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Investigation of Alternative Displays for Side Collision Avoidance Systems

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16. Abstract:

Side Collision Avoidance Systems (SCAS) are designed to warn of impending collisions and can detect not only adjacent vehicles but vehicles approaching at such a speed that a collision would occur if a lane change were made. Side object detection systems (SODS) represent a subset of SCAS; they warn of the presence of adjacent vehicles only, whether or not there is a lane change. Despite a measure of success in producing first-generation SODS devices, relatively little is known about Driver Vehicle Interface (DVI) requirements for these complex human-machine systems. The DVI is important because it affects the ability of drivers to detect, understand, and correctly respond to the warning information presented by the system. In the current study, a large range of alternative SODS DVI designs were identified and evaluated to determine potential DVI characteristics that enhance driver acceptance. Key issues, including driver preferences for the format, location, and symbology of SODS alerts, were addressed using static mock-ups and displays in a driving simulator. With respect to the information provided to drivers by a SODS device, three types of information were perceived as valuable: (1) a status indication at vehicle start-up, (2) a caution alert under 'no intent to turn' situations, and (3) a hazard alert under 'intent to turn' situations. With respect to alert design for an 'intent to turn' situation, the Vehicle in Blind Spot, Prescriptive Arrow, and Descriptive Car Crash designs (all in red), accompanied by a tone seem to meet basic requirements of a SODS alert in terms of driver preference, perhaps because they provide directional information about the location of a potential threat vehicle. These alerts should be investigated further under more representative conditions in future research.

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LIST OF ABBREVIATIONS

AASHTO................ American Association of State Highway and Transportation Officers
ANOVA.............................. .... Analysis of Variance
CVO .... Commercial Vehicle Operations
DVI.............................. .... Driver Vehicle Interface
FARS.............................. ....Fatal Accident Reporting System
GES .... General Estimates System
LCD.............................. .... Liquid Crystal Display
LED .... Light-Emitting Diode
NHTSA.............................. .... National Highway Traffic and Safety Administration
SCAS.............................. .... Side Collision Avoidance System
SODS.............................. .... Side Object Detection System
SR.............................. .... Stimulus Response

CHAPTER 1. INTRODUCTION

BACKGROUND

The increasing frequency of collisions and near-collisions associated with lane change or merge maneuvers continues to be a key concern within the traffic safety community. For example, 1993 motor vehicle crash data compiled from the Fatal Accident Reporting System (FARS) and the General Estimates System (GES) indicate that angle or sideswipe collisions accounted for over 41% of total crashes (National Highway Traffic Safety Administration [NHTSA], 1994). Such concerns are perhaps even greater for commercial vehicle operations (CVO); for combination-unit trucks, crashes involving backing, turning, lane changes, or merge maneuvers accounted for 19% of total crash involvements in 1991 (NHTSA, 1994).

In response to the high number of crashes associated with lane change and merging maneuvers, the automotive electronics industry has initiated a number of efforts to develop in-vehicle countermeasures capable of detecting objects to the side of a vehicle and providing a warning to the driver, i.e., Side Collision Avoidance Systems or SCAS. SCAS are designed to warn of impending collisions and can detect not only adjacent vehicles but vehicles approaching at such a speed that a collision would occur if a lane change were made. For example, Autosense Ltd. is developing an infrared-based collision warning device for blind-spot obstacle detection (Hyland, 1995). With this system, drivers are alerted to the presence of an object in the blind spot by an icon that flashes in the side view mirror. Similar devices are being developed by a host of electronics and automobile manufacturers. Side sensing systems (or “blind spot” sensors) are intended primarily to be used as supplements to outside side/rear mirror systems, and to aid drivers during lane change, merging, and turning maneuvers (NHTSA, 1993).

Side object detection systems (SODS) represent a subset of SCAS; they warn of the presence of adjacent vehicles only, whether or not there is a lane change. SODS devices encompass a wide range of sensor technologies. Both active and passive sensor technologies are being used as the core hardware technology of collision avoidance systems. Active technologies include radar (millimeter wave, or microwave), ultrasonic, and laser devices. Although the physics are very different across these devices, the basic principles of operation are similar. Active obstacle detection sensors in production or under development consist of one or more transmitter and receiver units mounted on the side of the vehicle. These units send data to a central processor that determines if an obstacle of interest has been detected and, if so, displays a visual and/or auditory warning to the driver. Passive sensors, which include infrared and video devices, send the infrared or video signal directly to a display mounted inside the vehicle, where the external scene to the side of the vehicle can be viewed in real-time by the driver. Although collision avoidance devices that would automatically take control of a vehicle (e.g., steering, braking, or acceleration) in the event of an impending collision are technologically feasible and being considered (Mironer & Hendricks, 1994; Verway et al., 1993), informing the driver and warning the driver of an obstacle or a potential collision is still the method of choice.

Despite a measure of success in producing first-generation collision avoidance systems in general and SODS in particular, relatively little is known about Driver Vehicle Interface (DVI) requirements for these complex human-machine systems. The DVI is important because it affects the ability of drivers to detect, understand, and correctly respond to the warning information presented by the system. The DVI includes such characteristics as alerting mechanisms and designs and required control functions. Across the range of driving situations and tasks, the implications of driver perception, performance, and preferences on the design of these DVI characteristics are largely unknown. For both passenger vehicle applications and the CVO environment, a number of critical design and implementation issues remain to be addressed. Key DVI issues associated with collision warning systems for use in the driving environment are identified and briefly discussed below.

Uncertainties About Alert Modality and Design

SODS alerts may be auditory, visual, tactile, or some combination of these three modalities. Within the driving environment, each of these three modalities is associated with some advantages and disadvantages. The auditory channel can have an advantage over the visual channel due to its attention-getting qualities (McCormick & Sanders, 1982). The use of auditory messages might allow better time-sharing of limited processing resources; i.e., bi-modal time sharing may be superior to intra-modal time-sharing (Wickens, 1984). In particular, auditory alerts reduce the visual load on the driver (Wolf, 1987) and are well-suited to a collision-warning situation, in which immediate action is required. However, their attention-getting abilities can become annoying to a driver if the alerts occur frequently or are associated with a high false alarm rate. Furthermore, the ambient noise levels within the cab of a commercial vehicle can approach 100 decibels, leading to concerns about required intensity levels of the alerts and possible auditory masking (McCormick & Sanders, 1982) of the alerts for CVO applications. While components of sounds such as speed, fundamental frequency, repetition units, and inharmonicity have been successfully manipulated to vary the perceived urgency of sounds (Hellier, Edworthy, & Dennis, 1993), relative urgency is but one aspect of obstacle detection/collision avoidance messages that auditory displays might be used to present. In addition, auditory displays are frequently disabled by users, apparently because of increases in subjective workload (King & Corso, 1993).

Preliminary human factors design guidelines for the auditory alert component of collision warning devices have been compiled by Lemer, Kotwal, Lyons, and Gardner-Bonneau (1993). Although SODS devices are intended to provide alerts in both critical (e.g., potential collisions) and non-critical (e.g., object detected only) situations these guidelines provide a useful starting point for the design of the SODS DVI; the Lemer et al., 1993, guidelines for auditory warnings are summarized below in table 1.

Table 1. Preliminary human factors design guidelines for the auditory alert component of collision warning devices (from Lerner et al., 1993).

FEATURES OF AUDITORY DISPLAYS	PRELIMINARY HUMAN FACTORS GUIDELINES
General Characteristics	Auditory displays should not be used for status information due to their high saliency.
Directionality	The source of an auditory alert in 3-dimensional space should be consistent with the direction of the hazard.
Coding	Higher repetition rates, higher intensities, higher frequencies, and larger frequency oscillations within auditory patterns should be used to distinguish imminent crash avoidance warnings from cautionary warnings.
Fundamental Frequencies	Frequencies in the 500 to 3000 Hz range are recommended.
Spectral Characteristics	Complex sounds, as opposed to pure sinusoidal waveforms, should be used.
Intensity	Warnings should be at least 20dB, but no more than 30dB, above the above the masked threshold.
Onset and Offset Rates	Onset rates should be > ldB/msec but < IOdB/msec. Offset rates should be equal to onset rates.
Warning Duration	For single sounds, duration should be between 200 and 500 msec. For complex sounds, duration should be between 200 and 300 msec.
Warning Repetition	A single sound or tone should be repeated for as long as the warning condition exists.

Visual alerts are less intrusive than auditory alerts and the location of the display in a vehicle can be used as a cue to the direction of the impending collision (e.g., co-located with a side-view mirror). Nonetheless, the visual channel is the more traditional mode for the presentation of driving information, and is associated with relatively higher information rates (Sorkin, 1987) than the auditory channel. However, driving requires a great deal of visual scanning just to maintain proper lane position and situational awareness of surrounding traffic conditions. Using a visual display to present collision avoidance alerts introduces yet another visual task, at precisely the same time that drivers' attention should be external to the vehicle. Preliminary human factors design guidelines for the visual alert component of collision warning devices have also been compiled by Lemer et al. (1993); these guidelines are summarized below in table 2.

Table 2. Preliminary human factors design guidelines for the visual alert component of collision warning devices (from Lerner et al., 1993).

FEATURES OF VISUAL DISPLAYS	PRELIMINARY HUMAN FACTORS GUIDELINES
General Characteristics	May provide descriptive information and are recommended for most levels of warning
Location	Primary displays should be located within +/- 15 degrees of drivers' expected line of sight in a given crash avoidance warning situation.
Usability	Drivers should not be required to transpose, compute, interpolate, or translate the warning information.
Legibility	Warnings should be legible at a glance. Display characters should subtend at least 12 arcminutes of visual angle.
Critical Warnings	Should be presented using a red, flashing indicator that is brighter and more conspicuous than other proximal displays. Flash rates should be 5 flashes per second, with equal on and off cycle times. Drivers should not be able to turn the displays off.
Cautionary Warnings	Should be presented using continuous red or continuous yellow/amber indicator. If no target is detected, then no display should be presented. Indicator lights should subtend a visual angle of 1 degree.
Status Indicators	Should be separate from warning displays, yet visible from drivers' position. Should provide indication of power to the device. Green indicators should be used to indicate that the device is turned on and has passed diagnostic testing; red or yellow/amber should be used to indicate that the device is turned on and has not passed diagnostic testing. Flashing indicators should not be used.

