AN EXAMINATION OF DRIVER PERFORMANCE UNDER REDUCED VISIBILITY CONDITIONS WHEN USING AN IN-VEHICLE SIGNING INFORMATION SYSTEM (ISIS)

by

Dennis James Collins

Thesis submitted to the Faculty of the
Virginia Polytechnic Institute and State University
in partial fulfillment of the requirements for the degree of

Master of Science
in
Industrial and Systems Engineering

APPROVED

Dr. Thomas A. Dingus, Chairman

Dr. Walter W. Wierwille

Dr. Vicki L. Neale

April 10, 1997
Blacksburg, Virginia

Keywords: Driver performance, ISIS, adverse weather

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(ABSTRACT)

Recent technological innovations and the need for increased safety 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 under eight conditions. The eight conditions consisted of a daylight-clear weather-ISIS condition, a daylight-clear weather-No ISIS condition, a daylight-rain-ISIS condition, a daylight-rain-No ISIS condition, a night-clear weather-ISIS condition, a night-clear weather-No ISIS condition, a night-rain-ISIS condition, and a night-rain-No ISIS condition. 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 was evaluated to determine driver preference and acceptance of the ISIS display.

The results indicated that use of the ISIS display led to reduced speeds and greater reaction distances for all drivers. Evidence was found that seems to indicate that older drivers may receive a greater benefit in complex, unfamiliar, or low visibility situations. Evidence was also found that indicates that all drivers may receive a greater benefit at night for the complex or unfamiliar situations. Subjectively, the majority of the drivers indicated that the ISIS display made them more aware of road sign information.

ACKNOWLEDGMENTS

I would like to thank Dr. Thomas A. Dingus, whose advice, support, and experience made this research possible. I would also like to thank the other members of my thesis committee, Dr. Walter W. Wierwille and Dr. Vicki L. Neale, for their support and suggestions.

Thanks are also due Andy Petersen for his hardware development and support, and to Brian Daily for his software development and support. This research could not have been completed without their hard work.

I would like to express my gratitude to Wayne Biever and Shannon Hetrick for the hours they spent with me in the research vehicle. The graduate students and staff at the Virginia Tech Center for Transportation Research also have my thanks and gratitude for their suggestions, advice, and help during this research.

This research was sponsored by Battelle, the Federal Highway Administration, and the Virginia Tech Center for Transportation Research. Their financial support was essential to the successful completion of this research.

Finally, my thanks goes out to James C. Collins, Deborah M. Collins, Jennifer L. Collins, and my wife, Katrina M. Collins. Without the love and support of my family, this effort would not have been possible.

TABLE OF CONTENTS

TABLE OF CONTENTS, CONT.

TABLE OF CONTENTS, CONT.

LIST OF TABLES

LIST OF TABLES, CONT.

LIST OF TABLES, CONT.

LIST OF FIGURES

INTRODUCTION

Researchers and engineers have long been aware that driving is a difficult and hazardous task, describing the driver as "an outdated human with stone age characteristics and performance who is controlling a fast, heavy machine in an environment packed with unnatural, artificial signs and signals" (Rumar, 1981). Expanding on this statement, Dewar (1988) concludes that humans were designed to walk and run, not travel at the speeds found on the highways; nor, he concludes, were humans designed to move about with facility at night. The problems associated with driving become even greater when one realizes that driving is a particularly good example of a real-world divided attention task, since even under routine conditions, the driver must coordinate several tasks together (Hancock and Parasuraman, 1992).

Safely operating a motor vehicle has only grown more difficult as the number of motor vehicles on the roads and highways of the nation has increased. As of 1989, U.S. traffic levels reached more than two trillion vehicle-miles per year, and it is estimated they will continue to grow by four percent per year. At the present rate of growth, it is estimated that there will be over one billion vehicles on the roads of the world by the year 2020, and traffic levels will have reached four trillion vehicle miles (Banks, 1991). As the demands on the roadway system have increased, road capacity has been unable to increase significantly, resulting in an increase in congestion and a corresponding increase in the number of traffic incidents and accidents. Currently, in the United States, traffic accidents are the leading cause of death for persons 38 years of age or younger and are the leading cause of accidental death up to the age of 78 (National Safety Council, 1991). If the current trends continue, it is estimated that there will be one serious accident per second and one fatality per minute by the year 2020 (Michon, 1990).

One way to handle this increased traffic congestion and decreased safety is the development and implementation of Intelligent Transportation Systems (ITS). ITS (formerly known as Intelligent Vehicle Highway Systems, or IVHS) is the application of advanced information processing and communications, sensing, and control technologies to surface transportation. The objectives of ITS include: promoting more efficient use of the existing highway network, increasing safety and mobility, and decreasing the environmental cost of travel (Transportation Research Board, 1993).

Two major areas of ITS are Commercial Vehicle Operations (CVO) systems and Advanced Traveler Information Systems (ATIS). These systems will provide the primary means by which commercial and private vehicle drivers will interact with ITS. ATIS provides information to the driver while he or she is in the vehicle using In-Vehicle Information Systems (IVIS). IVIS allows the driver access to a wide variety of information, including (1) roadway and signing information, (2) routing and navigation information, (3) safety advisory and warning information, and (4) motorist information services. Each type of information is provided by a separate subsystem under the umbrella of IVIS. 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 a system that provides non-commercial routing, warning, regulatory, and advisory information which is currently depicted on external roadway signs. IRANS are systems that provide drivers with information about how to get from one place to another as well as information on traffic congestion. IVSAWS are those systems that provide warning of unsafe conditions affecting the roadway ahead of the driver, thus providing the driver with 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 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.

Although simulator studies have suggested potential benefits, introduction of ISIS into a vehicle poses its own safety risks. The ISIS system is almost certain to contain a visual component, and this component will likely require close visual monitoring by the driver. It has been estimated that approximately ninety percent of all information that drivers use to accomplish the driving task is obtained visually (Rockwell, 1972). The additional visual requirements imposed by the ISIS are likely to force the driver to divert his or her attention from the driving task, creating uncertainty and possibly a less safe condition.

The goal of this research is to investigate the use of ISIS technology under normal and adverse conditions, such as driving under conditions of reduced visibility (during rainy weather or at night), to determine what hazards may be posed and what benefits, if any, are realized.

