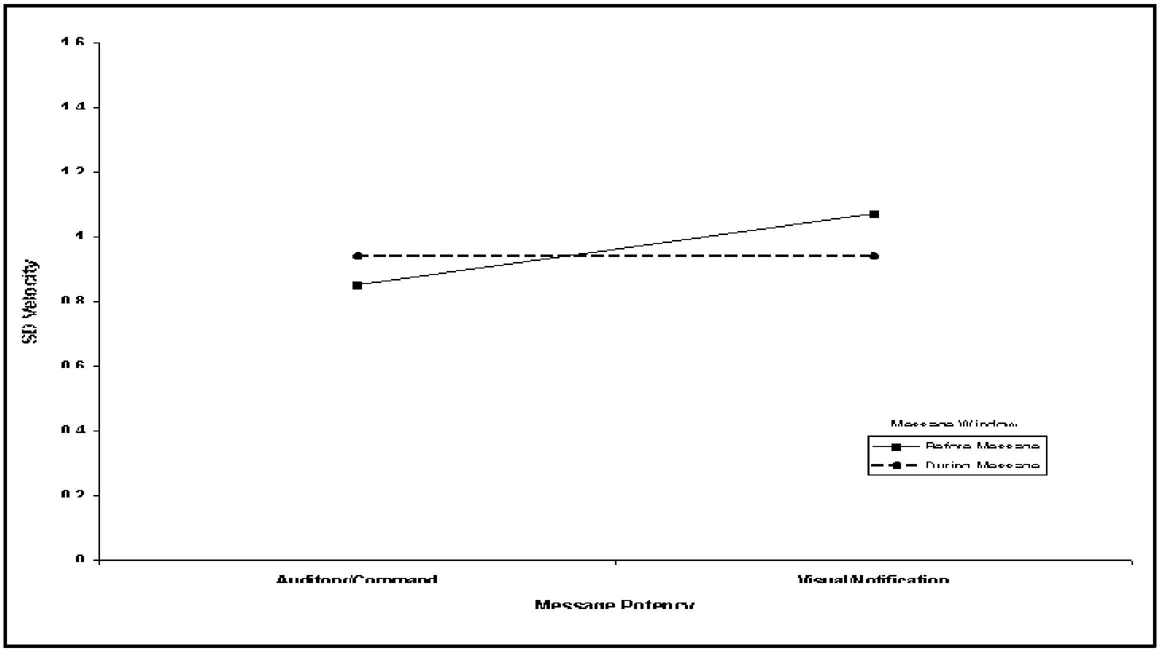

Figure 19. SD of velocity as a function of message potency and message window.

The obtained interaction, $F(1,16) = 9.28$, $p<0.01$, is depicted in figure 19. Simple effect tests showed that for auditory/command messages, there was no significant difference between the before and during message windows, $F(1,16) = 2.92$, $p>.05$. However, for the visual/notification messages, SD of velocity was significantly less during message presentation than before message onset, $F(1,16) = 6.72$, $p<0.05$. This suggests that the visual/notification messages may have drawn drivers attention away from the roadway, and as a result, inputs to the accelerator were suppressed.

COMPLIANCE DATA

Navigation Messages

In total, only two drivers made a navigation error (each driver made only one). Both of these errors occurred when the driver received the message in a visual/notification format. Time to compliance was operationalized as time between message presentation and activation of the turn signal. Twelve drivers did not activate the turn signal for one or more of the six turns and these data points were replaced with the mean time for that driver. The mean time to turn signal activation was 4.6 seconds for auditory/command messages and 4.4 seconds for visual/

notification messages. This difference was neither practically important nor statistically significant, $F(1,16) = 0.24$, $p > .05$. Time to compliance was compared for drivers who received advance warning and drivers who did not (figure 20). As expected, drivers who received advanced notification of a turn were prepared to turn sooner (indicated by turn signal activation) after the onset of the actual navigation message (3.6 seconds) than those who did not receive advance notification (5.4 seconds), $F(1, 16) = 12.0$, $p<0.01$. This suggests that the advance notification messages were used by drivers to help them prepare for upcoming turns. This is of great relevance for ATIS designers.

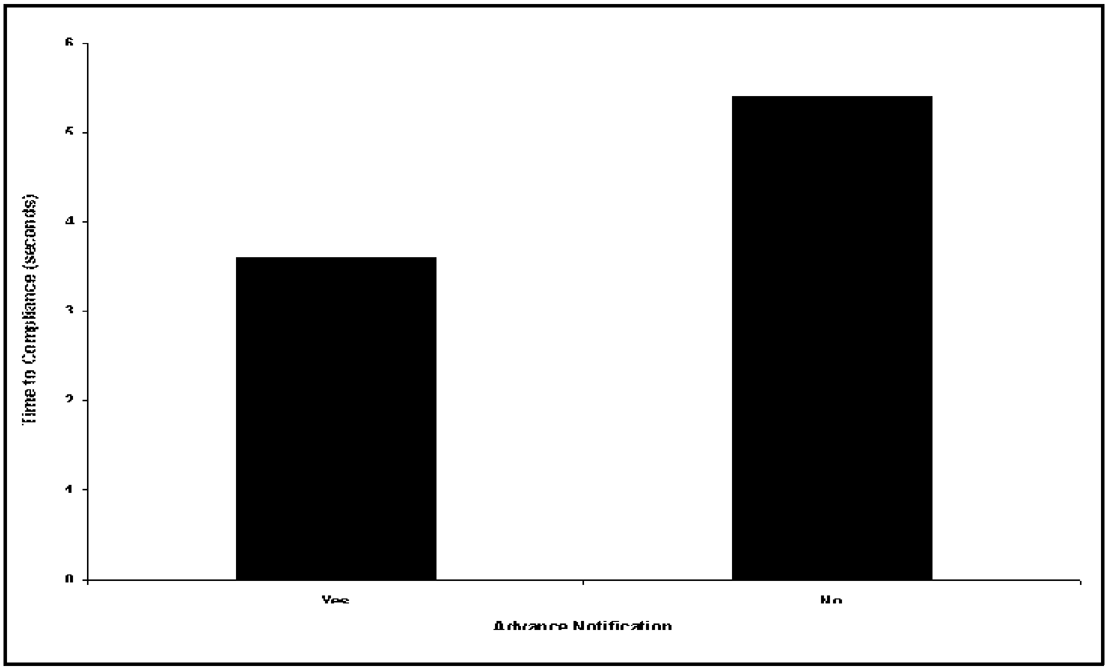

Figure 20. Time to compliance for navigation messages as a function of advance notification.

ISIS Messages

An examination of the data revealed that compliance to ISIS messages differed according to roadway characteristics. That is, ISIS messages that referred to immediate roadway characteristics (i.e., sharp turn or crosswalk) requiring the driver to slow down received higher rates of compliance than ISIS messages that referred to changes in the posted speed limit. These two message types were examined separately. To determine compliance to ISIS messages, the maximum change in velocity during the 5-second period after message onset was calculated. A negative change indicated that the driver decelerated, whereas a positive change indicated that the driver accelerated.

ISIS Messages—Roadway Characteristics

Table 4 illustrates, for ISIS messages necessitated by roadway characteristics, the percentage of drivers who slowed down and sped up as a function of the vehicle's velocity at message onset (below or above the posted speed limit). All subjects were driving above the speed limit; therefore, it is not surprising that overall there was a high compliance rate (85 percent). Compliance was higher with auditory/command messages (92 percent) than with visual/notification messages (79 percent); however, the difference was not statistically significant, $F(1,16) = 1.80$, $p>.05$.

Table 4. Percentage of drivers who complied with ISIS messages warning of immediate roadway changes as a function of message potency.

Action	Velocity at Message onset	Message Potency	
		Auditory/Command	Visual/Notification
Accelerated	At or below speed limit	0%	0%
	Above speed limit	8%	21%
Decelerated	At or below speed limit	0%	0%
	Above speed limit	92%	79%

<u>ISIS Messages—Posted Speed Limits</u>

Table 5 illustrates, for ISIS messages necessitated by speed limit signs, the percentage of drivers who slowed down and sped up as a function of the vehicle's velocity at message onset (below or above the new speed limit) and message potency. Even though 77 percent of the drivers receiving auditory/command messages were already driving below the new speed limit, 67 percent of them slowed down further upon receiving the ISIS message. In contrast, 71 percent of drivers receiving the visual/notification messages were driving below the new speed limit, and only 33 percent slowed further.

Table 5. Percentage of drivers who complied to ISIS messages warning of speed limit changes as a function of message potency.

Action	Velocity at Message Onset	Message Potency	
		Auditory/Command	Visual/Notification
Accelerated	At or below new speed limit	10%	38%
	Above new speed limit	0%	6%
Decelerated	At or below new speed limit	67%	33%
	Above new speed limit	23%	23%

Clearly, the auditory/command messages were very effective at eliciting responses from the driver. Irrespective of vehicle velocity, mean compliance to auditory/command messages was 90 percent, whereas mean compliance to visual/notification messages was only 56 percent, $F(1, 20) = 18.8$, $p<0.001$.

IVSAWS Messages

Compliance to IVSAWS messages was recorded as a binary variable; drivers either signaled to change lanes within 10 seconds of message onset (complied) or did not signal within 10 seconds (did not comply). Overall, compliance was mixed in response to the IVSAWS message. Across all six IVSAWS messages, drivers complied to 66 percent of message presentations. Table 6 demonstrates compliance to IVSAWS messages as a function of message potency. Compliance was much higher in response to auditory/command messages (87 percent) than in response to visual/notification messages (44 percent), $F(1, 16) = 36.9$, $p<0.001$.

Table 6. Percentage of drivers who signaled to change lanes within 10 seconds of IVSAWS message onset.

Action	Message Potency	
	Auditory/Command	Visual/Notification
Did not change lanes	13%	56%
Did change lanes	87%	44%

In summary, compliance is higher to auditory/command messages than to visual/notification messages. It is clear that urgent messages, where a response from the driver is critical, should be presented using the auditory/command format.

DRIVER PREFERENCE DATA

Figure 21 displays drivers' preference for general/service information (i.e., Shoe Sale at the Bon Marche, Arboretum Open Dawn to Dusk) on interstate, downtown, and residential roads. On interstate and residential roads, non-rush hour drivers rated such information more favorably than rush hour drivers. Although the difference was not found to be significant when all three road types were included in the analysis, $F(1, 22) = 3.02$, $p>0.05$, excluding "residential" road type from the analysis revealed a significant effect of traffic density on driver preference, $F(1, 22) = 6.60$, $p<0.05$.

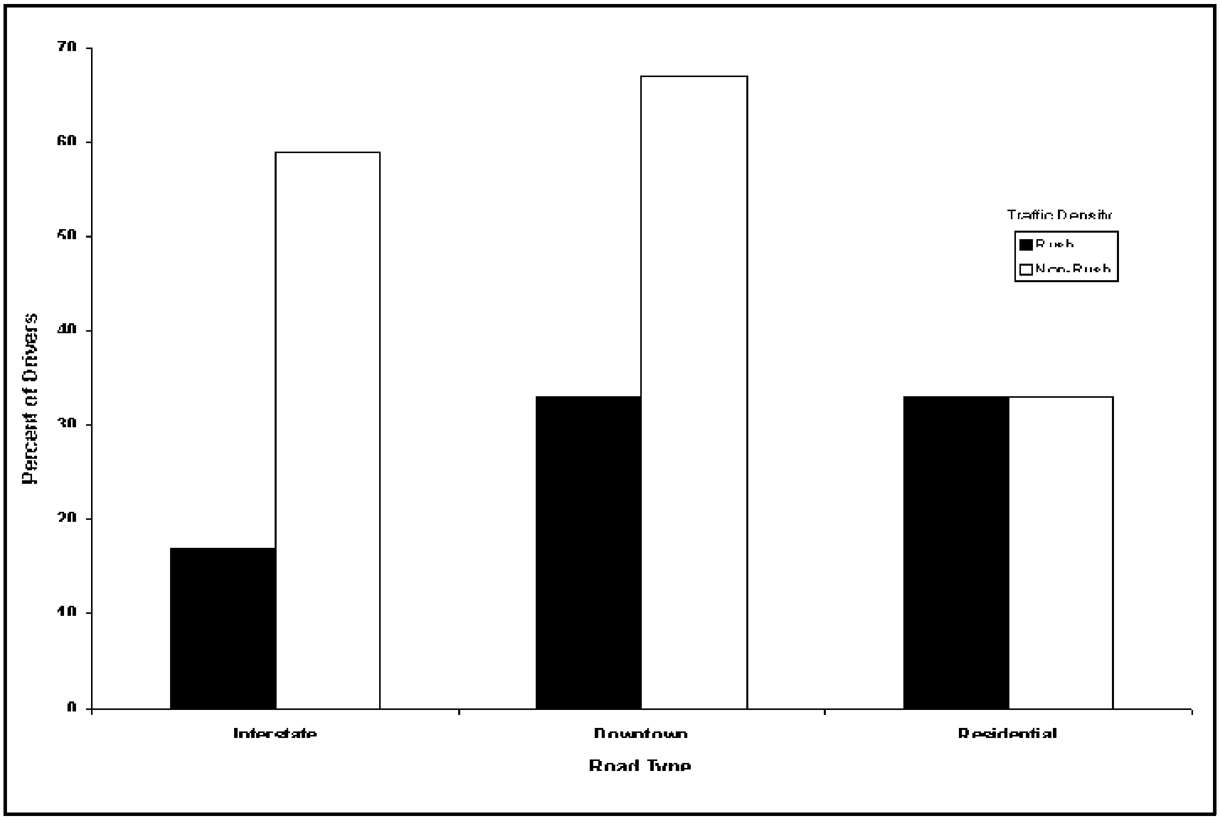

Figure 21. Percent of drivers that responded "Yes" to "Would you find General/Service Information useful when driving on Interstate, downtown and residential roads?"

