Development of Human Factors Guidelines for Advanced Traveler Information Systems (ATIS) and Commercial Vehicle Operations (CVO): An Examination of Driver Performance Under Reduced Visibility Conditions When Using an In-Vehicle Signing and Information System (ISIS)

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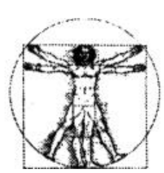

FOREWORD

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 describes the results of a field study conducted to investigate the effects of using an In-Vehicle Information System (IVIS) when the driving under reduced visibility conditions. The study examines issues regarding benefits of an IVIS display in complex, unfamiliar, or low visibility conditions.

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.

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NOTICE

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16. Abstract
Recent technological innovations and the need for increased safety and congestion reduction on the world's roads have led to the introduction of In-Vehicle Information Systems (IVIS). These systems will provide navigation and advisory information to drivers while they are driving. One aspect of these systems, In-Vehicle Signing Information Systems (ISIS), would provide the warning, regulatory, and advisory information that is currently found on road signs. These systems may be of particular benefit when external elements such as rain, snow, or night driving reduce or eliminate the opportunity for drivers to detect road signs. This study attempts to determine what benefits, if any, are realized by drivers using this system.

Fifty-eight drivers operated an instrumented Oldsmobile Aurora, either with or without an ISIS, under a variety of visibility conditions. The visibility conditions included either rain or no rain, and either day or night driving. Younger drivers (18-30 years old) and older drivers (65 years or older) took part in this study.

Three measures of driver performance were collected along with subjective preference data. Each measure was evaluated in order to determine what impact, if any, weather, time of day, age, and ISIS use had on performance. Subjective data were evaluated in order to determine driver preference and acceptance of the ISIS display.

The results indicated that use of the ISIS display led to more appropriate speeds and greater reaction distances for all drivers. Evidence was found that seems to indicate that drivers may receive a particular benefit from ISIS in complex, unfamiliar, or low visibility situations. Subjectively, the majority of the drivers indicated that the ISIS display made them more aware of road sign information, and the acceptance rate among drivers was high.

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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

ANOVA . . . . Analysis of Variance
ATIS . . . . Advanced Traveler Information Systems
CCFT . . . . Cold Cathode Fluorescent Tubes
CVO . . . . Commercial Vehicle Operators
FOV . . . . Field of Vision
GLM . . . . General Linear Model
IMSIS . . . . In-Vehicle Motorist Services Information Systems
IRANS . . . . In-Vehicle Routing Navigation Systems
ISIS . . . . In-Vehicle Signing Information System
IVIS . . . . In-Vehicle Information System
IVSAWS . . . . In-Vehicle Safety Advisory and Warning Systems
MUTCD . . . . Manual on Uniform Traffic Control Devices
NPTS . . . . Nationwide Personal Transportation Survey
TFT . . . . Thin Film Translator

EXECUTIVE SUMMARY

Experiment 15 is one of a series of studies aimed at investigating ATIS/CVO applications and their effect on driver behavior and performance. The ultimate goal of these studies is the development of a set of ATIS/CVO design guidelines.

A field experiment was conducted to investigate the benefits of using an In-Vehicle Signing Information System (ISIS) under conditions where external factors reduce or eliminate the driver's opportunity to see road signs. This research focused on four primary areas:

- The inclusion of rain and clear weather conditions,
- The inclusion of both day and night driving,
- Driver performance under varying conditions, including ISIS use,
- The differences between older and younger drivers when using such a system.

To investigate these areas, five research questions were posed. Each question involved comparing driver performance when using the ISIS with performance without the ISIS:

- Are there, in general, benefits associated with an ISIS system?
- Will additional benefits be realized under adverse weather conditions?
- Will additional benefits be realized during night driving?
- Will older drivers gain additional benefits from such a system?
- Does the system adversely impact driver performance or behavior?

Fifty-eight drivers participated in this experiment. Thirty-five were ages 18-30 and 23 were ages 65-75. A 1995 Oldsmobile Aurora was used as the data collection vehicle. Participants drove on a prescribed route approximately 5.5 miles long, taking from 15 to 25 minutes to complete the drive. During the course of the drive, data were collected for 15 events. The events included:

- Marked advisory situations, such as winding roads.
- Unmarked advisory situations, such as curves.
- Marked regulatory situations, such as stop signs and yield signs.
- Unmarked regulatory situations, such as missing stop ahead signs.

To measure driver performance, three dependent measures were collected: (1) end event speed, referring to the speed at which the driver was traveling at the end of an event; (2) maximum deceleration, referring to the maximum deceleration experienced during an event; and (3) reaction distance, referring to the distance at which the driver reacted to the event (measured from the end of the event). In addition, subjective measures of driver acceptance were also collected via questionnaire.

Considering each of the five research questions, the results of this experiment can be summarized as follows:

1. *Are there, in general, benefits associated with an ISIS system?*
    - Driver end event speeds were, in general, significantly lower when using the ISIS system.

- Driver reaction distances were, in general, significantly greater when using the ISIS system.
- Drivers felt they were significantly more aware of road sign information, that the information was more timely, and that it was easier to gather the information with the ISIS system.

2. *Will additional benefits be realized under adverse weather conditions?*
   - The general ISIS benefits listed above were still present under adverse weather conditions.
   - No overall additional benefits were found, in general, under adverse weather conditions.
   - Some evidence seems to indicate that additional benefit may be realized under adverse weather conditions for specific events.

3. *Will additional benefits be realized during night driving?*
   - The general benefits listed above were still present during night driving.
   - Evidence points toward increased benefits at night for complex, unfamiliar, or low visibility events.

4. *Will older drivers gain additional benefits from such a system?*
   - The general benefits listed above were still present for older drivers.
   - No additional benefits relating to weather or time of day were found for older drivers.

5. *Does the system adversely impact driver performance or behavior?*
   - No adverse performance or behavior changes were observed.
   - Some drivers did find the attention signal distracting and annoying, with more younger drivers complaining than older drivers.

The following conclusions and recommendations can be made from this study:

- Results indicate a clear benefit in terms of reduced speed and reaction distance when using an ISIS display.
- Drivers were able to draw information from the ISIS without adversely affecting performance.
- Older drivers seem to drive more cautiously when using an ISIS.
- The ISIS display may be more beneficial for complex, unfamiliar, or low visibility events.
- Users should be able to control the intensity of the auditory alert.
- Research is required to investigate the use of such systems in complex visual environments and in conjunction with other aspects of IVIS technology.

Based on the results of this experiment, the following guidelines are recommended for ISIS use:

- Designers of future ATIS systems should strongly consider including ISIS features. There appear to be ISIS benefits and no detriments due to ISIS use.

- The ISIS display should be activated so that drivers have sufficient time to perceive and interpret the display, determine the appropriate response, and execute that response. In this study, the ISIS system was engaged approximately 3 to 5 seconds before an event, which appears to provide an ISIS benefit and results in a high level of driver acceptance.

- A warning or attention signal should be provided to minimize the distraction from the driving task caused by the system. The signal given in this experiment appeared to allow the drivers to focus on the driving task until a new piece of information was presented to them.

- Drivers should be able to adjust the volume of the attention signal within a given range. In this experiment, a number of drivers felt that the attention signal was too loud and distracting. Allowing the drivers to adjust the volume of such a signal (but not set it so low that it cannot be heard, or turn it off) will reduce this annoyance and distraction.

- Drivers should be able to control what information appears on the ISIS display. This experiment showed that some drivers may benefit from additional warnings in specific situations, while others may not. Allowing the driver to tailor the system to his or her personal needs would increase the efficiency, use, and acceptance of the system.

INTRODUCTION

BACKGROUND

Recent technological advances have led to the development and introduction of Advanced Traveler Information Systems (ATIS) into the automotive environment. One of the goals of such systems, as outlined by ITS America (1995), is to present information to the driver so that it is quickly understood and is not distracting. Human factors research is being performed on this issue and others that arise when ATIS is introduced into the real-world driving environment. One current effort is to create guidelines for the development and implementation of such systems with the goal of creating safe, efficient, and effective interactions between the driver and the system.

ATIS allow the driver access to a wide variety of information, including (1) supplementary roadway and signing information, (2) routing and navigation information, (3) safety advisory and warning information, and (4) motorist information services. A separate system under the umbrella of ATIS provides each of these types of information to the driver. The four subsystems are: (1) In-Vehicle Signing Information Systems (ISIS), (2) In-Vehicle Routing and Navigation Systems (IRANS), (3) In-Vehicle Safety Advisory and Warning Systems (IVSAWS), and (4) In-Vehicle Motorist Services Information Systems (IMSIS).

Perez and Mast (1992) provide descriptions of each of the four subsystems. They define ISIS as systems that provide non-commercial routing, warning, regulatory, and advisory information that is currently depicted on external roadway signs. IRANS provide drivers with information about how to get from one place to another, as well as provide information on traffic congestion. IVSAWS provide warning of unsafe conditions affecting the roadway ahead of the driver, allowing the driver the opportunity to take corrective or preventative action. IMSIS provide commercial information to the driver, such as restaurants, hotels, and historical landmarks. ATIS that provide some of these subsystems are commercially available, and have been the subject of a number of studies. As an example, the Etak system (which incorporates IRANS) has been the subject of a number of studies to evaluate factors such as attentional demand and effectiveness (Dingus, Antin, Hulse, and Wierwille, 1989; Antin, Dingus, Hulse, and Wierwille, 1990).

Extensive laboratory, simulator, and field studies have been conducted on ATIS in general and on systems containing specific subsystems (most notably the IRANS and IMSIS subsystems). However, little field research has been conducted on the ISIS subsystem. Simulator studies, however, have indicated that such systems will provide benefits to drivers, especially older drivers. In addition, such systems seem to be particularly effective in reduced visibility conditions (Marshall and Mahach, 1996). The experiment presented here expands on the laboratory and simulator studies on ISIS by conducting a field test of such a system.

RATIONALE FOR THE STUDY

One of the main advantages of using an In-vehicle Signing and Information System (ISIS) is the ability to receive information inside the vehicle when elements outside the vehicle reduce or eliminate the opportunity to gather that information from the external environment. Weather conditions, such as rain or snow, can reduce the opportunity to obtain this information externally. Road geometry or foliage can eliminate the opportunity altogether. Since one of the most helpful aspects of ISIS is that it can give the driver information when it may be unavailable or untimely externally, the effectiveness of such a system under these conditions becomes a primary issue for study. Areas of focus for the present study include:

- Are there, in general, benefits associated with the ISIS system?
- Will additional benefits be realized under adverse weather conditions?
- Will additional benefits be realized during night driving?
- Will older drivers gain additional benefits from the system?
- Does the system adversely impact driver performance or behavior?

Adverse Weather Conditions

Clearly, adverse weather conditions such as rain, fog, or snow adversely affect driving. Several theoretical and common sense reasons can be offered to explain this phenomena. Friction is reduced on a wet surface, resulting in a need for greater stopping distances. Curves become slippery when wet, especially at high speeds. Visibility may be reduced by the rain or snow itself or by the glare caused by wet, shining surfaces. Ice also creates a problem, reducing friction and making roads more slippery. Researchers have suggested that better warning signs and lighting, better road geometry, and better paved surfaces can improve safety under adverse weather conditions (Brodsky and Hakkert, 1988). Brodsky and Hakkert (1988) also found that a driver is approximately three times as likely to be involved in an accident during rainy or wet pavement conditions. Providing drivers with information in such a way that it cannot be obscured by external elements, and at a time that allows for a proper response given the roadway conditions, may be key to improving safety under such conditions.

Daytime vs. Nighttime Driving

In general, nighttime driving is associated with a higher risk of crash involvement due to factors such as reduced visibility, fatigue, and higher incidence of alcohol use. Statistics for driving reveal that there are 10.4 fatal involvements, 3.5 injury involvements, and 9.1 crash involvements per 100 million miles at night, as opposed to only 2.2 fatal involvements, 1.9 injury involvements, and 5.9 crash involvements during the day (Massie, Campbell and Williams, 1995). The visibility of road signs also decreases significantly at night, with the problem being more pronounced for older drivers. At night, glare can also pose a problem for drivers of all ages. A potential solution to this problem is to provide drivers with road sign information inside the vehicle, thereby removing the problems associated with reduced visibility and glare.

Older Drivers

Age has been found to be a significant factor in driving behavior in a number of studies. When one considers that, in the United States, elderly drivers constitute the fastest growing segment of the driving population (Transportation Research Board, 1988), the need to consider age in driving performance measures becomes clear. Older drivers may experience a wide range of problems with many aspects of driving, including greater difficulty in conditions of low illumination and problems detecting highway signs and markers (Yee, 1985; Babbitt, Kline, Schieber, Sekuler, and Fozard, 1989; Kline, Kline, Fozard, Kosnik, Schieber, and Sekuler, 1992).

Nighttime acuity has been found to be a problem for the older driver. Even a healthy 20-year-old with 20/20 vision will have, in effect, 20/40 vision at night. The visual acuity of an older driver, corrected to 20/20 with glasses, will drop to 20/70 or 20/80 in the dark. Furthermore, when adults reach the age of 60, they require three times as much light on an object to see it as clearly as they did at 20 years (Pitts, 1982). Additional problems may be caused by presbyopia, glaucoma, cataracts, and glasses (Sekuler, Kline, and Dismukes, 1982; Rockwell, Augsburger, Smith, and Freeman, 1988).

Previous studies have shown that older drivers must dedicate a higher percentage of visual attention to the roadway than younger drivers. Older drivers have also shown reduced performance than younger drivers during the operation of secondary automotive tasks (Monty, 1984; Dingus, Antin, Hulse and Wierwille, 1988). Older drivers also may have greater limitations in their sensory, cognitive, and psychomotor skills. Ponds, Brouwer, and Van Wolffelaar (1988) found a decline in dual task performance for older subjects, suggesting that aging impairs the ability to divide attention. Their data suggested that this impairment was restricted to old age (above 60 years).

Older drivers are also more likely to be involved in collisions. In their study of the 1990 Nationwide Personal Transportation Survey (NPTS) data, Massie et al. (1995) discovered that persons over 74 years of age were 3.8 times as likely to be involved in a fatal crash when compared with drivers of all ages. Furthermore, the same group of drivers was found to be twice as likely to be involved in a crash resulting in injury, and twice as likely to be involved in any crash. It has been found that the accidents involving older drivers most frequently involve failure to heed signs, yield the right of way, or turn properly (Huston and Janke, 1986; Planek, 1973). For these reasons, older drivers were included in this experiment.

METHOD

GENERAL APPROACH

To examine the effects of an ISIS system on driver performance, as well as the effects of time of day and weather on driver use of such a system, an ISIS consisting of 15 events was developed and tested using a Virginia Tech Center for Transportation Research instrumented vehicle.

EXPERIMENTAL DESIGN

A 2 x 2 x 2 x 2 x 2 between subjects design was used for this study. The variables of Age, Weather, Time of day, Gender, and ISIS use were investigated. Due to logistics issues during data collection, Gender was dropped from the study (see the Results section for a detailed description of the logistics issues encountered). The Age variable had two levels, younger (18-30 years old) and older (65 years and older). Weather consisted of two levels: a clear, or no rain, condition and a steady rain condition. Time of day consisted of two levels, day and night. ISIS/no ISIS refers to whether the participant drove with the ISIS display or without it. A route running through Blacksburg and the Ellet Valley area, Virginia, was selected for the test bed. For a map of the test route, see appendix A-1.

PARTICIPANTS

Ninety-six drivers were to have participated in this study. However, due to both the logistics associated with getting a data collection run completed during an active period of rain, and a reluctance on the part of older drivers (especially older female drivers) to drive during night clear or night rain conditions, 58 drivers actually participated in this experiment. Thirty-five of the participants were between the ages of 18 and 30 (younger drivers), and 23 were between 65 and 75 (older drivers). For the younger drivers, 16 were male and 19 were female. For the older drivers, 14 were male and 9 were female. For a breakdown of subjects by treatment condition, refer to Table 1. Younger drivers were recruited through flyers posted on the Virginia Polytechnic Institute and State University campus and an advertisement in the local newspaper. Older drivers were recruited through retirement communities, advertisements in local newspapers, and flyers posted at local merchants.

Table 1. The design matrix, showing participants by experimental condition.

	Younger				Older			
	Rain		Clear		Rain		Clear	
	Day	Night	Day	Night	Day	Night	Day	Night
ISIS	5	3	5	6	3	1	5	3
No ISIS	4	2	5	5	2	0	5	4

Younger subjects were paid $10.00 per hour and older subjects were paid $15.00 per hour for approximately 1 hour of research time. Due to the nature of the older population in the area (a number of retired faculty and staff from the university), reasonable equality in terms of education level was achieved between the older and younger subjects.

In order to be a participant, subjects were required to: (1) be a licensed driver, (2) drive a minimum of twice a week in Blacksburg, Virginia, or the surrounding area, (3) pass a health screening questionnaire, (4) have a minimum 20/40 visual acuity, wearing corrective lenses if necessary, and (5) pass a hearing test.

APPARATUS

Driver behavior was investigated on-road using an instrumented 1995 Oldsmobile Aurora four-door sedan (Figure 1). The primary apparatuses used in the study were: (1) the automobile, (2) cameras and sensors, (3) software and hardware interfaces for information portrayal and data collection, and (4) an ISIS display.