Research Goals

The primary goal of this research was to explore the effect that use of an in-vehicle visual display has on safety, as measured by driver performance. A secondary goal was to investigate conditions of reduced visibility to determine how they affect driver performance. The interaction of reduced visibility conditions and ISIS use was examined. Specific questions addressed were:

1. Are there, in general, benefits associated with the 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 the system?
5. Does the system adversely impact driver performance or behavior?

LITERATURE REVIEW

The literature of interest for the topic at hand is divided along the dimensions of adverse driving conditions, safe driver performance, and ISIS systems. To facilitate organization of the following information, seven major headings will be addressed. First will be adverse weather conditions, followed by daytime vs. nighttime driving, driver age, highway signs, ISIS systems, and measures of driver performance.

Adverse Weather Conditions

Almost everyone would agree that weather conditions such as rain, fog, or snow adversely affect driving. Several theoretical and common sense reasons can be offered to explain why rain or snow can be hazardous to traffic. Friction is reduced on a wet surface, resulting in a need for greater stopping distances. In addition, curves become slippery, 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. These problems are exacerbated during night driving. Many retro reflective materials (used for road signs) lose much of their reflective power in wet conditions (Organization for Economic Co-operation and Development, 1976). 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). Statistically, it has been found that both the maximum rainfall on any given day in a month and the average daily rainfall in a month affect the frequency and type of accidents. An increase in the maximum daily rainfall is correlated with an increase in sideswipe, parked-vehicle, fixed-object, and overturn collisions. An increase in the average daily rainfall in the month is correlated with an increase in rear-end collisions (Shankar, Mannering, and Barfield, 1995). Brodsky and Hakkert (1988) found that analyzing historical data on fatal accidents in the U. S. during rainy weather resulted in an increased risk of approximately three, meaning it is approximately three times as likely that a driver will be involved in an accident during rainy or wet pavement conditions.

Daytime vs. Nighttime Conditions

In general, nighttime driving is associated with a higher probability of crash involvement due to factors such as reduced visibility, fatigue, and higher incidence of alcohol use. Driving statistics 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 et. al, 1995). The visibility of road signs also decreases significantly at night, with the problem being more pronounced for older drivers. At night, glare can pose a problem for drivers of all ages. Any system that improves visibility of signs at night and allows drivers greater reaction times will have a tremendous impact on safety at night.

Driver Age

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.

When elderly drivers are surveyed, they report greater difficulty in conditions of low illumination and problems detecting highway signs, and markers (Yee, 1985). Kline et al. (1992), support this finding; they found eight problems that were strongly age related in a survey of driving related visual problems - one of these problems was reading signs quickly enough to be able to react to them. This data is further supported by Babbitt, Kline, Schieber, Sekuler, and Fozard (1989), who surveyed 400 drivers and found seven age-related problems, one of which was reading signs in time to respond to them.

Night time 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 clearly as they did at 20 years (Pitts, 1982). Evans et al. (1985) found that younger drivers were capable of discriminating signs at greater distances than older drivers despite equivalent visual acuity. Contrast sensitivity was found to be more closely related to a driver's ability to discriminate highway signs than visual acuity.

Presbyopia, the inability of the eye to focus sharply on nearby objects (resulting from loss of elasticity of the crystalline lens), becomes progressively apparent after the mid-40's and peaks between 60 and 70 (Rockwell et al., 1988). Drivers who wear reading glasses to correct this condition do not wear them during driving, as their distance vision would be blurred. This results in the presbyopic condition being present during driving. Bifocal wearers, on the other hand, wear their glasses while driving. Bifocal lenses generally give the best near vision at a distance of 400 mm. At a longer distance (e.g., 750 mm, a common distance from driver to instrument panel), the lenses are too powerful to allow clear focus. To compound the problem, other visual impairments, such as glaucoma and cataracts, are much more common among those 65 and over (Sekuler et al, 1982).

Previous studies have shown that older drivers must dedicate a higher percentage of visual attention to the roadway than do 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, 1989). Older drivers also may have great limitations in their sensory, cognitive, and psychomotor skills. Ponds et al. (1988) found a decline in dual task performance for older subjects, suggesting that aging impairs the ability to divide attention. Their data suggested this impairment was restricted to older persons (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). This suggests that including ISIS information in vehicles may help older drivers overcome many of these problems.

Highway Signs

In order to be effective, a traffic control device (sign) should give the driver adequate time to perceive, identify, decide, and perform any necessary maneuver. The total time to complete a reaction to a sign (referred to as the PIEV time - Perception, Identification, Emotion, and Volition) can vary from three seconds to ten seconds depending on the judgment required. Adequate distances are of particular importance when the sign is a warning sign (Federal Highway Administration, 1988). This can result in a problem when it is noted that the letter heights used on signs today is based on the assumption that an inch-high letter is visible from 50 feet (Forbes and Holmes, 1939). This assumption comes from a 1939 study, a time when only seven percent of the population was 65 or older. This assumption requires drivers have a visual acuity of roughly 20/25, which exceeds the visual ability of about 40 percent of drivers 65 to 74. Also, younger drivers suffer reduced acuity at night, and may be unable to discern roadside signs as well. A study of traffic symbol recognition revealed that the average recognition distances for twelve common signs ranged from 1500 feet down to 750 feet during the day, and that nighttime distances were approximately 83% of the daytime distances (Zwahlen, Hu, Sunkara, and Duffus, 1991). Kline and Fuchs (1993) examined recognition distances of text, symbolic, and improved symbolic signs among younger, middle-aged, and older drivers. They concluded that the older drivers had a significantly shorter recognition distance than the younger drivers, while the middle-aged drivers were not statistically different from either group. Another study (Paniati, 1988) examined legibility and comprehension of 22 warning signs, and reached two conclusions: First, the younger subjects had legibility distances significantly greater than those of the older subjects. Second, different symbols were legible at different distances. The representative sample of 22 warning signs resulted in average legibility distances ranging from 46 to 215 meters. Sivak et al. (1981) found that older drivers had a legibility distance only 65 to 77 percent of younger drivers at night. In a review of the literature, the Transportation Research Board recommended that the Manual on Uniform Traffic Control Devices (MUTCD) "adopt a performance standard for highway and street signs based on the degree to which a sign ensures the minimum required visibility distance of the older population", specifically suggesting bigger and brighter signs (Transportation Research Board, 1988). This suggests that including ISIS in vehicles will make warning signs more obvious and clear and will give the driver more time to perceive, identify, and respond to them.