Figure 22 shows drivers' response to "Please indicate if you would prefer to receive the information automatically while driving, automatically but only when stopped, by requesting the information, or not at all," asked for each of the five message types (navigation/route guidance, hazard warning, regulatory, vehicle monitoring, and general/service). One subject did not respond to the question for the message type general/service; missing data point was replaced by the median response to that question. Statistical analysis revealed a significant effect of message type on drivers' preference, $F(4, 92) = 23.03$, $p<0.001$. Most of the drivers preferred to receive navigation/route guidance, hazard warning and regulatory messages automatically while driving, whereas they preferred to receive vehicle monitoring and general/service messages automatically while stopped or upon request only.

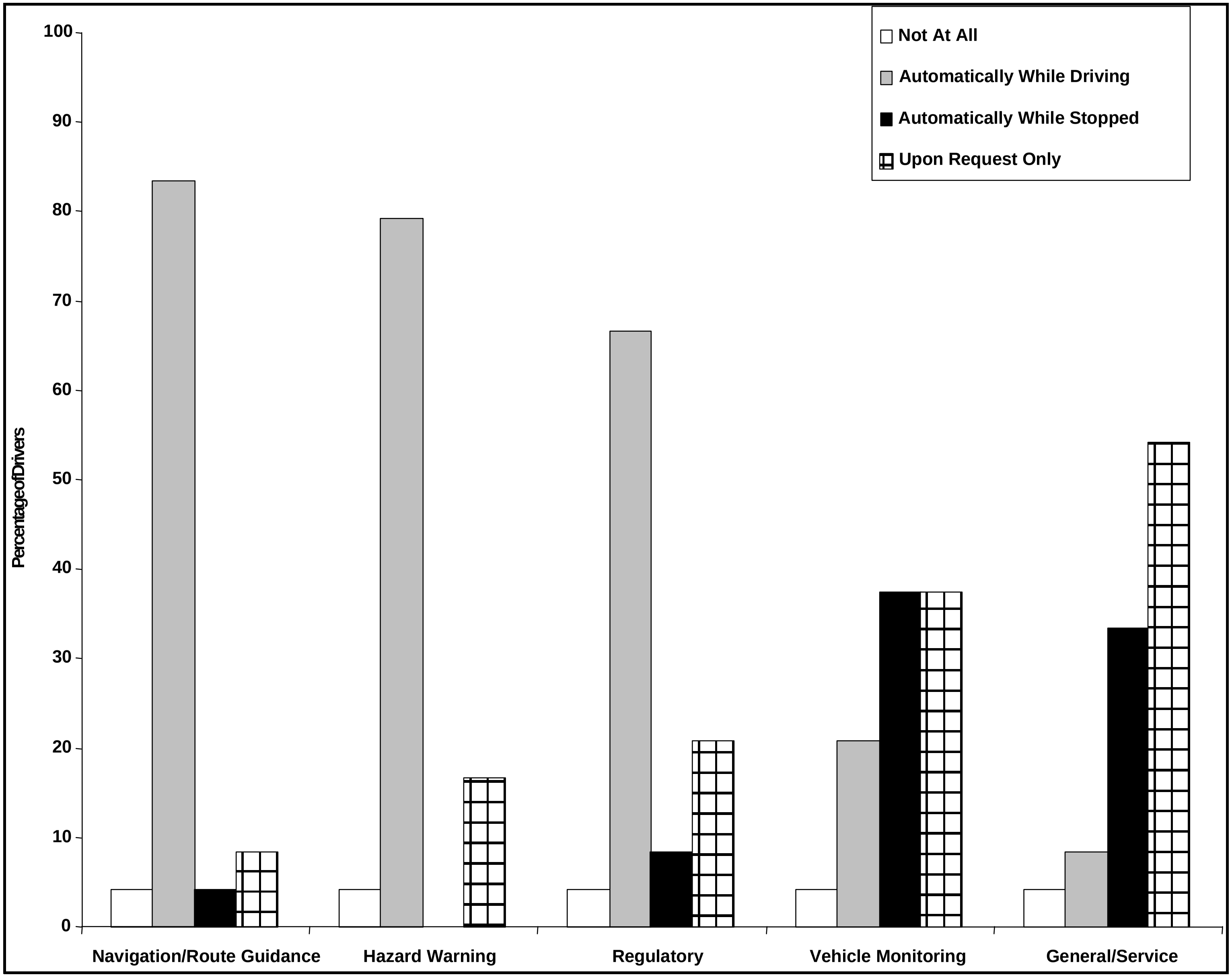

Figure 22. Driver preference for automatic delivery of five types of in-vehicle information.

DISCUSSION

This discussion is organized around the three hypotheses stated earlier in the report regarding the independent variables of message potency, advance notification, and highway conditions. Each is considered in turn.

MESSAGE POTENCY

Compliance to auditory/command messages was much higher than to visual/notification messages (tables 5 and 6). This is particularly important for messages related to driver safety, such as speed and hazard warnings. Thus, ATIS design guidelines should emphasize the power of auditory/command messages. Anecdotally, the in-vehicle experimenter reported that drivers tended to "automatically" follow such guidance without much independent verification of the immediate appropriateness of the message. For example, drivers receiving these messages tended to change lanes abruptly as instructed, without carefully checking that such maneuvers were safe. ATIS designers should be aware that the power of auditory/command messages carries an attendant risk, and so this message format should be reserved only for urgent messages of high priority.

The number of large steering wheel reversals was impacted by message potency (figure 16) with more reversals for the auditory/command messages versus the visual/notification messages. This is consistent with greater compliance to auditory/command messages, especially for IVSAWS, which have high priority for drivers.

Visual/Notification messages suppressed the SD of velocity, whereas auditory/notification messages did not (figure 19). This implies that drivers reading visual messages did not issue accelerator control inputs while messages were being processed, which is consistent with the idea that auditory input can require less attentional capacity due to higher stimulus-response compatibility (Kantowitz, Triggs, and Barnes, 1990). Note that this result cannot be explained by visual/notification messages being longer than auditory/command messages and hence requiring more driver capacity, because the auditory messages used in this experiment were longer than the visual messages (appendix A).

ADVANCE NOTIFICATION

Previous ATIS guideline efforts (see Campbell, Carney, and Kantowitz.,1998, for a review) found advance notification to help drivers and we expected similar results. As expected, advance notification reduced time to compliance for navigation messages (figure 20). The 1.8-second advantage gained by advance notification is large enough to make a practical difference on the road. Hence, ATIS design guidelines should advocate use of advanced notification. Drivers use and benefit from advanced notification.

HIGHWAY CONDITIONS

As anticipated, increasing road demand caused changes in driving performance measures such as average deviation of STWA (figure 14), number of large steering wheel reversals (figure 15), and

SD of velocity (figures 17 and 18). These results serve as a successful check on the internal validity of this field experiment and do not illustrate anything new or startling.

Traffic density did influence the kind of ATIS messages that drivers wanted to receive (figure 22). Drivers did not want to receive general/service information during rush hour, particularly on interstates and downtown roads.

HELPFUL NEGATIVE RESULTS

Negative results occur when manipulations of an independent variable do not control a dependent variable. While the methodology of science and statistics makes it impossible to prove a negative result, such outcomes can be of considerable interest and importance to ATIS designers. Since the present experiment had sufficient statistical power to provide many statistically reliable results, we believe that the most likely explanation for the negative results discussed in this section is that they are true negative results rather than being attributable to lack of power in the experiment.

The most important negative results had to do with presentation of ATIS messages during the message-window interval. The number of large steering wheel reversals did not increase relative to the before-message window when the message was presented (figure 15). This is an important outcome for ATIS designers because it suggests that attention to vehicle control was not impaired while the ATIS messages were presented.

Similar negative results were obtained for manipulation of information density, counter to our expectations. Presenting up to three messages per minute did not increase driver latency to acknowledge a message (figure 12), average deviation of STWA (figure 14), and SD of velocity (figure 19). This is good news for ATIS designers since it shows that presenting three messages per minute does not draw any more attention from driving than presenting one message per minute. Of course, this result only holds for the short messages tested in this experiment but these brief messages were typical of those used in ATIS displays.

CONCLUSIONS

Given the difficulties associated with on-road field experiments where experimental control is sacrificed to obtain results in a realistic driving environment, this experiment was quite productive. Empirical support was provided for several guideline principles.

Results confirmed and expanded those of earlier simulator studies regarding message potency (Lee et al., 1996). Furthermore, the dangers of too-potent messages when drivers obeyed ATIS instructions without checking road conditions were made salient. Such results in a simulator experiment could be dismissed because no driver ever perished in a simulator crash. However, observing such outcomes on the road in heavy traffic not only confirms simulator results but also emphasizes that it is possible for in-vehicle messages to be too effective. This is an important topic for future research.

APPENDIX A: ATIS MESSAGES PRESENTED

Table 7. Messages presented in both visual/notification and auditory/command styles.

Message Type	Visual/Notification	Auditory/Command
Navigation	15th Ave Ahead	Turn left on 15th Avenue
	2nd Ave Ahead	Turn left on 2nd Avenue
	Bellevue Exit Ahead	Take next exit to Bellevue Way
	8th Ave Ahead	Turn left on 8th Avenue
	84th Street Ahead	Bear right to 84th Street
	Montlake Blvd Exit Ahead	Take the Montlake Blvd. Exit
ISIS	Sharp Turn Ahead	Slow down. Sharp turn ahead.
	Crosswalk Ahead	Slow down. Crosswalk ahead.
	Speed Limit 40 mph	Slow down
	Speed Limit 30 mph	Slow down
	Speed Limit Radar Enforced	Slow down. Speed limit enforced by radar.
	Speed Limit 50	Slow down
IVSAWS	Congestion Ahead	Take next exit. Congestion ahead.
	Potholes in Lane Ahead	Change lanes. Potholes in lane ahead.
	Accident in Lane Ahead	Change lanes. Accident in lane ahead.
	Chemical Spill in Lane Ahead	Change lanes. Chemical spill in lane ahead.
	Stopped Vehicle in Lane Ahead	Change lanes. Stopped vehicle in lane ahead.
	Slow Vehicle in Lane Ahead	Change lanes. Slow vehicle in lane ahead.

Table 8. Messages presented in visual/notification style only.

Message Type	Visual Notification
General/Service	Farmers Market: Open
	New REI Store: Now Open
	Seattle Aquarium: Adults: $7.15
	Welcome to Bellevue
	Shoe Sale at the Bon Marche
	Visit Mercer Slough Park
	Arboretum Open Dawn to Dusk
	Welcome to Clyde Hill
	Kayaks Rentals $8.00 / hour
	Chevron Gas $1.39 / gallon
	Governor A.B. Rossini Bridge
	Visit Pike Place Market
	Henry Art Gallery Closed
Vehicle Monitoring	Check Brake Fluid
	Replace High Beams Lamps
	Emissions Test Required in 30 Days
	Oil Change Needed in 300 Miles
	Rotate Tires in 300 Miles
	Low Tire Pressure
	Tune-up Due
	Windshield Wiper Fluid Low
	Replace Air Filter
	Service Airbag

APPENDIX B: DRIVER PREFERENCE QUESTIONNAIRE AND RESULTS

Numbers in parentheses indicate frequency counts of drivers' responses, unless indicated otherwise.

Subject ID #: _________

Thank you for participating in Battelle's on-road study. Please answer the following questions regarding your experience with the Advanced Traveler Information System.

1. What is the highest level of education that you have completed?

(0) Grade School
(0) High school or GED
(24) College/University (if currently attending, please state year)

2. During a typical week, how many times do you drive:

on I-5	(mean = 3.8)
on I-90 bridge	(mean = 0.6)
on 520 bridge	(mean = 0.9)
in Bellevue	(mean = 0.7)
in Downtown Seattle	(mean = 1.5)

3. Have you ever driven with an Advanced Traveler Information System?

(0) Yes (24) No

Questions 4 to 6 refer to your comfort level with computers. Please circle the statement that best represents your opinion.