Although the selection of auditory vs. visual forms of information display will depend on a number of situation-specific variables, Deatherage (1972, p. 124) developed general guidelines for selecting auditory vs. visual display modalities. These guidelines are presented below in table 3.

Table 3. General guidelines for the selection of auditory vs. visual forms of information presentation (from Deatherage, 1972).

USE AUDITORY PRESENTATION IF:	USE VISUAL PRESENTATION IF:
1. The message is simple	1. The message is complex
2. The message is short	2. The message is long
3. The message will not be referred to later	3. The message will be referred to later
4. The message deals with events in time	4. The message deals with location in s[ace
5. The message calls for immediate action	5. The message does not call for immediate action
6. The visual system of the person is overburdened	6. The auditory system of the person is overburdened
7. The receiving location is too bright or dark-adaptation integrity is necessary	7. The receiving location is too noisy
8. The person's job requires him to move about continua	8. The person's job allows him to remain in one position

Tactile displays typically provide stimuli in the form of mechanical vibration or electrical impulses (McCormick & Sanders, 1982). Tactile alerts might be transmitted through the seat back, the steering wheel, or even the accelerator pedal. For example, Janssen and Nilsson (1990) conducted a simulator study using an "intelligent gas pedal" that applied a counterforce to the driver's foot as a collision alert. They found that the alert was associated with a reduction in headway on the part of their subjects. Importantly, headway reduction was not accompanied or offset by any inappropriate steering, acceleration, or braking behaviors.

Preliminary human factors design guidelines for the tactile alert component of collision warning devices have also been provided by Lemer et al. (1993); these guidelines are summarized below in table 4.

Table 4. Preliminary human factors design guidelines for the tactile alert component of collision warning devices (from Lerner et al., 1993).

FEATURES OF TACTILE	PRELIMINARY HUMAN FACTORS GUIDELINES
General Characteristics	Either mechanical vibration (e.g., in the seat pan or steering wheel, or counterforces on vehicle controls (e.g., force on accelerator pedal) may be used.
Compatibility with Driver Response	The type and location of the tactile alert should be easily associated by the driver with the appropriate response.
Attention-getting Abilities	The warning should adequately capture drivers' attention without startling the driver.
Frequencies	For vibrotactile displays, frequencies of 100-300 Hz should be used, frequencies of 3 Hz should be avoided.
Intensity	Intensity of vibrotactile displays should be 20 to 30 dB above the masked vibratory threshold, as measured in the vehicle in typical driving conditions.
Duration	Vibrotactile displays should continuously cycle until the situation no longer exists, the driver has taken appropriate corrective action, or the display has been manually terminated.
Pulse Rate	Vibrotactile displays may be of two types, continuous or pulsed.

Driver Response Time to Alerts

A key issue in the development and design of SODS devices is the perception-reaction times of drivers to alerts. Although this issue has been extensively studied within the human factors community, a range of findings have been reported. Wortman and Matthias (1983) measured the nighttime braking response times of 839 drivers to the onset of an amber signal at an intersection and reported mean values ranging from 1.09 to 1.55 seconds. Chang, Messer, and Santiago (1985) conducted a similar study, but in daytime as well and on both dry and wet roadways, and reported mean response times of 1.3 seconds and 95th percentile values of 2.5 seconds. Lemer (1993), measured the perception-response times of both younger and older drivers to a simulated on-the-road emergency and reported a mean reaction time of 1.5 seconds and 85th percentile value of 1.9 seconds. AASHTO (1984; see also Taoka, 1990) uses a design reaction time of 2.5 seconds to determine stopping distance when designing roadway elements such as signs, road curvatures, and traffic signal visibility and timing. Fundamentally, an alert must be presented early enough in the total timeframe of the potential collision event for the driver to perceive and understand the alert, and to take appropriate action. Thus, assumptions made about driver capabilities to perceive and to respond to collision alerts affect virtually every design parameters of a

SODS, from requirements for sensor range and scanning rate to limits on system processing time and the optimum modality for the collision alert.

Control Requirements by Drivers

It is not clear which SODS parameters should be adjustable by the driver. Options for driver control include turning the system on and off, switching between alert modalities (e.g., auditory vs. visual presentation of alerts), modifying the intensity of the alert (e.g., loudness or brightness), and adjusting the sensitivity of the system and timing of alerts. For example, in order to better reflect their own driving styles and prevailing driving conditions, drivers may want to adjust the distance setting or time-to-collision parameter of a collision avoidance system. Such an adjustment would have the practical consequence of allowing drivers to select either a more- or less- conservative timing logic for the system, thus changing the timing of alert presentation in response to an potentially unsafe driving condition. Such an control function might increase user acceptance of the system and reduce “nuisance” alarms (see below). However, it also increases the likelihood that the alerts will be presented too late for the driver to make an appropriate response within a given collision scenario unless other measures are built into the system.

Lerner et al. (1993) have provided preliminary human factors guidelines for control functions associated with in-vehicle crash avoidance displays. These guidelines suggest that a single master control should be provided to simultaneously adjust the intensity of all displays within a specific mode (i.e., auditory, visual, tactile). They also recommend that the design of physical characteristics of the controls such as size, labeling, shape, and texture adhere to standard human engineering principles (e.g., those found in MIL-STD- 1472D).

Stimulus-response (SR) Compatibility of Alerts

Stimulus-response compatibility is another key concept in human factors design (Kantowitz, Triggs, & Barnes, 1990). It refers to the relationship, both geometric and conceptual, between a stimulus such as a display, and a response, such as a control action. For example, the debate in aviation about the relative merits of outside-in (moving airplane) versus inside-out (moving horizon) artificial horizon indicators is an argument about stimulus-response compatibility.

Figure 1 shows a recent model of stimulus-response compatibility (Kantowitz, et al., 1990) based upon a nested hierarchy of frames, rules, and response tendencies, Without going into fine detail, it is sufficient for present purposes merely to note that a frame is a well-developed knowledge structure based upon driver experience and training. Plans and actions that run counter to established frames, i.e., low stimulus-response compatibility, are potentially problematic.

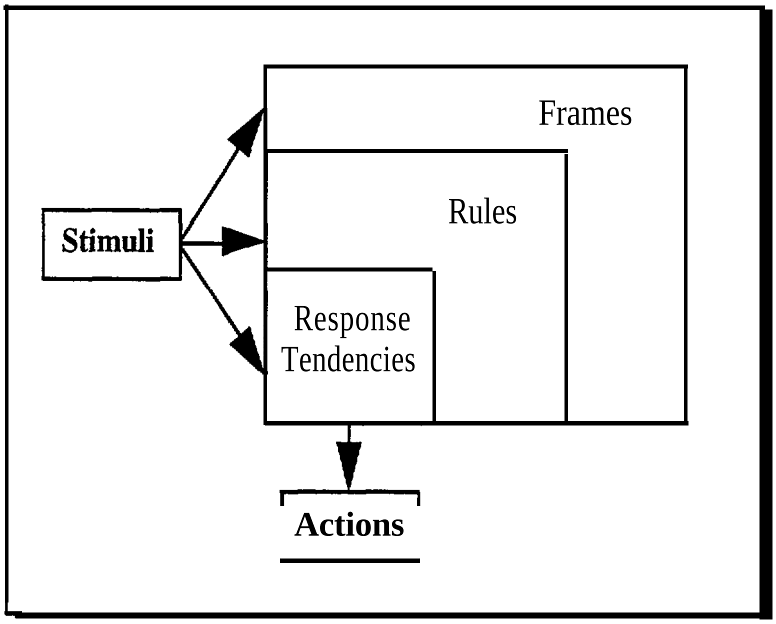


Figure 1. Nested hierarchical relations among frames, rules, and response tendencies as sources of stimulus-response compatibilities.

Stimulus-response compatibility is an important concept to side-object warning systems because of the range of combinations associated with the locations of the detected object (left or right side object), possible locations for a visual alert (e.g., rear-view or side-view mirrors), and possible control actions by the driver in response to an alert (e.g., do nothing, slow down, turn right, or turn left). Thus, side-object detection system warnings that exhibit low stimulus-response compatibility can confuse drivers, increase task demands, create extra workload, and lead to lower trust in the system.

False Alarms

A false alarm occurs when a signal or target is said to be present when in fact no such signal or target is present. In the context of collision avoidance systems, two types of false alarms are relevant. First, a "real" false alarm occurs when a collision alert is presented to the driver in the absence of any crash-relevant obstacle or event. Second, a "nuisance" false alarm occurs under circumstances in which the driver feels that the alert itself, or the urgency associated with the alert, is incorrect or inappropriate. In either case, false alarms will reduce the trust and confidence that the driver places in the system, thus reducing system effectiveness. In general, users are most reluctant to rely upon equipment they do not trust (Lee & Moray, 1992). When trust in the device is too low and an alarm is presented, drivers may spend additional time verifying the problem, thus slowing appropriate collision-avoidance actions. Alternatively, they may choose to ignore the alarm, thus completely defeating the purpose of the system,

Inappropriate Levels of Driver Trust in the System

Just as having too little trust in a collision avoidance system can reduce system effectiveness, having too much trust in the system can lead to a host of other performance concerns. For example, putting too much trust in an imperfect system may lead to a false sense of security on the part of the driver. Similar problems have occurred in comparable domains. In the aircraft environment, for example, inappropriately high levels of trust in automated flight systems can cause pilots to ignore other sources of flight data or to forego established and prudent flight procedures (Danaher, 1980). In general, when trust in the device is too high, drivers may (1) assume that the system will detect any "target" obstacle or impending collision and therefore reduce their own vigilance levels or (2) be willing to accept higher levels of driving risk and, for example, neglect typical safety or collision avoidance behaviors such as checking rear and side view mirrors before changing lanes.

Familiarization Requirements

Drivers will need time in order to become familiar with the various capabilities and modes of operation of collision avoidance systems. Despite their potential for increasing safety, these devices represent a new on-board system that drivers must learn how to use while driving. In this context, Mazzae and Garrott (1995) compared the performance and subjective opinions of CVO drivers using on-board SODS and standard mirror systems. Although the collision avoidance system did not improve object detection performance, drivers reported that they thought the system was beneficial. Thus, Mazzae and Garrott (1995) speculated that drivers needed more time to become comfortable with the device and familiar with using the device. SODS devices share many of the human factors concerns associated with the implementation and use of automated systems. In particular, the introduction of such devices changes the human operator's role from one of continuous manual control to one with decreased manual control, but increased monitoring requirements. Such changes suggest the need for changes in the amount and nature of driver training in order to take full advantage of the benefits that collision avoidance systems can provide.