ISIS Systems

A major human factors concern in the development and implementation of ISIS systems is that the addition of visually displayed information may divert visual attention away from primary visual tasks such as lane tracking and obstacle detection (Zwahlen and DeBald, 1986; Dingus, Antin, Hulse, and Wierwille, 1988; Parkes and Coleman, 1990). This concern has led to research on both visual and auditory presentation of information. This research has resulted in mixed results, with some studies finding that presenting information visually resulted in a less safe condition, which other studies have found just the opposite. In one study on the effect of both visual and auditory sensory modalities in an ISIS system, Mollenhauer et al. (1994) found that although auditory presentation resulted in a greater recall of information, measures of driving performance (lane position deviations, rapid steering movements, and road-heading error) were worse under auditory presentation, indicating a less safe condition. Conversely, an experiment by Labiale (1990) indicated that complex visual messages affected vehicle course control more severely than did complex auditory messages. Labiale recommended using aural messages of 7 to 9 units, or using an aural message as a prompt for a simple visual display. Clearly, either method of presentation places additional demand on the driver and may pose increased risk. Fleischman et al. (1991) proposed to combat the problems associated with visual displays by restricting their use, reducing the information density of the display, and using an auditory mode to present an attention signal or information.

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 fifteen events was developed and tested using a Virginia Tech Center for Transportation Research instrumented vehicle. Each participant drove once under one treatment combination, allowing all factors of interest to be examined.

Experimental Design

A 2 x 2 x 2 x 2 x 2 between subjects design was proposed for this study. The variables of Age, Weather, Time of day, Gender, and ISIS use were to be investigated. Due to problems during data collection, Gender was dropped from the study (see *Results* for a detailed description of the problems encountered). The variable of Age had two levels, namely younger (18-30 years old) and older (65 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, namely day and night. ISIS consisted of two levels and indicated if the participant drove with the ISIS display or without it. Three dependent measures were collected for each participant. These measures are described in detail below. A route running through the Blacksburg and Ellet Valley, Virginia, area was selected for the test bed. For a map of the test route, see appendix A.

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

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 twenty-three 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 above. Younger drivers were recruited through flyers posted on the Virginia Polytechnic Institute and State University campus and an advertisement in the local paper. Older drivers were recruited through retirement communities, advertisements in local newspapers, and flyers posted at local merchants.

Younger subjects were paid $10.00 per hour and older subjects were paid $15.00 per hour, for approximately one 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 was achieved between the older and younger subjects.

In order to be a participant, persons were required to: (1) be a licensed driver, (2) drive a minimum of twice a week in Blacksburg, Virginia or the surrounding areas, (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.

<u>Apparatus</u>

Driver behavior was investigated on-road using an instrumented 1995 Oldsmobile Aurora four-door sedan (Figure 1). The primary apparati 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.

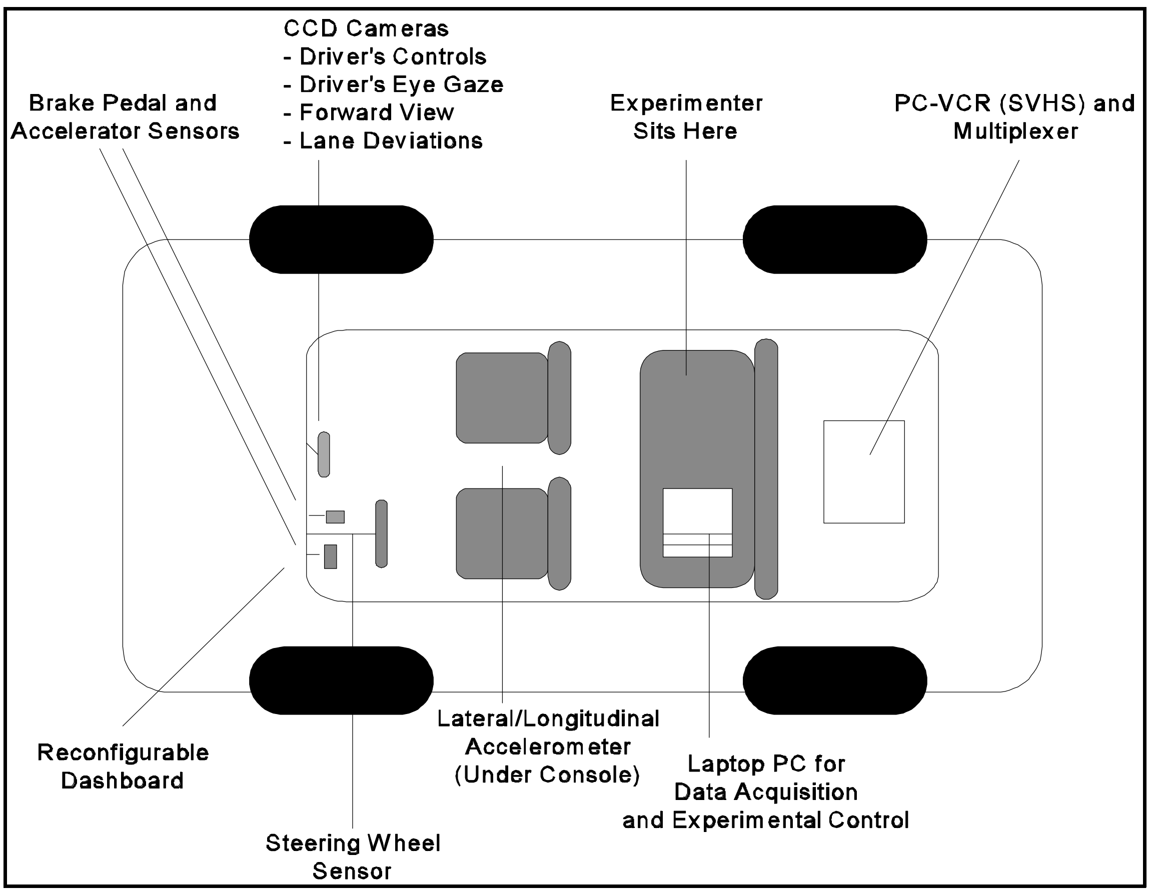

Figure 1. Diagram of the Instrumented Vehicle.

Automobile

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. All data collection records were time stamped to an accuracy of +/- 0.1 second.