4. I like working with computers.

Strongly disagree		Disagree	Neutral	Agree	Strongly agree
(1)	(0)	(3)	(8)	(12)	

5. I feel comfortable working with computers.

Strongly disagree		Disagree	Neutral	Agree	Strongly agree
(1)	(0)	(3)	(6)	(14)	

6. Working with a computer makes me very nervous.

Strongly disagree		Disagree	Neutral	Agree agree	Strongly
(10)	(11)	(2)	(4)	(1)	

The following questions refer to the laptop component that was responsible for tracking the vehicle. Please circle the answer that best reflects your opinion.

7. I liked the vehicle tracking system

Strongly disagree	Disagree	Neutral	Agree	Strongly agree
(1)	(1)	(5)	(14)	(3)

8. I would not use the vehicle tracking system if it were in my car.

Strongly disagree	Disagree	Neutral	Agree	Strongly agree	
(3)	(9)	(8)	(3)	(0)	(1 missing)

9. I would purchase a vehicle tracking system similar to the one I used today for my own car.

Strongly disagree	Disagree	Neutral	Agree	Strongly agree
(4)	(7)	(7)	(5)	(1)

10. I found the vehicle tracking system useful.

Strongly disagree	Disagree	Neutral	Agree	Strongly agree
(1)	(0)	(7)	(13)	(3)

11. I found the vehicle tracking system difficult to use.

Strongly disagree	Disagree	Neutral	Agree	Strongly agree
(5)	(12)	(6)	(1)	(0)

12. I did not use the vehicle tracking system at all.

True	False
(4)	(20)

The following questions refer to the visual and auditory messages that were presented to you. Please circle the response that best represents your opinion.

13. I liked the Advanced Traveler Information System.

Strongly disagree	Disagree	Neutral	Agree	Strongly agree
(0)	(3)	(3)	(15)	(3)

14. I would use a system like this if it were in my car.

Strongly disagree	Disagree	Neutral	Agree	Strongly agree	
(0)	(5)	(6)	(9)	(3)	(1 missing)

15. I would purchase this system for my own car.

Strongly disagree	Disagree	Neutral	Agree	Strongly agree
(2)	(9)	(6)	(6)	(1)

16. It is dangerous for me to use this system while driving.

Strongly disagree	Disagree	Neutral	Agree	Strongly agree
(4)	(14)	(3)	(3)	(0)

17. I found the system useful.

Strongly disagree	Disagree	Neutral	Agree	Strongly agree
(0)	(3)	(3)	(14)	(4)

18. I found the system difficult to use.

Strongly disagree	Disagree	Neutral	Agree	Strongly agree
(5)	(15)	(3)	(1)	(0)

19. In general, this system presented.......

(Please choose the one answer that best reflects your opinion).

(10) Too much information

(9) The right amount of information

(2) Not enough Information (3 missing)

20. In general, the information was presented......

(Please choose the one answer that best reflects your opinion).

(0) Too soon

(15) At the right time

(9) Too late

The next 5 questions (Q 21 to 25) ask you about various types of information provided by Advanced Traveler Information Systems. Please refer to the table below that lists the types of information and provides examples.

Information Type	**Examples**
Navigation/Route Guidance	Turn left on 2nd Ave.
Hazard Warnings	Congestion ahead, accident ahead, potholes ahead
Regulatory Information	Speed limits, crosswalks, sharp turns
Vehicle Monitoring Information	Oil change, windshield wiper fluid low
General/Service	Arboretum open dawn to dusk

21. Please indicate whether you would like to have each of the following types of information in your own Advanced Traveler Information System.

	YES	**NO**	
Navigation/Route Guidance	(23)	(1)	
Hazard Warnings	(23)	(1)	
Regulatory	(18)	(6)	
Vehicle Monitoring	(14)	(10)	
General/Service	(8)	(15)	(1 missing)

22. For each of the roadway types below, please check which types of information you would find useful. (Please check all that apply).

	Interstate (I-5 etc.)	**Downtown (Seattle)**	**Residential (Suburban)**
Navigation/ Route Guidance	(17)	(22)	(23)
Hazard Warning	(21)	(21)	(12)
Regulatory	(11)	(16)	(18)
Vehicle Monitoring	(17)	(15)	(13)
General/Service	(9)	(12)	(8)

23. For each of the following types of information, please indicate if you would prefer to receive the information visually, verbally, both, or not at all.

	Visual	**Verbal**	**Both**	**Not at all**	
Navigation/Route Guidance	(4)	(4)	(15)	(1)	
Hazard Warning	(7)	(8)	(8)	(1)	
Regulatory	(7)	(7)	(8)	(2)	
Vehicle Monitoring	(10)	(6)	(3)	(4)	(1 missing)
General/Service	(7)	(7)	(2)	(7)	(1 missing)

24. For each of the following types of information, please indicate if you would prefer to receive the information automatically while driving, automatically but only when stopped, or by requesting the information.

	Not at all	Automatically while driving	Automatically while stopped	Upon request only
Navigation/Route Guidance	(1)	(20)	(1)	(2)
Hazard Warning	(1)	(19)	(0)	(4)
Regulatory	(1)	(16)	(2)	(5)
Vehicle Monitoring	(1)	(5)	(9)	(9)
General/Service	(1)	(2)	(8)	(12) (1 missing)

25. How much trust would you place in each of the following types of information presented by the Advanced Traveler Information System? Please circle a number from 1 to 5, where 1 = no trust and 5 = complete trust.

	1	2	3	4	5
Navigation/Route Guidance	(1)	(0)	(1)	(13)	(3)
Hazard Warning	(2)	(3)	(10)	(5)	(4)
Regulatory	(1)	(0)	(5)	(15)	(3)
Vehicle Monitoring	(2)	(2)	(4)	(10)	(6)
General/Service	(2)	(0)	(6)	(7)	(9)

26. Using the Advanced Traveler Information System, I would have confidence in my ability to navigate through Seattle.

Strongly disagree	Disagree	Neutral	Agree	Strongly agree
(0)	(0)	(4)	(4)	(6)

27. Using the Advanced Traveler Information System, I would have confidence in my ability to navigate through an unfamiliar city

Strongly disagree	Disagree	Neutral	Agree	Strongly agree
(0)	(1)	(5)	(12)	(6)

28. I would appreciate having advance notification of turns (i.e., Prepare to turn right at 45th St.).

Strongly disagree	Disagree	Neutral	Agree	Strongly agree	
(0)	(1)	(0)	(9)	(13)	(1 missing)

29. For which of the following types of hazards would you want the Advanced Traveler Information System to present a warning message?

(21) Traffic congestion ahead
(23) Accident ahead
(18) Construction ahead
(21) Disabled vehicle in lane ahead
(15) Slow vehicle in lane ahead (i.e., tow truck)
(22) Stopped vehicles in lane ahead (i.e., utility truck)
(21) Emergency vehicles approaching (i.e., Ambulance)
(16) Pot holes in lane ahead
(20) Chemical spill in lane ahead
Other, Please list:______________

30. If there was an obstruction on the roadway ahead, would you prefer if the system: (Please choose only one).

(11) Notified you of the nature of the problem
(i.e., "Construction in Lane Ahead")

(13) Suggested an action to avoid the obstruction
(i.e., "Move Left Construction Ahead")

31. When do you want to be notified of the speed limit? (Please choose all that apply).

(16) Every time the speed limit changes
(11) Anytime the vehicle is exceeding the speed limit
(17) Special circumstances that necessitate a change in speed
(i.e., slippery road, cross walk, sharp turn)

32. If you were driving 40 mph in a 35 mph zone, would you prefer if the system: (Please choose only one).

(22) Notified you of the speed limit (i.e., "Speed Limit is 35 mph")
(1) Suggested an action to comply with the limit (i.e., "Slow Down") (1 missing)

Thank you for your participation.

APPENDIX C: SUBJECT SELECTION PHONE QUESTIONNAIRE AND DRIVER DEMOGRAPHIC CHARACTERISTICS QUESTIONNAIRE

Subject Selection Phone Questionnaire

Subject Name ______________________________ **Phone Number _________**

Age _______ **Gender ______ (1 = M, 0 = F)**
[Exclude if under 18 or over 45]

Experimenter, please read:

The experiment we are recruiting for today requires you to drive our instrumented vehicle—a 1994 Saturn wagon. You will be driving with two experimenters in the vehicle. You may be required to drive on residential, downtown, and freeway roads in Seattle and Bellevue. Also, you may be asked to drive during rush hour traffic. All information observed and collected from your participation will be held confidential. Under no circumstances will it be reported to the police or your insurance company. In total you will be driving for about 11/2 hours during dusk or night time conditions. Is this something you feel comfortable doing?
[If yes] I have a few questions to ask you.

1) Do you have an active driver's license? _____Yes (1) _____ No (2)
[Exclude subject if answer is NO]

2) How many times per week do you drive?

_____ < 1X ______ 1X ______ 2 or more
[Exclude if answer is 1 × or less]

3) Do you wear corrective lenses while driving?

Glasses ______
Bi-focals ______
Tri-focals ______
Hard Contacts ______
Soft Contacts ______

4) We are scheduling times between 4:00 p.m. and 10:00 p.m. This means you will be driving during dusk or night time conditions. Do you feel comfortable driving at dusk or night time?
Yes____ No____
[Exclude if subject answer is NO]

5) Due to the nature of the study, we ask that you DO NOT take any drugs that could affect your driving abilities such as prescribed, over-the-counter, or recreational drugs, including alcohol, 24 hours prior to your scheduled date. Do you have any problems complying with this request?
Yes____ No____
[Exclude if subject answer is YES]

Driver Demographics Phone Questionnaire

Subject Name ______________________________ **Phone Number _________**

Age _______ **Gender ______ (1 = M, 0 = F)**

1) How many years have you been a licensed driver?: _____

2) How many years have you driven in Seattle?: _____

3) How many years have you lived in the Seattle area? _____

4) Town of residence : ________________________ Zipcode _______________

5) What is the average number of miles you drive annually?

G less than 5,000
G 5,000 - 9,999
G 10,000 - 19,999
G 20,000 - 39,999
G 40,000 - 69,999
G 70,000 - 99,999
G more than 100,000

6) Where did you learn about this research? ___________________________________

APPENDIX D: EXPERIMENTER PROTOCOL

RECEPTION PROTOCOL

! Meets participant by the reception desk on Battelle campus approximately 10 min prior to the time the study should begin.

! Escort participants to the instrumented vehicle (located on campus) and have them fill out the consent and demographic information forms.

VERIFY THAT SUBJECT HAS DRIVER'S LICENSE WITH THEM

INSTRUCTIONS (READ)

Purpose of Study

Welcome to Battelle. The purpose of this study is to understand how drivers feel about Advanced Traveler Information Systems. The goal of an Advanced Traveler Information Systems (or ATIS) is to increase safety of all road users and also reduce travel time and traffic congestion. These systems provide information to the driver such as:

! Directions to get from point A to B.
! Information about changes in speed limits or road conditions.
! Information about traffic conditions such as traffic jams.
! Warnings about possible hazards on the roadway such as accidents or icy roads.

These systems may also provide information about:

! Local attractions
! Restaurants and hotels in the area.

These systems may also be connected to the vehicle's own computer system, and may provide vehicle diagnostic information to allow you to monitor the status of the vehicle. For example the system may tell you when the fuel level is low.

To allow you to form an opinion of the Advanced Traveler Information System, we are going to ask you to drive with the system installed in our Saturn wagon. This study will require you to drive for approximately 1 hour. The ATIS will guide you along freeways, downtown roads, and residential roads. Your primary responsibility will be to drive safely and in accordance with all traffic rules. Remember that you will have to pay any consequences of your actions (i.e., speeding tickets and fines). Please try to drive as you normally would in your own vehicle. Your secondary responsibility is to follow the instructions provided by the ATIS, when, and only when, it is safe to do so.

Before we continue, are you comfortable with the task we are asking of you today? Remember, it is your right to withdraw from this study at any time. Both of us will be in the car with you so, if, when you are driving, you do not feel comfortable with the task, please tell the experimenter. We will guide you to a safe place to pull over and drive you back here to Battelle.

As you can see the car is equipped with an emergency brake. This brake will only be used in the event of a real emergency, such as if the car is in danger of leaving the road, or striking another object. Despite the presence of the safety brake, you are completely responsible for the operation of the vehicle at all times. If the emergency brake is required, the experiment will be ended immediately.

INTRODUCING DRIVERS TO THE SATURN

The first thing we will do is get you settled in the vehicle. As you will be driving for an hour, take the time now to make sure you will be comfortable.

Seat

Experimenter: Encourage subjects to adjust seat in any way they wish. Do not allow subjects to adjust the steering wheel. Be aware of the computer equipment directly behind the seat.

To adjust seat fore/aft position*:* Lift up the lever under the right hand side of the seat, adjust the seat, then put the lever down to lock seat to its new position.