In summary, SODS devices have the potential to increase the safety of the driving task. However, as seen above, the introduction of collision-avoidance technologies into the driving environment is not issue-free. As with any new automotive technology involving the driver, many issues associated with driver perception, performance, and preferences must be addressed. In addition to the general human factors guidelines for collision warning devices summarized above, Lerner et al. (1993) have provided preliminary human factors guidelines for SODS or "blind-spot" systems. These guidelines are summarized below in table 5.

Table 5. Preliminary human factors design guidelines for blind-spot devices (from Lerner et al., 1993).

FEATURES OF BLIND-SPOT DEVICES	PRELIMINARY HUMAN FACTORS GUIDELINES
Application	Should be used to alert the driver to the presence of potentially conflicting vehicles located in areas of poor visibility lateral to the vehicle.
Visual Display Location	Should be +/- 15 degrees vertically above, and horizontally forward of, the line-of-sight of the side view mirror on the same side of the vehicle as the related detector system. Some indication of the direction of the hazard should be provided
Areas of Coverage	The sensor should cover the entire blind-spot, but should not extend more than 10 feet laterally from the side of the vehicle.
Auditory Displays	May be used to indicate directionality, should only be provided for imminent crash situations.
Tactile Displays	Directional warnings should only be provided for imminent crash situations.
Termination of Warnings	Imminent crash avoidance warnings when the detected object no longer meets the defining criteria for “imminent.” of the system senses an appropriate corrective maneuver being made by the driver. Cautionary warnings should remain on as long as a target object is detected in the warning zone.
Transient Manual Override of Warnings	Should not be provided for visual displays. Should be provided for tactile and auditory displays.
Detector Sensitivity Adjustment	May be provided to allow the driver to adjust the range of the sensor to reduce sensitivity and false alarm rates.

Introduction to the Current Study

The objective of the current study was to collect and analyze data to identify characteristics of the SODS DVI that enhance driver acceptance. A range of key research questions associated with the introduction of SODS devices into the driving environment were addressed:

- What is the preferred location for the SODS display?
- What is the preferred symbology for the SODS display?
- What is the preferred color for the SODS display?
- What is the preferred form of auditory alerts?
- What information should SODS present to drivers?
- Are there any age or gender differences associated with preferences for the SODS DVI design?

Both analytical and empirical activities were conducted to address these questions. In this study, a large range of alternative SODS DVI designs were identified and evaluated to determine potential DVI characteristics that enhance driver acceptance. This study included useability assessments with static mock-ups and displays; subjective dependent measures were also obtained.

CHAPTER 2. METHODS

GENERAL APPROACH

Through the collection and analysis of subjective opinion data, this research investigated DVI characteristics of SODS alerts that are associated with increased system effectiveness through improved driver acceptance. This laboratory study explored alert understandability, preferences, and acceptability in order to limit the alert alternatives investigated in future on-the-road studies. To examine drivers' preferences for SODS alerts, a number of SODS alerts were developed and tested across four display locations in the Battelle Automobile Simulator. SODS alerts were presented in two scenarios: 'intent to turn', where subjects were asked to rate the alert as if it had been activated when they were preparing to turn or change lanes; and 'no intent to turn', where subjects were asked to rate the alert as if it had activated even though they had no intent to turn or change lanes. Six multiple choice questions were answered after each alert was presented. In addition, stated preferences for alert design were obtained, as were records of the number of alert presentations required before the subjects noticed that an alert had been activated.

SUBJECTS

A total of 48 subjects participated in this study. Sixteen subjects (eight males and eight females) were recruited from each of the following three age groups: 25 years and under, 26 to 54 years, and 55 years and over. All subjects were licensed drivers who drove at least twice a week in the Seattle area. Subjects were recruited from organizations in the Seattle metropolitan area, including the University of Washington, senior citizen's activity centers, churches, and other organizations. Subjects were paid $5 per hour for their participation and were eligible for a bonus of up to $10.00.

APPARATUS

Drivers' preferences for different SODS alert alternatives were investigated using the Battelle Automobile Simulator test buck. Specialized displays, including a small 2" x 1.5" LCD (liquid crystal display), were used to present the SODS alerts. Four display locations were assessed in the study.

Automobile Test Buck

The automobile test buck, built by Walter Dorwin Teague Associates, Inc., was constructed using a 1986 Merkur XR4Ti automobile. The original side and top body work, from 12 inches in front of the Firewall to 20 inches behind the drivers seat, has been maintained to conserve the feel of a real automobile. The floor pan has been replaced by a wood base to provide easy movement of the buck. The dash of the automobile has been modified to allow multiple configurations, including combinations of active matrix LCD touch-screens and electroluminescent displays, and a completely analog instrument panel. A small fan was also included in the instrument panel to provide air circulation to the driver. The steering column is that of the Merkur with no modifications. The steering wheel has been modified to include up to twelve push-button switches (six on each side of the wheel) placed at approximately 130 and 240 degrees. These switches connect to the digital input port of a Computer Dynamics CIO-D1024 card. The steering shaft is also connected to a torque motor which can be adjusted to produce accurate roadway feedback to the driver. Interior lights are located in the center of the headliner near the front windshield and can provide light for the driver as needed. The rear of the vehicle is open to allow access to the rear speakers. Both doors are operational with side view mirrors. The buck also has adjustable driver and passenger seats.

The front "windshield" is completely enclosed. The left side of the windshield houses a 20-inch multisync color monitor providing a simulated roadway display for the various driving scenarios. The monitor is covered with a black wooden hood and the right side of the windshield is covered with a black piece of plastic to reduce the ambient background lighting. The front windshield enclosure can be removed completely for use with the three screen option allowing free vision in all directions.

Driving Scenarios

The simulated roadway (developed using the Systems Technology, Inc., simulator software) was comprised of three lanes of traffic moving in the same direction as the subject's vehicle, and two lanes of traffic traveling in the opposite direction. For the purpose of this study, steering, acceleration, and braking were controlled by the computer and driving speed was constant. Thus, subjects viewed the road from the driver's perspective without being required to control the car. The roadway consisted of numerous curves, intersections, bill boards, other vehicles and pedestrians. No side view mirror or rear view mirror image was available to the subjects.

Four scenarios were developed in total, two 25 minute 'intent to turn' scenarios, and two 15 minute 'no intent to turn' scenarios. In the 'intent to turn' scenarios, subjects were asked to imagine they were driving on the interstate, had activated their turn signal, and were preparing to change lanes. In the 'no intent to turn' scenarios, subjects were asked to imagine they were driving on the interstate, the road was clear in front of them, and they had no desire to change lanes. The roadway geometry and traffic volume were the same in the 'intent to turn' and 'no intent to turn' scenarios.

Targets

As an incentive, to ensure that subjects paid attention to the roadway, a monetary bonus was offered to subjects for detecting and correctly responding to the occurrence of red cars on the roadway. The subjects were asked to press the left button, marked "front" on the steering wheel, if a red target car was approaching in on-coming traffic and the right button, marked "rear", if it was approaching from behind. There were six targets presented in each of the 25 minute scenarios, and four targets presented in each of the 15 minute scenarios. Subjects received 50 cents for each correctly identified target, for a maximum possible bonus of $10.00.

SODS Alert Locations

Display

Four alert locations, plus Muth Mirror condition, were investigated, using a Casio LCD, Model # EV-500. Each of these is described below:

Driver Side. The LCD was installed on the driver side door. From the driver's perspective, the display was located directly beneath the side-view mirror.

Top of Dash. The LCD was installed 13" (33cm) to the right and 6" (15.24cm) above the center of the steering wheel.

Rear View Mirror. The LCD was installed immediately below the test buck's rear view mirror.

Passenger Side. The LCD was installed on the passenger side door, directly below the mirror.

Muth Mirrors. Two Muth Mirrors were installed in the location of the test buck's regular driver side and passenger side mirrors. A characteristic of these mirrors is that, when activated, a small, inverted, red triangle appears via backlighting in the top interior comer of the mirror. The Muth Mirror was activated by a switch operated by the experimenter and served as a visual alert.

Description of the SODS Alerts

Individual alerts were selected based on current alert design across a number of SODS devices under development, as well as on standard human factors practices regarding warning system design.

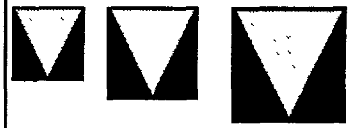
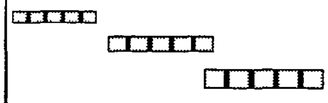
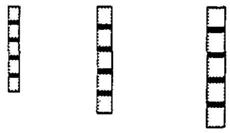
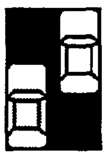
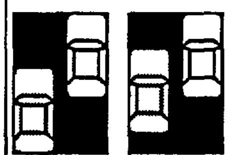
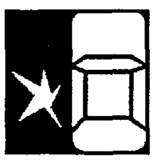
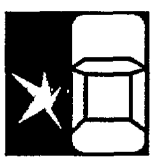
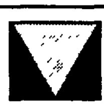
The visual alerts and auditory tones were generated and displayed using a 586 Pentium computer. Each visual alert subtended at least 1 .O degrees of visual angle from the average seating position, but they may have been slightly larger or smaller depending on the precise seating location of the subject. Twenty-four red alerts were presented in the 'intent to turn' scenario and eighteen amber alerts were presented in the 'no intent to turn' scenario. Each alert was presented for a duration of five seconds. The visual alerts were comprised of a combination of text, symbols, and icons. These icons were either descriptive, in that they provided information about a driving condition, or prescriptive, in that they provide information about how the driver should respond to the condition.

The SODS alerts examined included the following dynamic characteristics: static, flashing, moving, and size increase. The dynamic property of the alert refers to various characteristics of the alert, including its on/off cycle, appearance, and size. Static refers to the alert remaining on for a duration of five seconds. Flashing refers to the entire alert cycling on and off; the flashing alerts completed 4 cycles per second, flashing at a rate of 0.25 seconds with equal on-off durations. Moving refers to an element within the visual alert that alternates between two positions across different cycles of the alert. To be consistent with the dynamic property of the flashing cycles, the moving alerts also have a rate of 0.25 seconds. In the study, movement was generated by sequentially presenting two alerts that looked identical but were placed at slightly different locations on the display, giving the appearance of movement. Size change refers to an icon or symbol that grows in size across different cycles of the alert. Each icon in this condition was generated in three sizes. The smallest image subtended a visual angle of 1.0 degree. The size increased to 1.3 arcminutes (middle image) and then to 1.6 arcminutes (large image). The smallest image was the same as used in the static condition. The on time of each image at each size was 0.25 seconds.