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.
- An experimenter's brake pedal was mounted in the front passenger-side.
- A fire extinguisher, first aid kit, and cellular phone were located in the experimental vehicle.
- None of the data collection equipment interfered with any part of the driver's normal field-of-view.
- Two trained in-vehicle experimenters were in the vehicle at all times. Emergency protocol was established prior to testing.

Cameras and Sensors

Eye Glance Camera. The eye glance camera allowed monitoring of eye movements. Its field-of-view 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.

Forward-View Camera. 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 3 x 480 dots 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 table 2 (Liquid Crystal Displays Group, 1995).

Table 2. 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.	

ISIS Information. 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 Mircografix Picture Publisher 6.0. For a full-sized example of the ISIS display, please refer to appendix B. All images used on the ISIS display can be found in appendix C.

Independent and Dependent Variables

Independent Variables. As discussed above, four independent variables were manipulated in this experiment. These 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 from the end of an event at which a driver reacted to that 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 D). 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, VA. After arriving at the CTR, the participant was given an overview of the study and he/she completed an informed consent form (appendix E). Next, he/she was asked to answer a health screening questionnaire and was given a simple vision test (appendices F and G, respectively). After these were completed, the participant was escorted to the test vehicle.

One of the experimenters would then drive the test vehicle to the start of the practice route and allow the participant to take over the driver's seat. With the car was in park, the experimenter reviewed general information concerning the operation of the test vehicle (e.g., lights, seat adjustment, mirrors, windshield wipers, etc.; (appendix H). The participant was then asked to operate each control and set it 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 I). 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, eighteen symbols were randomly presented to the driver. The driver was asked to review these symbols to ensure he/she knew what each symbol meant. The driver was encouraged to ask questions or to ask for clarification or explanation if necessary. This presentation included all fifteen 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 H) were given. The driver then proceeded to the practice segment.

Practice Segment. For the practice segment, the participants drove a practice route of approximately one mile to allow the participant become familiar with the handling of the vehicle; no ISIS was used. 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 emergency brake if needed. (See appendix I for front seat experimenter protocol). The experimenter in the rear seat controlled the presentation of information (see appendix J). A marker was inserted into the data set when new information was presented on the ISIS display. (This procedure is referred to a "flagging" the data set). 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 fifteen 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 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 him/her back to the prescribed route. Upon returning to the CTR, a preference questionnaire was administered (appendix K). After answering the questionnaire, drivers were debriefed and paid for their time.

Route Events. The experimental route consisted of fifteen events over the course of 5.5 miles. Events were defined experimentally as permanent geometric or situational features which required reaction by the driver. Route events were divided into two categories based on whether or not a road sign existed to warn the driver about the event. The first category, marked events, consisted of those events which were marked with a road sign. The second category, unmarked events, were those events which 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 3. The ISIS displays for each event can be found in appendix C. A listing of event ISIS distances and visibility distances for each event can be found in appendix L.

Table 3. 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

Marked Events. There were eleven marked events over the course of the experimental run. For these events, the ISIS system displayed information regarding the event approximately five 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 five seconds before the start of the event (e.g., a stop ahead sign or a curve sign on the dashboard display). 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 K). 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 ninety-six drivers, only fifty-eight people took part in this study. To maintain sufficient statistical power for the experiment despite the missing cells the data were divided into four subsets.

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 (over 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 4. 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 refers 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 was collected for each subset, and will be discussed as well. Although the data collection equipment in the test vehicle collected additional measures, it is believed that those additional measures would not add to the knowledge gained in this experiment, and therefore were not analyzed. 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.

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 which 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 5.

Table 5. 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 M, table M-1 for the complete ANOVA table) was completed for all fifteen events taken together.

Age, $F(1,30)=8.48$, $p=0.0067$, was found to be significant across all 15 events. The younger drivers had a higher mean end event speed (30.85 mph) than the older drivers (28.64 mph). Examination of the individual events (see table six) 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 15 events for end speeds. Those drivers who had the ISIS had a lower mean end event speed (28.06 mph) than those who drove without the system (31.66 mph). 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 6). 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 in the emerged in the significant effects.

Maximum Deceleration. No significant effects were found across all fifteen events for maximum deceleration. (For a complete ANOVA table, refer to appendix M, table M-2). P values for the individual events can be seen in table 7.

ISIS was significant for the highest number of individual events, with five (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, and an unmarked reverse curve). For two of these five of 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 6. P Values for 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
<u>Age</u>	**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
<u>ISIS</u>	**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 7. 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 all 15 events. This interaction can be seen in figure 4.