To adjust seat's reclining angle*:* Lift up the lever on the left hand side of the seat and adjust seat to new position.

To adjust head restraint*:* Simply move restraint on back of seat up and down to desired height. [Tell subject to put on seatbelt.]

To operate seatbelt*:* Pull seatbelt from above your left shoulder, and secure it in the clasp to your right.

Mirrors

[Tell subject to adjust rear view mirror, making sure the back window is centered when they look in the rear view mirror.]

To adjust the rear view mirror, simply move it to the desired position.
[Tell subject to adjust side mirrors, making sure they will be able to see cars coming from their left and right sides.]

To adjust driver's side mirror, move the knob to the right of the mirror.

To adjust passenger mirror, use the "right mirror" button on the panel located to your right below the gear shift.

[Tell subject to place the key in the ignition switch, located on the right side of the wheel, and turn it just to the first notch so they will be able to try out some of the systems of the car.]

Lights

The lights are located on the lever to the left of the steering wheel. They are currently in the "off" position.

To turn on the parking lights*:* Turn the lever up one notch to the parking lights icon.
[Tell subject to turn on parking lights.]

To turn on the headlights: Turn the lever up another notch to the headlights icon.
[Tell subject to turn on headlights.]

High beams*:* If you should need to activate the highbeam lights, pull the lever all the way toward you, then release it. A blue light will come on between the speedometer and the tachometer on the instrument panel to indicate that the highbeams are on.
[Tell subject to turn on highbeams.]

To turn off the highbeams, do the same thing you did to activate them—pull the lever all the way toward you, then release it.
[Tell subject to turn off highbeams.]
Notice that the blue light on the instrument panel is gone.
[Tell subject to turn the headlights off by turning the lever back to the "off" position.]

To operate the turn signals: Move this entire light lever (lever to the left of the wheel) up to signal left [tell subject to practice signaling left]; move it down to signal right. [Tell subject to practice signaling right].

To activate the hazard lights*:* Push down the hazard knob located on the top of the center of the steering wheel [Tell subject to practice activating hazard signal]. To turn off the hazard lights, simply press down on the same button again to release it [Tell subject to turn off hazard lights].

Windshield Wipers

To operate front windshield wipers*:* The windshield wiper controls are located on the lever on the right of the steering wheel. The wipers are currently in the "off" position. For intermittent wipers, raise the entire lever up one notch [Tell subject to do this]; for low speed wipers, raise the entire lever up another notch [Tell subject to do this], and for high-speed wipers, raise the lever up to the highest notch [Tell subject to do this]. To wash the windshield, pull the entire lever toward you [Tell subject to practice this].

To operate the rear windshield wipers*:* On the same lever (to the right of the wheel), but moving toward the center of the wheel, there are the numbers 1, 2, and 3. To the left of these numbers is a ring with a small bump on it that you can shift up and down to control the rear wipers. They are currently in the "off" or "1" position. To activate the rear wipers, shift the bump on the ring up to the "2" position [Tell subject to do this] and to wash the rear windshield, shift the bump on the ring up to the "3" position [Tell subject to do this].

Climate Control/Ventilation

Throughout the drive the windows will remain closed so you can hear the auditory messages. If you find you need to adjust the temperature in the car, please tell the experimenter in the passenger seat—she will do it for you.

Horn

Two horn buttons are located on the lower left and right of the steering wheel. [Tell subject to practice activating the horn by pushing one of these buttons.]

Instrument Panel

Take a minute to familiarize yourself with the instrument panel. To the far left is the fuel gauge, and to the right of that is the speedometer. To the right of the speedometer is the tachometer, which shows the engine speed in rpms. To the far right of the panel is the coolant temperature indicator.

Preparing to Drive

[Tell subjects to keep their hands at the 9:00 and 3:00 positions on the wheel throughout the drive.]

To release emergency brake*:* The emergency brake is located to your right. To release it, push in on the button and lower the brake lever [Tell subject to do this].

Gear shift*:* Take a minute to familiarize yourself with the gearshift. The gear is currently in park; below that the gear shifts to reverse, then to neutral, then to drive. Below that are third and second gear, which you would only use if you were going down an extremely steep hill.

Ignition*:* When we are ready to start the car, place the key into the ignition switch located on the right of the wheel and turn the key one more notch away from you.

Practice Phase 1: Vehicle Alone

We will start today by allowing you some time to get used to the vehicle. I will provide directions as we go. When you are ready, go ahead and start the car.
[*Subject is instructed to back out of parking space and drive the introductory loop—through the Battelle parking lot, onto a residential street, and back to Battelle. If driver passes Phase 1 criteria move onto Phase 2—if not repeat Phase 1.]*

Do you feel comfortable driving this vehicle on freeways and downtown streets?
[If yes, continue. If, no, repeat practice route. If not comfortable after second time, pay the subject for his/her time and allow them to leave.]

INTRODUCTION TO THE ATIS (VEHICLE STATIONARY)

Now, let’s take a few minutes to become acquainted with the Advanced Traveler Information System. There are two components to the ATIS we are using today. Although each component has its own screen, they work hand-in-hand to provide relevant information to you, as the driver. The first component of the ATIS is a vehicle tracking system called the Retki System. This is really the brains of the system. It uses satellites to track our location as we drive throughout Seattle. You can see the red star (point to it). This is where we are right now (just off 45th St. NE). This star will move along with us and track our position throughout our drive today.

The black line you see on the screen (point to it) is the route that the Retki has chosen for us today. An ATIS will allow a driver to enter information at the beginning of a trip. For example, I can tell the system that I want to drive from here to Vancouver, BC, and that I want to take the most scenic route, the fastest route, or the least traveled route. Based on the information I provided the Retki earlier today, this is the route the Retki has chosen for us.

This is the key to the whole ATIS; when this is operational, the system can provide accurate and relevant messages to you. You can check to see that the system is still tracking you by watching this display. This star will change to a red arrow, and as you drive, the star will move along the map with us. For safety reasons, you can only look at this display when the car is stopped. A safety screen blocks the map out when you are driving. If you want to, you can monitor the status when stopped at a traffic light or when you are in traffic. Just ask the experimenter and they will turn the laptop so you can see it.

The second part of the ATIS is the system that provides instructions and other information. ATIS information can come in one of two forms: (1) Visual, or (2) Auditory. Today, you will be seeing and hearing several examples of both visual and auditory displays. The system will notify you when there is a message for you by presenting a tone. As soon as you are ready to receive the message, press this lit button [show button]. If you don’t press the button, the display will come on after 10 seconds. The visual display will always be on for 5 seconds.

Let’s review some examples.
[Experimenter type <exp14> enter subject data. Use P# for practice message sequence]

Trial Message

Tone sounds, subject is instructed to press button, Visual Message “Welcome to Battelle” is presented for 5 seconds.

Let’s see what happens if you don’t press the red button.:
Tone sounds, subject does not press red button, Visual message “Welcome to Battelle” is presented for 5 seconds.

Navigation

One type of information you will receive from the ATIS is directions to make turns. In fact the ATIS will be your only source of directions. Once we start, we will not be allowed to provide any directions to you. If the ATIS does not provide directions to you, you should assume you should go straight.

Visual*: Press Space to Cue (42nd St. Ahead—Right Arrow)*
That tone you heard indicates that there is a message waiting for you. When you are ready go ahead and press the red button. This is an example of what a message may look like. This tells you that you are to turn on 45th St. ahead.

Now, let's review an auditory message.
Press Space to cue (Turn right on 42nd St.)
Again, the tone indicates that a message is waiting for you. When you are ready, press the red button. The auditory message will play.

Again if you don't press the red button, the display will come on automatically after 10 seconds. *Cue messages, have subjects wait, at end of message ask* "What action would you take if you saw this message?"

Cue Visual (turn Left)—wait 10 seconds—watch for display.
Cue Auditory (turn left)—wait 10 seconds— listen for message.

Any questions?

Repeat:
Cue Next Visual (bear right)—ask subjects what they would do in response.
Cue next Auditory (bear right)—ask subjects what they would do in response.

Continue until subject fully understands.

READ TO ADVANCED WARNING CONDITION ONLY
In addition to messages that will tell you to take your next turn, there will also be messages that warn you of an upcoming turn. The messages will come on automatically without a tone. The messages will always be auditory and will always sound like this—play "Prepare to turn left on 45th St." Upon hearing this, you should prepare to move to the left lane when it is safe to prepare for your turn.

Play second message and verify that the subject understands.

ISIS

In addition to navigation messages the ATIS may also present information such as regulatory and advised speed limits. Although you should always follow the rules of the road as you know them and you should not rely only on this system to monitor your speed, it will warn you to slow down in accordance with selected posted and advised speed limits. These messages may be either visual or auditory.

[Cue Visual ISIS "Slow Down".] Again, a tone will be presented. When you are ready to receive the message press the red button. The message will be presented here for 5 seconds.

Also, some of these messages will be auditory.
Cue auditory message.
Cue visual "Crosswalk" message.
What would you do in response to this message? This message is designed to give you a little advance notice that a cross walk is ahead, and you may want to slowdown or stop for a pedestrian. You should always slow down to prepare to stop for pedestrians at all crosswalks.

Cue auditory Sharp Turn Ahead. This message warns you of road characteristics that require you to reduce your speed.

IVSAWS

Other messages may warn you of hazards or problems on the roadway. These messages are designed to allow you to optimize travel, by reducing time spent in traffic jams, and routing you around potential problems such as poor road conditions or accidents.

Cue Visual "Construction in Lane Ahead." This implies that you should change lanes to avoid the construction ahead. As no lane is recommended, it does not matter which lane you choose, as all other lanes are clear. It is recommended that you change lanes as soon as it is safe to do so.

Cue Auditory "Vehicle Stopped Ahead." If you saw this message, what action would you take? Again, the system advises you to change lanes. As no lane is specified, it indicates that all other lanes are clear. You are advised to change lanes as soon as it is safe to do so.

General/Service

Advanced Traveler Information Systems are being used widely right now in rental cars. Therefore many of the users are tourists or travelers who are new to the Seattle area. Therefore some messages may provide information about local services or attractions. They are simply to provide extra information to the driver about the area. This is an example. *Cue example*. It does not require a response from you.

Vehicle Monitoring

Also, there is a push to integrate all computer systems of the vehicle into one, so that drivers do not need to monitor several computer screens while driving. As a result, this ATIS is linked to the automobile monitoring system. So it will provide information about the status of the car. For example, the ATIS will warn drivers if the fuel level is too low. These will require no action on your part tonight. *Cue example*.

Do you have any questions?

Phase 3—Driving with the ATIS

Let's try these out while you are driving now. Again we will go for a short drive in the Laurelhurst community. This time the ATIS will guide you. Remember to use the ATIS only to augment your driving—always follow the rules of the road as you know them.

Drive same practice route as in Phase 1—with criteria checklist completed by both experimenters. [If subject passes, move on; if not, repeat Phase 3.]

Drive to Springbrook Garage.

EYE TRACKER SETUP

READ: I am going to set up the eye tracker now. This helmet sits on your head with the glass visor in front of your eyes. It is important that the visor is on tight enough so that it doesn't move around. However, it is also important that it is not on too tight so you are comfortable wearing this for an hour. Please tell me as I adjust it when you think it is too tight.

Get visor on head and adjust. OK, its important that this visor does not move once it is on your head. Please try not to touch it. This visor is specially treated to be able to provide us with accurate information. It is very important that you do not touch the glass. If you need to adjust it, or take it off when you are driving, please let me know. We will find a safe place for you to pull over and help you take it off.

1) *Have subject rest head against headrest—or a position they can hold comfortably*
2) *Adjust visor so pupil is visible and cornea is in bottom half*
3) *Adjust camera so all 9 points are visible and cover about 80 percent of screen*
4) *Discriminate pupil—then cornea*
5) *Type /sw—click mouse on each of 9 points—then press enter*
6) *Type /ec—have subject look at each point*
7) *Verify calibration. Ensure that when subject looks at message display, scene plane changes to "1."*

EXPERIMENTAL ROUTE

Before you arrived today the Retki system has decided on the best route for us today based on traffic conditions and other road conditions. It will provide you with directions, as well as other information. As I mentioned before, these systems are not always 100 percent reliable. They use satellites to determine our position—so if for some reason something blocks a satellite (i.e., a building), the Retki may lose our position temporarily. If this happens, we will provide you verbal directions until the Retki picks up again.

Do you have any questions? Once we leave the parking garage, we will not be allowed to answer any questions. You will be guided by the ATIS. If you follow the directions it provides you, we will end up back here at Battelle.

Remember, drive as you would drive your own vehicle—use the ATIS to help you drive, but do not rely on it as your sole source of information. Posted signs on the road always take priority. Your first priority is always to drive safely and obey all traffic laws.

[Experimenter: Begin all data collection computers. Cue the first message.]