Two auditory alerts were presented in the ‘intent to turn’ scenario only. Also, one of these auditory alerts was paired with a visual alert to test preference for the combination. Table 6 illustrates all alerts and their dynamic properties presented in the study. In the ‘intent to turn’ scenario, these alerts were presented in red. In the ‘no intent to turn’ scenario, these alerts were presented in yellow.

Importantly, some of the alerts were directional in the sense that alert elements corresponded to the location of a potential threat vehicle. For example, with the ‘Vehicle in Blind Spot’ alert the threat vehicle (in red or yellow) was to the right of our vehicle (in white) when presented on the passenger side location and to the left when presented on the driver side location. A similar alert design/logic was used with the other “directional” icons such as the Prescriptive Arrow, the Descriptive Car Crash, and the Descriptive Car Crash plus Tone.

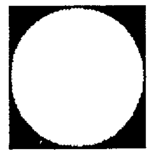
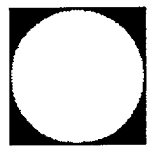
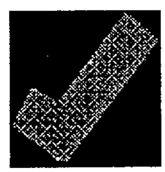
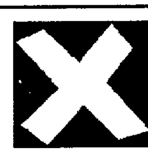
Table 6. Alerts presented in the study.

ALERT	STATIC/FLASHING	SIZE INCREASE	MOVING
Inverted Triangle			NA
Five Horizontal LEDs			NA
Five Vertical LED's			NA
Barber Pole	NA	NA	
Barber Pole and Caution	NA	NA	
Vehicle in Blind Spot		NA	
Prescriptive Arrow			NA
Descriptive Car Crash			NA
Tone 1 & Descriptive Car Crash		NA	NA
Muth Mirror		NA	NA

SODS Status Indicators

Six SODS status indicators were developed and displayed. Each was displayed in the location assigned to the particular subject (i.e., either in the driver side, rear view mirror, dash panel, or passenger side location). Three of the status indicators (the Green Circle, Green Circle + System OK, and Green Checkmark) were designed to indicate that the system was functioning properly and three (the Red Circle, Red Circle + System Malfunction, and Red X) indicated that the system was malfunctioning. The SODS status indicators can be seen in table 7.

Table 7. Status indicators.

STATUS INDICATOR	STATIC/FLASHING
Green Circle	
Red Circle	
Green Circle + System OK	
Red Circle + System Malfunction	
Green Checkmark	
Red X	

Multiple Choice Questions

After each alert was presented, subjects were asked to respond to six multiple choice questions (see appendix A). The goal of these questions was to obtain information regarding effectiveness, comprehension, and annoyance associated with each alert. Subjects were asked to choose the response that most closely reflected their opinion. Each question had five response options. The question order was counterbalanced across subjects to reduce possible effects of question order.

After seeing each of the status indicators, subjects were asked to answer one multiple choice question (see appendix A). The goal of this question was to obtain information regarding both the effectiveness and comprehension of the status indicator. Subjects were asked to choose the response that most closely reflected their opinion. The question had five response options.

EXPERIMENTAL DESIGN

Independent Variables

The experiment consisted of two phases, a SODS Alert Phase and a Status Indicator Phase, which are described below:

SODS Alert Phase. This study employed a mixed experimental design with two between-subject variables (age and display location) and three within subject variables (scenario, alert, and question). Three age groups were tested; 25 years and under, 26 to 54 years, and 55 years and over. Subjects viewed the SODS alerts in one of four display locations: (1) driver side mirror, (2) top of dash, (3) rear-view mirror, and (4) passenger side mirror. All subjects provided their opinion of the alerts in both the 'intent to turn' and 'no intent to turn' scenarios. The first scenario, 'intent to turn', asked subjects to evaluate the SODS alerts as if they had activated their turn signal and were preparing to change lanes. The second scenario, 'no intent to turn', asked subjects to evaluate the SODS alerts as if they had not activated their turn signal and did not intend to turn or change lanes. The order of scenario presentation was counterbalanced across subjects. The 24 alerts for the 'intent to turn' scenario were randomly assigned to one of two groups to allow subjects a break after viewing 12 alerts. The order of alerts within each group was the same for all subjects; however, the presentation order of the two groups was counterbalanced. The 18 alerts for the 'no intent to turn' scenario were also randomly assigned to two groups of 9 and presented in a counterbalanced fashion. Each subject answered the same six multiple choice questions after viewing each alert. Six different question orders were used based on the Latin square ordering technique.

Status Indicator Phase. Six status indicators were presented to all subjects in the same order as shown in table 7. Three indicated system functioning, three indicated system malfunction. The status indicators were presented in the same display location assigned to individual subjects as the SODS alerts.

Dependent Variables

As outlined in tables 8 and 9, data were collected during two separate phases of the experiment; the SODS Alerts Phase, and the Status Indicators Phase. The dependent variables collected in each of these phases are listed below.

Table 8. Dependent variables associated with the SODS alert phase of data collection.

SODS ALERTS
Multiple Choice Questions (6)
Stated Preferences for Alerts
Number of Presentations Required

Table 9. Dependent variables associated with the status indicator base of data collection.

STATUS INDICATORS
Multiple Choice Question (1)
Stated Preferences for Status

The phases for the dependent variables are described below:

SODS Alerts Phase. In this phase, a total of 42 SODS alerts were presented to each subject. Subjects were instructed to inform the experimenter whenever they saw or heard an alert. If an alert was presented and the subject did not respond, the alert was presented again until a response was given. The number of times each alert was presented before it was responded to was recorded by the experimenter. Subjects answered six multiple choice questions for each alert, stating their response out loud for the experimenter to record. The six questions can be found in appendix A. After all of the SODS alerts were presented, subjects were encouraged to design their own SODS alerts for both the ‘intent to turn’ and ‘no intent to turn’ scenarios. The experimenter asked subjects to consider such things as: shape, color, location, and sound of their ideal alert.

SODS Status Indicator Phase. In this phase, six status indicators were presented, three indicating the system was functioning, and three indicating the system was malfunctioning. One multiple choice question was asked after each presentation (see appendix A, question #7). In addition, subjects were encouraged to draw what they believed to be the ideal status indicator both for when the system was functioning and when it was malfunctioning.

PROCEDURE

The initial screening for participant suitability was done by telephone. The “SODS Subject Selection Phone Questionnaire” (appendix B) was administered at this time, The purpose of the screening procedure was to ensure an equal number of subjects in each age and gender group. Potential subjects who did not have an active driver’s license, drove less than twice per week, or who were color blind were eliminated from the subject pool. Those who met the criteria outlined above were scheduled for a laboratory experiment time.

Upon arrival at the testing site, subjects were asked to read and sign the informed consent form, “NHTSA Research Participation Consent Form” (appendix C). The experimenter began by reading a brief description of the study, including general information about the purpose and operation of a SODS device (see appendix D). After the subjects had been given an overview of the study, they were taken to the simulator and seated in the test buck. The experimenter explained that they would be viewing the roadway as if they were driving down the road; however, the computer would actually be controlling the steering, acceleration, and braking. The experimenter emphasized to subjects that they should remain attentive to the roadway as if they were actually driving their own vehicle.

Next, the bonus payment scheme was explained. Subjects were told they would receive 50 cents every time they noticed a red car on the roadway. They were told to press the left hand button marked “front” if the red car was driving towards them in on-coming traffic, and the right hand button marked “rear” if the red car was approaching them from behind.

Subjects were familiarized with the driving scene via a short practice scenario. This scenario demonstrated the target cars and the experimenter verified that the subject could recognize the targets and respond appropriately. Additionally, two sample alerts (one visual and one auditory) were presented. The visual alert was presented in the display location assigned to that subject. The subject was instructed to inform the experimenter verbally every time they became aware that either an auditory or a visual alert was being presented to them. Finally, a board displaying the multiple choice questions was shown to the subjects who read each question and the response alternatives in order to familiarize themselves with them and to ask any questions they might have.

To begin the experimental trials, one of the two driving scenarios (i.e., “intent to change lanes” or “no intent to change lanes”) was described to the subject. The subject was then asked to imagine themselves in that driving scenario based on their driving experience. As the subject viewed the roadway, the alerts were presented sequentially. Each alert was presented after approximately 30 to 60 seconds of driving for a duration of 5 seconds, except auditory alerts which were presented for one “play” cycle. After each alert was presented and attended to, subjects were shown the poster board which listed the six multiple choice, subject opinion questions. Subjects were asked to report out loud which response most accurately expressed their opinion of the alert. The experimenter recorded the subjects’ responses.

After all of the alerts for the first scenario were presented, subjects were given a 5 minute break. After the subjects completed the rest break, the second driving scenario was described. The subjects were asked to imagine themselves in this scenario while alerts were again presented sequentially. Note that the same alerts were presented for both scenarios. Subjects were again asked to provide a response to the six multiple choice questions.

After all 42 of the SODS alerts had been shown, subjects were asked to comment on the alerts they had seen and to think about how they would design their own SODS alert. Subjects were encouraged to draw a picture of what this alert would look like. The experimenter asked specific questions about stated preferences for SODS alerts (see appendix E).

The status indicators were then presented in the same display location as the SODS alerts had been. During this time there was no driving scene. After each status indicator, subjects answered one multiple choice question. After all six of the status indicators had been shown, subjects were asked to comment on them and to think about how they would design their own SODS status indicator. Subjects were encouraged to draw a picture of what this status indicator would look like and to provide preferences for the status indicator.

In total, the entire study lasted about two hours per subject. At the conclusion of the experiment, each subject was asked whether they had any final questions or comments regarding the study. These comments, if any, were noted. The payment from was then completed, the subjects were paid and thanked for their participation.

CHAPTER 3. RESULTS AND DISCUSSION

Data were collected for each of the 48 subjects during both the SODS Alert Phase and SODS Status Indicator Phase of this study. In the SODS alert phase, the number of presentations as well as the individual responses to the multiple choice questions following each alert were analyzed. In addition, stated preference for the SODS alerts were obtained. In the SODS status indicator phase, the subjects' response to a single multiple choice question was the primary dependent variable of interest; stated preference data were also obtained. Following data entry and verification of basic data integrity, the data were subjected to a number of analyses which screened for missing data and outliers. All analyses were conducted using the BMDP, V.7.0 statistical software package.