Automobile

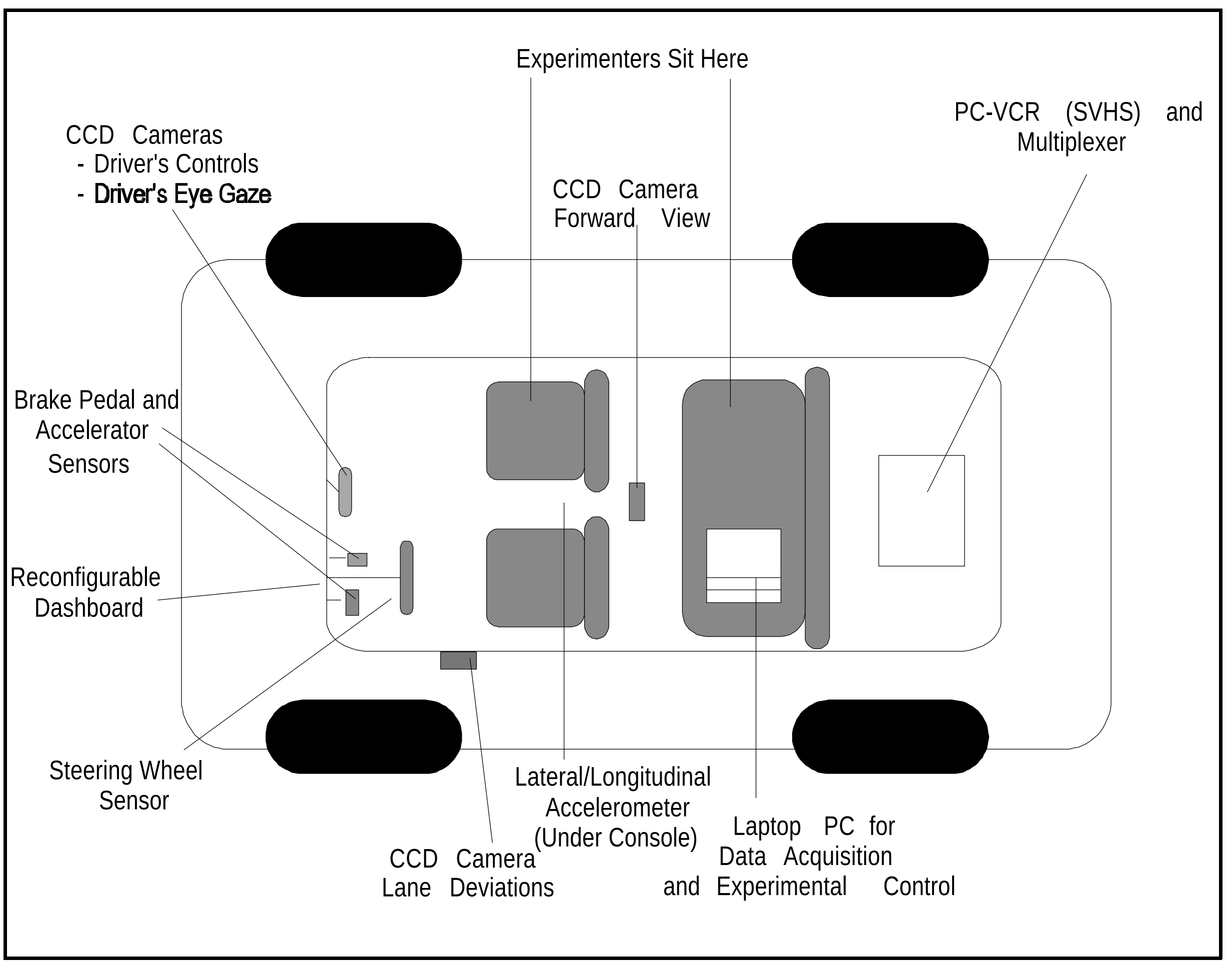

Figure 1. Diagram of the instrumented vehicle.

The instrumentation in the vehicle provided the means to collect, record, and reduce a number of data items, including measures of attention demand, measures of navigation performance, safety-related incidents, and subjective opinions of the participants. The system consisted of video cameras to record pertinent events and eye movement data, an experimenter control panel to record time and duration of events and information on the ISIS display, sensors for the detection of variations in driving performance and behavior, and a custom analog-to-digital interface and computer to log the data in the required form for analysis. The vehicle's data collection system allowed for the collection and storage of several forms of data. The system provided the capability to store data on a computer in the form of one line of numerical data every 0.1 seconds during a data run. The videotape record provided by the cameras' view was time-stamped and synchronized with the computer data stream so that post-test data reduction and data set merging could occur in the laboratory.

Safety Requirements

The following safety measures were provided as part of the instrumented vehicle system. Such measures helped minimize risks to participants during the experiment:

- All data collection equipment was mounted such that, to the greatest extent possible, it did not pose a hazard to the driver in any foreseeable instance.
- Driver-side and passenger-side air bags were provided.
- Two trained in-vehicle experimenters were in the vehicle at all times. An emergency protocol was established prior to testing.
- A fire extinguisher, first aid kit, and cellular phone were located in the experimental vehicle.
- An experimenter's brake pedal was mounted in the front passenger-side.
- None of the data collection equipment interfered with any part of the driver's normal field of view (FOV).

Cameras and Sensors

<u>Eye Glance Camera</u>

The eye glance camera allowed monitoring of eye movements, and its FOV accommodated drivers of varying heights and seating positions. The view of the subject's eyes was clear and in focus, allowing eye movement classification in the laboratory. The eye glance camera was located in the center rear-view mirror and did not obscure the driver's view or impair his/her use of the mirror.

<u>Forward-View Camera</u>

The forward-view camera provided a wide view of the forward roadway without substantial distortion. The camera had an auto-iris and provided a high quality picture in all but the most severe daylight glare conditions. The forward-view camera was located in the center rear-view mirror and did not obscure any part of the driver's view of the roadway or impair his/her use of the mirror. The forward-view camera served to collect relevant data from the forward scene (e.g., traffic density, signs and markers, and headway).

Sensors

The steering wheel, speedometer, accelerator, and brake were all instrumented. The steering wheel sensor provided steering position data accurate to within +/- 1 degree. The brake and accelerator sensors provided brake position to within +/- 0.1 inch. An accelerometer provided acceleration readings in the lateral and longitudinal planes of the vehicle. The accelerometers provided values for vehicle acceleration and deceleration up to and including hard braking behavior, as well as intense turning. The sensor provided a signal that was read by the A/D interface at a rate of 10 times per second.

Software and Hardware Interfaces

Multiplexer and PC-VCR

A quad-multiplexer integrated up to four camera views and included a time stamp onto a single videotape record. A PC-VCR received a time stamp from the data collection computer and displayed the time stamp continuously on the multiplexed view of the videotaped record. In addition, the PC-VCR had the capability to read and mark event data provided by the data collection computer and perform high-speed searches for event marks. The PC-VCR operated in an S–VHS format so that each multiplexed camera view had 200 horizontal lines of resolution.

Data Collection Computer

The data collection computer provided reliable data collection, manipulation, and hard drive storage under conditions present in a vehicle environment. The computer had a 16-channel analog-to-digital capability, standard QWERTY keyboard, and a 9-inch diagonal color monitor. Computer memory and processing capabilities were: 12 megabytes RAM, 1.2 gigabyte hard drive, and Pentium processor.

Video/Sensor/Experimenter Control Panel Interface

A custom interface was constructed to integrate the data from the experimenter control panel, driving performance sensors, and speedometer with the data collection computer. In addition, the interface provided a means to accurately read and log the time stamp from the PC-VCR to an accuracy of +/- 0.1 second. The time stamp was coded such that a precise location could be synchronized from any of the videotaped records to the computer data record for post-test laboratory reduction and file integration.

Audio Data Collection System

An audio track of the videotape record of the experiment contained the commentary of the experimenter, driver communication, and any system-generated audio.

The ISIS Display

A display mounted in the dash provided information to the driver. The display was a Sharp TFT-LCD Module, Model No. LQ64D142. It was located 1.2 cm from the center of the dash, adjacent and to the right of the speedometer (figure 2). The dash configuration included an overhang, protruding 15.6 cm from a display cover, to help mitigate the effects of glare (figure 3).

Figure 2. **Display location.**

Figure 3. **Driver view of ISIS through steering wheel.**

The Sharp TFT-LCD Module, Model No. LQ64D142 display is a color active matrix liquid crystal display incorporating an amorphous silicon thin film transistor (TFT). The back light system is an edge-lighting configuration with two cold cathode fluorescent tubes (CCFT). Lamp frequency of the CCFT is typically 35 KHz, with a range of 20 KHz to 60 KHz. Graphics and text can be displayed on a 640 x 480 pixel panel with up to 4,096 colors. Basic colors that can be displayed by module are black, blue, green, light blue, red, purple, yellow, and white. These basic colors can be displayed in 16 gray scales (from 4-bit data signals), therefore, rendering a total of 4,096 possible colors because of the display's 12-bit data signals. Optical characteristics include a horizontal viewing angle range of 35° off perpendicular, to the left and right, retaining a contrast ratio of 10:1 or greater. Mechanical specifications for the display are listed in appendix A-2 (Liquid Crystal Displays Group, 1995).

<u>ISIS Information</u>

The ISIS provided an in-vehicle display of notification and regulatory information that is currently depicted on roadway signs. Notification information informed drivers of changes in the roadway, such as advisory speed limits, bridges, tunnels, and curves. Regulatory information included signs such as speed limits, stop signs, and yield signs.

When new information was presented on the display, an alerting tone, lasting 0.45 second, was given. The display was active until the test vehicle passed the existing sign (in those cases where the event was marked), or until the test vehicle had moved into the event (in those cases where the event was not marked). No changes were made to the roadway conditions; this meant, in the case of marked events, that the ISIS served as a supplement to the existing road signs. The signs used as part of the ISIS were adapted from an on-line repository (Moeur, 1996) and conform to the standards in the Manual on Uniform Traffic Control Devices (MUTCD). These images were colorized and modified to match those signs encountered on the test route using Micrografix Picture Publisher 6.0. For a full-sized example of the ISIS display, please refer to appendix A-3. All images used on the ISIS display can be found in appendix A-4.

INDEPENDENT AND DEPENDENT VARIABLES

Independent Variables

As discussed above, the four independent variables that were manipulated in this experiment were:

- *ISIS Use*: Two levels of ISIS use were included: (1) no ISIS and (2) ISIS. The no ISIS condition served as a baseline.
- *Time of Day*: Participants drove either during the day or at night. For experimental purposes, night was defined as that time when the reading on a photometer was less than 5.0 lux. A photometer reading was taken at the start of data collection to determine when the reading would be less than 5.0 lux. All the night cells occurred after this time of day.
- *Weather*: Participants drove under a clear weather condition or a steady rain condition. The steady rain condition was operationally defined as rain heavy enough to require the driver to have the windshield wipers operating on the intermittent setting or higher for the entire drive.

! *Age*: Two age groups of drivers were used: younger drivers (18-30 years) and older drivers (65-75 years).

Dependent Variables

The dependent variables measured the impact of ISIS use and the potential system benefits. All dependent measures related to the end of the event. The end of an event was defined as the point at which the experimental vehicle passed the event's road sign (in the case of a marked event) or a predetermined point after the driver had to initiate a response to the event. The specific measures collected were as follows:

! *End event speed*: Vehicle speed at the end of an event was recorded to determine what factors, if any, affected the speed at which the vehicle was traveling at the end of an event. Lower end event speeds would indicate lower vehicular speeds when entering curves, etc., which would imply increased safety.

! *Reaction distance*: The distance at which a driver reacted to an event was determined by examining the accelerator position, brake position, velocity, and acceleration data. This reaction distance was analyzed to determine which factors, if any, affected driver reaction.

! *Longitudinal acceleration/deceleration measures and braking data*: Braking behavior can provide a sensitive measure of performance (Monty, 1984). If drivers are inattentive, the brake must be depressed harder and the resulting deceleration is greater than in a normal attention situation.

! *Subjective acceptance and preference data*: A post-test questionnaire consisting of a seven-point Likert-type scale was utilized to assess participant acceptance and preference issues associated with the use of the display and display conditions.

PROCEDURES

Participant Screening and Training

Participants were initially screened over the telephone regarding age, gender, driving experience, and health (appendix A-5). If participants qualified for this experiment, a time was scheduled for testing. Participants were instructed to meet experimenters at the Virginia Tech Center for Transportation Research (CTR), Blacksburg, Virginia. After arriving at the CTR, the participant was given an overview of the study and he/she completed an informed consent form (appendix A-6). Next, he/she was asked to answer a health screening questionnaire and was given a simple vision test (appendices A-7 and A-8, respectively). After these were completed, the participant was escorted to the test vehicle.

One of the experimenters then drove the test vehicle to the start of the practice route and allowed the participant to drive. With the car in park, the experimenter reviewed general information concerning the operation of the test vehicle (e.g., lights, seat adjustment, mirrors, windshield wipers, etc. (appendix A-9). The participant was then asked to operate each control and set the seat and mirrors for his/her driving comfort. When the participant felt comfortable with the controls, the experimenter administered a hearing test. This test determined the participant's ability to understand verbal navigational commands and hear the auditory alert cues (appendix A-9). Next, the experimenter explained the ISIS displays if the participant was to drive with the system. As a pre-test to familiarize drivers with the ISIS, 18 symbols were randomly presented to the driver. The driver was asked to review these symbols to ensure that he/she knew the meaning of each symbol. The driver was encouraged to ask questions or to ask for clarification or explanation if necessary. This presentation included all 15 of the symbols that would appear en-route. Additional symbols were included in order to give the illusion that the system was actually sensing elements in the environment. Once the participant was comfortable with both the vehicle and the ISIS, final instructions (appendix A-9) were given. The driver then proceeded to the practice segment.

Practice Segment

For the practice segment, the participants drove a practice route of approximately 1 mile to allow the participant become familiar with the handling of the vehicle. No ISIS was used during the practice segment. Once the drivers completed this segment, they were asked if they felt comfortable with the car. If the answer was "no," drivers were allowed to continue driving. Drivers were allowed to continue as long as needed in order to feel comfortable with the vehicle. When drivers indicated that they felt comfortable with the car, the data collection began.

On-Road Data Collection

Two experimenters were in the vehicle with the driver. An experimenter in the front seat gave navigational instructions and served as a safety monitor by using the second emergency brake pedal if needed (see appendix A-10 for front seat experimenter protocol). The experimenter in the rear seat controlled the presentation of information (see appendix A-11). A marker was inserted into the data set when new information was presented on the ISIS display. ISIS information was stored as a slide format in a computer located in the trunk of the vehicle. The experimenter triggered the presentation of information for the ISIS when previously-determined landmarks in the route were reached. The participants were not informed of this simulation until after the study.

The experimental route took approximately 15 minutes to drive, and was approximately 5.5 miles long. The route began at the intersection of Nellie's Cave Road and Woodland Hills Road on the outskirts of the town of Blacksburg, and ended just after completion of the last event (see appendix A-1 for a map of the route and images of representative events). This route consisted of narrow, country roads with several elevation changes. Traffic density on this road was low. If a wrong turn was made, the experimenter in the front seat would let the driver complete the turn and then direct the driver back to the prescribed route. Upon returning to the CTR, a preference questionnaire was administered (appendix A-12). After answering the questionnaire, drivers were debriefed and paid for their time.

Route Events

The experimental route consisted of 15 events over the course of 5.5 miles. Events were defined experimentally as permanent geometric or situational features that required reaction by the driver. Route events were divided into two categories based on whether a road sign existed to warn the driver about the event. The first category, marked events, consisted of those events that were marked with a road sign. The second category, unmarked events, were those events that had no signs to warn drivers (either no sign existed or the sign was missing prior to the study). A complete listing of events can be found in table 2. The ISIS displays for each event can be found in appendix A-4. A listing of event ISIS distances and visibility distances for each event can be found in appendix A-13.

Table 2. Route events and types.

Event No.	Description	Type
1	Stop Ahead	Unmarked
2	Stop	Marked
3	Reverse Turn - 15 MPH	Marked
4	Winding Road - 30 MPH	Marked
5	Reverse Curve - 30 MPH	Marked
6	Speed Limit 35 MPH	Marked
7	One Lane Tunnel - 25 MPH	Marked
8	End 35 MPH Speed Limit	Marked
9	“Y” Curve - 25 MPH	Marked
10	Yield	Marked
11	Curve	Unmarked
12	Winding Road	Unmarked
13	One-Lane Bridge	Marked
14	Reverse Curve	Unmarked
15	Reverse Curve	Unmarked

<u>Marked Events</u>

There were 11 marked events over the course of the experimental run. For these events, the ISIS system displayed information regarding the event approximately 5 seconds before the driver could see the actual road sign. The ISIS system remained active until the test vehicle passed the road sign.

Unmarked Events

In addition to the marked events, four unmarked events occurred during the drive. For these events, the ISIS system displayed information about the event approximately 5 seconds before the start of the event, defined as the point where a sign would be placed if one were present. The ISIS system remained active until the test vehicle entered the event.

Post-Test Data Collection (Questionnaire)

At the conclusion of the test run, drivers returned to the research building at the Center for Transportation Research and completed a preference questionnaire (appendix A-12). After completing the questionnaire, subjects were debriefed and paid.

RESULTS AND DISCUSSION

Recall from the method section that although the original experimental design called for the participation of 96 drivers, only 58 subjects took part in this study. To maintain sufficient statistical power for the experiment despite the missing cells, the data were divided into four subsets (table 3).

These subsets allowed the analysis of selected factors as part of the experiment. Due to missing data, it was decided to eliminate gender from the analysis. Relative to the effect of age and many other factors, gender differences related to driving are small. In addition, the older driver - rain - night cell could not be used in the analysis. Despite substantial recruiting efforts (more than 120 subjects were contacted), the vast majority of the older drivers contacted would not drive at night in the rain. This was particularly true of the female drivers.

Table 3. Data subsets and associated factors.