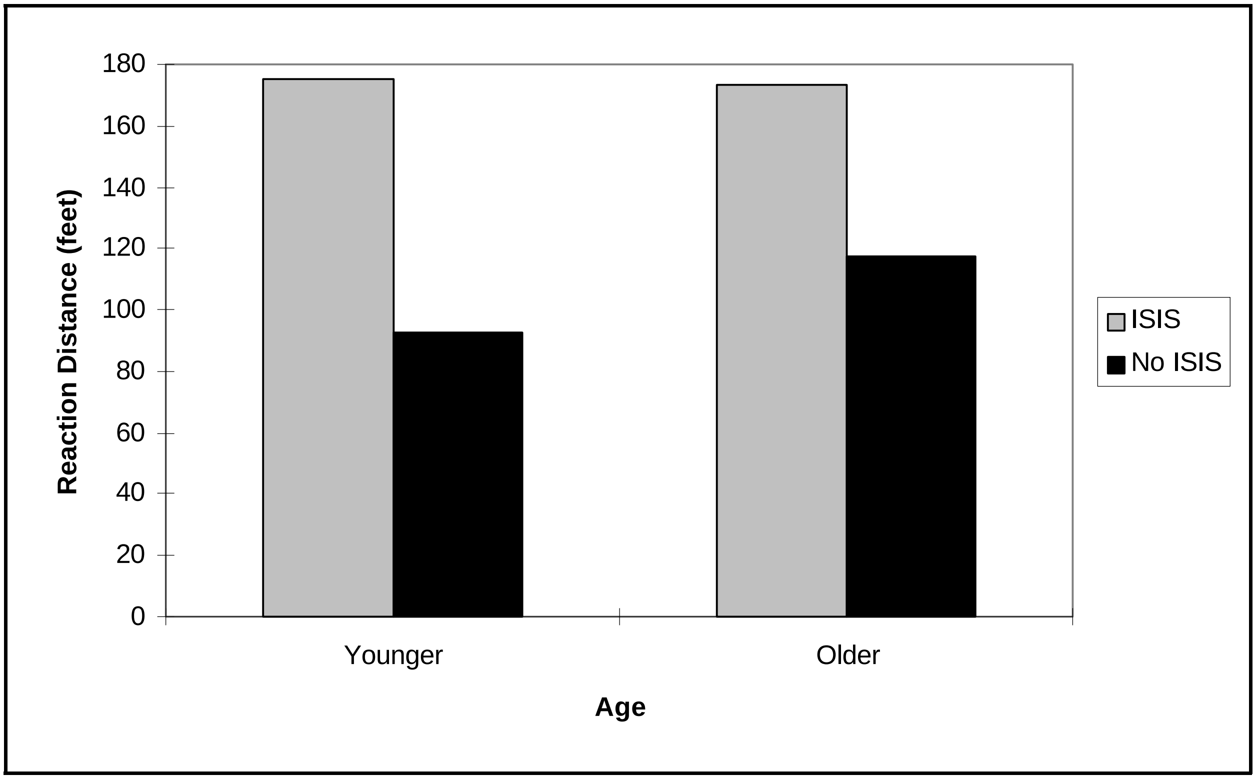

Figure 4. Mean Reaction Distance by Age*ISIS for All Events, Clear Weather Assessment.

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. This indicates less of a benefit for the older drivers. This reduced benefit may be explained by the caution displayed by the older drivers. 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, receive less of a benefit from the early warning provided by the system.

An examination of the individual events (see table 8) revealed that this 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 for all 15 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). For Event 1, the shorter distance may be explained by the geometry of the road and the fact that the event was unmarked. As a driver approaches this event during the day, he or she can clearly see that the road continues downhill, curves, and then forms a "T" with another road. At night, this is not as evident. The daytime drivers may initiate an earlier response since they can tell when they will have to stop. Similar reasoning can be used to explain the significance for both Events 7 and 9; the daytime drivers can see the event before the nighttime drivers and therefore initiate an earlier response. Event 9 is a complex intersection. Daytime drivers may be more aware of this complexity, and initiate an earlier response. The results of the individual event analysis seem to indicate that time plays a part in those situations where visual cues allow a driver to use his or her judgement; at night, those cues are diminished or missing, and the driver may not respond as soon as they would under daylight conditions.

ISIS, F(1,30)=318.02, p=0.0001, was the last significant effect across all fifteen 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 increases reaction distances regardless of the type of the 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 8. 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 9 below:

Table 9. 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 under ANOVA. Please see appendix M, tables M-4 to M-10).

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 one, with daytime drivers more aware (mean=6.3000) of road sign information than nighttime drivers (mean=5.7222). Age was significant for question two, with older drivers feeling information was more timely (mean=6.0000) than the younger drivers (mean=5.2381). Age was also significant for question five, 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 to the way they are defined in the clear weather assessment. Weather consisted of two levels: a no rain, or clear, condition and a rain condition. Participants by experimental condition can be found in table 10.

Table 10. 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 the first effect found to be significant with respect to the event end speeds of the younger drivers across all fifteen events. Clear weather driving resulted in a mean end event speed of 30.85 mph, while driving in the rain resulted in a mean end event speed of 32.75 mph. (For a complete ANOVA table, please see appendix M, table M-11). At first glance, this appears to contradict what you might expect. Common sense would dictate that drivers would slow down during rainy weather. Despite common sense, this does not appear to be the case here. This increase in speed could be explained by two facts: first, younger drivers perceive less risk than their older counterparts (Finn and Bragg, 1986). The younger drivers would perceive less risk on rainy roads, and might not adjust their speed accordingly. Second, the younger drivers may in fact be aware of the increased risk of rain, and may choose to apply the brake less often, reasoning they are 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 11). Event 3 cautions the driver to take the curve at 15 mph, event 5 warns of a 30 mph 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 the second significant effect for event end speed for younger drivers across all fifteen events. Participants using the ISIS system had a mean end event speed of 30.16 mph, while those without the system has a mean end event speed of 33.33 mph. Clearly, the ISIS display caused drivers to have a lower end speed. Examination of the individual events (see table 11) revealed ISIS to be significant for over 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 11). These additional significant effects did not have a discernable 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. This relationship is depicted in figure 5 below.