As noted above, this study was intended as a screening study, and not as a definitive experiment to determine a precise SODS DVI. The goal has been to identify clear "winners" and "losers" with respect to SODS DVI options. Our analytical methods therefore focused on descriptive, and not inferential, statistics. A number of non-orthogonal variables were included in the study, in part to reduce the number of SODS alert alternatives, and in part to identify important variables for future research. With respect to the multiple choice data, chi-square techniques are not an appropriate analytical method since their expected values cannot, a *priori*, be identified. We could treat the percentages of response choices as score data and use Analysis of Variance (ANOVA), but a much larger sample size would have been required in order to evaluate the effects of interaction involvng more than two independent variables.

Therefore, for each dependent measure, we have identified criteria for assessing the importance or meaningfulness of differences between levels of independent variables. For the multiple choice questions and the stated preferences, we have examined the distributions of responses and have looked for some of the following characteristics in assessing the significance of the results: (1) a strong consensus (e.g., 50% or greater) for a particular response, and (2) large differences in responses (e.g., at the extreme ends of the distribution) across experimental conditions. For the number of alert presentations required, mean differences of approximately 0.3 presentations or greater are considered to be important or meaningful for DVI design and future research. In our initial review of the data, differences of 0.3 or greater seemed to distinguish meaningful differences from chance or inconsistent differences across experimental conditions. Also, many of the results below are discussed in the context of the different display locations, as two-way interactions. For example, we have examined the effects of the individual alert designs nested within each display location. This is primarily because display location was a between-subjects variable that was expected to exert considerable influence over subject responses.

In this regard, the results reported below should be interpreted cautiously for several reasons. First, subjects in the study had no little or no exposure to collision avoidance devices like SODS prior to this study. Thus, their responses to the alerts reflected their immediate impressions, as opposed to the preferences that they might state after several weeks of use and exposure to a SODS device. This leads to a second caution, relating to the obvious differences between the experimental environment and real-world conditions. Subjects were not interacting with the simulator, nor were they checking side-view mirrors as they might during lane change or merge driving maneuvers. Thus, we might expect a more precise and representative set of findings if such data were obtained under real-world conditions. Third, the results reflect representative drivers' opinions about the alerts, as well as what state that they want in a SODS DVI.

SODS ALERT PHASE

Effects of Display Location

Responses to Multiple Choice Questions

Appendix A provides the multiple choice questions and the list of possible responses for each question. Table 10 provides the percentage of responses for each multiple choice question response option as a function of display location. For each question, we have highlighted the response with the highest percentage of responses. As seen in the table, there was a similar pattern of responses for the four display locations. However, some differences in response profiles across the display locations are apparent.

Table 10. Percentage of responses as a function of display location.

DISPLAY LOCATION	QUESTION NUMBER	SUBJECT RESPONSE				
		A	B	C	D	E
DRIVER SIDE	1	6.3	20.8	34.7	34.3	3.8
	2	12.7	19.8	11.9	10.9	44.6
	3	5.8	1.2	12.1	*41.9*	9.1
	4	18.3	6.5	20.8	13.5	*40.9*
	5	7.7	*34.5*	6.5	20.0	31.2
	6	5.2	14.3	15.9	21.3	*43.3*
REAR VIEW MIRROR	1	4.2	25.8	*37.5*	25.2	7.3
	2	5.6	19.4	22.7	22.3	*30.0*
	3	6.7	4.8	10.6	37.9	*40.0*
	4	20.8	4.2	19.4	18.3	*37.3*
	5	7.3	*33.3*	16.7	24.6	18.1
	6	8.8	12.7	17.5	26.9	*34.2*
DASH PANEL	1	3.1	16.7	29.0	*41.9*	9.2
	2	6.9	19.6	16.3	20.2	*36.9*
	3	7.3	4.4	13.5	35.4	*39.4*
	4	22.7	6.2	26.0	11.5	*33.7*
	5	11.7	*38.8*	10.6	11.0	27.9
	6	13.8	8.7	16.9	12.1	*48.5*
PASSENGER SIDE	1	3.9	23.4	*37.0*	27.9	7.8
	2	9.7	21.4	12.1	*31.6*	25.1
	3	4.8	3.7	27.5	30.1	*34.0*
	4	21.0	9.7	18.4	18.8	*32.0*
	5	13.0	*31.4*	11.9	21.6	22.1
	6	10.2	8.4	20.8	*33.1*	27.5

For question #l***, "To what extent would this alert be effective at getting your attention?,"*** the most frequent response for the dash panel location *was "I would notice it right away, even if I wasn't expecting it."* For all the display other locations, the most frequent response was "*I would probably notice it sooner or later, even if I wasn't expecting it."*

For question #2, ***"To what extent does this alert communicate a sense of urgency to you?,"*** almost half of the responses (44.6%) in the dash panel location were *"I would immediately stop changing lanes until I was certain the side was clear."* While this was almost the most frequent response for the other display locations, the distribution of responses for the other locations suggest a somewhat lower level of perceived urgency.

Surprisingly, there appear to be no meaningful differences across display locations to question ***#4, "To what extent does this alert communicate the location of the potential danger?"*** In particular, the driver and passenger side locations did not appear to provide any advantage to the subject in terms of identifying either the left or right side of the vehicle as containing a potential danger. Interpretation of these data, however, must reflect the fact that there was no side view image presented in the side view mirrors as there would be during normal driving.

Stated Preferences for Alert Design

Table 11 shows the stated preferences for alert location. Since no restrictions were placed on the subjects' stated preferences, responses ranged across the automobile interior. However, as seen in the table, there was a strong preference for a forward, i.e. around the dash panel, location for the SODS alert. This preference for a SODS alert located on or near the dash panel was seen in both the intent (approximately 50% of responses) and no intent (approximately 52% of responses) driving scenarios.

Table 11. Stated preferences for display location as a function of driving scenario.

LOCATION	INTENT	NO INTENT
Dashboard behind wheel	18.75%	25.00%
Top dash, center of wheel	12.50%	10.42%
Both driver and passenger mirrors	12.50%	6.25%
Other	10.41%	12.50%
Too dash. left of wheel	8.33%	8.33%
Top dash right of wheel	8.33%	6.25%
None specified	6.25%	4.17%
Rear mirror	4.17%	2.08%
Center console	4.17%	4.17%
Driver mirror	4.17%	N/A
HUD on windshield	4.17%	N/A
No data	4.17%	8.33%
General dash area	2.08%	2.08%
Would not have a 'no intent' alert	N/A	10.42%

Number of Required Presentations

Table 12 provides the number of alert presentations required for subjects to indicate that they have seen the alert, as a function of display location. As seen in the table, there were no meaningful differences in the number of required presentations associated with display location.

Table 12. Number of presentations as a function of display location.

	DRIVER SIDE	REAR VIEW MIRROR	DASH PANEL	PASSENGER SIDE
Mean	1.15	1.20	1.08	*1.21*
SD	0.59	0.69	0.39	0.70
Minimum	1.0	1.0	1.0	1.0
Maximum	6.0	5.0	5.0	6.0

Summary

Responses to the multiple choice questions and the subjects' stated preferences suggest that the dash panel location provides an advantage for both the alerts's overall effectiveness and for driver preferences. These findings may well reflect our subjects' previous experience with automobile alerts. That is, since visual alerts are typically located on or near the dash panel, drivers may be more accustomed to this location and therefore automatically prefer this location to other locations.

Effects of Specific Alert Designs

Responses to Multiple Choice Questions

Tables 13, 14, 15, and 16 show the distribution of responses to the multiple choice questions as a function of driving scenario, with each of the four tables corresponding to a different display location.

For question #l, ***"To what extent would this alert be effective at getting your attention?,"*** there was a fairly consistent pattern of results across the four display locations. Specifically, three alerts, the Descriptive Car + Tone, as well as both of the individual tones, were associated with high levels of effectiveness at getting the subjects' attention. In fact, in some cases, these three alerts were so good at getting subjects' attention that they bordered on being distracting to the subjects. The Muth Mirror alert was extremely effective at getting the subjects' attention when located on the driver side of the vehicle, but was not rated any better at getting attention than were the other alerts when located on the passenger side of the vehicle.

For question ***#2, "To what extent does this alert communicate a sense of urgency to you?,"*** several SODS alerts seemed to be consistently associated with a high degree of urgency across all four display locations. These alerts include: the Vehicle in Blind Spot, Prescriptive Arrow, Descriptive Car Crash, Descriptive Car Crash + Tone, the two tones, and the Muth Mirror alert.

For question #3, ***"To what extent would this alert be annoying to you?,"*** the Descriptive Car Crash + Tone, as well as both of the individual tones, were all associated with high levels of "annoyance," across all display locations. Much of this perception is associated with the use of auditory alerts in the 'no intent' condition, in which the majority of subjects stated a preference for no tone. The use of a tone seemed to be welcome, however, when the driver was intending to turn or change lanes. For most of the other alerts, subjects indicated that they would generally appreciate having the alert.

For question #4, ***"To what extent does this alert communicate the location of the potential danger?,"*** four alerts were consistently associated with high levels of conveying the location of the potential danger. These alerts were Vehicle in Blind Spot, Prescriptive Arrow, Descriptive Car Crash, Descriptive Car Crash + Tone. The Barber Pole and Caution and Muth Mirror alerts were associated with high levels of conveying the location of the potential danger when presented on the driver side. The Inverted Triangle, Horizontal and Vertical LEDs (light-emitting diodes), Barber Pole, and the two tones, were not viewed as being very effective at conveying the location of the potential danger. These results are encouraging, since the Vehicle in Blind Spot, Prescriptive Arrow, Descriptive Car Crash, Descriptive Car Crash + Tone alerts were designed to convey location information to the driver. These results therefore suggest that such information can be effectively conveyed to drivers via a SODS DVI.

For question #5, ***" To what extent does this display/alert communicate the nature of the situation?,"*** the results were almost identical to those associated with question 4. That is, the Vehicle in Blind Spot, Prescriptive Arrow, Descriptive Car Crash, and Descriptive Car Crash + Tone alerts were associated with high levels of conveying the nature of the alert situation to a driver. Again, the less descriptive alerts, such as the Inverted Triangle, Horizontal and Vertical LEDs, Barber Pole, and the two tones, were not viewed as being very effective at conveying the nature of the alert situation to a driver.