APPENDIX E: RESEARCH PARTICIPATION CONSENT FORM

You have been recruited to participate in a study that will examine human factors issues related to driver behavior, performance, and traffic safety. During this study you may be driving on rural, residential, downtown, and freeway roads in a Saturn passenger vehicle. You will encounter traffic and other driving situations just the same as in everyday driving. Your primary goal is to drive safely, following all traffic regulations.

The risks associated with this experiment are similar to driving in your own vehicle. However, if you feel uncomfortable in the driving situation, please tell the experimenter who will guide you to a safe location where you may stop the vehicle. You may withdraw from the study at any time and you will be paid for the time you have participated.

All data obtained are for research purposes only, and will remain confidential. In fact, your name and this consent form will be kept separate from all data collected. No individual information will be reported to any licensing authorities or insurance companies. The information will be reviewed only by Battelle and U.S. Dept. Of Transportation scientists, and the data will reside at Battelle.

By signing this form, you certify that you meet the following minimum requirements for on-road research participation:

- Over the age of 18.
- Hold a valid Washington State driver's license.
- Have not consumed any alcohol in the past 24 hours.
- Have not taken any prescription, over-the-counter, or recreational drugs that may affect judgment or the ability to drive.

If you have any questions or desire further information about this study, please contact Becky Hooey at Battelle/Seattle (206) 528-3201. If you have concerns about the treatment of subjects in this study, please contact Jenny Greenway of Battelle's Human Subjects Committee at (614) 424-6587.

I have read the statement and agree to permit the use of my responses for research purposes.

______________________________	____________	____________
Signature of Participant	Date of Birth	Today's Date
______________________________		____________
Signature of Investigator		Today's Date

RECORD OF PAYMENT

______________________________ ______________________

Please Print Name Social Security Number

_____ hours @ $__.__ per hour = $__.__

______________________________ ___________

Signature of Participant Today's Date

_____________________________ __________

Signature of Investigator Today's Date

APPENDIX F: ANOVA TABLES

DRIVER PERFORMANCE DATA

Table 9. ANOVA of message-initiation latency.

Source	SS	DF	Mean Square	F	P
Age (A)	11.41010	1	11.41010	2.83	0.1120
Traffic (T)	8.99312	1	8.99312	2.23	0.1548
Gender (G)	0.70503	1	0.70503	0.17	0.6814
Age × Traffic	4.03487	1	4.03487	1.00	0.3321
Age × Gender	7.00435	1	7.00435	1.74	0.2061
Traffic × Gender	1.11325	1	1.11325	0.28	0.6065
Age × Traffic × Gender	7.82737	1	7.82737	1.94	0.1826
Error	64.53295	16	4.03331		
Road Demand (R)	1.60829	2	0.80414	1.66	0.2057
R × Age	0.27073	2	0.13537	0.28	0.7577
R × Traffic	1.05624	2	0.52812	1.09	0.3478
R × Gender	9.89543	2	4.94772	10.23	0.0004
R × Age × Traffic	0.04624	2	0.02313	0.05	0.9534
R × Age × Gender	2.68537	2	1.34268	2.78	0.0773
R × Traffic × Gender	0.61875	2	0.30938	0.64	0.5341
R × Age × Traffic × Gender	0.82305	2	0.41152	0.85	0.4365
Error	15.47974	32	0.48374		
Information Density (I)	0.313.82	2	0.15691	0.16	0.8516
I × Age	2.13375	2	1.06688	1.10	0.3458
I × Traffic	2.73413	2	1.36706	1.41	0.2596
I × Gender	4.64852	2	2.32426	2.39	0.1076
I × Age × Traffic	1.07680	2	0.53840	0.55	0.5800

Source	SS	DF	Mean Square	F	P
I × Age × Gender	4.18967	2	2.09484	2.16	0.1323
I × Traffic × Gender	0.64613	2	0.32307	0.33	0.7196
I × Age × Traffic × Gender	1.47088	2	0.73544	0.76	0.4773
Error	31.09301	32	0.97166		
Road Demand × Information Density (R × I)	1.03220	4	0.25805	0.41	0.8007
(R × I) × Age	3.80645	4	0.95161	1.51	0.2091
(R × I) × Traffic	1.18247	4	0.29562	0.47	0.7577
(R × I) × Gender	3.02559	4	0.75640	1.20	0.3186
(R × I) × Age × Traffic	0.92622	4	0.23156	0.37	0.8306
(R × I) × Age × Gender	3.11341	4	0.77835	1.24	0.3042
(R × I) × Traffic × Gender	0.35674	4	0.08918	0.14	0.9660
(R × I) × Age × Traffic × Gender	0.44591	4	0.11148	0.18	0.9494
Error	40.26955	64	0.62921		
Repetition (T)	0.82968	1	0.82968	1.67	0.2152
T × Age	0.44802	1	0.44802	0.90	0.3570
T × Traffic	0.00010	1	0.00010	0.00	0.9888
T × Gender	0.37148	1	0.37148	0.75	0.4006
T × Age × Traffic	0.01193	1	0.01193	0.02	0.8790
T × Age × Gender	1.17063	1	1.17063	2.35	0.1448
T × Traffic × Gender	0.30136	1	0.30136	0.60	0.4480
T × Age × Traffic × Gender	0.07600	1	0.07600	0.15	0.7012
Error	7.96999	16	0.49812		

Source	SS	DF	Mean Square	F	P
Road Demand × Repetition (R × T)	4.35381	2	2.17691	4.35	0.0214
(R × T) × Age	3.91113	2	1.95556	3.91	0.0304
(R × T) × Traffic	0.07582	2	0.03791	0.08	0.9273
(R × T) × Gender	4.68738	2	2.34369	4.68	0.0165
(R × T) × Age × Traffic	0.61118	2	0.30559	0.61	0.5494
(R × T) × Age × Gender	3.48336	2	1.74168	3.48	0.0430
(R × T) × Traffic × Gender	0.11431	2	0.05715	0.11	0.8925
(R × T) × Age × Traffic × Gender	0.81963	2	0.40982	0.82	0.4501
Error	16.02350	32	0.50073		
Information Density × Repetition (I × T)	2.29148	2	1.14574	2.27	0.1201
(I × T) × Age	3.92371	2	1.96186	3.88	0.0310
(I × T) × Traffic	0.96451	2	0.48226	0.95	0.3959
(I × T) × Gender	1.14238	2	0.57119	1.13	0.3357
(I × T) × Age × Traffic	0.45027	2	0.22513	0.45	0.6445
(I × T) × Age × Gender	0.50063	2	0.25032	0.50	0.6141
(I × T) × Traffic × Gender	0.97417	2	0.48708	0.96	0.3924
(I × T) × Age × Traffic × Gender	0.70900	2	0.35450	0.70	0.5035
Error	16.17844	32			
Road Demand × Information Density × Repetition (R × I × T)	2.57765	4	0.64441	1.11	0.3598
(R × I × T) × Age	2.11503	4	0.52876	0.91	0.4634
(R × I × T) × Traffic	1.41578	4	0.35394	0.61	0.6573

Source	SS	DF	Mean Square	F	P
(R × I × T) × Gender	1.02807	4	0.25702	0.44	0.7774
(R × I × T) × Age × Traffic	0.31716	4	0.07929	0.14	0.9682
(R × I × T) × Age × Gender	1.87643	4	0.46911	0.81	0.5248
(R × I × T) × Traffic × Gender	2.78212	4	0.69553	1.20	0.3205
(R × I × T) × Age × Traffic × Gender	0.50249	4	0.12562	0.22	0.9284
Error	37.17059	64	0.58079		

Table 10. ANOVA of average deviation of the STWA.

Source	SS	DF	Mean Square	F	P
Age (A)	102.09376	1	102.09376	1.34	0.2638
Traffic (T)	133.01042	1	133.01042	1.75	0.2048
Gender (G)	34.56000	1	34.56000	0.45	0.5100
Age × Traffic	74.55376	1	74.55376	0.98	0.3370
Age × Gender	67.33500	1	67.33500	0.88	0.3609
Traffic × Gender	161.89352	1	161.89352	2.13	0.1641
Age × Traffic × Gender	185.55574	1	185.55574	2.44	0.1380
Error	1217.68019	16	76.10501		
Message Window (MW)	247.89796	1	247.89796	27.74	0.0001
MW × Age	1.04167	1	1.04167	0.12	0.7372
MW × Traffic	1.01407	1	1.01407	0.11	0.7406
MW × Gender	7.82042	1	7.82042	0.88	0.3634
MW × Age × Traffic	12.23130	1	12.23130	1.37	0.2592
MW × Age × Gender	0.02894	1	0.02894	0.00	0.9553
MW × Traffic × Gender	29.55560	1	29.55560	3.31	0.0877
MW × Age × Traffic × Gender	34.48004	1	34.48004	3.86	0.0671
Error	142.97500	16	8.93594		

Source	SS	DF	Mean Square	F	P
Road Demand (R)	124.65396	2	62.32698	2.19	0.1286
R × Age	96.20048	2	48.10024	1.69	0.2007
R × Traffic	88.71813	2	44.35906	1.56	0.2262
R × Gender	13.70757	2	6.85379	0.24	0.7875
R × Age × Traffic	50.79438	2	25.39719	0.89	0.4198
R × Age × Gender	13.46965	2	6.73483	0.24	0.7908
R × Traffic × Gender	141.78794	2	70.89397	2.49	0.0989
R × Age × Traffic × Gender	32.82030	2	16.41015	0.58	0.5677
Error	911.25979	32	28.47687		
Message Window × Road Demand (MW × R)	47.14739	2	23.57369	1.01	0.3745
(MW × R) × Age	28.07021	2	14.03510	0.60	0.5533
(MW × R) × Traffic	37.32128	2	18.66064	0.80	0.4574
(MW × R) × Gender	0.73674	2	0.36837	0.02	0.9843
(MW × R) × Age × Traffic	53.73308	2	26.86654	1.15	0.3281
(MW × R) × Age × Gender	5.85975	2	2.92987	0.13	0.8822
(MW × R) × Traffic × Gender	54.21628	2	27.10814	1.16	0.3249
(MW × R) × Age × Traffic × Gender	25.12363	2	12.56182	0.54	0.5881
Error	744.81834	32	23.27557		
Information Density (I)	600.18110	2	300.09055	3.58	0.0396
I × Age	103.65528	2	51.82764	0.62	0.5453
I × Traffic	14.05750	2	7.02875	0.08	0.9198
I × Gender	49.76028	2	24.88014	0.30	0.7453
I × Age × Traffic	28.38694	2	14.19347	0.17	0.8450

Source	SS	DF	Mean Square	F	P
I × Age × Gender	36.61194	2	18.30597	0.22	0.8051
I × Traffic × Gender	61.50676	2	30.75338	0.37	0.6959
I × Age × Traffic × Gender	180.87148	2	90.43574	1.08	0.3522
Error	2683.48763	32	83.85899		
Message Window × Information Density (MW × I)	15.56509	2	7.78255	0.71	0.5002
(MW × I) × Age	16.30361	2	8.15180	0.74	0.4844
(MW × I) × Traffic	2.83231	2	1.41616	0.13	0.8796
(MW × I) × Gender	14.27111	2	7.13556	0.65	0.5293
(MW × I) × Age × Traffic	9.51148	2	4.75574	0.43	0.6526
(MW × I) × Age × Gender	15.67843	2	7.83921	0.71	0.4978
(MW × I) × Traffic × Gender	68.33065	2	34.16533	3.11	0.0584
(MW × I) × Age × Traffic × Gender	50.73787	2	25.36893	2.31	0.1158
Error	351.81611	32	10.99425		
Road Demand × Information Density (R × I)	691.50972	4	172.87743	3.57	0.0108
(R × I) × Age	50.00778	4	12.50195	0.26	0.9035
(R × I) × Traffic	74.57667	4	18.64417	0.39	0.8183
(R × I) × Gender	40.72736	4	10.18184	0.21	0.9317
(R × I) × Age × Traffic	36.19305	4	9.04826	0.19	0.9443
(R × I) × Age × Gender	34.45643	4	8.61413	0.18	0.9489
(R × I) × Traffic × Gender	91.66200	4	22.91550	0.47	0.7549
(R × I) × Age × Traffic × Gender	94.65060	4	23.66265	0.49	0.7437
Error	3096.06242	64	48.37598		