Subset	Factors
Clear Weather Only	Age, Time of Day, ISIS
Younger Only	Weather, Time of Day, ISIS
Older, Clear Weather Only	Time of Day, ISIS
Older, Day Only	Weather, ISIS

The results for this study will be described in four sections, one section for each of the subsets of data. For each subset, three measures of driver performance were taken: (1) end event speeds, which refer to the speed the driver was going at the end of the event; (2) maximum deceleration, which refers to the maximum longitudinal deceleration experienced during the event; and (3) reaction distance, which refers to the distance from the end of the event at which the subject initiated a response. In addition, subjective preference data were collected for each subset, and will be discussed as well. All analyses were conducted using the SAS® 6.11 software package. Due to missing data (typical of field experiments), analyses were conducted using the General Linear Model (GLM) procedure (Littell, Freund, and Spector, 1991). For this experiment, an α level of 0.05 was used. Note that since several analyses were conducted on various subsets of data, and since an α level of 0.05 was used, the potential for type I error is increased. Therefore, the reader is cautioned against placing too much emphasis on a single significant outcome that approaches p=0.05.

MARKED VERSUS UNMARKED EVENTS

A post-hoc analysis examining event type (marked or unmarked) and ISIS was conducted. The interaction between type and ISIS was not significant for any of the four subsets, and therefore was not pursued further. Instead, events were examined individually, since differences in events would naturally lead to increases in variance that could mask the effects of the independent variables. Individual analyses were also conducted to determine the effects of differing event types. Both overall and individual events will be discussed below.

CLEAR WEATHER ASSESSMENT

As outlined above, examining the clear weather only data allowed investigation of the relationship between Age, Time of day, and ISIS use. The variable age consisted of two levels: 18-30 years old, and 65-75 years old. The variable time consisted of two levels: day and night. The variable ISIS consisted of two levels and indicated if the participant drove with the ISIS system or without it. Participants by experimental condition can be seen in table 4.

Table 4. Participants by experimental condition for the clear weather assessment.

	Younger		Older	
	Day	Night	Day	Night
ISIS	5	6	5	3
No ISIS	5	5	5	4

Event End Speed

An Analysis of Variance (ANOVA) using the GLM procedure (see appendix B, table 26, for the complete ANOVA table) was completed for all 15 events taken together.

Age, $F(1,30)=8.48$, $p=0.0067$, was found to be significant across all the events. The younger drivers had a higher mean end event speed (30.85 mi/h) than the older drivers (28.64 mi/h). Examination of the individual events (see table 5) revealed that age was significant for 6 of the 15 events. The first two events are regulatory events, warning drivers of an approaching stop and indicating the stop itself. Older drivers have been found to exhibit higher risk perception than younger drivers (Finn and Bragg, 1986). This higher perception may account for the age effect found here, with the older drivers perceiving more risk and responding by decreasing their speed. Events 4 and 5 both involve curves; again, the higher perception of risk on the part of the older drivers may account for the significance of age. Event 7 involves a one-lane tunnel. This is also a high-risk event, and the differences in perception may have led to the significance of the age effect. The last individual event having a significant age effect was event 8, an “End 35 MPH speed” sign. The older drivers may have preferred a more gradual increase in speed as the response to this event than the younger drivers, leading to different speeds at the end of the event, and a corresponding significant age effect. This preference may be a result of the older drivers’ natural cautious behavior.

ISIS, $F(1,30)=20.84$, $p=0.0001$, was also found to be significant across all the events for end speeds. Those drivers who used the ISIS had a lower mean end event speed (28.06 mi/h) than those who drove without the system (31.66 mi/h). On an individual event basis, ISIS was found to be significant for 12 of the 15 events. ISIS was significant for all events involving curves on the experimental route, both marked and unmarked. This indicates that the extra warning provided by the system may have been of particular benefit when it occurred before the actual sign was visible (in the case of marked events) or when no external warning was present (in the case of unmarked events). The ISIS was also found to be significant for two of the regulatory signs (event 1, unmarked stop ahead, and event 6, marked speed limit), but not the others (event 2, marked stop sign; event 8, marked end 35 MPH limit sign; and event 10, marked yield), indicating that the system may provide meaningful benefits under selected regulatory conditions, such as stop ahead or speed limit situations.

Additional effects were found to be significant for individual signs (see table 5). Time was significant for three of the events: event 5, a marked reverse curve; event 7, a marked one-lane tunnel; and event 10, a marked yield. In each case, nighttime drivers had a higher end speed than the daytime drivers. These results may indicate that drivers may use visual cues to determine their response to an event; at night, these cues would be reduced (or absent), and the drivers would not make the same decision as in the daylight. No additional patterns emerged in the significant effects.

Maximum Deceleration

No significant effects were found across all events for maximum deceleration. (For a complete ANOVA table, refer to appendix B, table 27). P values for the individual events can be seen in table 6.

ISIS was significant for five individual events (event 3, a marked reverse turn; event 4, a marked winding road; event 9, a marked "Y" curve; event 10, a marked yield; and event 14, an unmarked reverse curve). For two of these five events (events 10 and 14), use of the ISIS resulted in lower maximum decelerations. No pattern as to type is apparent between these two events; one is marked, the other is not, and one is regulatory while the other is advisory. This reduced deceleration caused by the ISIS display may be a result of the geometry of these events.

Although additional effects were found to be significant for individual events, no event had more than two significant effects. No patterns or trends could be discerned from the data. This lack of general significance would seem to indicate that the attention of the clear weather drivers (as measured by maximum deceleration) was not affected to a large degree by Age, Time, or their interactions.

Table 5. P values by individual events for end event speed, clear weather assessment.

	Event														
Effect	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Age	**0.0014**	**0.0394**	0.4312	**0.0010**	**0.0001**	0.1864	**0.0113**	**0.0474**	0.0898	0.1766	0.4653	0.5983	0.1753	0.9164	0.3393
Time	0.4524	0.4462	0.4221	0.0683	**0.0248**	0.8245	**0.0491**	0.7755	0.8158	**0.0242**	0.6985	0.6074	0.4520	0.2949	0.2348
ISIS	**0.0277**	0.1599	**0.0002**	**0.0001**	**0.0001**	**0.0087**	**0.0160**	0.5668	**0.0004**	0.6178	**0.0426**	**0.0231**	**0.0009**	**0.0187**	**0.0348**
Age*Time	0.6781	0.0996	**0.0065**	**0.0252**	0.8531	0.5730	0.5510	0.7229	0.1949	0.6624	0.6491	0.5460	0.4448	**0.0005**	0.6077
Age*ISIS	0.8893	0.4727	0.5143	0.2497	0.6699	0.9417	0.6958	0.9695	0.6706	0.4474	0.2300	0.1636	0.7584	0.3986	0.3723
Time*ISIS	0.3128	0.4364	**0.0418**	0.5212	**0.0217**	0.2339	0.7576	0.6401	0.8267	0.0530	0.4640	0.0671	0.2384	0.4860	0.3909
Age*Time*ISIS	0.8794	0.4298	0.0847	0.3772	0.7326	0.6819	0.4492	0.1470	0.6074	0.3151	0.8269	0.9766	0.5806	0.3848	0.3739

(Significant p values are in bold type. Factors found to be significant in the overall analysis are in bold and underlined type.)

Table 6. P values by individual events for maximum deceleration, clear weather assessment.

	Event														
Effect	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Age	**0.0003**	0.0838	0.5939	0.5596	0.2740	0.2665	0.4296	0.6257	0.7717	0.6407	0.3456	**0.0302**	0.5873	0.9117	0.1708
Time	0.4588	0.6306	0.8191	0.7947	0.0931	0.8127	0.4600	0.4359	0.3874	0.0632	**0.0212**	0.1237	0.7688	0.1257	**0.0381**
ISIS	0.0765	0.6278	**0.0042**	**0.0066**	0.0595	0.2239	0.9026	0.4358	**0.0413**	**0.0365**	0.7215	0.5753	0.3769	**0.0186**	0.0575
Age*Time	0.1995	0.5997	0.5101	0.6447	0.6877	0.2265	0.4865	0.9131	0.6067	0.3881	0.6973	0.8994	0.7542	**0.0178**	0.4786
Age*ISIS	**0.0096**	0.5767	0.3898	0.6500	0.1398	0.5310	0.4692	0.5306	0.6165	0.4054	0.9376	0.0762	**0.0065**	0.3917	0.7919
Time*ISIS	0.5010	0.8565	0.2245	0.9615	0.6367	0.7929	0.4283	0.4483	0.5269	0.1655	0.1622	0.1860	**0.0231**	0.8246	0.6550
Age*Time*ISIS	0.8196	0.5660	0.9359	0.9099	0.9933	0.2894	0.7270	0.7304	0.1431	0.9041	0.1879	0.3223	0.2767	0.3234	0.8849

(Significant p values are in bold type. Factors found to be significant in the overall analysis are in bold and underlined type.)

Reaction Distance

The interaction of Age and ISIS, F(1,30)=10.89, p=0.0025, was found to be significant across the events. This interaction can be seen in figure 4.

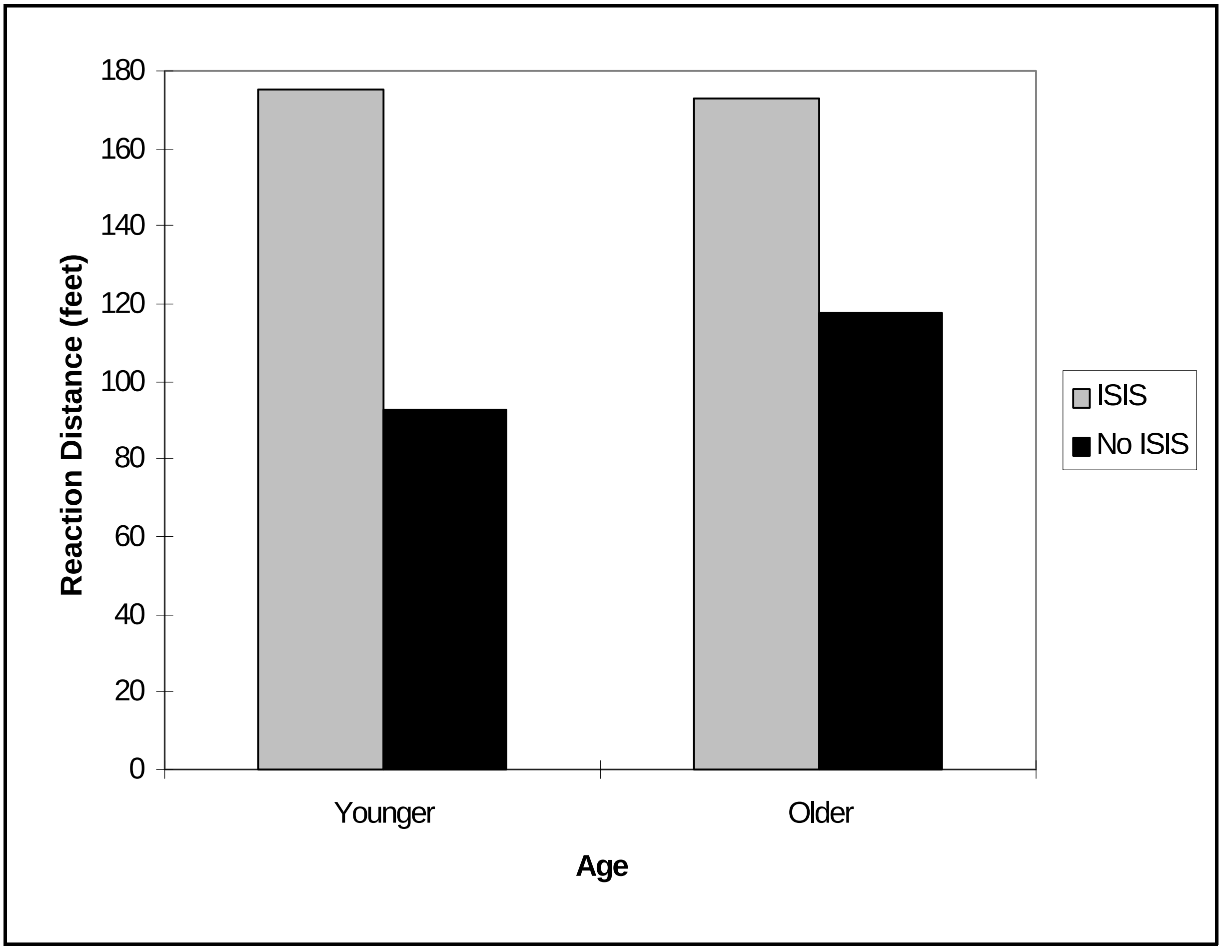

Figure 4. Mean reaction distance for Age*ISIS for all events, clear weather assessment.

This interaction indicates that the ISIS system did result in greater reaction distances for both the younger and older groups. The older drivers had a greater reaction distance under the no ISIS condition. Under the ISIS condition, both groups had approximately the same reaction distance. As stated above, older drivers exhibit a greater risk perception than younger drivers. This difference in risk perception may lead to an earlier response on the part of the older drivers; they would, therefore, show a smaller difference due to a larger baseline distance.

An examination of the individual events (see table 7) revealed that the Age/ISIS interaction was significant for five events: event 3, a marked reverse turn; event 9, a marked "Y" curve; event 11, an unmarked curve; event 12, an unmarked winding road; and event 13, a marked one-lane bridge. Four of these five events involve curves. This may indicate that older drivers demonstrate even more caution in these types of situations. This additional caution would result in the interaction seen here. For the last event, the nature of the event (meeting oncoming traffic) may have led to additional caution on the part of the older drivers, which in turn resulted in the significance of this interaction.

Time, $F(1,30)=14.90$, $p=0.0006$, was found to be significant across the events. The daytime drivers had a shorter reaction distance (322.05 feet) than the nighttime drivers (351.79 feet). This difference could be explained by the increased caution of drivers at night. Examination of individual events revealed time to be significant for event 1, unmarked stop ahead; event 7, marked one-lane tunnel; event 9, marked “Y” curve; and event 11, unmarked curve (see table 7). All of these events had more limited sight distances at night, which may have resulted in greater caution under this condition.

ISIS, $F(1,30)=318.02$, $p=0.0001$, was also significant across the events. The drivers with an active ISIS display had a longer reaction distance (412.78 feet) than those drivers without the display (259.49 feet). Examination of individual events (see table 7) revealed the ISIS display to have a significant effect for every event except event 10, the marked yield sign. This indicates that the ISIS display would increase reaction distances regardless of the type of event (marked or unmarked, regulatory or advisory).

Additional factors were found to be significant for individual events, but upon examination, no patterns with regards to the event type or geometry of the road were found.

Table 7. P values by individual events for reaction distance, clear weather assessment.

	Event														
Effect	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Age	0.1903	0.0890	0.0256	0.3438	0.6646	0.1778	0.0533	0.9407	0.4255	0.3054	0.3490	0.7691	0.7283	**0.0074**	0.8599
Time	**0.0118**	0.5630	0.6239	0.1713	0.8329	0.6544	**0.0180**	0.2113	**0.0002**	0.7386	**0.0403**	0.4780	0.2908	0.6318	0.8712
ISIS	**0.0001**	**0.0008**	**0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.0001**	0.2574	**0.0001**	**0.0001**	**0.0001**	**0.0413**	**0.0001**
Age*Time	0.9438	0.4664	**0.0371**	0.9338	0.8493	0.3040	0.9226	0.2170	0.2955	0.0694	0.9699	0.2528	0.1502	0.2376	0.7598
Age*ISIS	0.2113	0.6242	**0.0387**	0.5273	0.8585	0.9769	0.5073	0.8801	**0.0388**	0.0814	**0.0400**	**0.0183**	**0.0224**	0.4299	0.3692
Time*ISIS	0.4896	**0.0460**	0.8004	0.0848	0.2942	0.3898	0.2326	0.5781	0.5244	0.2538	0.7464	**0.0006**	0.6643	0.3247	0.5401
Age*Time*ISIS	0.4611	0.4531	0.1621	0.5606	0.6824	0.6926	0.9923	0.2475	**0.0210**	0.4147	0.8473	0.4429	0.1371	0.3307	0.2582

(Significant p values are in bold type. Factors found to be significant in the overall analysis are in bold and underlined type.)

Subjective Preference Data

Recall that at the end of the test run, participants were asked to complete a preference questionnaire. The mean responses for the clear weather subjects, by ISIS use, are listed in table 8.

Table 8. Mean subjective question responses by ISIS, clear weather assessment.

Question	ISIS	No ISIS
No. 1: How aware of road sign information were you during the drive? (1=Not Aware, 7=Extremely Aware)	6.5789	5.4737 *
No. 2: How timely was the presentation of the road sign information during the drive? (1=Not Timely, 7=Extremely Timely)	6.5263	4.6316 *
No. 3: How safe did you feel during the drive? (1=Extremely Safe, 7=Extremely Unsafe)	2.7368	2.7895
No. 4: How difficult was it to gather road sign information during the drive? (1=Not Difficult, 7=Extremely Difficult)	1.4737	2.6842 *
No. 5: How distracting was the road sign information during the drive? (1=Not distracting, 7=Extremely Distracting)	2.2632	1.5263 *
No. 6: I would find such a system as this to be useful to me while driving. (1=Strongly agree, 7=Strongly disagree)	2.1579	2.0000
No. 7: I would find a system such as this to be a desirable option in my car. (1=Strongly agree, 7=Strongly Disagree)	2.1579	2.2105

(* indicates a significant difference for ANOVA. Please see appendix B, tables 29 to 35.)