For question # 6, ***" To what extent would you confuse this alert with something else?," five*** alerts, the Barber Pole and Caution, Vehicle in Blind Spot, Prescriptive Arrow, Descriptive Car Crash, and Descriptive Car Crash + Tone were consistently associated with being different and distinct across all four display locations. The tones were generally identified as being less distinct.

Table 17 presents findings on the alert design variable in a somewhat different way. In this table, rather than looking at individual alerts, we have broadly characterized a subset of the alerts according to whether or not the alerts inherently contain information about the location of a potential threat vehicle. Thus, data from the Vehicle in Blind Spot, Prescriptive Arrow, and Descriptive Car Crash alerts have been grouped and labeled "Directional Alerts" since they all show the location (right or left side) of the potential threat vehicle. Data from the Inverted Triangle, Five Horizontal LEDs, Five Vertical LEDs, Barber Pole, and Barber Pole with Caution alerts have been similarly grouped and labeled "Non-directional Alerts" since they do not provide any information regarding the location of the potential threat vehicle. As seen in table 17, the results from this transformation of the alert design variable are fairly consistent across all four display locations. The responses to questions #2,4,5, and 6 all favor the directional alerts.

Specifically, the directional alerts (Vehicle in Blind Spot, Prescriptive Arrow, and Descriptive Car Crash) were consistently viewed by subjects as: (1) communicating more urgency than the non-directional alerts, (2) better able to communicate the location of the potential danger than the non-directional alerts, (3) better able to comunicate the nature of the situation than the non-directional alerts, and (4) being more unique than the non-directional alerts. For the dash panel location only, the directional alerts were also perceived to be better at getting the subjects' attention than the non-directional alerts.

Summary

The results associated with the individual alerts were fairly consistent across all four display locations. Within the context of the current study therefore, there do not seem to be any special advantages or disadvantages associated with display location with respect to the individual SODS alerts investigated. Of particular interest is the finding that three alerts, the Descriptive Car Crash + Tone, plus the individual tones were rated highly for both their ability to get the subjects' attention as well as to annoy the subjects. This suggests that the use of tones should be limited to driving conditions in which getting the drivers' attention is critical, such as 'intent to turn' situations in which a potential danger is sensed by the SODS device.

Several alerts, the Vehicle in Blind Spot, Prescriptive Arrow, Descriptive Car Crash, Descriptive Car Crash + Tone, the two tones, and the Muth Mirror alert, were consistently associated with conveying urgency - a useful feature for a SODS alert. Each of these alerts except for the Muth Mirror alert were also perceived as being effective at communicating both the location of the potential danger as well as the nature of the situation. In addition, none of these alerts were perceived as being annoying or as being confusable with other displays.

Several alerts, such as the Inverted Triangle, Horizontal and Vertical LEDs, and Barber Pole alerts, were not annoying or confusing to subjects. However, they did not convey either urgency or information about the situation to the subjects.

Also, the use of directional alerts that directly provide information on the location of a potential threat vehicle seems to provide some benefits in terms of conveying urgency and communicating the location of the potential changes and the nature of the situation.

Table 13. Percentage of responses as a function of display location by alert design, driver side only

DISPLAY LOCATION	ALERT DESIGN	QUESTION NUMBER	SUBJECT RESPONSE A	B	C	D	E
DRIVER SIDE	INVERTED TRIANGLE	1	10.2	33.9	30.5	25.4	0.0
		2	18.6	23.7	8.5	11.9	37.3
		3	5.1	0.0	11.9	47.5	35.6
		4	30.5	8.5	23.7	20.3	16.9
		5	13.6	49.2	8.5	10.2	18.6
		6	6.9	20.7	*29.3*	22.4	20.7
	FIVE HORIZONTAL LEDS	1	13.3	18.3	*56.7*	11.7	0.0
		2	23.3	18.3	15.0	8.3	*35.0*
		3	8.3	0.0	10.0	*56.7*	25.0
		4	*30.0*	10.0	25.0	20.0	15.0
		5	15.0	*50.0*	8.3	10.0	16.7
		6	10.0	21.7	21.7	*25.0*	21.7
	FIVE VERTICAL LEDS	1	10.0	33.3	*40.0*	16.7	0.0
		2	20.0	25.0	11.7	6.7	*36.7*
		3	6.7	1.7	6.7	*53.3*	31.7
		4	*33.3*	5.0	28.3	16.7	16.7
		5	15.0	*48.3*	10.0	10.0	16.7
		6	10.0	20.0	20.0	*30.0*	20.0
	BARBER POLE	1	12.5	25.0	*45.8*	16.7	0.0
		2	12.5	*33.3*	8.3	16.7	29.2
		3	4.2	0.0	12.5	*50.0*	33.3
		4	20.8	12.5	*25.0*	20.8	20.8
		5	20.8	*41.7*	8.3	8.3	20.8
		6	12.5	20.8	12.5	20.8	*33.3*
	BARBER POLE AND CAUTION	1	0.0	20.8	*54.2*	16.7	8.3
		2	8.3	16.7	16.7	12.5	*45.8*
		3	0.0	0.0	12.5	45.8	41.7
		4	8.3	0.0	8.3	0.0	83.3
		5	0.0	8.3	4.2	45.8	41.7
		6	0.0	4.2	8.3	20.8	66.7
	VEHICLE IN BLIND SPOT	1	6.3	27.0	*34.9*	31.7	0.0
		2	4.8	14.3	14.3	15.9	*50.8*
		3	1.6	0.0	4.8	39.7	*54.0*
		4	1.6	3.2	9.5	4.8	*81.0*
		5	6.3	6.3	3.2	19.0	*65.1*
		6	0.0	3.2	7.9	22.2	*66.7*

Table 13. Percentage of responses as a function of display location by alert design, driver side only (continued).

DISPLAY LOCATION	ALERT DESIGN	QUESTION NUMBER	SUBJECT RESPONSE				
			A	**B**	**C**	**D**	**E**
DRIVER SIDE	**PRESCRIPTIVE ARROW**	1	4.9	23.0	*41.0*	31.1	0.0
		2	9.8	16.4	13.1	9.8	*50.8*
		3	0.0	1.6	13.1	39.3	*45.9*
		4	18.0	3.3	16.4	8.2	*54.1*
		5	1.6	26.2	6.6	24.6	*41.0*
		6	0.0	14.8	18.0	14.8	*52.5*
	DESCRIPTIVE CAR CRASH	1	3.5	21.1	*45.6*	29.8	0.0
		2	10.5	17.5	14.0	15.8	*42.1*
		3	0.0	0.0	12.3	47.4	40.4
		4	3.5	0.0	17.5	5.3	73.7
		5	1.8	8.8	1.8	*50.9*	36.8
		6	0.0	7.0	12.3	21.1	*59.6*
	DESCRIPTIVE CAR CRASH & TONE	1	0.0	0.0	0.0	79.2	20.8
		2	8.3	20.8	4.2	4.2	62.5
		3	16.7	4.2	29.2	4.2	45.8
		4	4.2	4.2	16.7	12.5	62.5
		5	0.0	25.0	0.0	29.2	*45.8*
		6	4.2	12.5	4.2	16.7	*62.5*
	TONE 1	1	0.0	0.0	0.0	*79.2*	20.8
		2	4.2	20.8	8.3	4.2	*62.5*
		3	20.8	4.2	20.8	16.7	*37.5*
		4	20.8	12.5	*33.3*	20.8	12.5
		5	4.2	*62.5*	12.5	0.0	20.8
		6	8.3	16.7	20.8	12.5	*41.7*
	TONE 2	1	0.0	0.0	0.0	70.8	29.2
		2	8.3	20.8	12.5	4.2	54.2
		3	25.0	8.3	20.8	12.5	*33.3*
		4	33.3	12.5	29.2	16.7	8.3
		5	0.0	75.0	8.3	0.0	16.7
		6	16.7	29.2	12.5	12.5	29.2
	MUTH MIRROR	1	0.0	0.0	8.3	*91.7*	0.0
		2	8.3	16.7	8.3	16.7	*50.0*
		3	0.0	0.0	12.5	41.7	*45.8*
		4	4.2	20.8	*25.0*	*25.0*	*25.0*
		5	4.2	*41.7*	8.3	29.2	16.7
		6	0.0	0.0	4.2	25.0	*70.8*

Table 14. Percentage of responses as a function of display location by alert design, rear view mirror only.

DISPLAY LOCATION	ALERT DESIGN	QUESTION NUMBER	SUBJECT RESPONSE				
			A	B	C	D	E
REAR VIEW MIRROR	INVERTED TRIANGLE	1	10.0	28.3	48.7	20.0	0.0
		2	8.3	21.7	31.7	25.0	13.3
		3	5.0	8.3	11.7	43.3	31.7
		4	30.0	6.7	33.3	21.7	8.3
		5	8.3	*55.0*	23.3	6.7	6.7
		6	15.0	18.3	*23.3*	*23.3*	20.0
	FIVE HORIZONTAL LEDS	1	10.0	31.7	55.0	1.7	1.7
		2	6.7	23.3	35.0	21.7	13.3
		3	8.3	3.3	11.7	46.7	30.0
		4	43.3	3.3	28.3	23.3	1.7
		5	13.3	56.7	21.7	5.0	3.3
		6	18.3	16.7	*26.7*	*26.7*	11.7
	FIVE VERTICAL LEDS	1	8.3	31.7	*50.0*	10.0	0.0
		2	13.3	*26.7*	35.0	11.7	13.3
		3	6.7	5.0	8.3	*50.0*	30.0
		4	*46.7*	3.3	23.3	20.0	6.7
		5	20.0	*51.7*	16.7	11.7	0.0
		6	21.7	23.3	20.0	21.7	13.3
	BARBER POLE	1	8.3	37.5	41.7	12.5	0.0
		2	8.3	33.3	20.8	25.0	12.5
		3	0.0	4.2	0.0	58.3	37.5
		4	33.3	0.0	29.2	37.5	0.0
		5	16.7	*41.7*	25.0	12.5	4.2
		6	16.7	12.5	20.8	*37.5*	12.5
	BARBER POLE AND CAUTION	1	0.0	37.5	45.8	16.7	0.0
		2	8.3	12.5	25.0	25.0	29.2
		3	4.2	0.0	0.0	50.0	45.8
		4	4.2	0.0	12.5	25.0	58.3
		5	4.2	4.2	12.5	50.0	29.2
		6	4.2	0.0	12.5	20.8	*62.5*
	VEHICLE IN BLIND SPOT	1	0.0	29.0	*37.1*	32.3	1.6
		2	0.0	14.5	16.1	19.4	*50.0*
		3	0.0	4.8	3.2	38.7	53.2
		4	3.2	1.6	6.5	8.1	*80.6*
		5	0.0	6.5	4.8	24.2	64.5
		6	0.0	0.0	4.8	27.4	*67.7*

Table 14. Percentage of responses as a function of display location by alert design, rear view mirror only (continued).