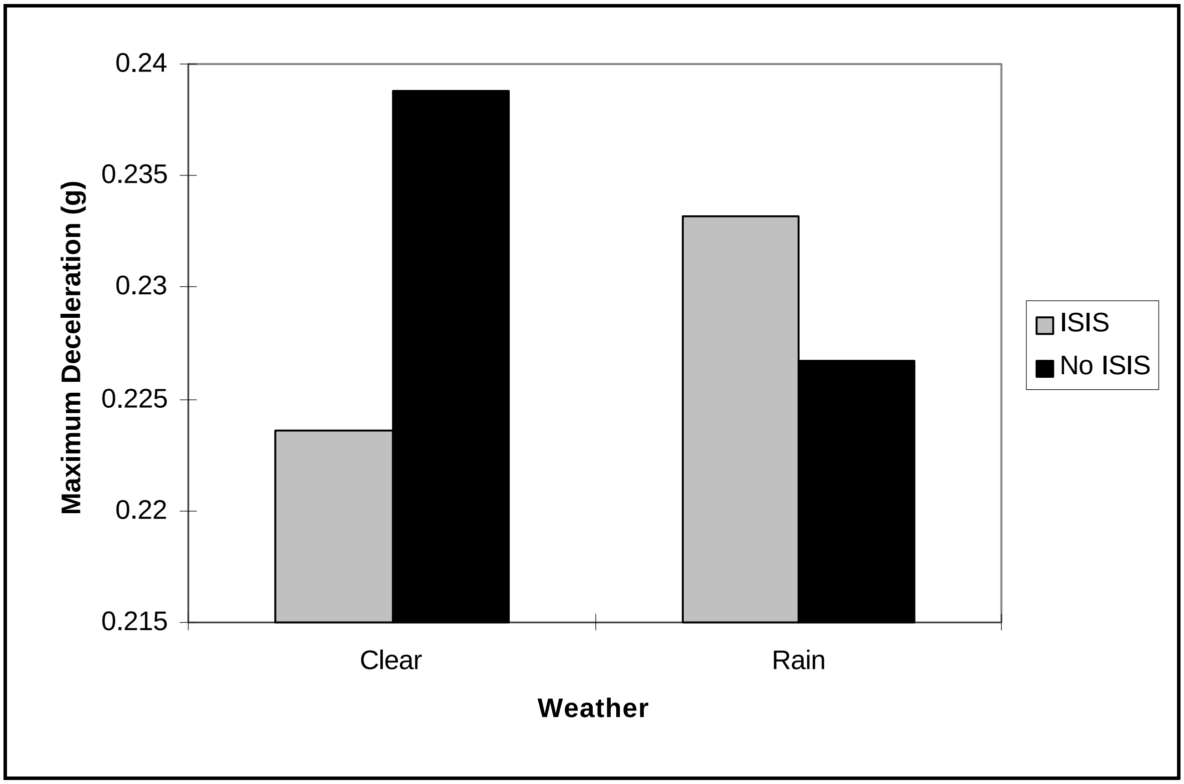

Figure 5. Mean Maximum Deceleration by Weather*ISIS for All Events, Younger Driver Assessment.

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 show increased caution and lower deceleration. The presence of the ISIS display may take some of this attention away from the roadway, distracting the driver, and resulting in a greater maximum deceleration.

Looking at individual events (table 12) 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. For these two events, the younger drivers may have needed the extra warning provided by the ISIS under clear conditions, while under rainy conditions, that system was more of a distraction than a benefit. 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 12).

Table 11. 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**
Weather	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**
ISIS	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

Table 12. 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
Weather*ISIS	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 all 15 events. Those drivers that 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). 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).

Time, F(1,27)=6.20, p=0.0192, was the last significant effect found across all fifteen events. Daytime drivers had a mean reaction distance of 325.65 feet, while nighttime drivers had a mean reaction distance of 356.16 feet.

Time was significant for individual Events 6, 9, and 10 (see table 13). 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 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 its long length.

Table 13. 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 below.

Table 14. 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 M, tables M-14 to M-20).

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 that information. The younger drivers also indicated they felt 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 four, 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 participants by experimental condition can be seen in table 15.

Table 15. Participants by Experimental Condition for the Older Driver, Clear Weather Assessment

	Day	Night
ISIS	5	3
No ISIS	5	4

End Event 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 mph, while those without the system has a mean end event speed of 30.29 mph. The complete ANOVA table can be found in appendix M, table M-21.

Looking at individual event data (see table 16) 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 M, table M-22). Examination of the individual events (see table 17) revealed ISIS to be significant for Event 1, the unmarked stop ahead, and Event 9, the marked "Y" curve. The significance found for event one 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 startled the driver, or the driver may have not determined how to interpret the warning provided by the system, and reacted instinctually. The significance found for Event 9 may be due to the nature of the ISIS interval (Event 9 had the longest distance) or due 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.

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 to the no ISIS condition (mean= 251.22). (For the complete ANOVA table, please see appendix M, table M-23).

Examination of the individual events (see table 18) 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.

One additional significant effect was found for Event 12, an unmarked winding road. Given the singular nature of this significance, it will not be discussed here.

Table 16. 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
ISIS	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 17. 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 18. 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 below by ISIS use.

Table 19. 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 M, tables M-24 to M-30).

The older, clear weather drivers felt they were more aware of the information and that the information was more timely when they used the ISIS system. They did not find the ISIS system to be significantly more distracting than ordinary driving.

Time was found to be significant for question one, with the daytime drivers reporting they were more aware of sign information (mean=6.6000) than the nighttime drivers (mean=5.7500). This seems to indicate that older drivers have more problems detecting road sign information at night. Time was also found to be significant for question six, with the nighttime drivers feeling 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 20.

Table 20. Participants by Experimental Condition for the Older Driver, Daytime Assessment

	Clear	Rain
ISIS	5	3
No ISIS	5	2

End Event 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 fifteen 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 M, table M-31).

An examination of individual events for significant effects can be found in table 21. This examination showed 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 there, 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 fifteen events were discovered for this subset. (For the complete ANOVA table, please see appendix M-32). An examination of individual events revealed the significant effects seen in table 22 below. 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 M-33).

Significant p values for individual events can be seen in table 23 below. 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 the older drivers in terms of increased reaction distance for marked or unmarked regulatory and advisory events.

Weather was found to be significant for Events 13 (marked one lane bridge), 14 (unmarked reverse curve), and 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 21. 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 22. 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 23. 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 the table below:

Table 24. 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 M, tables M-34-40 for complete table).

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

Weather was found to be a significant factor for question six, 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 seven, with clear drivers finding the system more desirable (mean=1.8824) than the rainy drivers (mean=3.0000). These results may indicate problem with the ISIS system under rainy conditions, or may indicate the older drivers' concern for systems that would take their attention away from the road during adverse conditions.

CONCLUSIONS

Recall from the Introduction, five research questions were posed concerning the benefits of an ISIS display: (1) Are there, in general, benefits associated with the ISIS display? (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 the 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 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 three to five 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 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 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 affect may be a result of the perception of risk during rainy weather driving and driver reaction to the ISIS; under the poor conditions, the younger drivers made a quicker response 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.

<u>Additional Benefits During Night Driving</u>
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 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 my be a result of decreased visual ability at night.

<u>Additional Benefits for Older Drivers</u>
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 those events which are highly complex. 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 an ISIS display will have based on event complexity.

<u>Adverse System Impact on Behavior or Performance</u>
No adverse performance or behavioral affects were found across all four subsets for all fifteen 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.

Examination of individual events were in agreement with the overall picture. The drivers were able to successfully respond to all of the fifteen 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) 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. From the results of this experiment, it appears that activating the ISIS approximately three to five seconds before an event gives the driver enough time.

(2) 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.

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

(4) Drivers should be able to control what information appears on the ISIS display. Some drivers may benefit from additional warnings in specific situations, while others would 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 acted alone. 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 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 drivers were willing to drive in the rain, with even fewer 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 chose 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 affect, if any, event complexity has on the benefits associated with ISIS use at night.

(6) Research 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) An observer effect may have been present. Given that two experimenters were in the vehicle during the drive, participants may have been exercising greater than normal caution. This caution may have led to decreased speeds, and may be the cause of some of the differences found here.

(9) The older drivers may have had a higher likelihood of having driven the experimental route previously. This increased familiarity may have affected the results found here.