Source	SS	DF	Mean Square	F	P
Message Window × Road Demand × Information Density (MW × R × I)	100.98977	4	25.24744	1.26	0.2965
(MW × R × I) × Age	34.95014	4	8.73753	0.43	0.7830
(MW × R × I) × Traffic	26.40838	4	6.60210	0.33	0.8578
(MW × R × I) × Gender	17.28195	4	4.32049	0.21	0.9292
(MW × R × I) × Age × Traffic	37.45060	4	9.36265	0.47	0.7606
(MW × R × I) × Age × Gender	74.06435	4	18.51609	0.92	0.4572
(MW × R × I) × Traffic × Gender	116.94102	4	29.23525	1.45	0.2265
(MW × R × I) × Age × Traffic × Gender	82.74158	4	20.68539	1.03	0.3991
Error	1286.34394	64	20.09912		
Message Potency (MP)	697.32228	1	697.32228	15.75	0.0011
MP × Age	113.68005	1	113.68005	2.57	0.1286
MP × Traffic	116.60042	1	116.60042	2.63	0.1242
MP × Gender	64.02667	1	64.02667	1.45	0.2466
MP × Age × Traffic	28.96672	1	28.96672	0.65	0.4305
MP × Age × Gender	21.40741	1	21.40741	0.48	0.4968
MP × Traffic × Gender	40.73352	1	40.73352	0.92	0.3517
MP × Age × Traffic × Gender	19.44000	1	19.44000	0.44	0.5170
Error	708.39019	16	44.27439		
Message Window × Message Potency (MW × MP)	2.00296	1	2.00296	0.18	0.6764
(MW × MP) × Age	1.88907	1	1.88907	0.17	0.6851
(MW × MP) × Traffic	2.20018	1	2.20018	0.20	0.6618
(MW × MP) × Gender	0.45375	1	0.45375	0.04	0.8422
(MW × MP) × Age × Traffic	1.81500	1	1.81500	0.16	0.6910

Source	SS	DF	Mean Square	F	P
(MW × MP) × Age × Gender	12.08894	1	12.08894	1.09	0.3117
(MW × MP) × Traffic × Gender	17.17042	1	17.17042	1.55	0.2311
(MW × MP) × Age × Traffic × Gender	5.90042	1	5.90042	0.53	0.4761
Error	177.26649	16	11.07916		
Road Demand × Message Potency (R × MP)	303.59891	2	151.79946	2.54	0.0950
(R × MP) × Age	44.93655	2	22.46828	0.38	0.6901
(R × MP) × Traffic	12.65965	2	6.32983	0.11	0.9000
(R × MP) × Gender	46.66465	2	23.33233	0.39	0.6804
(R × MP) × Age × Traffic	78.89405	2	39.44702	0.66	0.5243
(R × MP) × Age × Gender	68.07933	2	34.03967	0.57	0.5720
(R × MP) × Traffic × Gender	35.40364	2	17.70182	0.30	0.7461
(R × MP) × Age × Traffic × Gender	74.11340	2	37.05670	0.62	0.5448
Error	1915.92091	32	59.87253		
Message Window × Road Demand × Message Potency (MW × R × MP)	35.44863	2	17.72432	0.50	0.6121
(MW × R × MP) × Age	12.99350	2	6.49675	0.18	0.8339
(MW × R × MP) × Traffic	93.76281	2	46.88140	1.32	0.2817
(MW × R × MP) × Gender	27.32715	2	13.66358	0.38	0.6841
(MW × R × MP) × Age × Traffic	52.11813	2	26.05906	0.73	0.4884
(MW × R × MP) × Age × Gender	62.98961	2	31.49480	0.89	0.4223
(MW × R × MP) × Traffic × Gender	30.90271	2	15.45136	0.43	0.6513
(MW × R × MP) × Age × Traffic × Gender	24.33840	2	12.16920	0.34	0.7128
Error	1137.89352	32	35.55917		

Source	SS	DF	Mean Square	F	P
Information Density × Message Potency (I × MP)	734.69481	2	367.34740	4.04	0.0274
(I × MP) × Age	42.63954	2	21.31977	0.23	0.7925
(I × MP) × Traffic	89.96695	2	44.98347	0.49	0.6147
(I × MP) × Gender	58.46029	2	29.23014	0.32	0.7277
(I × MP) × Age × Traffic	109.49510	2	54.74755	0.60	0.5541
(I × MP) × Age × Gender	66.23620	2	33.11810	0.36	0.6979
(I × MP) × Traffic × Gender	169.75399	2	84.87700	0.93	0.4040
(I × MP) × Age × Traffic × Gender	513.15112	2	256.57556	2.82	0.0746
Error	2912.96985	32	91.03031		
Message Window × Information Density × Message Potency (MW × I × MP)	21.72287	2	10.86143	1.13	0.3345
(MW × I × MP) × Age	0.82343	2	0.41171	0.04	0.9580
(MW × I × MP) × Traffic	31.77954	2	15.88977	1.66	0.2064
(MW × I × MP) × Gender	14.57444	2	7.28722	0.76	0.4757
(MW × I × MP) × Age × Traffic	38.60333	2	19.30167	2.01	0.1500
(MW × I × MP) × Age × Gender	112.90899	2	56.45449	5.89	0.0066
(MW × I × MP) × Traffic × Gender	25.91194	2	12.95597	1.35	0.2731
(MW × I × MP) × Age × Traffic × Gender	42.71194	2	21.35594	2.23	0.1241
Error	306.62797	32	9.58212		
Road Demand × Information Density × Message Potency (R × I × MP)	330.50338	4	82.62585	2.37	0.0621
(R × I × MP) × Age	45.69533	4	11.42383	0.33	0.8588
(R × I × MP) × Traffic	32.44986	4	8.11246	0.23	0.9192

Source	SS	DF	Mean Square	F	P
(R × I × MP) × Gender	227.74027	4	56.93507	1.63	0.1774
(R × I × MP) × Age × Traffic	342.68477	4	85.67119	2.45	0.0547
(R × I × MP) × Age × Gender	68.80519	4	17.20130	0.49	0.7412
(R × I × MP) × Traffic × Gender	108.65908	4	27.16477	0.78	0.5437
(R × I × MP) × Age × Traffic × Gender	414.14695	4	103.53674	2.96	0.0260
Error	2234.95904	64	34.92124		
Message Window × Road Demand × Information Density × Message Potency (MW × R × I × MP)	145.55991	4	36.38998	2.34	0.0648
(MW × R × I × MP) × Age	48.48213	4	12.12053	0.78	0.5435
(MW × R × I × MP) × Traffic	68.53602	4	17.13400	1.10	0.3643
(MW × R × I × MP) × Gender	32.33653	4	8.08413	0.52	0.7220
(MW × R × I × MP) × Age × Traffic	56.74917	4	14.18729	0.91	0.4631
(MW × R × I × MP) × Age × Gender	34.87450	4	8.71890	0.56	0.6926
(MW × R × I × MP) × Traffic × Gender	50.06181	4	12.51545	0.80	0.5274
(MW × R × I × MP) × Age × Traffic × Gender	204.73736	4	51.18434	3.29	0.0164
Error	996.77540	64	15.57462		

Table 11. ANOVA of number of large steering wheel reversals.

Source	SS	DF	Mean Square	F	P
Age (A)	1.70134	1	1.70134	1.23	0.2830
Traffic (T)	1.49334	1	1.49334	1.08	0.3135
Gender (G)	0.02756	1	0.02756	0.02	0.8893
Age × Traffic	0.94274	1	0.94274	0.68	0.4204
Age × Gender	1.13680	1	1.13680	0.82	0.3773

Source	SS	DF	Mean Square	F	P
Traffic × Gender	0.01402	1	0.01402	0.01	0.9209
Age × Traffic × Gender	0.98280	1	0.98280	0.71	0.4109
Error	22.05861	16	1.37866		
Message Window (MW)	1.28190	1	1.28190	3.88	0.0664
MW × Age	0.47696	1	0.47696	1.44	0.2469
MW × Traffic	0.04800	1	0.04800	0.15	0.7080
MW × Gender	0.12231	1	0.12231	0.37	0.5513
MW × Age × Traffic	0.12663	1	0.12663	0.38	0.5445
MW × Age × Gender	0.23010	1	0.23010	0.70	0.4161
MW × Traffic × Gender	1.05840	1	1.05840	3.21	0.0923
MW × Age × Traffic × Gender	0.77400	1	0.77400	2.34	0.1453
Error	5.28342	16	0.33021		
Road Demand (R)	13.27308	2	6.63654	22.19	0.0000
R × Age	0.97551	2	0.48775	1.63	0.2116
R × Traffic	0.13689	2	0.06844	0.23	0.7967
R × Gender	2.00833	2	1.00417	3.36	0.0475
R × Age × Traffic	0.92288	2	0.46144	1.54	0.2292
R × Age × Gender	0.85363	2	0.42681	1.43	0.2549
R × Traffic × Gender	0.99810	2	0.49905	1.67	0.2045
R × Age × Traffic × Gender	0.31141	2	0.15570	0.52	0.5991
Error	9.56994	32	0.29906		
Message Window × Road Demand (MW × R)	0.22417	2	0.11208	0.71	0.5015
(MW × R) × Age	0.16641	2	0.08321	0.52	0.5974

Source	SS	DF	Mean Square	F	P
(MW × R) × Traffic	0.49585	2	0.24793	1.56	0.2257
(MW × R) × Gender	0.17525	2	0.08763	0.55	0.5816
(MW × R) × Age × Traffic	0.32488	2	0.16244	1.02	0.3713
(MW × R) × Age × Gender	0.02507	2	0.01253	0.08	0.9243
(MW × R) × Traffic × Gender	0.00601	2	0.00300	0.02	0.9813
(MW × R) × Age × Traffic × Gender	0.15920	2	0.07960	0.50	0.6107
Error	5.08611	32	0.15894		
Information Density (I)	1.79675	2	0.89837	2.21	0.1266
I × Age	0.05301	2	0.02651	0.07	0.9371
I × Traffic	0.48304	2	0.24152	0.59	0.5586
I × Gender	0.19395	2	0.09698	0.24	0.7895
I × Age × Traffic	0.02790	2	0.01395	0.03	0.9664
I × Age × Gender	0.38334	2	0.19167	0.47	0.6289
I × Traffic × Gender	1.36746	2	0.68373	1.68	0.2026
I × Age × Traffic × Gender	3.40872	2	1.70436	4.18	0.0243
Error	13.03228	32	0.40726		
Message Window × Information Density (MW × I)	0.70520	2	0.35260	1.67	0.2039
M(W × I) × Age	0.49985	2	0.24993	1.18	0.3188
(MW × I) × Traffic	0.51869	2	0.25935	1.23	0.3058
(MW × I) × Gender	0.11536	2	0.05768	0.27	0.7625
(MW × I) × Age × Traffic	0.17418	2	0.08709	0.41	0.6652
(MW × I) × Age × Gender	0.03255	2	0.01628	0.08	0.9259
(MW × I) × Traffic × Gender	0.04400	2	0.02200	0.10	0.9012
(MW × I) × Age × Traffic × Gender	0.13969	2	0.06984	0.33	0.7205

Source	SS	DF	Mean Square	F	P
Error	6.74909	32	0.21091		
Road Demand × Information Density (R × I)	0.24024	4	0.06006	0.14	0.9652
(R × I) × Age	0.83330	4	0.20832	0.50	0.7372
(R × I) × Traffic	0.49605	4	0.12401	0.30	0.8792
(R × I) × Gender	0.02460	4	0.00615	0.01	0.9996
(R × I) × Age × Traffic	0.42497	4	0.10624	0.25	0.9062
(R × I) × Age × Gender	0.99318	4	0.24829	0.59	0.6685
(R × I) × Traffic × Gender	2.03312	4	0.50828	1.22	0.3132
(R × I) × Age × Traffic × Gender	1.52227	4	0.38057	0.91	0.4637
Error	26.77233	64	0.41832		
Message Window × Road Demand × Information Density (MW × R × I)	0.69239	4	0.17310	0.83	0.5129
(MW × R × I) × Age	0.21018	4	0.05255	0.25	0.9080
(MW × R × I) × Traffic	0.91052	4	0.22763	1.09	0.3702
(MW × R × I) × Gender	0.24636	4	0.06159	0.29	0.8807
(MW × R × I) × Age × Traffic	0.44361	4	0.11090	0.53	0.7142
(MW × R × I) × Age × Gender	0.79014	4	0.19753	0.94	0.4446
(MW × R × I) × Traffic × Gender	0.65986	4	0.16496	0.79	0.5371
(MW × R × I) × Age × Traffic × Gender	0.78596	4	0.19649	0.94	0.4474
Error	13.39574	64	0.20931		
Message Potency (MP)	1.88160	1	1.88160	4.53	0.0493
(MP) × Age	0.00002	1	0.00002	0.00	0.9942
(MP) × Traffic	0.36342	1	0.36342	0.87	0.3636