DISPLAY LOCATION	ALERT DESIGN	QUESTION NUMBER	SUBJECT RESPONSE				
			A	B	C	D	E
REAR VIEW MIRROR	PRESCRIPTIVE ARROW	1	0.0	33.3	*41.7*	21.7	3.3
		2	5.0	13.3	16.7	*35.0*	30.0
		3	1.7	1.7	13.3	33.3	*50.0*
		4	5.0	1.7	13.3	11.7	*68.3*
		5	1.7	10.0	16.7	*55.0*	16.7
		6	3.3	3.3	20.0	*41.7*	31.7
	DESCRIPTIVE CAR CRASH	1	1.7	22.4	*39.7*	36.2	0.0
		2	1.7	22.4	13.8	17.2	*44.8*
		3	0.0	3.4	8.6	36.2	*51.7*
		4	1.7	0.0	12.1	8.6	*77.6*
		5	3.4	12.1	10.3	*44.8*	29.3
		6	0.0	5.2	12.1	34.5	*48.3*
	DESCRIPTIVE CAR CRASH & TONE	1	0.0	0.0	0.0	*58.3*	41.7
		2	4.2	16.7	4.2	12.5	*62.5*
		3	20.8	4.2	25.0	8.3	*41.7*
		4	8.3	0.0	0.0	16.7	*75.0*
		5	4.2	8.3	12.5	*50.0*	25.0
		6	0.0	4.2	12.5	20.8	*62.5*
	TONE 1	1	0.0	0.0	0.0	*52.0*	48.0
		2	4.0	8.0	12.0	28.0	*48.0*
		3	28.0	8.0	20.0	8.0	*36.0*
		4	20.0	24.0	*28.0*	24.0	4.0
		5	4.0	*64.0*	24.0	8.0	0.0
		6	4.0	*40.0*	16.0	4.0	36.0
	TONE 2	1	0.0	0.0	0.0	*60.9*	39.1
		2	0.0	13.0	21.7	30.4	*34.8*
		3	*26.1*	13.0	*26.1*	13.0	21.7
		4	*26.1*	17.4	*26.1*	30.4	0.0
		5	0.0	69.6	26.1	4.3	0.0
		6	4.3	*30.4*	21.7	17.4	26.1
	MUTH MIRROR	1	--	--	--	--	--
		2	--	--	--	--	--
		3	--	--	--	--	--
		4	--	--	--	--	--
		5	--	--	--	--	--
		6	--	--	--	--	--

Table 15. Percentage of responses as a function of display location by alert design, dash panel only.

DISPLAY LOCATION	ALERT DESIGN	QUESTION NUMBER	SUBJECT RESPONSE				
			A	B	C	D	E
DASH PANEL	INVERTED TRIANGLE	1	4.5	18.2	36.4	*37.9*	3.0
		2	9.1	16.7	*28.8*	19.7	25.8
		3	9.1	4.5	15.2	*39.4*	31.8
		4	28.8	15.2	*37.9*	7.6	10.6
		5	15.2	*66.7*	10.6	1.5	6.1
		6	19.7	15.2	27.3	6.1	31.8
	FIVE HORIZONTAL LEDS	1	3.1	18.8	*51.6*	25.0	1.6
		2	12.5	*31.3*	17.2	17.2	21.9
		3	10.9	4.7	15.6	*46.9*	21.9
		4	*48.4*	10.9	23.4	12.5	4.7
		5	20.3	*59.4*	10.9	4.7	4.7
		6	*29.7*	14.1	25.0	4.7	26.6
	FIVE VERTICAL LEDS	1	6.1	22.7	*40.9*	30.3	0.0
		2	13.6	21.2	22.7	*25.8*	16.7
		3	10.6	6.1	13.6	*47.0*	22.7
		4	*39.4*	7.6	33.3	15.2	4.5
		5	22.7	*56.1*	16.7	0.0	4.5
		6	*31.8*	7.6	21.2	10.6	28.8
	BARBER POLE	1	11.5	15.4	*50.0*	19.2	3.8
		2	11.5	*26.9*	11.5	*26.9*	23.1
		3	7.7	3.8	*7.7*	30.8	*50.0*
		4	23.1	3.8	*42.3*	23.1	7.7
		5	7.7	*57.7*	15.4	11.5	7.7
		6	19.2	3.8	*30.8*	15.4	*30.8*
	BARBER POLE AND CAUTION	1	3.8	23.1	19.2	*38.5*	15.4
		2	3.8	19.2	30.8	11.5	34.6
		3	7.7	3.8	11.5	23.1	53.8
		4	19.2	7.7	15.4	11.5	46.2
		5	3.8	34.6	19.2	23.1	19.2
		6	7.7	3.8	23.1	15.4	50.0
	VEHICLE IN BLIND SPOT	1	1.5	22.7	19.7	*45.5*	10.6
		2	3.0	13.6	10.6	22.7	*50.0*
		3	0.0	1.5	1.5	37.9	59.1
		4	4.5	1.5	15.2	4.5	74.2
		5	4.5	9.1	3.0	7.6	75.8
		6	4.5	1.5	4.5	10.6	78.8

Table 15. Percentage of responses as a function of display location by alert design, Dash panel only (continued)

DISPLAY LOCATION	ALERT DESIGN	QUESTION NUMBER	SUBJECT RESPONSE				
			A	B	C	D	E
DASH PANEL	PRESCRIPTIVE ARROW	1	1.6	15.6	26.6	*46.9*	9.4
		2	1.6	18.8	12.5	15.6	*51.6*
		3	1.6	6.2	6.2	37.5	*48.4*
		4	10.9	1.6	17.2	12.5	*57.8*
		5	6.2	17.2	7.8	25.0	*43.7*
		6	1.6	3.1	12.5	18.8	*64.1*
	DESCRIPTIVE CAR CRASH	1	1.6	20.3	29.7	40.6	7.8
		2	4.7	12.5	10.9	28.1	43.7
		3	0.0	3.1	3.1	40.6	53.1
		4	6.2	1.6	15.6	4.7	*71.9*
		5	9.4	3.1	6.2	28.1	53.1
		6	3.1	3.1	7.8	15.6	*70.3*
	DESCRIPTIVE CAR CRASH & TONE	1	0.0	0.0	0.0	*69.2*	30.8
		2	0.0	23.1	7.7	15.4	*53.8*
		3	15.4	7.7	26.9	11.5	*38.5*
		4	0.0	3.8	26.9	15.4	*53.8*
		5	0.0	19.2	11.5	15.4	53.8
		6	0.0	7.7	3.8	11.5	76.9
	TONE 1	1	0.0	0.0	0.0	69.2	30.8
		2	3.8	19.2	3.8	15.4	57.7
		3	23.1	3.8	34.6	15.4	23.1
		4	34.6	0.0	34.6	26.9	3.8
		5	15.4	65.4	11.5	3.8	3.8
		6	15.4	15.4	19.2	15.4	34.6
	TONE 2	1	0.0	0.0	0.0	76.9	23.1
		2	7.7	19.2	15.4	11.5	46.2
		3	11.5	3.8	50.0	3.8	30.8
		4	30.8	11.5	42.3	11.5	3.8
		5	11.5	69.2	15.4	0.0	3.8
		6	7.7	30.8	15.4	19.2	26.9
	MUTH MIRROR	1	--	--	--	--	--
		2	--	--	--	--	--
		3	--	--	--	--	--
		4	--	--	--	--	--
		5	--	--	--	--	--
		6	--	--	--	--	--

Table 16. Percentage of responses as a function of display location by alert design, passenger side only.

DISPLAY LOCATION	ALERT DESIGN	QUESTION NUMBER	SUBJECT RESPONSE				
			A	B	C	D	E
PASSENGER SIDE	INVERTED TRIANGLE	1	9.1	21.8	*43.6*	21.8	3.6
		2	14.5	21.8	12.7	*41.8*	9.1
		3	5.5	0.0	30.9	*36.4*	27.3
		4	*38.2*	7.3	23.6	20.0	10.9
		5	16.4	*54.5*	14.5	10.9	3.6
		6	12.7	3.6	32.7	*40.0*	10.9
	FIVE HORIZONTAL LEDS	1	9.1	25.5	*49.1*	16.4	0.0
		2	18.2	23.6	20.0	*36.4*	1.8
		3	7.3	0.0	34.5	*36.4*	21.8
		4	*40.0*	12.7	20.0	18.2	9.1
		5	25.5	*45.5*	12.7	14.5	1.8
		6	21.8	*5.5*	30.9	*26.4*	5.5
	FIVE VERTICAL LEDS	1	7.3	32.7	*47.3*	12.7	0.0
		2	10.9	30.9	12.7	*40.0*	5.5
		3	9.1	1.8	30.9	*26.4*	21.8
		4	*38.2*	7.3	23.6	21.8	9.1
		5	27.3	*43.6*	10.9	18.2	0.0
		6	21.8	5.5	23.6	*41.8*	7.3
	BARBER POLE	1	9.1	31.8	*50.0*	9.1	0.0
		2	9.1	22.7	13.6	*40.9*	13.6
		3	4.5	4.5	18.2	*45.5*	27.3
		4	18.2	18.2	*26.4*	22.7	4.5
		5	9.1	*50.0*	22.7	13.6	4.5
		6	13.6	4.5	31.8	*36.4*	13.6
	BARBER POLE AND CAUTION	1	4.5	*36.4*	*26.4*	18.2	4.5
		2	9.1	18.2	18.2	*31.8*	22.7
		3	0.0	0.0	27.3	27.3	*45.5*
		4	13.6	4.5	18.2	18.2	45.5
		5	13.6	18.2	4.5	*26.4*	27.3
		6	4.5	9.1	13.6	*45.5*	27.3
	VEHICLE IN BLIND SPOT	1	1.7	27.6	*36.2*	31.0	3.4
		2	5.2	20.7	1.7	*31.0*	41.4
		3	3.4	3.4	13.8	31.0	*48.3*
		4	0.0	13.8	13.8	13.8	*58.6*
		5	0.0	8.6	13.8	15.5	*62.1*
		6	3.4	5.2	13.8	25.9	*51.7*

Table 16. Percentage of responses as a function of display location by alert design, passenger side only (continued).