Clearly, drivers felt more aware of sign information, that the information was more timely, and that it was easier to gather sign information when given the ISIS display. However, drivers found the ISIS display to be more distracting than ordinary driving. Insight into the nature of this distraction is provided by the participants' verbal comments to the experimenters. When asked to comment freely on the system, those drivers that mentioned distraction indicated that the warning or attention tone was the source of the distraction.

Time was significant for question 1, with daytime drivers more aware (mean=6.3000) of road sign information than nighttime drivers (mean=5.7222). Age was significant for question 2, with older drivers feeling that information was more timely (mean=6.0000) than the younger drivers (mean=5.2381). Age was also significant for question 5, with older drivers feeling less distracted (mean=1.4118) than the younger drivers (mean=2.2857).

YOUNGER DRIVER ASSESSMENT

Examining only the younger driver data allowed investigation of the relationship between weather, time of day, and ISIS use. The variables Time of day and ISIS were defined identically, as described previously, in the clear weather assessment. Weather consisted of two levels: a no rain, or clear, condition and a rain condition. The number of participants by experimental condition can be found in table 9.

Table 9. Participants by experimental condition for the younger driver assessment.

	Rain		Clear	
	Day	Night	Day	Night
ISIS	5	3	5	6
No ISIS	4	2	5	5

Event End Speed

Weather, $F(1,27)=5.31$, $p=0.0291$, was found to be significant with respect to the event end speeds of the younger drivers across all events. Clear weather driving resulted in a mean end event speed of 30.85 mi/h, while driving in the rain resulted in a mean end event speed of 32.75 mi/h. (For a complete ANOVA table, please see appendix B, table 36). This result is contradictory to what might be expected. This increase in speed could be explained by driver awareness of the increased risk of rain, and the resulting choice to apply the brake less often or less severely, reasoning that he/she is avoiding opportunities for a skid or a crash.

Examination of the individual events found weather to be significant for six events: event 3, a marked reverse turn; event 5, a marked reverse curve; event 10, a marked yield; event 11, an unmarked curve; event 12, an unmarked winding road; and event 15, an unmarked reverse curve (see table 10). Event 3 cautions the driver to take the curve at 15 mi/h, event 5 warns of a 30 mi/h winding road, event 10 is a yield at a complex intersection, and events 11, 12, and 15 are unmarked; the younger drivers may again not recognize the danger present when driving on such roads in the rain, accounting for the significance of weather.

ISIS, $F(1,27)=13.04$, $p=0.0012$, was a second significant effect for event end speed for younger drivers across all 15 events. Participants using the ISIS system had a mean end event speed of 30.16 mi/h, while those without the system had a mean end event speed of 33.33 mi/h. Clearly, the ISIS display caused drivers to have a lower end speed. Examination of the individual events (see table 10) revealed ISIS to be significant for more than half the events. ISIS appeared to impact end event speed for marked advisory events (event 3, a marked reverse turn; event 4, a marked winding road; event 5, a marked reverse curve; event 7, a marked one-lane tunnel; event 9, a marked "Y" curve; and event 13, a marked one-lane bridge) and low visibility unmarked events (event 14, an unmarked reverse curve, and event 15, an unmarked reverse curve).

Additional effects were found to be significant for individual events (see table 10). These additional significant effects did not have a discernible pattern with respect to event type or roadway geometry.

Maximum Deceleration

The interaction of Weather and ISIS, F(1,27)=4.22, p=0.0496, was also found to be significant with respect to maximum deceleration for the younger drivers (For a complete ANOVA table, please see appendix B, table 37). This relationship is depicted in figure 5.

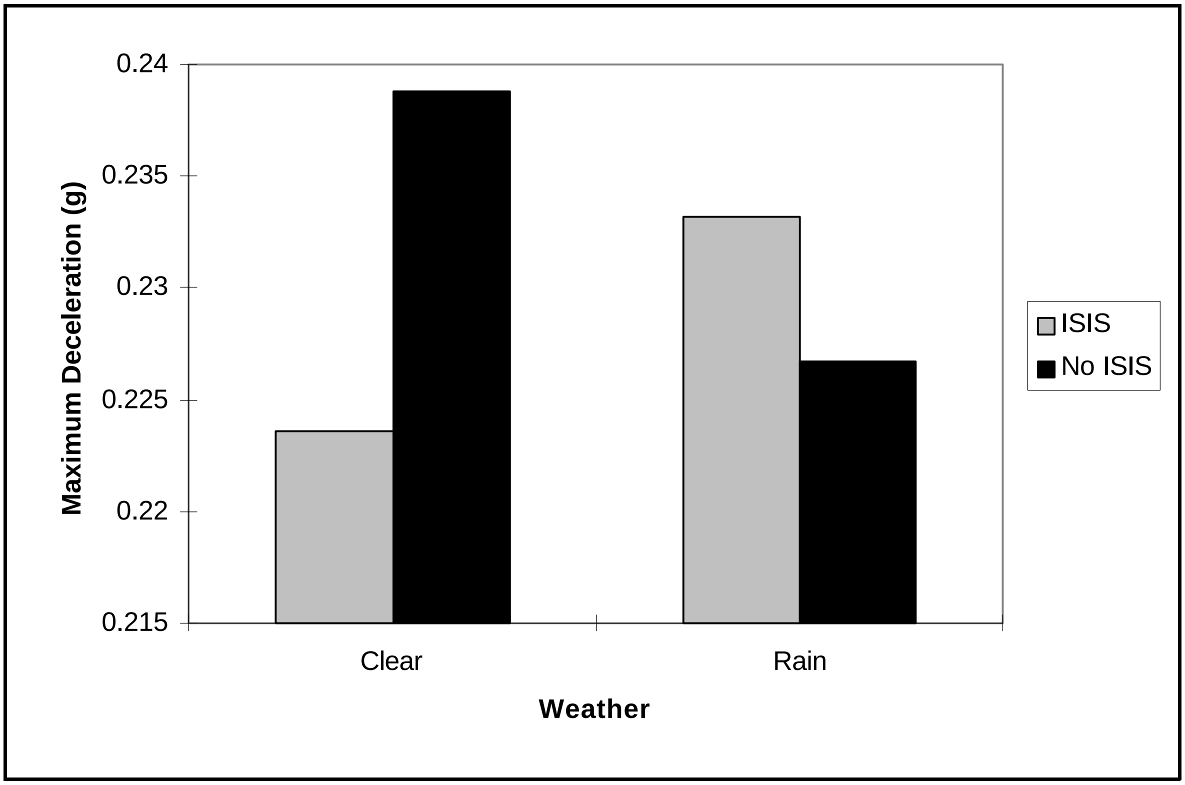

Figure 5. Mean maximum deceleration by Weather*ISIS for all events, younger driver assessment.

With the ISIS, the younger drivers had a lower maximum deceleration under clear conditions, while without the ISIS, the younger drivers had a lower maximum deceleration under rainy conditions. This interaction could be explained by how younger drivers interpret the ISIS information and their increased caution under rainy conditions. Under clear conditions, the ISIS provides the younger drivers with advanced warning and allows them more time to locate the point at which they will respond, and to plan their response. This leads to a lower maximum deceleration. Under the rain condition, the younger drivers may be exhibiting increased caution and lower deceleration.

Looking at individual events (table 11) shows that this interaction was significant for events 5, 13, and 14. Event 5, a marked reverse curve, is very similar to event 14, an unmarked reverse curve. The significance associated with event 13 (marked one-lane bridge) may be a result of the roadway conditions. During the rain conditions, the road in the vicinity of event 13 had a tendency to become covered with water. This generally prompted drivers to decelerate and attempt to maneuver around the water. This could account for the significance found here.

Additional significant effects were found for individual events. No pattern with respect to event type or geometry was found upon examination of these effects (see table 11).

Table 10. P values by individual events for end event speed, younger driver assessment.

	Event														
Effect	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Time	0.9204	0.3762	0.0901	0.2959	0.3744	0.8100	**0.0024**	0.7794	0.6626	**0.0072**	0.3894	0.1831	0.2060	0.5801	**0.0145**
<u>Weather</u>	0.3775	0.0776	**0.0239**	0.1315	**0.0369**	0.0978	0.4683	0.2189	0.4887	**0.0289**	**0.0351**	**0.0244**	0.2341	0.2359	**0.0085**
<u>ISIS</u>	0.0521	0.5636	**0.0038**	**0.0002**	**0.0001**	0.0538	**0.0065**	0.4729	**0.0171**	0.6208	0.3094	0.3025	**0.0145**	**0.0050**	**0.0361**
Time *Weather	0.6947	**0.0046**	0.1017	**0.0070**	0.1765	0.3768	0.6679	0.7382	0.1933	0.7376	0.3527	0.1488	0.8426	**0.0003**	0.0867
Time*ISIS	0.2273	0.2538	0.7111	0.8301	0.1170	0.1666	0.7183	0.7041	0.8078	0.4395	0.4802	0.1598	0.3325	0.9985	0.1930
Weather*ISIS	0.3257	0.1887	0.1734	0.1597	0.1584	0.6935	0.5771	0.8128	0.3168	0.4750	0.1352	**0.0207**	0.4655	0.5266	0.0936
Time*Weather *ISIS	0.6834	0.8222	0.9792	0.0979	0.3977	0.9385	0.3827	0.2371	0.9896	**0.0491**	0.7460	0.7906	0.7263	0.9063	0.1701

(Significant p values are in bold type. Factors found to be significant in the overall analysis are in bold and underlined type.)

Table 11. P values by individual events for maximum deceleration, younger driver assessment.

	Event														
Effect	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Time	0.1290	0.3387	0.8530	**0.0368**	0.2508	0.9897	0.4149	0.1754	0.3920	**0.0297**	0.6901	0.5762	**0.0065**	0.0846	0.1376
Weather	0.6009	0.8514	0.2302	0.7468	**0.0019**	0.2677	0.1282	0.7646	0.6475	0.4138	0.5229	0.8937	0.6163	0.0988	0.5580
ISIS	0.9299	0.4568	**0.0001**	**0.0241**	0.2684	0.4831	0.7754	0.1561	0.2014	0.0743	0.9266	0.1988	0.1070	0.1456	0.1888
Time*Weather	0.0510	0.3482	0.1419	**0.0063**	0.7228	0.3781	0.4292	0.5221	**0.0426**	0.2399	**0.0032**	0.3499	**0.0239**	**0.0440**	0.9436
Time*ISIS	0.3049	0.5458	0.3918	0.6916	0.3852	0.6925	0.6729	0.5672	0.4995	0.7430	0.2763	0.2220	0.3249	0.0814	0.0752
<u>Weather*ISIS</u>	0.3904	0.4094	0.3024	0.3253	**0.0069**	0.3476	0.6137	0.1929	0.8979	0.6199	0.7320	0.2576	**0.0350**	**0.0136**	0.3466
Time*Weather *ISIS	0.0741	0.3267	0.2897	0.6325	0.7403	0.4277	0.9996	0.8232	0.2327	0.0552	0.3064	0.3706	0.7342	**0.0300**	**0.0327**

(Significant p values are in bold type. Factors found to be significant in the overall analysis are in bold and underlined type.)

Reaction Distance

ISIS, F(1,27)=184.31, p=0.0001, was found to be significant across the events. Those drivers who used the ISIS system had a greater (mean=398.174 feet) reaction distance than did those who did not have the system (mean=270.34 feet; for a complete ANOVA table, please see appendix B, table 38). ISIS was significant for all individual events except event 10, a marked yield, and event 14, an unmarked reverse curve. ISIS appeared to increase reaction distances regardless of event type (marked or unmarked) or information type (regulatory or advisory). This result shows broad potential benefit for ISIS.

Time, F(1,27)=6.20, p=0.0192, was the last significant effect found across the events. Daytime drivers had a mean reaction distance of 325.65 feet, while nighttime drivers had a mean reaction distance of 356.16 feet. Drivers probably reacted sooner at night because of roadway and environmental uncertainties associated with decreased visibility.

Time was significant for individual events 6, 9, and 10 (see table 12). For event 6, a marked speed limit, the regulatory nature of the warning, coupled with the lack of visual cues at night, may have prompted increased caution. For event 9, the “Y” curve, the complexity of the intersection, coupled with the reduced visibility and lack of visual cues at night, may have had the same effect on reaction distance. The length of event 9 may also have played a part in this effect. In event 10, marked yield, the daytime drivers had a longer reaction distance (mean=344.10 feet) than the nighttime drivers (mean=295.67 feet). For this event, the lack of visual cues at night may have masked the complexity of this event and its inherent risk, leading to a shorter reaction distance at night.

Additional significant effects revealed no patterns with respect to event type or geometry, although event 9 had four significant factors. This high number of significant factors may be due to the unusual geometry and complexity of the event, or to its long length.

Table 12. P values by individual events for reaction distance, younger driver assessment.

	Event														
Effect	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
<u>**Time**</u>	0.2684	0.6950	0.0039	0.8800	0.4567	**0.0073**	0.8785	0.9045	**0.0090**	**0.0280**	0.2706	0.3044	0.0582	0.2936	0.1966
Weather	0.6206	0.1055	0.4574	0.8447	0.1593	0.8345	0.5458	0.2754	0.9900	0.5539	0.5686	0.1659	0.6536	0.0610	0.1338
<u>**ISIS**</u>	**0.0001**	**0.0002**	**0.0006**	**0.0008**	**0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.0007**	0.6327	**0.0001**	**0.0001**	**0.0001**	0.9730	**0.0001**
Time*Weather	0.1214	0.0528	0.4360	0.3101	0.4676	0.1891	**0.0203**	0.8847	**0.0203**	0.8973	0.5221	0.5421	0.7473	0.5537	0.0967
Time*ISIS	0.8491	0.8188	0.6059	0.3931	0.4444	0.3646	0.4776	0.2908	**0.0165**	0.6279	0.3879	**0.0225**	0.3167	0.5745	0.7990
Weather*ISIS	0.6470	0.3230	0.0710	0.9044	0.8804	0.8642	0.7866	0.1137	0.3542	0.2306	0.7398	0.4083	0.9040	0.1821	0.5666
Time*Weather *ISIS	0.8688	0.1507	0.0529	0.9496	0.1483	0.0262	0.0593	0.6437	0.6107	0.0882	0.3106	0.0685	0.9512	0.1634	0.5001

(Significant p values are in bold type. Factors found to be significant in the overall analysis are in bold and underlined type.)

Subjective Preference Data

Again, the responses of the younger subjects to the preference questionnaire are listed by ISIS use in the table 13.

Table 13. Mean subjective question responses by ISIS, younger driver assessment.

Question	ISIS	No ISIS
No. 1: How aware of road sign information were you during the drive? (1=Not Aware, 7=Extremely Aware)	6.6842	5.2500 *
No. 2: How timely was the presentation of the road sign information during the drive? (1=Not Timely, 7=Extremely Timely)	6.2632	4.2500 *
No. 3: How safe did you feel during the drive? (1=Extremely Safe, 7=Extremely Unsafe)	3.1053	2.5000
No. 4: How difficult was it to gather road sign information during the drive? (1=Not Difficult, 7=Extremely Difficult)	1.7368	3.1250 *
No. 5: How distracting was the road sign information during the drive? (1=Not distracting, 7=Extremely Distracting)	3.0526	1.8125 *
No. 6: I would find such a system as this to be useful to me while driving. (1=Strongly agree, 7=Strongly disagree)	2.6316	2.0625
No. 7: I would find a system such as this to be a desirable option in my car. (1=Strongly agree, 7=Strongly Disagree)	2.7368	2.1250

(* indicates a significant difference under ANOVA. See appendix B, tables 39 to 45.)

The younger drivers felt that the ISIS display made them more aware of sign information, that the information was more timely, and that it was easier for them to gather the information. The younger drivers also indicated that they felt that the ISIS was distracting. Again, based on the verbal comments of this group of drivers, it appears that the source of the distraction was the attention tone played at the presentation of new information.

Time was found to be significant for question 4, with the daytime drivers finding it easier (mean=1.8974) to gather road sign information than the nighttime drivers (mean=2.9375).

OLDER DRIVER, CLEAR WEATHER ASSESSMENT

Examining the older driver, clear weather data allowed investigation of the relationship between time of day and ISIS. These variables were defined as in the above assessments. The number of participants by experimental condition can be seen in table 14.

Table 14. Participants by experimental condition for the older driver, clear weather assessment.

	Day	Night
ISIS	5	3
No ISIS	5	4

Event End Speed

ISIS, F(1,13)=6.00, p=0.0292, was found to be significant across all events with respect to end event speeds for this subset of driver data. The drivers using the ISIS system had a mean end event speed of 26.80 mi/h, while those without the system has a mean end event speed of 30.29 mi/h. The complete ANOVA table can be found in appendix B, table 46.

Looking at individual event data (see table 15) showed that ISIS was significant for event 3, a marked reverse turn; event 4, a marked winding road; event 5, a marked reverse curve; event 6, a marked speed limit; event 9, a marked "Y" curve; and event 13, a marked one-lane bridge. Five of these six events (3, 4, 5, 9, and 13) are advisory events, and only one of those (13) is unmarked. This would seem to indicate that older drivers gain a benefit from the ISIS system for marked advisory events. For the unmarked events, it is possible that the drivers are already exercising caution due to the road conditions. This would lead to less of an impact on the part of the ISIS display. It also appears that older drivers gain a benefit in terms of reduced speeds when the event involves a decrease in the speed limit (event 6). None of the other regulatory signs showed a significant ISIS effect.

No patterns with respect to event type or geometry emerged upon further examination of individual events.

Maximum Deceleration

No significant effects were found across all events with respect to maximum deceleration for this subset (the ANOVA table can be found in appendix B, table 47). Examination of the individual events (see table 16) revealed ISIS to be significant for event 1, the unmarked stop ahead, and event 9, the marked "Y" curve. The significance found for event 1 might be due to the fact that event 1 represents the first time the driver encountered the system during the experimental run. The warning tone may have caused the driver to react more strongly than normal. The significance found for event 9 may be due to the nature of the ISIS interval (event 9 had the longest distance), or to the complex nature of the intersection itself (prompting drivers to decelerate rapidly upon approaching the intersection). No patterns were found among the other significant effects (see table 16).