Source	SS	DF	Mean Square	F	P
(MP) × Gender	0.01742	1	0.01742	0.04	0.8404
(MP) × Age × Traffic	0.15413	1	0.15413	0.37	0.5511
(MP) × Age × Gender	0.61974	1	0.61974	1.49	0.2397
(MP) × Traffic × Gender	0.09627	1	0.09627	0.23	0.6368
(MP) × Age × Traffic × Gender	0.01000	1	0.01000	0.02	0.8786
Error	6.65024	16	0.41564		
Message Window × Message Potency (MW × MP)	0.03840	1	0.03840	0.28	0.6045
(MW × MP) × Age	0.23404	1	0.23404	1.70	0.2105
(MW × MP) × Traffic	0.01467	1	0.01467	0.11	0.7482
(MW × MP) × Gender	0.01215	1	0.01215	0.09	0.7701
(MW × MP) × Age × Traffic	0.00472	1	0.00472	0.03	0.8553
(MW × MP) × Age × Gender	0.01483	1	0.01483	0.11	0.7468
(MW × MP) × Traffic × Gender	0.45192	1	0.45192	3.29	0.0887
(MW × MP) × Age × Traffic × Gender	0.24604	1	0.24604	1.79	0.1997
Error	2.20029	16	0.13752		
Road Demand × Message Potency (R × MP)	1.95069	2	0.97534	3.16	0.0560
(R × MP) × Age	1.26082	2	0.63041	2.04	0.1464
(R × MP) × Traffic	0.13970	2	0.06985	0.23	0.7988
(R × MP) × Gender	0.19386	2	0.09693	0.31	0.7328
(R × MP) × Age × Traffic	0.43171	2	0.21586	0.70	0.5045
(R × MP) × Age × Gender	0.09946	2	0.04973	0.16	0.8519
(R × MP) × Traffic × Gender	0.51469	2	0.25734	0.83	0.4438
(R × MP) × Age × Traffic × Gender	0.10143	2	0.05071	0.16	0.8493

Source	SS	DF	Mean Square	F	P
Error	9.88220	32	0.30882		
Message Window × Road Demand × Message Potency (MW × R × MP)	0.16001	2	0.08000	0.50	0.6108
(MW × R × MP) × Age	0.38416	2	0.19208	1.20	0.3138
(MW × R × MP) × Traffic	0.68974	2	0.34487	2.16	0.1321
(MW × R × MP) × Gender	0.00076	2	0.00038	0.00	0.9976
(MW × R × MP) × Age × Traffic	0.66475	2	0.33238	2.08	0.1415
(MW × R × MP) × Age × Gender	0.26189	2	0.13094	0.82	0.4497
(MW × R × MP) × Traffic × Gender	0.81860	2	0.40930	2.56	0.0929
(MW × R × MP) × Age × Traffic × Gender	0.08919	2	0.04459	0.28	0.7583
Error	5.11353	32	0.15980		
Information Density × Message Potency (I × MP)	2.12983	2	1.06492	1.79	0.1840
(I × MP) × Age	0.26312	2	0.13156	0.22	0.8032
(I × MP) × Traffic	0.02380	2	0.01190	0.02	0.9803
(I × MP) × Gender	0.57633	2	0.28816	0.48	0.6212
(I × MP) × Age × Traffic	0.35438	2	0.17719	0.30	0.7450
(I × MP) × Age × Gender	0.69094	2	0.34547	0.58	0.5660
(I × MP) × Traffic × Gender	0.52308	2	0.26154	0.44	0.6488
(I × MP) × Age × Traffic × Gender	7.51764	2	3.75882	6.30	0.0049
Error	19.08209	31	0.59632		
Message Window × Information Density × Message Potency (MW × I × MP)	1.00849	2	0.50424	2.60	0.0897
(MW × I × MP) × Age	0.29814	2	0.14907	0.77	0.4714

Source	SS	DF	Mean Square	F	P
(MW × I × MP) × Traffic	0.35874	2	0.17937	0.93	0.4066
(MW × I × MP) × Gender	0.07195	2	0.03597	0.19	0.8315
(MW × I × MP) × Age × Traffic	0.56011	2	0.28006	1.45	0.2507
(MW × I × MP) × Age × Gender	0.75650	2	0.37825	1.95	0.1585
(MW × I × MP) × Traffic × Gender	0.02467	2	0.01233	0.06	0.9385
(MW × I × MP) × Age × Traffic × Gender	0.15203	2	0.07602	0.39	0.6787
Error	6.20100	32	0.19378		
Road Demand × Information Density × Message Potency (R × I × MP)	0.29945	4	0.07486	0.21	0.9332
(R × I × MP) × Age	0.46827	4	0.11707	0.32	0.8603
(R × I × MP) × Traffic	0.60082	4	0.15020	0.42	0.7959
(R × I × MP) × Gender	0.17083	4	0.04271	0.12	0.9755
(R × I × MP) × Age × Traffic	0.96334	4	0.24084	0.67	0.6164
(R × I × MP) × Age × Gender	0.51247	4	0.12812	0.36	0.8393
(R × I × MP) × Traffic × Gender	0.58283	4	0.14571	0.40	0.8049
(R × I × MP) × Age × Traffic × Gender	5.69530	4	1.42382	3.95	0.0063
Error	23.06530	64	0.36040		
Message Window × Road Demand × Information Density × Message Potency (MW × R × I × MP)	1.42600	4	0.35650	1.34	0.2656
(MW × R × I × MP) × Age	0.88347	4	0.22087	0.83	0.5118
(MW × R × I × MP) × Traffic	1.15867	4	0.28967	1.09	0.3705
(MW × R × I × MP) × Gender	0.23658	4	0.05915	0.22	0.9252
(MW × R × I × MP) × Age × Traffic	0.24598	4	0.06150	0.23	0.9201

Source	SS	DF	Mean Square	F	P
(MW × R × I × MP) × Age × Gender	3.09796	4	0.77449	2.91	0.0284
(MW × R × I × MP) × Traffic × Gender	0.20226	4	0.05056	0.19	0.9429
(MW × R × I × MP) × Age × Traffic × Gender	3.96127	4	0.99032	3.72	0.0088
Error	17.05555	64	0.26649		

Table 12. ANOVA of SD of velocity.

Source	SS	DF	Mean Square	F	P
Age (A)	0.18874	1	0.18874	0.29	0.5946
Traffic (T)	5.66968	1	5.66968	8.86	0.0089
Gender (G)	0.73558	1	0.73558	1.15	0.2996
Age × Traffic	0.00901	1	0.00901	0.01	0.9070
Age × Gender	1.75230	1	1.75230	2.74	0.1175
Traffic × Gender	0.02952	1	0.02952	0.05	0.8327
Age × Traffic × Gender	0.55764	1	0.55764	0.87	0.3644
Error	10.23916	16	0.63995		
Message Window (MW)	0.03514	1	0.03514	0.12	0.7328
MW × Age	0.00016	1	0.00016	0.00	0.9817
MW × Traffic	0.03070	1	0.03070	0.11	0.7496
MW × Gender	0.32009	1	0.32009	1.10	0.3100
MW × Age × Traffic	0.08943	1	0.08943	0.31	0.5871
MW × Age × Gender	0.00396	1	0.00396	0.01	0.9086
MW × Traffic × Gender	0.03338	1	0.03338	0.11	0.7394
MW × Age × Traffic × Gender	0.05753	1	0.05753	0.20	0.6627
Error	4.65964	16	0.29123		

Source	SS	DF	Mean Square	F	P
Road Demand (R)	23.01338	2	11.50669	37.25	0.0000
R × Age	0.31381	2	0.15691	0.51	0.6065
R × Traffic	0.51668	2	0.25834	0.84	0.4426
R × Gender	0.30506	2	0.15253	0.49	0.6149
R × Age × Traffic	0.08844	2	0.04422	0.14	0.8672
R × Age × Gender	0.08779	2	0.04390	0.14	0.8681
R × Traffic × Gender	2.33247	2	1.16624	3.78	0.0337
R × Age × Traffic × Gender	0.66760	2	0.33380	1.08	0.3515
Error	9.88536	32	0.30892		
Message Window × Road Demand (MW × R)	0.15550	2	0.07775	0.27	0.7676
(MW × R) × Age	0.00899	2	0.00450	0.02	0.9847
(MW × R) × Traffic	3.19730	2	1.59865	5.48	0.0090
(MW × R) × Gender	1.01312	2	0.50656	1.74	0.1922
(MW × R) × Age × Traffic	3.60871	2	1.80435	6.19	0.0053
(MW × R) × Age × Gender	0.67902	2	0.33951	1.16	0.3250
(MW × R) × Traffic × Gender	1.00765	2	0.50383	1.73	0.1938
(MW × R) × Age × Traffic × Gender	0.86371	2	0.43186	1.48	0.2426
Error	9.33145	32	0.29161		
Information Density (I)	3.09240	2	1.54620	3.09	0.0594
I × Age	1.63947	2	0.81973	1.64	0.2104
I × Traffic	1.97855	2	0.98928	1.98	0.1552
I × Gender	0.66289	2	0.33144	0.66	0.5228

Source	SS	DF	Mean Square	F	P
I × Age × Traffic	3.16411	2	1.58205	3.16	0.0560
I × Age × Gender	0.18289	2	0.09145	0.18	0.8339
I × Traffic × Gender	0.63725	2	0.31863	0.65	0.5358
I × Age × Traffic × Gender	3.02310	2	1.51155	3.02	0.0630
Error	16.02405	32	0.50075		
Message Window × Information Density (MW × I)	0.57134	2	0.28567	0.79	0.4626
(MW × I) × Age	0.24349	2	0.12174	0.34	0.7167
(MW × I) × Traffic	0.13663	2	0.06831	0.19	0.8288
(MW × I) × Gender	0.31489	2	0.15745	0.44	0.6509
(MW × I) × Age × Traffic	0.04620	2	0.02310	0.06	0.9383
(MW × I) × Age × Gender	0.30510	2	0.15255	0.42	0.6595
(MW × I) × Traffic × Gender	0.21590	2	0.10795	0.30	0.7440
(MW × I) × Age × Traffic × Gender	0.03725	2	0.01863	0.05	0.9499
Error	11.57488	32	0.36172		
Road Demand × Information Density (R × I)	2.56318	4	0.64079	0.83	0.5116
(R × I) × Age	1.03041	4	0.25760	0.33	0.8546
(R × I) × Traffic	4.97886	4	1.24471	1.61	0.1824
(R × I) × Gender	3.68176	4	0.92044	1.19	0.3234
(R × I) × Age × Traffic	1.22830	4	0.30707	0.40	0.8098
(R × I) × Age × Gender	2.58063	4	0.64516	0.83	0.5081
(R × I) × Traffic × Gender	3.05208	4	0.76302	0.99	0.4209

Source	SS	DF	Mean Square	F	P
(R × I) × Age × Traffic × Gender	1.00431	4	0.25108	0.32	0.8603
Error	49.46335	64	0.77286		
Message Window × Road Demand × Information Density (MW × R × I)	2.74434	4	0.68609	1.82	0.1356
(MW × R × I) × Age	0.70068	4	0.17517	0.46	0.7612
(MW × R × I) × Traffic	2.57482	4	0.64370	1.71	0.1590
(MW × R × I) × Gender	0.18403	4	0.04601	0.12	0.9741
(MW × R × I) × Age × Traffic	1.77210	4	0.44303	1.18	0.3298
(MW × R × I) × Age × Gender	0.32013	4	0.08003	0.21	0.9306
(MW × R × I) × Traffic × Gender	0.46908	4	0.11727	0.31	0.8694
(MW × R × I) × Age × Traffic × Gender	1.68510	4	0.42128	1.12	0.3558
Error	24.11195	64	0.37675		
Message Potency (MP)	1.24139	1	1.24139	2.20	0.1575
MP × Age	0.00021	1	0.00021	0.00	0.9847
MP × Traffic	1.09868	1	1.09868	1.95	0.1820
MP × Gender	0.39741	1	0.39741	0.70	0.4138
MP × Age × Traffic	0.01178	1	0.01178	0.02	0.8869
MP × Age × Gender	0.30263	1	0.30263	0.54	0.4746
MP × Traffic × Gender	0.25799	1	0.25799	0.46	0.5087
MP × Age × Traffic × Gender	0.00217	1	0.00217	0.00	0.9513
Error	9.03199	16	0.56445		

Source	SS	DF	Mean Square	F	P
Message Window × Message Potency (MW × MP)	2.46294	1	2.46294	9.28	0.0077
(MW × MP) × Age	0.04070	1	0.04070	0.15	0.7006
(MW × MP) × Traffic	0.0076	1	0.00076	0.00	0.9580
(MW × MP) × Gender	0.00300	1	0.00300	0.001	0.9167
(MW × MP) × Age × Traffic	0.35648	1	0.35648	1.34	0.2635
(MW × MP) × Age × Gender	0.71128	1	0.71128	2.68	0.1212
(MW × MP) × Traffic × Gender	0.00706	1	0.00706	0.03	0.8725
(MW × MP) × Age × Traffic × Gender	0.00618	1	0.00618	0.02	0.8807
Error	4.24746	16	0.26547		
Road Demand × Message Potency (R × MP)	1.18652	2	0.59326	0.94	0.4004
(R × MP) × Age	1.68551	2	0.84275	1.34	0.2766
(R × MP) × Traffic	0.31393	2	0.15697	0.25	0.7809
(R × MP) × Gender	0.35866	2	0.17933	0.28	0.7541
(R × MP) × Age × Traffic	0.69928	2	0.34964	0.56	0.5794
(R × MP) × Age × Gender	1.16869	2	0.58435	0.93	0.4058
(R × MP) × Traffic × Gender	0.33062	2	0.16531	0.26	0.7708
(R × MP) × Age × Traffic × Gender	1.16367	2	0.58184	0.92	0.4073
Error	20.15379	32	0.62981		