(10) The issue of visual distraction was not addressed in this experiment. There is a trade-off between the benefits associated with ISIS and the need for the drivers to take their eyes from the road. It is possible that the risk associated with the driver taking his or her eyes from the road may outweigh the benefits associated with ISIS. Further research should address this issue.

(11) 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.

(12) Driver visual scan patterns were not examined. This issue is closely related to the visual distraction issue above. Further research could determine the effect ISIS has on scan patterns.

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APPENDIX A
Center for Transportation Research
Virginia Tech
Map of the Experimental Route and Event Images

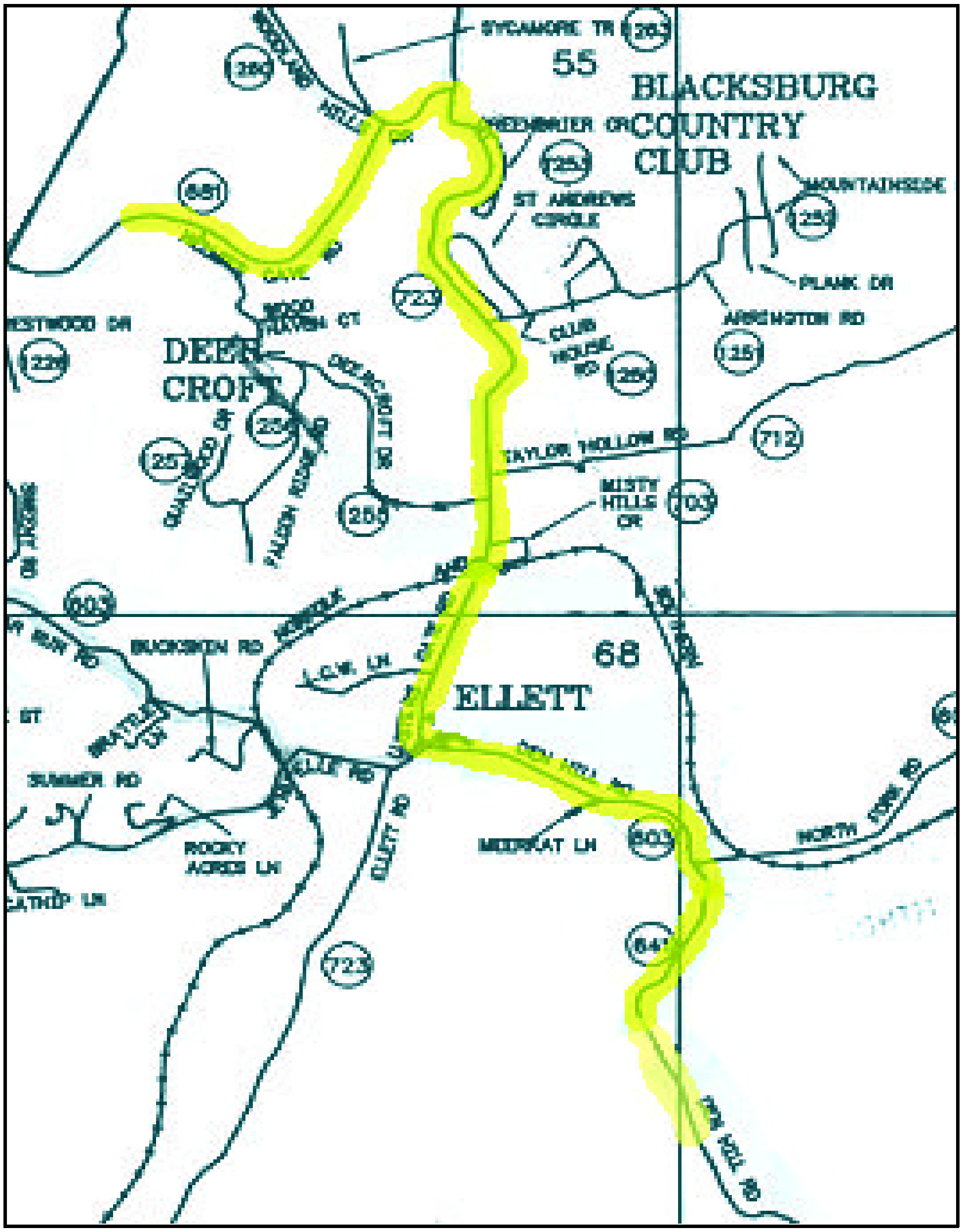


Figure A-1. Map of the Experimental Route

Figure A-2. Event 1: Unmarked Stop Ahead

Figure A-3. Event 4: Marked Winding Road

Figure A-4. Event 7: Marked One Lane Tunnel

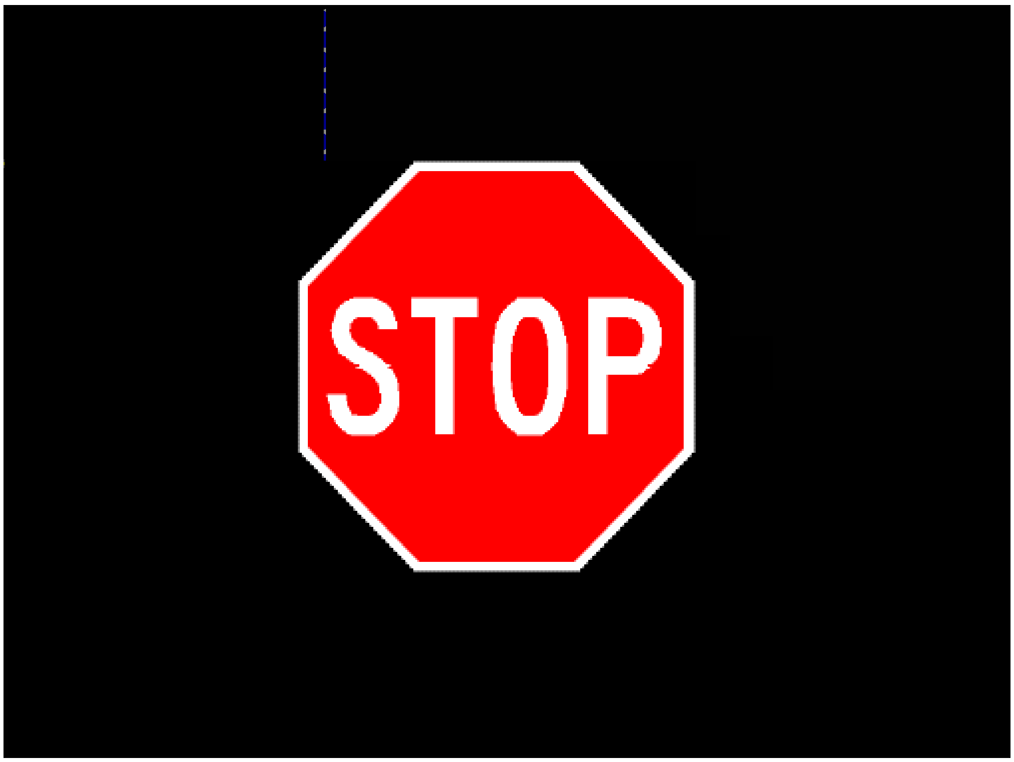
Figure A-5. Event 10: Marked Yield

Figure A-6. Event 12: Unmarked Winding Road

Figure A-7. Event 15: Unmarked Reverse Curve

APPENDIX B
Center for Transportation Research
Virginia Tech

Actual Portrayal Size of ISIS Information



APPENDIX C
Center for Transportation Research
Virginia Tech
ISIS Images

Image 1: Stop Ahead

Image 2: Stop

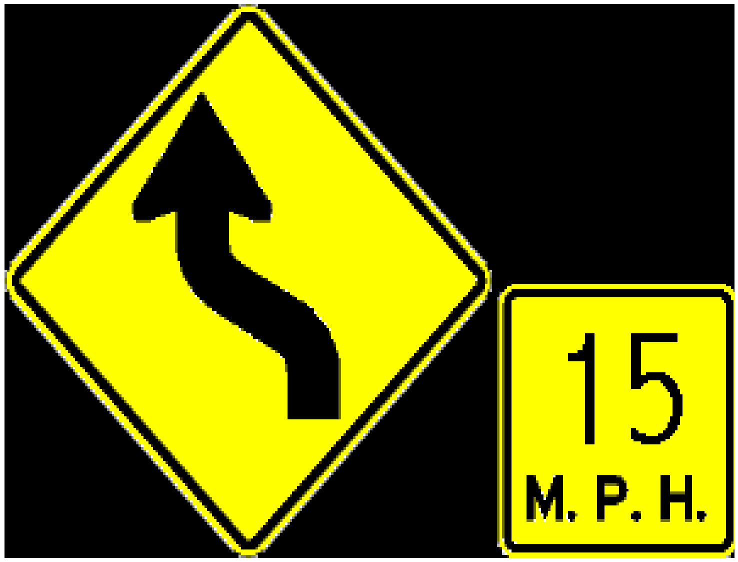


Image 3: 15 MPH Reverse Turn

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

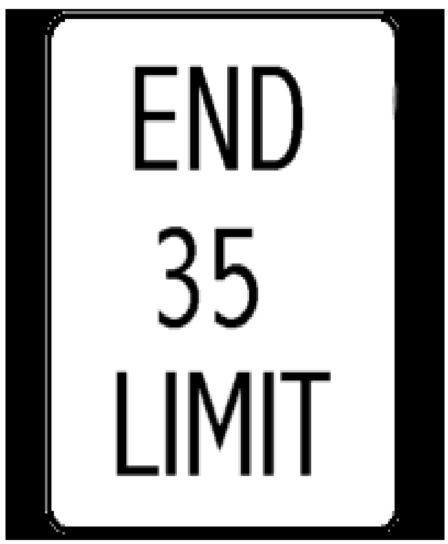


Image 8: End 35 MPH Speed Limit

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 D
Center for Transportation Research
Virginia Tech
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 E

Center for Transportation Research
Virginia Tech
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:

6. Read and sign an informed consent form.
7. Answer general and demographic questions.
8. Complete a vision test.
9. Complete a health screening questionnaire.
10. Read general information about the experimental vehicle.
11. Complete a hearing test.
12. 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.
13. Perform an experimental drive in the vehicle over a pre-defined route for which data will be collected.
14. 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 F

Center For Transportation Research
Virginia Tech
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 G

Center for Transportation Research
Virginia Tech
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.

- 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.

3. Show Driver's license. Must be valid. Out of state is okay.

4. 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.

- 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.

5. 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: ________________

6. 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 H

Center for Transportation Research
Virginia Tech
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 I

Center for Transportation Research
Virginia Tech
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 J

Center for Transportation Research
Virginia Tech
Rear Seat Experimenter Protocol

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

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 K

Center for Transportation Research
Virginia Tech
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 L

Center for Transportation Research
Virginia Tech
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 M: ANALYSIS OF VARIANCE TABLES
Center for Transportation Research