Reaction Distance

An examination of reaction distance for this subset of data revealed ISIS, $F(1,13)=236.73$, $p=0.0001$, to be significant. ISIS use resulted in a significantly longer reaction distance (mean=432.84) when compared with the no ISIS condition (mean= 251.22; for the complete ANOVA table, please see appendix B, table 48).

Examination of the individual events (see table 17) revealed ISIS to be significant for all events except event 2, the marked stop sign, event 10, the marked yield, and event 14, an unmarked reverse curve. This would indicate that the ISIS display provided the older, clear weather drivers with a benefit in terms of reaction distance for all the advisory events, both marked and unmarked. In addition, the ISIS display also provided a benefit for certain types of regulatory events; those relating to speed showed a significant ISIS effect. The unmarked regulatory event, the stop ahead, also showed significance. This may indicate that the ISIS system could provide a benefit in those circumstances where regulatory signs are blocked, missing, or difficult to see.

Table 15. P values by individual events for end event speed, older driver, clear weather assessment.

	Event														
Effect	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Time	0.5603	0.3135	0.1350	0.7356	0.1569	0.7463	0.3515	0.6016	0.1214	0.2455	0.2455	0.4578	0.9990	0.0864	0.3987
<u>ISIS</u>	0.2245	0.4249	**0.0172**	**0.0179**	**0.0010**	**0.0165**	0.0703	0.6679	**0.0025**	0.4634	0.4634	0.5172	**0.0333**	0.3051	0.5198
Time*ISIS	0.6646	0.9725	**0.0125**	0.8495	0.1704	0.4485	0.4773	0.3970	0.4440	0.5531	0.5531	0.2277	0.3173	0.3166	0.3876

(Significant p values are in bold type. Factors found to be significant in the overall analysis are in bold and underlined type.)

Table 16. P values by individual events for maximum deceleration, older driver, clear weather assessment.

	Event														
Effect	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Time	0.2777	0.5185	0.8189	0.8829	0.2708	**0.0485**	0.1988	0.5991	0.7032	0.1427	0.2050	0.3001	0.9936	**0.0241**	0.1138
ISIS	**0.0237**	0.5029	0.2728	0.0974	0.8169	0.3982	0.5939	0.2750	**0.0094**	0.1064	0.8325	0.4391	0.2377	0.3366	0.3375
Time*ISIS	0.8112	0.6219	0.5686	0.9064	0.8065	0.2398	0.3047	0.3966	0.3245	0.4845	0.0856	0.1530	**0.0472**	0.6262	0.7304

(Significant p values are in bold type. Factors found to be significant in the overall analysis are in bold and underlined type.)

Table 17. P values by individual events for reaction distance, older driver, clear weather assessment.

	Event														
Effect	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Time	0.1010	0.9495	0.4037	0.2120	0.8116	0.6730	0.1159	0.0919	0.0831	0.3763	0.1552	0.1416	0.7892	0.5974	0.8954
ISIS	**0.0030**	0.1212	**0.0011**	**0.0015**	**0.0079**	**0.0002**	**0.0017**	**0.0005**	**0.0007**	0.0985	**0.0001**	**0.0001**	**0.0001**	0.0546	**0.0001**
Time*ISIS	0.3428	0.1777	0.5501	0.0594	0.3707	0.7512	0.4522	0.2309	0.2795	0.8577	0.7221	**0.0297**	0.2192	0.9932	0.1496

(Significant p values are in bold type. Factors found to be significant in the overall analysis are in bold and underlined type.)

Subjective Preference Data

Mean subject responses to the preference questions are listed in table 18 by ISIS use.

Table 18. Mean subjective question responses by ISIS (older driver, clear weather).

Question	ISIS	No ISIS
No. 1: How aware of road sign information were you during the drive? (1=Not Aware, 7=Extremely Aware)	6.7500	5.8182 *
No. 2: How timely was the presentation of the road sign information during the drive? (1=Not Timely, 7=Extremely Timely)	6.4167	5.3636 *
No. 3: How safe did you feel during the drive? (1=Extremely Safe, 7=Extremely Unsafe)	3.2727	2.5833
No. 4: How difficult was it to gather road sign information during the drive? (1=Not Difficult, 7=Extremely Difficult)	1.2500	2.0000
No. 5: How distracting was the road sign information during the drive? (1=Not distracting, 7=Extremely Distracting)	1.7500	1.2727
No. 6: I would find such a system as this to be useful to me while driving. (1=Strongly agree, 7=Strongly disagree)	1.5833	2.3636
No. 7: I would find a system such as this to be a desirable option in my car. (1=Strongly agree, 7=Strongly Disagree)	1.8333	2.5455

(*indicates significance under ANOVA. See appendix B, tables 49 to 55.)

The older, clear weather drivers felt that they were more aware of the information and that the information was more timely when they used the ISIS system.

Time was found to be significant for question 1, with the daytime drivers reporting that they were more aware of sign information (mean=6.6000) than the nighttime drivers (mean=5.7500). This indicates that older drivers have more problems detecting road sign information at night.
Time was also found to be significant for question 6, with the nighttime drivers feeling that the system would be more useful (mean=1.2500) than the daytime drivers (mean=2.3333).

OLDER DRIVER, DAYTIME ASSESSMENT

Examining the older driver, daytime data allowed investigation of the relationship between weather and ISIS. The variables are defined identically to the way they were defined in the above assessments. Participants by experimental condition can be seen in table 19.

Table 19. Participants by experimental condition for the older driver, daytime assessment.

	Clear	Rain
ISIS	5	3
No ISIS	5	2

Event End Speed

For this subset of data, ISIS, F(1,11)=8.53, p=0.0139, was found to have a significant effect on end event speed across all events. End event speeds were significantly lower under the ISIS condition (mean=27.17) than under the no ISIS condition (mean= 31.40) (the complete ANOVA table can be found in appendix B, table 56).

An examination of individual events for significant effects can be found in table 20. This examination showed that the ISIS display was a significant factor for event 3, the marked reverse turn; event 4, the marked winding road; event 5, the marked reverse curve; event 6, the marked speed limit 35 MPH; event 9, the marked "Y" curve; event 13, the marked one-lane bridge; and events 14 and 15, unmarked reverse curves. This set of events is similar to the set of events found for the older driver, clear weather assessment of end event speed. As shown, the ISIS display appears to impact end event speed for the marked advisory signs. One difference between these sets of data, however, is the significant effect of ISIS on events 14 and 15 found here. It appears as if the ISIS system can also lead to reduced end event speeds for unmarked events as well.

No additional patterns with respect to event type or geometry were found in the examination of the significant effects for each event.

Maximum Deceleration

No significant effects on maximum deceleration across all events were discovered for this subset (for the complete ANOVA table, please see appendix B, table 57). An examination of individual events revealed the significant effects seen in table 21. No patterns were revealed by the significant effects found for events 8 and 11.

Reaction Distance

ISIS, F(1,11)=202.39, p=0.0001, was found to have a significant effect on reaction distance across all events for this subset of data. A mean reaction distance of 225.10 feet was found for those drivers who did not have the ISIS system, and a mean reaction distance of 422.48 feet was found for those drivers who did have the ISIS system (a complete ANOVA table can be found in appendix B, table 58).

Significant p values for individual events can be seen in table 22. ISIS was found to be significant for all events except event 10, the marked yield. This would indicate that the ISIS display can provide a benefit to older drivers in terms of increased reaction distance for marked or unmarked regulatory and advisory events.

Weather was found to be significant for event 13, marked one-lane bridge, event 14, unmarked reverse curve, and event 15, unmarked reverse curve. This significance may be a result of the nature of the event (unmarked) for events 14 and 15, or the geometry of the road for all three events. This may indicate that older drivers may receive a greater benefit under adverse conditions when the roadway is poorly marked and the geometry is severe.

No additional patterns were found when examining the individual sign data.

Table 20. P values by individual events for end event speed, older driver, daytime assessment.

	Event														
Effect	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Weather	0.4540	0.7239	0.0977	0.1459	**0.0333**	0.2367	0.1856	0.3725	0.8893	0.1428	0.8709	0.2872	0.2238	0.0819	0.0570
ISIS	0.4861	0.5088	**0.0034**	**0.0395**	**0.0001**	**0.0127**	0.1715	0.4248	**0.0031**	0.3943	0.7735	0.2007	**0.0166**	**0.0065**	**0.0214**
Weather*ISIS	0.5489	0.8012	0.5808	0.7733	0.2381	0.8099	0.5615	0.9497	0.4628	0.4165	0.5557	0.8502	0.9169	0.1072	0.1183

(Significant p values are in bold type. Factors found to be significant in the overall analysis are in bold and underlined type.)

Table 21. P values by individual events for maximum deceleration, older driver, daytime assessment.

	Event														
Effect	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Weather	0.8903	0.2729	0.4370	0.5843	0.6302	0.7031	0.3947	0.2832	0.6882	0.5341	0.9090	0.5134	0.0816	0.7928	0.6927
ISIS	0.6997	0.9652	0.2990	0.0713	0.1666	0.1618	0.7030	**0.0230**	0.2086	0.1555	**0.0087**	0.1860	0.0540	0.1183	0.9605
Weather*ISIS	0.1586	0.8238	0.7655	0.5235	0.0632	0.8975	0.9976	0.2320	0.6371	0.6650	0.6020	0.4307	0.1596	0.9145	0.5096

(Significant p values are in bold type. Factors found to be significant in the overall analysis are in bold and underlined type.)

Table 22. P values by individual events for reaction distance, older driver, daytime assessment.

	Event														
Effect	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Weather	0.8060	0.4501	0.1840	0.9611	0.7724	0.9219	0.0836	0.4128	0.6347	0.8970	0.7544	0.2041	**0.0422**	**0.0221**	**0.0083**
ISIS	**0.0012**	**0.0289**	**0.0020**	**0.0001**	**0.0024**	**0.0001**	**0.0026**	**0.0017**	**0.0007**	0.2572	**0.0003**	**0.0001**	**0.0001**	**0.0049**	**0.0001**
Weather*ISIS	0.4268	0.9841	0.4275	0.1847	0.6291	0.8734	0.3171	0.5516	0.7197	0.6606	0.5301	0.2616	0.1932	0.0605	0.1891

(Significant p values are in bold type. Factors found to be significant in the overall analysis are in bold and underlined type.)

Subjective Preference Data

Subject responses to the preference questions, by ISIS use, are listed in table 23.

Table 23. Mean subjective question responses by ISIS (older driver, daytime).

Question	ISIS	No ISIS
No. 1: How aware of road sign information were you during the drive? (1=Not Aware, 7=Extremely Aware)	6.7500	5.8182 *
No. 2: How timely was the presentation of the road sign information during the drive? (1=Not Timely, 7=Extremely Timely)	6.4167	5.3636
No. 3: How safe did you feel during the drive? (1=Extremely Safe, 7=Extremely Unsafe)	2.5830	3.2730
No. 4: How difficult was it to gather road sign information during the drive? (1=Not Difficult, 7=Extremely Difficult)	1.2500	2.0000
No. 5: How distracting was the road sign information during the drive? (1=Not distracting, 7=Extremely Distracting)	1.7500	1.2727
No. 6: I would find such a system as this to be useful to me while driving. (1=Strongly agree, 7=Strongly disagree)	1.5833	2.3636 *
No. 7: I would find a system such as this to be a desirable option in my car. (1=Strongly agree, 7=Strongly Disagree)	1.8333	2.5455 *

(* indicates significance in the ANOVA. See appendix B, tables 59-65 for complete table.)

The older, daytime drivers felt that they were more aware of road sign information with the ISIS than without. They also indicated that the ISIS system was more useful and was a more desirable option when they actually drove with the system.

Weather was found to be a significant factor for question 6, with clear weather drivers finding the system more useful (mean=1.6471) than the rainy weather drivers (mean=2.8333). The same effect was found for question 7, with clear weather drivers finding the system more desirable (mean=1.8824) than the rainy weather drivers (mean=3.0000). These results may indicate a problem with the ISIS system under rainy conditions, such as an older driver concern for systems that would take their attention away from the road during adverse conditions.

CONCLUSIONS

Recall from the Introduction that five research questions were posed concerning the benefits of an ISIS display: (1) Are there, in general, benefits associated with an ISIS system? (2) Will additional benefits be realized under adverse weather conditions? (3) Will additional benefits be realized during night driving? (4) Will older drivers gain additional benefits from such a system? and (5) Does the system adversely impact driver performance or behavior?

BENEFITS ASSOCIATED WITH ISIS USE

Use of the ISIS display resulted in a clear benefit for all four subsets of data. Drivers from all four groups had lower end event speeds when using the ISIS system. It is hypothesized that these lower end event speeds may indicate an increased level of situation awareness and therefore safety.

Another benefit was found in the reaction distances of the drivers. Drivers from all four subsets showed increased reaction distances when using the ISIS display. Again, increased reaction distances would indicate an increased level of safety. It must be noted, however, that the ISIS system was engaged approximately 5 seconds before the event or existing road sign. Therefore, any benefits associated with the system must be considered with this advance warning in mind. It is unknown if the same benefits would be shown with earlier or later activation of the ISIS system.

It can be further concluded that the ISIS display provided a benefit to drivers regardless of the type of event. Lower end event speeds and increased reaction distances were found for both marked and unmarked events. It is also interesting to note that increased reaction distances were seen for both regulatory (stop and yield) situations and advisory (winding road and curve) situations.

Subjectively, three of the four groups (the clear weather, younger, and older, clear weather drivers) felt that the ISIS display made them more aware of road sign information, and that the presentation of such information was more timely. Two of the four groups (clear weather and younger) felt that it was easier to gather information with the ISIS display.

ADDITIONAL BENEFITS UNDER ADVERSE WEATHER CONDITIONS

Recall from the Introduction that external conditions such as rain, snow, or fog can adversely affect driving performance for a variety of reasons. Note that although the ISIS display still impacted end event speed and reaction distance during the rain condition, no additional benefits were realized across all four subsets for all events under adverse weather conditions.

For one subset, the younger drivers, the weather appeared to affect ISIS use with respect to maximum deceleration, with a higher maximum deceleration with the ISIS in the rain. This increased deceleration would tend to indicate less attention to the roadway and a less safe condition. This effect may be a result of the perception of risk during rainy weather driving and driver reaction to the ISIS; under the poor weather conditions, the younger drivers responded more quickly to the system.

Subjectively, the older, daytime, clear weather drivers found the system to be more useful than did their rainy-weather counterparts. This may indicate that the system is made redundant by the older drivers' caution during poor weather, or that the older drivers are concerned with a system that takes their attention away from the roadway during bad weather.

ADDITIONAL BENEFITS DURING NIGHT DRIVING

Recall from the Introduction that nighttime driving is associated with an increased risk of a crash, and that reduced visibility and glare may pose a problem for drivers of all ages. The clear weather subset of drivers displayed lower end event speeds at night, which may be indicative of their increased caution. For the younger drivers, a similar effect was discovered, with greater reaction distances being found at night. Although the same general benefits discussed above were again found here, in general, no additional benefits were realized during night driving.

There is, however, some evidence that additional benefits may be realized on an individual event basis at complex, unfamiliar, or low visibility events. As an example, the Age and ISIS interaction found for reaction distance for the clear weather subjects showed this effect.

Subjectively, the older drivers report that they are more aware of road sign information during the day than at night. This may explain why few of the older persons contacted during this study were willing to drive at night; they are aware of their reduced ability to drive at night and are therefore less willing to do so. The older drivers also report the ISIS system to be more useful at night, which again may be a result of their decreased visual ability at night.

ADDITIONAL BENEFITS FOR OLDER DRIVERS

Older drivers experienced the same benefits as described above. Examination of individual events seems to indicate that older drivers will realize greater benefits from an ISIS display for environmentally complex situations. Recall from the Introduction that older drivers may experience reduced cognitive and sensory abilities. This may explain the increased benefit seen at complex events. Further research is recommended to examine the effect that an ISIS display will have based on event complexity.

ADVERSE SYSTEM IMPACT ON BEHAVIOR OR PERFORMANCE

No adverse performance or behavioral effects were found across all four subsets for all events. Use of the ISIS system did not interfere with the drivers' ability to control the vehicle and successfully respond to verbal directions and events as they occurred. None of the drivers appeared to defer to the system or to respond inappropriately to the information presented on the display.

The results of examination of individual events were in agreement with the overall picture. The drivers were able to successfully respond to all of the 15 individual events (one problem was discovered with the complex intersection for event 9, but the problem was not dependent on ISIS use or any of the other factors in this experiment). Given the nature of the information (low density) and the fact that presentation of the information was preceded by a warning tone, it is not surprising that driver performance or behavior was not impacted by the system.

One notable point is that the younger subjects found the attention signal of the ISIS display to be distracting and annoying, as did the older, daylight subjects. The older, clear weather subjects did not report the same level of distraction. This would seem to indicate that the preferred attention signal may be age-dependent (as may the preferred modality of the display).

RECOMMENDED ISIS GUIDELINES

Based on the results of this experiment, the following guidelines are recommended for ISIS use:

1. Designers of future ATIS systems should strongly consider including ISIS features. There appear to be ISIS benefits and no detriments due to ISIS use (e.g., figure 4).

2. The ISIS display should be activated so that drivers have sufficient time to perceive and interpret the display, determine the appropriate response, and execute that response. In this study, the ISIS system was engaged approximately 3 to 5 seconds before an event, which appears to provide an ISIS benefit and results in a high level of driver acceptance.