Source	SS	DF	Mean Square	F	P
Message Window × Road Demand × Message Potency (MW × R × MP)	1.73628	2	0.86814	2.55	0.0940
(MW × R × MP) × Age	0.52184	2	0.26092	0.77	0.4732
(MW × R × MP) × Traffic	0.25168	2	0.12584	0.37	0.6940
(MW × R × MP) × Gender	0.00480	2	0.00240	0.01	0.9930
(MW × R × MP) × Age × Traffic	0.12263	2	0.06132	0.18	0.8361
(MW × R × MP) × Age × Gender	2.22497	2	1.11249	3.27	0.0512
(MW × R × MP) × Traffic × Gender	0.90762	2	0.45381	1.33	0.2781
(MW × R × MP) × Age × Traffic × Gender	0.10171	2	0.05085	0.15	0.8619
Error	10.90074	32	0.34065		
Information Density × Message Potency (I × MP)	0.13158	2	0.06579	0.13	0.8788
(I × MP) × Age	1.31128	2	0.65564	1.29	0.2885
(I × MP) × Traffic	0.39193	2	0.19596	0.39	0.6826
(I × MP) × Gender	0.53602	2	0.26801	0.53	0.5946
(I × MP) × Age × Traffic	1.04121	2	0.52061	1.03	0.3697
(I × MP) × Age × Gender	2.17169	2	1.08584	2.14	0.1341
(I × MP) × Traffic × Gender	0.12590	2	0.06295	0.12	0.8837
(I × MP) × Age × Traffic × Gender	3.68997	2	1.84499	3.64	0.0377
Error	16.22866	32	0.50715		

Source	SS	DF	Mean Square	F	P
Message Window × Information Density × Message Potency (MW × I × MP)	0.03029	2	0.01514	0.06	0.9443
(MW × I × MP) × Age	0.17752	2	0.08876	0.34	0.7167
(MW × I × MP) × Traffic	0.17748	2	0.08874	0.34	0.7167
(MW × I × MP) × Gender	0.08537	2	0.04268	0.16	0.8512
(MW × I × MP) × Age × Traffic	0.09000	2	0.04500	0.17	0.8439
(MW × I × MP) × Age × Gender	1.03245	2	0.51622	1.96	0.1577
(MW × I × MP) × Traffic × Gender	0.29282	2	0.14641	0.56	0.5793
(MW × I × MP) × Age × Traffic × Gender	0.33159	2	0.16580	0.63	0.5397
Error	8.43753	32	0.26367		
Road Demand × Information Density × Message Potency (R × I × MP)	1.85048	4	0.46262	1.07	0.3811
(R × I × MP) × Age	2.52405	4	0.63101	1.45	0.2270
(R × I × MP) × Traffic	1.05561	4	0.26390	0.61	0.6586
(R × I × MP) × Gender	2.24144	4	0.56036	1.29	0.2832
(R × I × MP) × Age × Traffic	1.02379	4	0.25595	0.59	0.6715
(R × I × MP) × Age × Gender	2.80202	4	0.70051	1.61	0.1818
(R × I × MP) × Traffic × Gender	2.25223	4	0.56306	1.30	0.2809
(R × I × MP) × Age × Traffic × Gender	3.05943	4	0.76486	1.76	0.1476
Error	27.79494	64	0.43430		

Source	SS	DF	Mean Square	F	P
Message Window × Road Demand × Information Density × Message Potency (MW × R × I × MP)	0.19589	4	0.04897	0.15	0.9616
(MW × R × I × MP) × Age	1.68517	4	0.42129	1.30	0.2780
(MW × R × I × MP) × Traffic	0.94328	4	0.23582	0.73	0.5748
(MW × R × I × MP) × Gender	1.35247	4	0.33812	1.05	0.3903
(MW × R × I × MP) × Age × Traffic	1.71925	4	0.42981	1.33	0.2682
(MW × R × I × MP) × Age × Gender	0.73019	4	0.18255	0.57	0.6888
(MW × R × I × MP) × Traffic × Gender	0.94367	4	0.23592	0.73	0.5746
(MW × R × I × MP) × Age × Traffic × Gender	2.41811	4	0.60453	1.87	0.1263
Error	20.67420	64	0.32303		

COMPLIANCE DATA

Table 13. ANOVA of time to turn signal (after receiving a navigation message).

Source	SS	DF	Mean Square	F	P
Age (A)	17.08444	1	17.08444	1.88	0.1895
Traffic (T)	10.89000	1	10.89000	1.20	0.2901
Warning (W)	109.20250	1	109.20250	12.00	0.0032
Age × Traffic	7.84000	1	7.84000	0.86	0.3671
Age × Warning	0.30250	1	0.30250	0.03	0.8576
Traffic × Warning	13.56694	1	13.56694	1.49	0.2397
Age × Traffic × Warning	0.04694	1	0.04694	0.01	0.9436
Error	145.58222	16	9.09889		

Source	SS	DF	Mean Square	F	P
Road Demand (R)	368.39347	2	184.19674	24.55	0.0000
R × Age	17.24430	2	8.62215	1.15	0.3296
R × Traffic	17.00375	2	8.50187	1.13	0.3346
R × Warning	16.83375	2	8.41687	1.12	0.3382
R × Age × Traffic	4.47125	2	2.23562	0.30	0.7444
R × Age × Warning	3.93792	2	1.96896	0.26	0.7708
R × Traffic × Warning	9.64347	2	4.82174	0.64	0.5325
R × Age × Traffic × Warning	5.99764	2	2.99882		
Error	240.09111	32	7.50285		
Message Potency (MP)	2.56000	1	2.56000	0.24	0.6312
MP × Age	0.21778	1	0.21778	0.02	0.8883
MP × Traffic	0.04000	1	0.04000	0.00	0.9520
MP × Warning	4.34028	1	4.34028	0.41	0.5330
MP × Age × Traffic	4.41000	1	4.41000	0.41	0.5298
MP × Age × Warning	10.13361	1	10.13361	0.95	0.3447
MP × Traffic × Warning	7.56250	1	7.56250	0.71	0.4127
MP × Age × Traffic × Warning	0.38028	1	0.38028	0.04	0.8528
Error	171.03555		6	10.68972	
Road Demand × Message Potency (R × MP)	6.31625	2	3.15812	0.35	0.7054
(R × MP) × Age	4.11097	2	2.05549	0.23	0.7961
(R × MP) × Traffic	2.88875	2	1.44438	0.16	0.8516
(R × MP) × Warning	2.34764	2	1.17882	0.13	0.8771

Source	SS	DF	Mean Square	F	P
(R × MP) × Age × Traffic	17.93792	2	8.96896	1.00	0.3783
(R × MP) × Age × Warning	2.26681	2	1.13340	0.13	0.8815
(R × MP) × Traffic × Warning	4.78625	2	2.39312	0.27	0.7671
(R × MP) × Age × Traffic × Warning	26.14764	2	13.07382	1.46	0.2471
Error	286.37777	32	8.94931		

Table 14. ANOVA of compliance to ISIS messages—roadway characteristics.

Source	SS	DF	Mean Square	F	P
Age	0.02083	1	0.02083	0.14	0.7104
Traffic Density	0.18750	1	0.18750	1.29	0.2735
Gender	0.02083	1	0.02083	0.14	0.7104
Age × Traffic Density	0.52083	1	0.52083	3.57	0.0770
Age × Gender	0.18750	1	0.18750	1.29	0.2735
Traffic Density × Gender	0.02083	1	0.02083	0.14	0.7104
Age × Traffic Density × Gender	0.18750	1	0.18750	1.29	0.2735
Error	2.33333	16	0.14583		
Message Potency (MP)	0.18750	1	0.18750	1.80	0.1984
MP × Age	0.02083	1	0.02083	0.20	0.6607
MP × Traffic Density	0.18750	1	0.18750	1.80	0.1984
MP × Gender	0.02083	1	0.02083	0.20	0.6607
MP × Age × Traffic Density	0.02083	1	0.02083	0.20	0.6607
MP × Age × Gender	0.02083	1	0.02083	0.20	0.6607
MP × Traffic Density × Gender	0.18750	1	0.18750	1.80	0.1984
MP × Age × Traffic Density × Gender	0.18750	1	0.18750	1.80	0.1984
Error	1.6667	16	0.10417		

Table 15. ANOVA of compliance to ISIS messages—posted speed limits.

Source	SS	DF	Mean Square	F	P
Age (A)	0.04167	1	0.4167	0.24	0.6309
Traffic Density (TD)	0.37500	1	0.37500	2.14	0.1588
Age × Traffic Density	0.04167	1	0.04167	0.24	0.6309
Error	3.50000	20	0.17500		
Road Demand (R)	0.0000	1	0.0000	0.00	1.0000

Source	SS	DF	Mean Square	F	P
Road Demand × Age	0.16667	1	0.16667	0.95	0.3408
Road Demand × Traffic Density	0.16667	1	0.16667	0.95	0.3408
Road Demand × Age × Traffic Density	0.16667	1	0.16667	0.95	0.3408
Error	3.50000	20	0.17500		
Message Potency (MP)	2.66667	1	2.66667	18.82	0.0003
MP × Age	0.16667	1	0.16667	1.18	0.2910
MP × Traffic Density	0.16667	1	0.16667	1.18	0.2910
MP × Age × Traffic Density	0.16667	1	0.16667	1.18	0.2910
Error	2.83333	20	0.14167		
Road Demand × Message Potency (R × MP)	0.04167	1	0.04167	0.17	0.6824
(R × MP) × Age	0.04167	1	0.04167	0.17	0.6824
(R × MP) × Traffic Density	0.04167	1	0.04167	0.17	0.6824
(R × MP) × Age × Traffic Density	0.04167	1	0.04167	0.17	0.6824
Error	4.83333	20	0.24167		

Table 16. ANOVA of compliance to IVSAWS messages.

Source	SS	DF	Mean Square	F	P
Age (A)	0.00006	1	0.00006	0.00	0.9887
Traffic Density (TD)	0.00278	1	0.00278	0.01	0.9207
Age × Traffic Density	0.28577	1	0.28577	1.05	0.3204
Error	4.34722	16	0.27170		
Road Demand (R)	0.14977	2	0.07489	0.32	0.7266
Road Demand × Age	0.03413	2	0.01706	0.07	0.9293
Road Demand × Traffic Density	0.55794	2	0.27897	1.20	0.3139

Source	SS	DF	Mean Square	F	P
Road Demand × Age × Traffic Density	0.60556	2	0.30278	1.30	0.2854
Error	7.42778	32	0.23212		
Message Potency (MP)	5.20459	1	5.20459	36.87	0.0000
MP × Age	0.18418	1	0.18418	1.30	0.2701
MP × Traffic Density	0.42908	1	0.42908	3.04	0.1004
MP × Age × Traffic Density	0.06173	1	0.06173	0.44	0.5178
Error	2.25833	16	0.14115		
Road Demand × Message Potency (R × MP)	0.57177	2	0.28588	2.32	0.1150
(R × MP) × Age	0.02075	2	0.01037	0.08	0.9196
(R × MP) × Traffic Density	0.32687	2	0.16344	1.32	0.2802
(R × MP) × Age × Traffic Density	0.42891	2	0.21446	1.74	0.1922
Error	3.95000	32	0.12344		

DRIVER PREFERENCE DATA

Table 17. ANOVA of drivers' response to "Would you find General/Service Information useful when driving on Interstate, downtown, and residential roads?"

Independent Variable	SS	df	MS	F	p
Traffic Density	1.12500	1	1.12500	3.02	0.0962
Error	8.19444	22	0.37247		
Road Type	0.36111	2	0.18056	1.13	0.3335
Traffic Density × Road Type	0.58333	2	0.29167	1.82	0.1742
Error	7.05556	44	0.16035		

Table 18. ANOVA of drivers' response to "Would you find General/Service Information useful when driving on Interstate, downtown, and residential roads?" when road type "residential" is omitted from the analysis.

Independent Variable	SS	df	MS	F	p
Traffic Density	1.68750	1	1.68750	6.60	0.0175
Error	5.62500	22	0.25568		
Road Type	0.18750	1	0.18750	0.96	0.3376
Traffic Density × Road Type	0.02083	1	0.02083	0.11	0.7469
Error	4.29167	22	0.19508		

Table 19. ANOVA of drivers' response to "For each message type (Navigation/Route Guidance, Hazard Warning, Regulatory, Vehicle Monitoring, General/Service) indicate if you would prefer to receive the information automatically while driving, automatically but only when stopped, by requesting the information, or not at all."

Independent Variable	SS	df	MS	F	p
Message Type	26.61667	4	6.65417	23.03	0.0000
Error	26.58333	92	0.28895		

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