Virginia Tech

Table M-1. 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 M-2. 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 M-3. 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 M-4. 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 M-5. 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 M-6. 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 M-7. 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 M-8. 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 M-9. 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 M-10. 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 M-11. 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 M-12. 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 M-13. 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 M-14. 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 M-15. 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 M-16. 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 M-17. 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 M-18. 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 M-19. 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 M-20. 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 M-21. 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 M-22. 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 M-23. 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 M-24. 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 M-25. 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 M-26. 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 M-27. 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 M-28. 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 M-29. 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 M-30. 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 M-31. 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 M-32. 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 M-33. 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 M-34. Analysis of Variance Table for Subjective Preference, 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 M-35. Analysis of Variance Table for Subjective Preference, 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 M-36. Analysis of Variance Table for Subjective Preference, 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 M-37. Analysis of Variance Table for Subjective Preference, 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 M-38. Analysis of Variance Table for Subjective Preference, 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 M-39. Analysis of Variance Table for Subjective Preference, 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 M-40. Analysis of Variance Table for Subjective Preference, 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	-	-

VITA

Dennis James Collins was born May 8, 1972, in Fort Hood, Texas. He received a B. S. in Industrial and Systems Engineering from Virginia Tech in 1994. His work as a graduate student has included both teaching and research positions. His areas of interest include human factors in transportation, intelligent transportation systems (ITS), and safety. His research was conducted at the Virginia Tech Center for Transportation Research and was funded by Battelle and the Federal Highway Administration. He is a member of the Institute of Industrial Engineers (IIE), the Human Factors and Ergonomics Society (HFES), and the Society of American Military Engineers (SAME). He has accepted a position with DCS Corporation in Alexandria, VA, where he will be developing and testing night vision systems for military ground vehicles.