3. A warning or attention signal should be provided to minimize the distraction from the driving task caused by the system. The signal given in this experiment appeared to allow the drivers to focus on the driving task until a new piece of information was presented to them.

4. Drivers should be able to adjust the volume of the attention signal within a given range. In this experiment, a number of drivers felt that the attention signal was too loud and distracting. Allowing the drivers to adjust the volume of such a signal (but not set it so low that it cannot be heard, or turn it off) will reduce this annoyance and distraction.

5. Drivers should be able to control what information appears on the ISIS display. This experiment showed that some drivers may benefit from additional warnings in specific situations, while others may not. Allowing the driver to tailor the system to his or her personal needs would increase the efficiency, use, and acceptance of the system.

Future Research

From the results of this experiment, several areas for future research can be identified:

1. Research to address the benefits and problems associated with different timing could be conducted in order to determine the optimal point at which the system should be activated.

2. The effect of environmental information density on ISIS benefits should be examined. In the present research, the environmental information density was such that only two or

three signs were present in the external environment. In situations with higher density, such as in the downtown area of a major city, several signs may appear in close proximity. Drivers may find it difficult to extract the one piece of information they need given such high density. It is possible that additional benefits may be realized when using an ISIS display under such conditions. Also of interest is the integration of such a system with other IVIS technologies, such as IVSAWS or IMSIS. In this experiment, the ISIS was the only ATIS information provided. It is reasonable to expect that in actual commercial systems, the ISIS would be an element of a package. The interaction between the ISIS and the other types of systems would be of interest and should be addressed.

3. A further investigation should be conducted of the benefits associated with adverse weather. In this experiment, only rain was considered, and any rain requiring constant use of the windshield wipers of the test vehicle was considered sufficient. It is also possible that different weather conditions (such as fog or snow) or a heavier rain would have led to increased benefits. Future research to operationally define "steady rain" and to investigate the effect of steady rain, fog, and snow is recommended.

4. Few older drivers were willing to drive in the rain, and even fewer were willing to drive in the rain at night. While this cannot be quantified in this experiment, it does seem to indicate that older drivers are aware of their problems during poor weather driving, and choose not to drive under such conditions. This issue, and its impact on older driver mobility, needs to be addressed in further research.

5. Further research is recommended to determine what effect, if any, event complexity has on the benefits associated with ISIS use at night.

6. Research must be undertaken to examine the effect of driver selection of modality, volume, and type of information displayed. Greater (or additional) benefits may be realized when drivers are able to select and set system parameters.

7. Novelty effects were not considered in this experiment. It is possible that some of the differences observed here are due to a novelty effect, and that long-term observations would show reduced benefits or different results.

8. During this experiment, traditional, iconic signs were used on the ISIS. The use of text messages instead of, or in addition to, the iconic images may lead to different results. Also, providing more complex information on the display may affect the results.

APPENDIX A: PROTOCOLS, QUESTIONNAIRES, AND STIMULI

APPENDIX A-1

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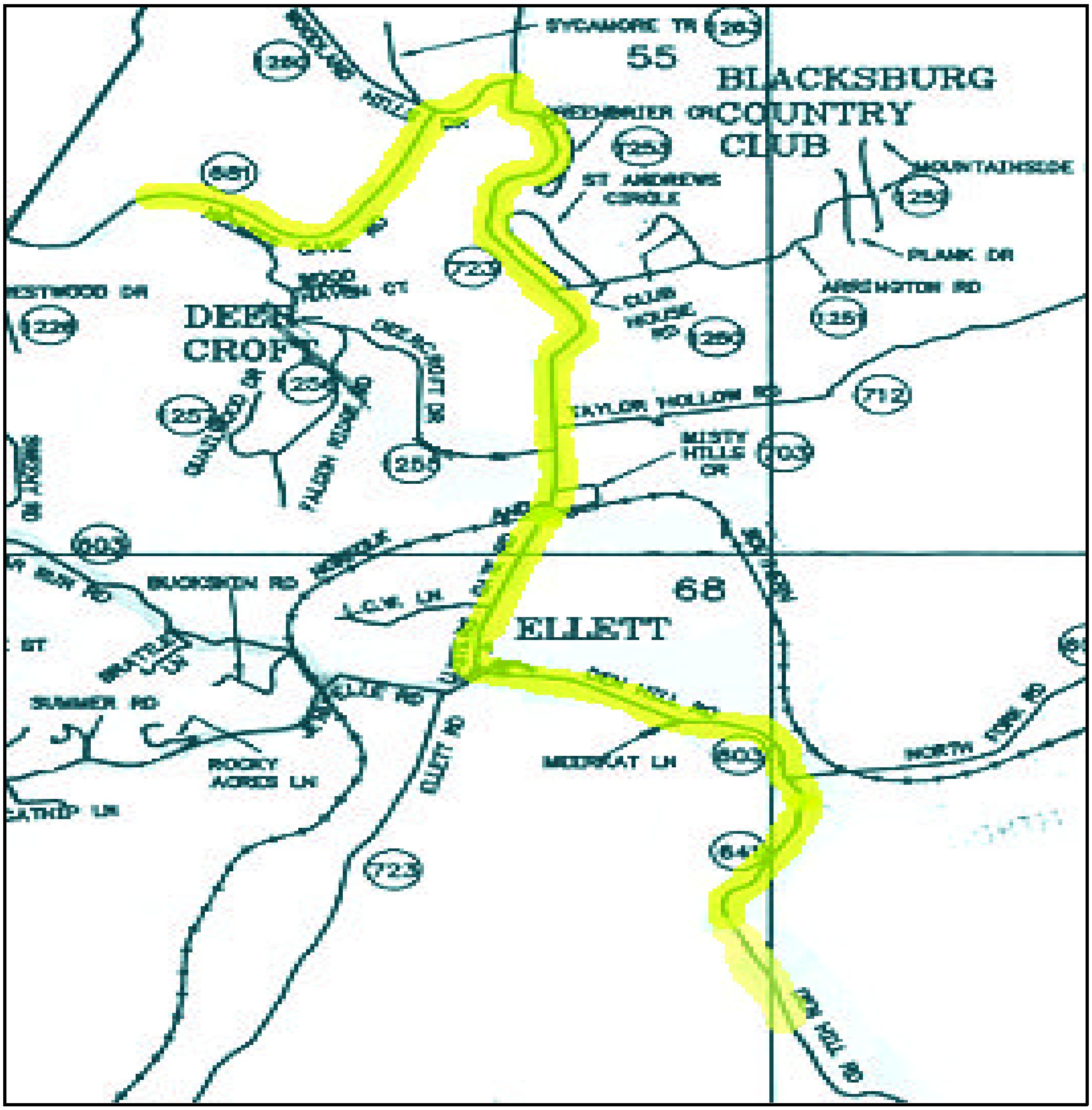

Figure 6. Map of the experimental route and event images.

Figure 7. Event 1: Unmarked stop ahead.

Figure 8. Event 4: Marked winding road.

Figure 9. Event 7: Marked one lane tunnel.

Figure 10. Event 10: Marked yield.

Figure 11. Event 12: Unmarked winding road.

Figure 12. Event 15: Unmarked reverse curve.

APPENDIX A-2

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Table 24. Physical specifications of the Sharp TFT-LCD Module, Model No. LQ64D142.

Parameter	Specification
Display size	16 cm diagonal (6.4 in.)
Active area	130.6 mm (H) x 97.0 mm (V)
Pixel format	640 pixels (H) x 480 pixels (V)
	(1 pixel = R + G + B dots)
Pixel pitch	0.204 mm (H) x 0.202 mm (V)
Pixel configuration	R, G, B, vertical stripe
Display mode	normally white
Unit outline dimensions*	175.0 mm (w) x 126.5 mm (h) x 9.5 mm (d)
Mass	235g ± 15g
Surface treatment	Anti-reflection, hard-coating (2H)
*Excluding back light cables. H = horizontal, V = vertical, w = width, h = height, d = depth.	

APPENDIX A-3

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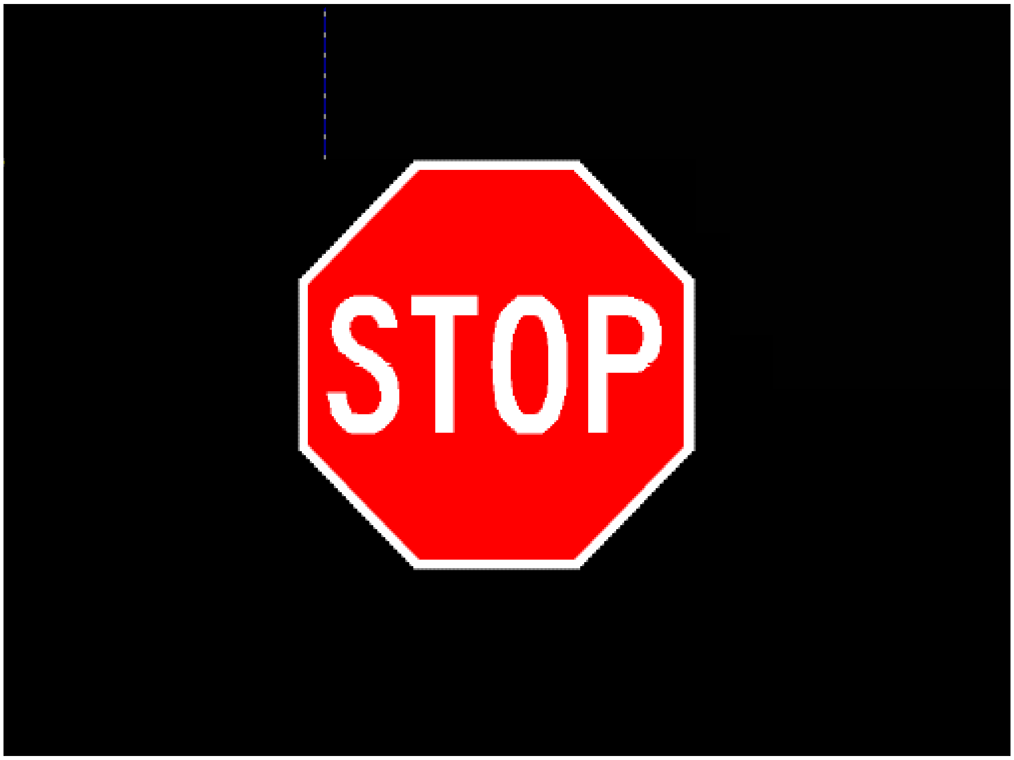

Figure 13. Actual portrayal size of ISIS information.

APPENDIX A-4

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ISIS Images

Image 1: Stop Ahead

Image 2: Stop

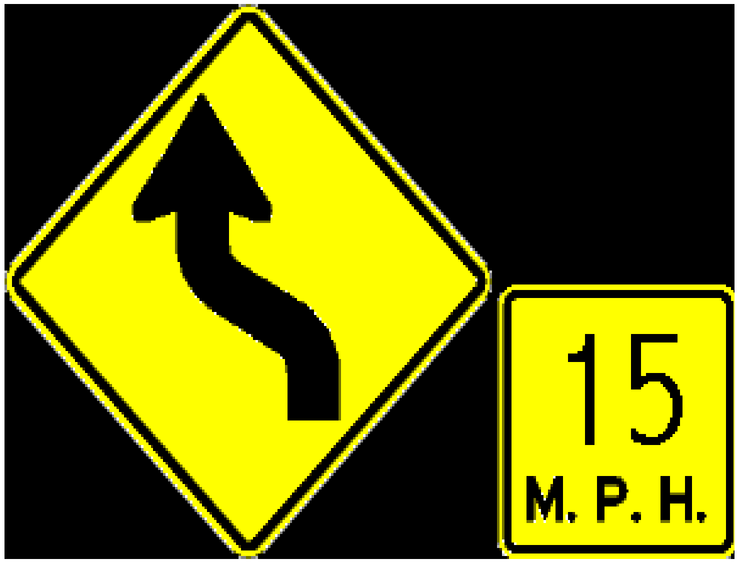

Image 3: 15 MPH Reverse Turn

Image 4: 30 MPH Winding Road

Image 5: 30 MPH Reverse Curve

Image 6: Speed Limit 35 MPH

Image 7: 25 MPH One Lane Tunnel

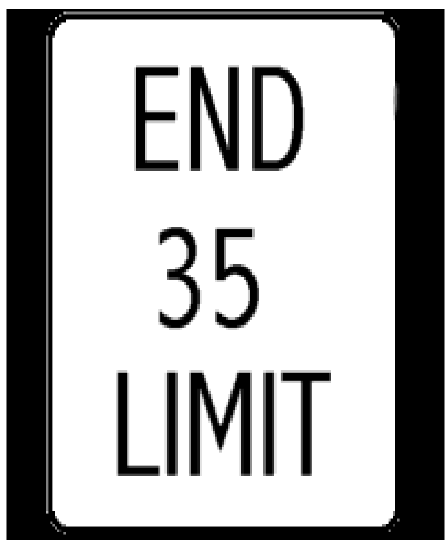

Image 8: End 35 MPH Speed

Image 9: 25 MPH "Y" Curve

Image 10: Yield

Image 11: Curve

Image 12: Winding Road

Image 13: One Lane Bridge

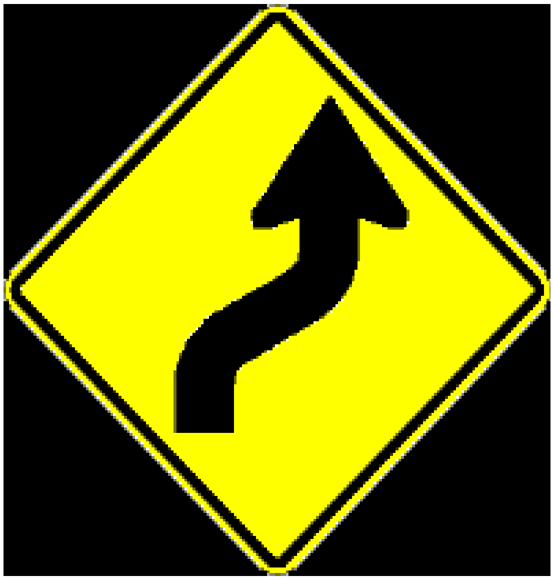

Image 14: Reverse Curve

Image 15: Reverse Curve

APPENDIX A-5

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Screening Questionnaire and Background Information

Participant's Name: _________________________________ **Participant ID: ____**

Participant's Phone: ________ **Gender: ___ (1=M, 2=F)** **Age: ___**

Pass: ______ Fail: ______

ADMINISTERED BY PHONE

NOTE TO INTERVIEWER: Ask the participant the following questions and record his/her responses. Participants are required to have a valid driver's license, drive at least twice a week, and not reveal any health conditions that would indicate increased risk to the driver.

PHONE INTERVIEWER: As part of the study, I need to ask you a few questions. Your answers will determine your eligibility for this study. This data will not be associated with your name, and will be treated confidentially.

1) To participate, you need to have a valid driver's license. Do you have one?
YES NO

2) How many times per week do you drive?

4 + 2 -3 X 1X <1X

3) Approximately how many miles do you drive per year?

______ Under 2,000
______ 2,000 - 7,999
______ 8,000 - 12,999
______ 13,000 - 19,999
______ 20,000 or more

4) What type of automobile do you drive most often?
Make (e.g., Ford, Toyota): ___________________
Model (e.g., Escort, Celica): ___________________
Year: ___________________

5) What level of education have you reached? (Check only one)

- ______ Some High School
- ______ Completed High School / G.E.D.
- ______ Some College
- ______ College Degree
- ______ Some Graduate Work
- ______ Completed Masters Degree
- ______ Completed Doctorate
- ______ Post-Doctorate Work

6) Are you in good general health? YES NO

7) Do you have a history of any of the following?

Visual Impairment YES NO
(If yes, please describe)

____

____

Hearing Impairment YES NO
(If yes, please describe)

____

____

Seizures or other lapses of consciousness YES NO
(If yes, please describe)

____

____

Any other disorders that would impair
your ability to drive YES NO
(If yes, please describe)

____

____

EXPERIMENTER: Also, since you will be driving a car, I need to ask you to refrain from drinking any alcohol for the 24 hours before the experiment. Is this all right with you?

YES NO

PHONE INTERVIEWER: If passes...Now I'd like to schedule a time when you can come to the Center for the study. If fails...Thanks for your time; unfortunately you do not qualify for this particular study. Would you be interested on being put on a participant list for future studies?

* SCHEDULE A TIME DATE AND TIME_________________________________

PHONE INTERVIEWER: Also, since you will be driving a car, I need to ask you to refrain from drinking any alcohol for the 24 hrs before the experiment. Is this all right with you?

YES NO

Thank you, I'll see you? (DATE and TIME). Let me provide you with directions to the Center...

APPENDIX A-6

Center for Transportation Research
Virginia Tech
Task K--Experiment 15

Informed Consent for Participant of Investigative Project

Title of Project: *An Examination of Driver Performance Under Reduced Visibility Conditions When Utilizing an In-vehicle Signing Information System (ISIS)*

Investigators: Dennis J. Collins, Dr. Tom Dingus

I. THE PURPOSE OF THIS RESEARCH/PROJECT

The purpose of this research is to evaluate how drivers perform when using an In-vehicle Signing Information System (ISIS) under a variety of weather conditions. The results of this experiment will help us to design effective, safe, and easy to use in-vehicle systems. The study involves ninety-six drivers of varying age and gender.

II. PROCEDURES

During the course of this experiment you will be asked to perform the following tasks:

1. Read and sign an informed consent form.
2. Answer general and demographic questions.
3. Complete a vision test.
4. Complete a health screening questionnaire.
5. Read general information about the experimental vehicle.
6. Complete a hearing test.
7. Participate in a training session in which you will learn about specific features of the vehicle and perform a test drive of the experimental vehicle until you are comfortable with it and the tasks you will perform as part of this experiment.
8. Perform an experimental drive in the vehicle over a pre-defined route for which data will be collected.
9. Answer questions regarding your preference of the data displayed in the vehicle.

After your experimental run, you will be driven back to the Center for Transportation Research, paid for your time and debriefed.

It is important for you to understand that we are evaluating the ISIS display in the vehicle, not you. Therefore, we simply ask that you perform to the best of your abilities. If you ever feel frustrated with the system, just remember that those are the things we need you to comment on when you complete the preference questionnaire. It is important that we know what you did and did not like. Your preferences provide information that is very important to this project.

III. RISKS

There are some risks and discomforts to which you are exposed in volunteering for this research. These risks are:

1.The risk of an accident normally associated with driving an automobile in light or moderate traffic, under clear or rainy conditions, and on straight and curved roadways.

2.The slight additional risk that an accident may occur while using the ISIS display. Previous research has indicated that this risk is minimal.

3.While you are driving the vehicle, you will be videotaped by cameras. Due to this, we ask that you not wear sunglasses. If, at any time, this impairs your ability to drive the vehicle, you are to notify the experimenter immediately.

The following precautions will be taken to ensure minimal risk to you:

4.The experimenter will monitor you during driving, and will ask you to stop if it is felt the risks are too great to continue. However, as long as you are driving the experimental vehicle, it remains your responsibility to drive in a safe, legal manner.

5.You are required to wear the lap and shoulder belt restraint system any time the vehicle is being operated. The vehicle is also equipped with a driver's side airbag supplemental restraint system.

6.The vehicle is equipped with a fire extinguisher, first-aid kit, and a cellular phone which may be used in an emergency.

7.The experimenter has a brake pedal to override the driver brake pedal to slow or stop the vehicle if necessary.

8.If an accident does occur, the experimenter will arrange medical transportation to a nearby hospital emergency room. You will be required to undergo examination by medical personnel in the emergency room.

9.All data collection equipment is mounted such that, to the greatest extent possible, it does not pose a hazard to you in any foreseeable case.

10.None of the data collection equipment interferes with any part of your normal field of view.

IV. BENEFITS OF THIS PROJECT

There are no direct benefits to you (other than payment). You may, however, find participation interesting. No promise or guarantee of benefits has been made to encourage you to participate. Your participation will make it possible to determine the benefits and hazards associated with ISIS use, and assist in improving safety in vehicles.

V. EXTENT OF ANONYMITY AND CONFIDENTIALITY

The data gathered in this experiment will be treated with confidentiality. After you have completed the experiment, your name will be removed from the data. Only a code will be used to identify the data. You are allowed to see your data and may remove it from the experiment. You must immediately inform the experimenter of this decision, as it will be difficult (or impossible) to track your data once the session is over. During the experiment, your eye movements will be videotaped by a camera. These video tapes will be stored in a locked filing cabinet at the Virginia Tech Center for Transportation Research, under the supervision of Dr. Thomas A. Dingus. Dennis J. Collins will have access to the tapes for the purposes of analysis. The tapes will be destroyed three months after the data has been analyzed and the results written up (approximately May 1997). At no time will the researchers release the results of the study to anyone other than individuals working on the project without your written consent.

VI. COMPENSATION

You will receive $__________ per hour for your participation in this experiment. This payment will be made to you at the end of your voluntary participation for the portion of the study that you complete.

VII. FREEDOM TO WITHDRAW

You are free to withdraw from this study at any time for any reason. Further, you are free to not answer any questions or respond to any experimental situations without penalty.

VIII. APPROVAL OF RESEARCH

This research has been approved, as required, by the Institutional Review Board for projects involving human subjects at Virginia Polytechnic Institute and State University, and by the Department of Industrial and Systems Engineering.

X. SUBJECTS RESPONSIBILITIES AND PERMISSION

I voluntarily agree to participate in this study, and I know of no reason I cannot participate. I have read and understand the informed consent and conditions of this project. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent for participation in this project. If I participate, I may withdraw at any time without penalty. I agree to abide by the rules of this project

____ __________
Signature Date

____
Name (please print)

Should I have any questions about this research or its conduct, I may contact:

Dennis J. Collins, Investigator
Phone: (540) 552-6461
Dr. Tom Dingus, Director, Center for Transportation Research
Phone: (540) 231-8831
T. H. Hurd, Director of Sponsored Programs
Phone: (540) 231-5281

APPENDIX A-7

Center For Transportation Research
Virginia Tech
Task K--Experiment 15

Health Screening Questionnaire

SUBJECT NUMBER: ____________

1. Are you in good general health? YES NO

If no, please list any health-related conditions your are experiencing or have experienced in the recent past.

____
____
____

2. Have you, in the last 24 hours, experienced any of the following conditions?

Inadequate sleep	YES	NO
Unusual hunger	YES	NO
Hangover	YES	NO
Headache	YES	NO
Cold Symptoms	YES	NO
Depression	YES	NO
Allergies	YES	NO
Emotional upset	YES	NO

3. Please list any prescription or non-prescription drugs you are currently taking or have taken in the last 24 hours.

____
____
____

4. List the approximate amount of alcohol (beer, wine, fortified wine, or liquor) you have consumed in the last 24 hours.

____
____
____

5. Are you taking any drugs of any kind other than those listed above? YES NO

6. If you are female, are you pregnant? YES NO

______________________________ ____________
Signature Date

APPENDIX A-8

Center for Transportation Research
Virginia Tech
Task K--Experiment 15

Experimenter Protocol for Assessment of Subject Suitability: Informed Consent, Proof of License, Health Screening, Vision Test, and Hearing Test

1. Greet Participant

2. Informed Consent

The first thing you need to do is to read and complete an Informed Consent form. It outlines what is expected of you during this experiment and what you can expect of the researchers. Please read it carefully. If you have any questions, please ask. When done, and all your questions have been answered, please sign and date the form if you agree to participate.

3. Give informed consent to participant.
   - Answer any questions the participant may have.
   - Have participant sign and date form.
   - Give participant a copy of the informed consent.

4. Show driver's license. Must be valid. Out of state is okay.

5. Administer "Health Screening Questionnaire"

This is a health questionnaire. Your answers to these questions will be treated confidentially. We ask these questions to ensure that driving the experimental vehicle will not pose a greater than normal risk to you.

6. Give health screening questionnaire to the participant.
   - Answer any questions the participant may have.
   - Have the participant sign and date the form.

NOTE TO EXPERIMENTER: The participant must be in good general health, have revealed no conditions and be taking no medication that would adversely affect their driving, have not been drinking, and must not be pregnant.

7. Vision Test

Follow me, and I'll administer the vision test.

- Take the subject to the Snellen chart in the ITS lab.
- Have the subject place his or her toes on the back edge of the tape line on the floor.
- Make sure the subject is wearing the glasses or contacts they wear while driving.

Look at the wall and read aloud the smallest line you can comfortably make out.

- If the subject reads every letter on their 1st line correctly, have them try the next line.
- Repeat this until they miss a letter, and record the acuity of the last line they got completely correct.
- If the subject does not correctly read every letter on their first line correctly, move up a line and have them try again.
- Repeat as needed and record the acuity of the first line they get completely correct.

Acuity Score: _____________

8. Hearing Test (administered in car with engine running).

I'm going to read a short list of words to you one at a time. After I say a word, please repeat it back to me. Do you have any questions?

- Read the following list of words to the subject:

	CORRECT	INCORRECT
STOP	_____________	_____________
TURN	_____________	_____________
LEFT	_____________	_____________
RIGHT	_____________	_____________
BEGIN	_____________	_____________
INTERSECTION	_____________	_____________

<u>SCORING</u>

In order to participate, the subject must:

1) Have a valid driver's license.
2) Have visual acuity of 20/40 or better.
3) Pass the health screening questionnaire.
4) Pass a hearing test.

If a subject does not qualify, thank them for their time, pay them for their time, and let them go.

APPENDIX A-9

Center for Transportation Research
Virginia Tech
Task K--Experiment 15

Vehicle Briefing, ISIS Preview, and Final Instructions

1. Vehicle Briefing

Before we begin, I'd like to tell you that I'll be reading from a script for much of our time together. This ensures that I won't forget to tell you something you'll need to know. So, if I sound formal at times, please understand that this is a requirement of the study.

- Have the participant sit in the driver's seat of the car.

Please adjust the seat so you are comfortable and can see the entire dashboard. Then, please fasten your seat belt and adjust the left, right, and rearview mirrors to your liking.

Next, we'd like to take a few minutes to familiarize you with the experimental vehicle. Since this car may be different from your car, we'd like to show you some of the controls you may need during your drive. As I point to each control and explain how it works, I'd like you to operate it.

- Identify and demonstrate the following controls:

  Windshield Wipers
  Lights
  Horn
  Turn Signals
  Defrosters
  Defoggers

Also, please note that this car is equipped with Anti-Lock Brakes (ABS) and airbags for your safety. Do you understand how these technologies work?

- If the subject is not familiar with one (or both), explain how they operate

In addition to those safety features, the front seat experimenter will have access to an emergency brake pedal which he will use in case of an emergency. Do you have any questions about this safety feature?

- Answer any questions and continue.

2. ISIS Preview

If the participant will be driving with the ISIS display:

This car is equipped with an In-vehicle Signing Information System, or ISIS. This system displays information currently found on road side signs. This information can be advisory, such as curve or winding road signs, or regulatory, such as stop or speed limit signs. This system consists of the display in the dashboard and a computer in the trunk which runs the ISIS software. Using a positioning system, the software can track your position and provide the appropriate signs. Please obey all speed limits and follow the directions associated with the other signs. The front seat experimenter will assist you be giving you navigation information during the drive. Do you have any questions?

- Answer any questions and continue.

Now I will show you examples of the types of signs you may encounter during your drive. Please review these pictures, and if you are not sure of the meaning of any of the signs, please ask.

- Show example pictures to participant.

When new ISIS information is displayed on the screen, the computer provides an attention signal. I will play a sample signal so you will know what it sounds like.

- Play sample tone.

Do you have any questions about the display, the tone, or the ISIS system in general?

- Answer any questions.

3. Final Instructions

Now we're ready to begin the experiment. If, at any time, you feel unsafe or that the task is too difficult, please stop. It is very important that you follow all posted speed limits and advisory signs (including those appearing on the display). Although we will be in the vehicle, neither <name> (name of front seat experimenter) or I will be able to speak to you for the duration of the experimental run except to give you directions or to answer your specific questions about the experiment, the car, or the roadway. The first part of the drive is a "warm-up" to allow you to become familiar with the car. Do you have any questions?

- Answer any questions and continue.

You can begin driving whenever you are ready. Just continue down this road. <Name> (front seat experimenter) will give you directions as you go.

After completion of the experiment:

- Return to CTR
- Administer the preference questionnaire.
- Pay and debrief the participant. Make sure the payment log is signed.
- Answer any questions about the study in general.
- Thank them for participating.

APPENDIX A-10

Center for Transportation Research
Virginia Tech
Task K-- Experiment 15

Front Seat Experimenter Protocol

The front seat experimenter (secondary experimenter) has two primary tasks during an experimental run. These are:

1. Monitor the environment for unsafe or hazardous conditions that could pose a risk to the participant, experimenters, or experimental vehicle. If such a condition is present, take appropriate action. This action can include, in case of emergency, operation of the experimenter brake located on the floor of the car on the passenger's side.

2. Provide navigational information to the participant during the course of the experiment. The front seat experimenter must have a thorough working knowledge of the route and will provide information on upcoming turns to the participant.

In addition to these tasks during the experiment, the front seat experimenter has the following responsibilities during training:

3. Help participant adjust seat and mirrors, if needed.

4. Perform vehicle briefing.

APPENDIX A-11

Center for Transportation Research
Virginia Tech
Task K--Experiment 15

Rear Seat Experimenter Protocol

The rear seat experimenter (primary experimenter) has four primary tasks during an experimental run.

1. Set up the vehicle for the experiment. Specific tasks include:
   (1) Connect all computer cables.
   (2) Power up trunk (ISIS computer).
   (3) Power up data collection computer.
   (4) Connect video monitor.
   (5) Power up video monitor.
   (6) Load video cassette.

2. Initialize data collection at the end of the "warm-up" drive. Specific tasks include:
   (1) Enter subject number.
   (2) Enter experiment number.
   (3) Enter weather condition.
   (4) Enter time of day.
   (5) Enter age group of participant.
   (6) Enter ISIS condition.
   (7) Begin data collection.

3. Activate ISIS at pre-determined points and flag the data set. As the experimental vehicle passes the appropriate landmark, the rear seat experimenter must activate the next ISIS screen (if the participant is under the ISIS condition) and insert a flag into the data stream to mark the start and end of a data interval.

4. Monitor the video and data feeds for problems. If there is a problem with either, the rear seat experimenter is to stop the experiment at once.

In addition, the rear seat experimenter has three tasks during training:

5. Administer the hearing test.

6. Administer the ISIS Preview.

7. Administer the Final Instructions.

APPENDIX A-12

Center for Transportation Research
Virginia Tech
Task K--Experiment 15

Preference Questionnaire

Please read the following questions and circle the number that best describes how you feel.

1. How aware of road sign information were you during the drive?

1	2	3	4	5	6	7
Not Aware						Extremely Aware

2. How timely was the presentation of road sign information during the drive?

1	2	3	4	5	6	7
Not Timely						Extremely Timely

3. How safe did you feel during the drive?

1	2	3	4	5	6	7
Extremely Safe						Extremely Unsafe

4. How difficult was it to gather road sign information during the drive?

1	2	3	4	5	6	7
Not Difficult						Extremely Difficult

5. How distracting was the road sign information during the drive?

1	2	3	4	5	6	7
Not Distracting						Extremely Distracting

A system is being designed to display road sign information in a vehicle, such as stop ahead, speed limits, and winding road warnings. This information will be displayed in a timely manner on the dashboard of the vehicle. Please provide your opinion about such a system by answering the following questions:

6. I would find such a system as this to be useful to me while driving.

1	2	3	4	5	6	7
Strongly Agree						Strongly Disagree

7. I would find a system such as this to be a desirable option in my car.

1	2	3	4	5	6	7
Strongly Agree						Strongly Disagree

APPENDIX A-13

Center for Transportation Research
Virginia Tech
Task K--Experiment 15

Table 25. ISIS and visible distances.

Event No.	Description	Type	ISIS distance (feet)	Visible distance (feet)
1	Stop Ahead	Unmarked	238	N/A
2	Stop	Marked	162	130
3	15 MPH Reverse Curve	Marked	254	254
4	30 MPH Winding Road	Marked	341	297
5	30 MPH Reverse Curve	Marked	793	793
6	Speed Limit 35 MPH	Marked	605	491
7	25 MPH One Lane Tunnel	Marked	420	344
8	End 35 MPH Limit	Marked	592	430
9	25 MPH "Y" Curve	Marked	1104	431
10	Yield	Marked	419	419
11	Curve	Unmarked	634	N/A
12	Winding Road	Unmarked	518	N/A
13	One Lane Bridge	Marked	780	530
14	Reverse Curve	Unmarked	528	N/A
15	Reverse Curve	Unmarked	525	N/A

APPENDIX B: ANALYSIS OF VARIANCE TABLES

Center for Transportation Research
Virginia Tech
Task K -- Experiment 15

Table 26. Analysis of variance table for end event speed, clear weather assessment, all events.

Independent Variable	df	MS	F	p
Age	**1**	**740.46**	**8.48**	**0.0067**
Time	1	42.80	0.49	0.4893
ISIS	**1**	**1819.96**	**20.84**	**0.0001**
Age*Time	1	49.96	0.57	0.4554
Age*ISIS	1	15.34	0.18	0.6782
Time*ISIS	1	53.79	0.62	0.4388
Age*Time*ISIS	1	29.53	0.34	0.5653
Subjects(Age*Time*ISIS)	30	87.34	-	-

Table 27. Analysis of variance table for maximum deceleration, clear weather assessment, all events.

Independent Variable	df	MS	F	p
Age	1	0.00	0.06	0.8017
Time	1	0.00	0.89	0.3539
ISIS	1	0.00	1.18	0.2865
Age*Time	1	0.00	0.48	0.4933
Age*ISIS	1	0.01	2.83	0.1028
Time*ISIS	1	0.01	1.58	0.2180
Age*Time*ISIS	1	0.01	1.79	0.1904
Subjects(Age*Time*ISIS)	30	0.00	-	-

Table 28. Analysis of variance table for reaction distance, clear weather assessment, all events.

Independent Variable	df	MS	F	p
Age	1	21989.45	2.52	0.1228
Time	**1**	**129922.05**	**14.90**	**0.0006**
ISIS	**1**	**3296887.66**	**378.02**	**0.0001**
Age*Time	1	5886.19	0.67	0.4178
Age*ISIS	**1**	**94972.94**	**10.89**	**0.0025**
Time*ISIS	1	553.75	0.06	0.8028
Age*Time*ISIS	1	31512.22	3.61	0.0670
Subjects(Age*Time*ISIS)	30	8721.50	-	-

Table 29. Analysis of Variance table for subjective preferences, clear weather assessment. Question 1: How aware of road sign information were you during the drive?

Independent Variable	df	MS	F	p
Age	1	0.58	0.85	0.3649
Time	**1**	**3.14**	**4.61**	**0.0399**
ISIS	**1**	**11.36**	**16.71**	**0.0003**
Age*Time	1	1.13	1.66	0.2069
Age*ISIS	1	0.60	0.88	0.3560
Time*ISIS	1	0.11	0.16	0.6918
Age*Time*ISIS	1	1.12	1.65	0.2092
Subjects(Age*Time*ISIS)	30	0.68	-	-

Table 30. Analysis of variance table for subjective preferences, clear weather assessment. Question 2: How timely was the presentation of road sign information during the drive?

Independent Variable	df	MS	F	p
Age	**1**	**6.82**	**5.91**	**0.0213**
Time	1	0.00	0.00	0.9774
ISIS	**1**	**31.31**	**29.73**	**0.0001**
Age*Time	1	1.05	0.91	0.3471
Age*ISIS	1	1.60	1.39	0.2478
Time*ISIS	1	0.99	0.86	0.3610
Age*Time*ISIS	1	1.37	1.19	0.2843
Subjects(Age*Time*ISIS)	30	1.16	-	-

Table 31. Analysis of variance table for subjective preferences, clear weather assessment. Question 3: How safe did you feel during the drive?

Independent Variable	df	MS	F	p
Age	1	0.23	0.05	0.8288
Time	1	4.14	0.87	0.3587
ISIS	1	0.13	0.03	0.8699
Age*Time	1	0.61	0.13	0.7239
Age*ISIS	1	5.07	1.06	0.3106
Time*ISIS	1	3.63	0.76	0.3899
Age*Time*ISIS	1	0.23	0.05	0.8280
Subjects(Age*Time*ISIS)	30	4.77	-	-

Table 32. Analysis of variance table for subjective preferences, clear weather assessment. Question 4: How difficult was it to gather road sign information during the drive?

Independent Variable	df	MS	F	p
Age	1	5.60	3.25	0.0814
Time	1	2.33	1.35	0.2544
ISIS	**1**	**14.30**	**8.30**	**0.0073**
Age*Time	1	0.00	0.00	0.9655
Age*ISIS	1	0.68	0.39	0.5355
Time*ISIS	1	0.23	0.13	0.7188
Age*Time*ISIS	1	1.02	0.59	0.4486
Subjects(Age*Time*ISIS)	30	1.72	-	-

Table 33. Analysis of variance table for subjective preferences, clear weather assessment. Question 5: How distracting was the road sign information during the drive?

Independent Variable	df	MS	F	p
Age	**1**	**6.86**	**6.23**	**0.0183**
Time	1	0.75	0.68	0.4170
ISIS	1	4.43	4.02	0.0541
Age*Time	1	1.03	0.94	0.3409
Age*ISIS	1	0.78	0.71	0.4058
Time*ISIS	1	0.89	0.81	0.3761
Age*Time*ISIS	1	0.89	0.81	0.3752
Subjects(Age*Time*ISIS)	30	1.10	-	-

Table 34. Analysis of variance table for subjective preferences, clear weather assessment. Question 6: I would find such a system as this to be useful to me while driving.

Independent Variable	df	MS	F	p
Age	1	6.57	3.92	0.0569
Time	1	4.08	2.44	0.1291
ISIS	1	0.11	0.06	0.8013
Age*Time	1	0.03	0.02	0.9032
Age*ISIS	1	1.29	0.77	0.3862
Time*ISIS	1	0.00	0.00	0.9904
Age*Time*ISIS	1	0.99	0.59	0.4479
Subjects(Age*Time*ISIS)	30	1.68	-	-

Table 35. Analysis of variance table for subjective preferences, clear weather assessment. Question 7: I would find a system such as this to be a desirable option in my car.

Independent Variable	df	MS	F	p
Age	1	3.17	1.20	0.2825
Time	1	2.35	0.89	0.3532
ISIS	1	0.06	0.02	0.8834
Age*Time	1	0.41	0.16	0.6960
Age*ISIS	1	0.24	0.09	0.7637
Time*ISIS	1	0.13	0.05	0.8246
Age*Time*ISIS	1	0.01	0.00	0.9449
Subjects(Age*Time*ISIS)	30	2.65	-	-

Table 36. Analysis of variance table for end event speed, younger driver assessment, all events.

Independent Variable	df	MS	F	p
Time	1	10.38	0.13	0.7249
Weather	**1**	**436.30**	**5.31**	**0.0291**
ISIS	**1**	**1070.56**	**13.04**	**0.0012**
Time*Weather	1	92.48	1.13	0.2980
Time*ISIS	1	53.95	0.66	0.4247
Weather*ISIS	1	120.04	1.46	0.2371
Time*Weather*ISIS	1	32.49	0.40	0.5346
Subjects(Time*Weather*ISIS)	27	82.11	-	-

Table 37. Analysis of variance table for maximum deceleration, younger driver assessment, all events.

Independent Variable	df	MS	F	p
Time	1	0.00	0.11	0.7398
Weather	1	0.00	0.09	0.7707
ISIS	1	0.00	0.08	0.7736
Time*Weather	1	0.00	0.02	0.8900
Time*ISIS	1	0.12	2.36	0.1358
Weather*ISIS	**1**	**0.02**	**4.22**	**0.0496**
Time*Weather*ISIS	1	0.01	2.72	0.1105
Subjects(Time*Weather*ISIS)	27	0.01	-	-

Table 38. Analysis of variance table for reaction distance, younger driver assessment, all events.

Independent Variable	df	MS	F	p
Time	**1**	**64388.01**	**6.20**	**0.0192**
Weather	1	6270.08	0.60	0.4438
ISIS	**1**	**1913522.26**	**184.31**	**0.0001**
Time*Weather	1	24109.40	2.32	0.1392
Time*ISIS	1	16364.53	1.58	0.2201
Weather*ISIS	1	627.50	0.06	0.8077
Time*Weather*ISIS	1	3469.19	0.33	0.5680
Subjects(Time*Weather*ISIS)	27	10381.93	-	-

Table 39. Analysis of variance table for subjective preferences, younger driver assessment. Question 1: How aware of road sign information were you during the drive?

Independent Variable	df	MS	F	p
Weather	1	0.30	0.42	0.5222
Time	1	0.28	0.38	0.5415
ISIS	**1**	**17.89**	**24.73**	**0.0001**
Weather*Time	1	0.02	0.03	0.8732
Weather*ISIS	1	0.14	0.19	0.6675
Time*ISIS	1	0.02	0.02	0.8865
Weather*Time*ISIS	1	0.66	0.92	0.3466
Subjects(Time*Weather*ISIS)	27	0.72	-	-

Table 40. Analysis of variance table for subjective preferences, younger driver assessment. Question 2: How timely was the presentation of road sign information during the drive?

Independent Variable	df	MS	F	p
Weather	1	0.02	0.02	0.8917
Time	1	0.88	0.81	0.3775
ISIS	**1**	**35.38**	**32.31**	**0.0001**
Weather*Time	1	3.83	3.50	0.0724
Weather*ISIS	1	0.46	0.42	0.5211
Time*ISIS	1	3.33	3.04	0.0925
Weather*Time*ISIS	1	4.20	3.83	0.0607
Subjects(Time*Weather*ISIS)	27	1.10	-	-

Table 41. Analysis of variance table for subjective preferences, younger driver assessment. Question 3: How safe did you feel during the drive?

Independent Variable	df	MS	F	p
Weather	1	1.03	0.30	0.5858
Time	1	2.37	0.70	0.4093
ISIS	1	2.09	0.62	0.4385
Weather*Time	1	0.15	0.05	0.8322
Weather*ISIS	1	0.11	0.03	0.8601
Time*ISIS	1	3.66	1.08	0.3071
Weather*Time*ISIS	1	0.10	0.03	0.8655
Subjects(Time*Weather*ISIS)	27	0.10	-	-

Table 42. Analysis of variance table for subjective preferences, younger driver assessment. Question 4: How difficult was it to gather road sign information during the drive?

Independent Variable	df	MS	F	p
Weather	1	0.60	0.37	0.5490
Time	**1**	**14.94**	**9.10**	**0.0055**
ISIS	**1**	**20.33**	**12.37**	**0.0016**
Weather*Time	1	6.44	3.92	0.0580
Weather*ISIS	1	0.06	0.04	0.8487
Time*ISIS	1	1.37	0.83	0.3694
Weather*Time*ISIS	**1**	**6.98**	**4.25**	**0.0490**
Subjects(Time*Weather*ISIS)	27	1.64	-	-

Table 43. Analysis of variance table for subjective preferences, younger driver assessment. Question 5: How distracting was the road sign information during the drive?

Independent Variable	df	MS	F	p
Weather	1	1.35	0.95	0.3375
Time	1	0.27	0.19	0.6651
ISIS	**1**	**13.68**	**9.66**	**0.0044**
Weather*Time	1	1.56	1.10	0.3039
Weather*ISIS	1	0.84	0.59	0.4475
Time*ISIS	1	0.82	0.58	0.4535
Weather*Time*ISIS	1	0.76	0.54	0.4696
Subjects(Time*Weather*ISIS)	27	1.42	-	-

Table 44. Analysis of variance table for subjective preferences, younger driver assessment. Question 6: I would find such a system as this to be useful to me while driving.

Independent Variable	df	MS	F	p
Weather	1	0.78	0.44	0.5105
Time	1	4.28	2.44	0.1299
ISIS	1	3.05	1.74	0.1984
Weather*Time	1	0.00	0.00	0.9735
Weather*ISIS	1	0.14	0.08	0.7813
Time*ISIS	1	0.65	0.37	0.5479
Weather*Time*ISIS	1	0.00	0.00	0.9444
Subjects(Time*Weather*ISIS)	27	1.75	-	-

Table 45. Analysis of variance table for subjective preferences, younger driver assessment. Question 7: I would find a system such as this to be a desirable option in my car.

Independent Variable	df	MS	F	p
Weather	1	0.05	0.02	0.8940
Time	1	1.79	0.71	0.4081
ISIS	1	4.71	1.86	0.1841
Weather*Time	1	0.47	0.19	0.6698
Weather*ISIS	1	3.83	1.51	0.2297
Time*ISIS	1	0.02	0.01	0.9220
Weather*Time*ISIS	1	0.00	0.00	0.9596
Subjects(Time*Weather*ISIS)	27	2.54	-	-

Table 46. Analysis of variance table for end event speed, older driver clear weather assessment, all events.

Independent Variable	df	MS	F	p
Time	1	0.22	0.00	0.9653
ISIS	**1**	**677.28**	**6.00**	**0.0292**
Time*ISIS	1	73.67	0.65	0.4336
Subjects(Time*ISIS)	13	112.80	-	-

Table 47. Analysis of variance table for maximum deceleration, older driver clear weather assessment, all events.

Independent Variable	df	MS	F	p
Time	1	0.01	1.31	0.2727
ISIS	1	0.00	0.16	0.6964
Time*ISIS	1	0.01	3.28	0.0934
Subjects(Time*ISIS)	13	0.04	-	-

Table 48. Analysis of variance table for reaction distance, older driver clear weather assessment, all events.

Independent Variable	df	MS	F	p
Time	1	35484.54	4.16	0.0623
ISIS	**1**	**2020880.26**	**236.73**	**0.0001**
Time*ISIS	1	11101.39	1.30	0.2747
Subjects(Time*ISIS)	13	8536.67	-	-

Table 49. Analysis of variance table for subjective preferences, older driver clear weather assessment. Question 1: How aware of road sign information were you during the drive?

Independent Variable	df	MS	F	p
Time	**1**	**3.58**	**7.31**	**0.0141**
ISIS	**1**	**5.60**	**11.43**	**0.0031**
Time*ISIS	1	1.08	2.21	0.1539
Subjects(Time*ISIS)	13	0.49	-	-

Table 50. Analysis of variance table for subjective preferences, older driver clear weather assessment. Question 2: How timely was the presentation of road sign information during the drive?

Independent Variable	df	MS	F	p
Time	1	0.27	0.28	0.6011
ISIS	**1**	**8.13**	**8.38**	**0.0093**
Time*ISIS	1	2.79	2.88	0.1061
Subjects(Time*ISIS)	13	0.97	-	-

Table 51. Analysis of variance table for subjective preferences, older driver clear weather assessment. Question 3: How safe did you feel during the drive?

Independent Variable	df	MS	F	p
Time	1	8.26	1.42	0.2484
ISIS	1	2.07	0.36	0.5583
Time*ISIS	1	0.07	0.01	0.9138
Subjects(Time*ISIS)	13	5.83	-	-

Table 52. Analysis of variance table for subjective preferences, older driver clear weather assessment. Question 4: How difficult was it to gather road sign information during the drive?

Independent Variable	df	MS	F	p
Time	1	3.07	2.32	0.1444
ISIS	1	2.86	2.16	0.1580
Time*ISIS	1	0.00	0.00	0.9721
Subjects(Time*ISIS)	13	1.33	-	-

Table 53. Analysis of variance table for subjective preferences, older driver clear weather assessment. Question 5: How distracting was the road sign information during the drive?

Independent Variable	df	MS	F	p
Time	1	0.00	0.00	0.9605
ISIS	1	1.24	1.90	0.1845
Time*ISIS	1	0.00	0.00	0.9603
Subjects(Time*ISIS)	13	0.65	-	-

Table 54. Analysis of variance table for subjective preferences, older driver clear weather assessment. Question 6: I would find such a system as this to be useful to me while driving.

Independent Variable	df	MS	F	p
Time	**1**	**6.57**	**4.99**	**0.0377**
ISIS	1	2.30	1.75	0.2018
Time*ISIS	1	2.03	1.55	0.2288
Subjects(Time*ISIS)	13	1.32	-	-

Table 55. Analysis of variance table for subjective preferences, older driver clear weather assessment. Question 7: I would find a system such as this to be a desirable option in my car.

Independent Variable	df	MS	F	p
Time	1	2.45	1.35	0.2592
ISIS	1	1.86	1.03	0.3230
Time*ISIS	1	1.65	0.91	0.3518
Subjects(Time*ISIS)	13	1.81	-	-

Table 56. Analysis of variance table for end event speed, older driver daytime assessment, all events.

Independent Variable	df	MS	F	p
Weather	1	268.26	2.00	0.1850
ISIS	**1**	**1143.92**	**8.53**	**0.0139**
Weather*ISIS	1	36.02	0.27	0.6146
Subjects(Weather*ISIS)	11	134.13	-	-

Table 57. Analysis of variance table for maximum deceleration, older driver daytime assessment, all events.

Independent Variable	df	MS	F	p
Weather	1	0.00	0.09	0.7739
ISIS	1	0.00	2.14	0.1715
Weather*ISIS	1	0.00	0.00	0.9885
Subjects(Weather*ISIS)	11	0.00	-	-

Table 58. Analysis of variance table for reaction distance, older driver daytime assessment, all events.

Independent Variable	df	MS	F	p
Weather	1	44566.73	4.77	0.0516
ISIS	**1**	**1892515.12**	**202.39**	**0.0001**
Weather*ISIS	1	16744.05	1.79	0.2078
Subjects(Weather*ISIS)	11	9350.73	-	-

Table 59. Analysis of variance table for subjective preferences, older driver daytime assessment. Question 1: How aware of road sign information were you during the drive?

Independent Variable	df	MS	F	p
Weather	1	0.38	0.54	0.4734
ISIS	**1**	**3.77**	**5.33**	**0.0324**
Weather*ISIS	1	0.02	0.03	0.8567
Subjects(Weather*ISIS)	19	0.71	-	-

Table 60. Analysis of variance table for subjective preferences, older driver daytime assessment. Question 2: How timely was the presentation of road sign information during the drive?

Independent Variable	df	MS	F	p
Weather	1	0.82	0.83	0.3742
ISIS	1	3.59	3.63	0.0719
Weather*ISIS	1	1.38	1.40	0.2515
Subjects(Weather*ISIS)	19	0.99	-	-

Table 61. Analysis of variance table for subjective preferences, older driver daytime assessment. Question 3: How safe did you feel during the drive?

Independent Variable	df	MS	F	p
Weather	1	0.87	0.14	0.7115
ISIS	1	2.15	0.35	0.5633
Weather*ISIS	1	0.12	0.02	0.8899
Subjects(Weather*ISIS)	19	6.21	-	-

Table 62. Analysis of variance table for subjective preferences, older driver daytime assessment. Question 4: How difficult was it to gather road sign information during the drive?

Independent Variable	df	MS	F	p
Weather	1	0.04	0.03	0.8739
ISIS	1	1.33	0.93	0.3480
Weather*ISIS	1	0.99	0.69	0.4174
Subjects(Weather*ISIS)	19	1.44		

Table 63. Analysis of variance table for subjective preferences, older driver daytime assessment. Question 5: How distracting was the road sign information during the drive?

Independent Variable	df	MS	F	p
Weather	1	0.45	0.71	0.4091
ISIS	1	0.89	1.43	0.2473
Weather*ISIS	1	0.01	0.02	0.9030
Subjects(Weather*ISIS)	19	0.63	-	-

Table 64. Analysis of variance table for subjective preferences, older driver daytime assessment. Question 6: I would find such a system as this to be useful to me while driving.

Independent Variable	df	MS	F	p
Weather	**1**	**11.49**	**13.39**	**0.0017**
ISIS	**1**	**11.65**	**13.58**	**0.0016**
Weather*ISIS	**1**	**8.96**	**10.44**	**0.0044**
Subjects(Weather*ISIS)	19	0.86	-	-

Table 65. Analysis of variance table for subjective preferences, older driver daytime assessment. Question 7: I would find a system such as this to be a desirable option in my car.

Independent Variable	df	MS	F	p
Weather	**1**	**10.08**	**8.15**	**0.0101**
ISIS	**1**	**9.88**	**7.99**	**0.0108**
Weather*ISIS	**1**	**7.67**	**6.20**	**0.0222**
Subjects(Weather*ISIS)	19	1.24	-	-

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