DISPLAY LOCATION	ALERT DESIGN	QUESTION NUMBER	SUBJECT RESPONSE				
			A	B	C	D	E
DASH PANEL	PRESCRIPTIVE ARROW	1	0.0	21.8	*45.5*	25.5	7.3
		2	9.1	14.5	12.7	30.9	*32.7*
		3	0.0	9.1	21.8	29.1	*40.0*
		4	12.7	7.3	12.7	14.5	*52.7*
		5	10.9	10.9	5.5	*43.6*	29.1
		6	0.0	7.3	20.0	*38.2*	34.5
	DESCRIPTIVE CAR CRASH	1	0.0	25.0	*40.4*	26.9	7.7
		2	7.7	23.1	7.7	21.2	*40.4*
		3	0.0	3.8	21.2	28.8	*46.2*
		4	3.8	1.9	13.5	7.7	*73.1*
		5	1.9	5.8	5.8	34.6	*51.9*
		6	3.8	3.8	11.5	30.8	*50.0*
	DESCRIPTIVE CAR CRASH & TONE	1	0.0	4.5	0.0	*68.2*	27.3
		2	13.6	4.5	18.2	18.2	*45.5*
		3	9.1	4.5	*40.9*	13.6	31.8
		4	0.0	18.2	13.6	18.2	*50.0*
		5	0.0	18.2	13.6	27.3	*40.9*
		6	9.1	13.6	9.1	18.2	*50.0*
	TONE 1	1	0.0	4.5	4.5	*63.6*	27.3
		2	4.5	22.7	13.6	22.7	*36.4*
		3	13.6	9.1	*26.4*	13.6	27.3
		4	22.7	13.6	22.7	*36.4*	4.5
		5	4.5	*68.2*	18.2	4.5	4.5
		6	9.1	*31.8*	18.2	9.1	*31.8*
	TONE 2	1	0.0	4.5	0.0	*54.5*	40.9
		2	0.0	27.3	9.1	27.3	*36.4*
		3	4.5	9.1	*54.5*	9.1	22.7
		4	*40.9*	13.6	13.6	27.3	4.5
		5	22.7	*54.5*	13.6	4.5	4.5
		6	13.6	*26.4*	13.6	22.7	13.6
	MUTH MIRROR	1	0.0	22.7	31.8	*36.4*	9.1
		2	4.5	18.2	13.6	18.2	*45.5*
		3	4.5	4.5	18.2	27.3	*45.5*
		4	13.6	9.1	13.6	*31.8*	*31.8*
		5	18.2	*27.3*	18.2	*27.3*	9.1
		6	4.5	4.5	18.2	31.8	*40.9*

Table 13. Percentage of responses as a function of display location by alert design, driver side only

DISPLAY LOCATION	ALERT DESIGN	QUESTION NUMBER	SUBJECT RESPONSE				
			A	B	C	D	E
DRIVER SIDE	NON- DIRECTIONAL	1	10.1	27.3	*44.1*	17.6	0.9
		2	18.5	22.9	11.9	10.1	*36.6*
		3	5.7	0.4	10.1	*51.5*	32.2
		4	*27.8*	7.5	23.8	17.2	23.8
		5	13.7	*44.1*	8.4	13.7	20.3
		6	8.4	19.0	20.8	24.8	*27.0*
	DIRECTIONAL	1	5.0	23.8	*40.3*	30.9	0.0
		2	8.3	16.0	13.8	13.8	*48.1*
		3	0.6	0.6	9.9	42.0	*47.0*
		4	7.7	2.2	14.4	6.1	*69.6*
		5	3.3	13.8	3.9	30.9	*48.1*
		6	0.0	8.3	12.7	19.3	*59.7*
REAR VIEW MIRROR	NON- DIRECTIONAL	1	8.3	32.0	*47.8*	11.4	0.4
		2	9.2	23.7	*31.6*	20.6	14.9
		3	5.7	4.8	8.3	*48.2*	32.9
		4	*35.5*	3.5	26.8	23.7	10.5
		5	13.2	*47.8*	20.2	12.7	6.1
		6	16.7	16.7	21.9	*25.0*	19.7
	DIRECTIONAL	1	0.6	28.3	*39.4*	30.0	1.7
		2	2.2	16.7	15.6	23.9	*41.7*
		3	0.6	3.3	8.3	36.1	*51.7*
		4	3.3	1.1	10.6	9.4	75.6
		5	1.7	9.4	10.6	*41.1*	37.2
		6	1.1	2.8	12.2	34.4	*49.4*
DASH PANEL	NON- DIRECTIONAL	1	5.2	19.8	*41.1*	30.6	3.2
		2	10.9	*23.0*	22.6	20.6	*23.0*
		3	9.7	4.8	13.7	*40.7*	31.0
		4	*35.1*	10.1	31.0	12.9	10.9
		5	16.5	*57.7*	13.7	5.2	6.9
		6	24.2	10.5	25.0	8.9	*31.5*
	DIRECTIONAL	1	1.5	19.6	25.3	*44.3*	9.3
		2	3.1	14.9	11.3	22.2	*48.5*
		3	0.5	3.6	3.6	38.7	*53.6*
		4	7.2	1.5	16.0	7.2	*68.0*
		5	6.7	9.8	5.7	20.1	*57.7*
		6	3.1	2.6	8.2	14.9	*71.1*

Table 17. Percentage of responses as a function of display location by alert type (continued).

PASSENGER SIDE	**NON- DIRECTIONAL**	1	8.1	28.2	45.9	16.3	1.4
		2	13.4	24.4	15.3	*38.8*	8.1
		3	6.2	1.0	30.1	*36.4*	26.3
		4	*34.0*	9.6	23.4	20.1	12.9
		5	20.6	*45.0*	12.9	16.7	4.8
		6	16.7	5.3	27.8	39.7	10.5
	DIRECTIONAL	1	0.6	24.8	40.6	27.9	6.1
		2	7.3	19.4	7.3	27.9	38.2
		3	1.2	5.5	18.8	29.7	44.8
		4	5.5	7.9	13.3	12.1	61.2
		5	4.2	8.5	8.5	30.9	47.9
		6	7.4	5.5	15.2	31.5	45.5

Stated Preferences for Alert Designs

Table 18 shows subject preferences for alert colors. As seen in the table, subjects confirmed our choice of color for the 'intent' scenario, with red as the preferred alert color (approximately 8 1% of responses). Preferences in the 'no intent' scenario were mixed, with 43 percent of subjects preferring red and 16 percent preferring yellow (amber). Ln table 18 and subsequent tables, varying percentages of subjects indicated that they preferred "other" alert colors or designs. Generally, these "other" preferences represented slight variations on the option presented. Subjects frequently had difficulties describing what this "other" alert would look like.

Table 18. Stated preferences for alert colors as a function of driving scenario.

COLOR	**INTENT**	**NO INTENT**
Red	81.25%	43.75%
Yellow (Amber)	6.25%	16.67%
Green	**NR**	10.42%
Would not have alert	**NA**	10.42%
No data	4.17%	8.33%
Other	4.17%	4.17%
White	4.17%	2.08%
Blue	**NR**	2.08%
None Specified	**NR**	2.08%

Table 19 shows subject preferences for alert design. As seen in the table, subjects preferred (35% for the 'intent' scenario; 27% in the 'no intent' scenario) an icon that showed a plan view of both the SODS-equipped vehicle, as well as a target vehicle on either the left or right side of the vehicle. This suggests a desire for a fairly simple, unambiguous alert that is "rich" in terms of the information that it conveys. Twenty-seven percent of subjects in both scenarios preferred an unspecified “other” alert, while 18 percent in the ‘intent’ scenario preferred a prescriptive arrow.

Table 19. Stated preferences for alert design as a function of driving scenario.

ALERT DESIGN	INTENT	NO INTENT
Vehicle in blind spot	35.42%	27.08%
Other	27.08%	27.08%
Prescriptive arrow	18.75%	6.25%
Inverted triangle	4.17%	6.25%
Descriptive car crash	4.17%	6.25%
No data	4.17%	8.33%
Muth Mirror	2.08%	**NR**
Would not have alert	**NA**	10.42%
Barber pole	**NR**	4.17%
None specified	**NR**	2.08%
Text	**NR**	2.08%

Table 20 shows subject preferences for auditory alerts. As seen in the table, 60 percent of the subjects preferred an auditory alert in the ‘intent to turn’ conditions, but would not want an auditory alert (62% preferred no sound) if they were not intending to turn. Table 21 shows subject preferences for the type of sound used in an auditory alert for the ‘intent to turn’ condition. As seen in the table, subjects, when they stated a preference, were evenly split between using a human voice (25%) and using a beeping tone (25%).

Table 20. Stated preferences for auditory alerts as a function of driving scenario.

AUDITORY ALERT	INTENT	NO INTENT
Yes	60.42%	18.75%
No	35.42%	62.50%
No data	4.17%	8.33%
Would not have ‘no intent’ alert	**NA**	10.42%

Table 21. Stated preferences for sound types as a function of driving scenario.

SOUND TYPES	INTENT	NO INTENT
Human voice	25.00%	4.17%
Beep or some tone	25.00%	8.33%
Would not have sound	25.00%	72.92%
Up and down tone	4.25%	2.08%
Other	6.25%	4.17%
Long tone	4.17%	**NR**
No data	4.17%	8.33%
None specified	4.17%	**NR**

Number of Required Alert Presentations

Table 22 shows the number of required alert presentations as a function of alert and display location. Individual alerts showed few differences across the four display locations. One alert however, the Barber Pole icon, was consistently associated with a greater number of required alert presentations.

Table 22. Mean Number of presentations as a function of display location by alert design.

	DRIVER SIDE	REAR VIEW MIRROR	DASH PANEL	PASSENGER SIDE
INVERTED TRIANGLE	1.220	*1.289*	1.030	1.273
FIVE HORIZONTAL LEDS	1.183	1.150	1.078	*1.273*
FIVE VERTICAL LEDS	1.233	1.233	1.182	*1.255*
BARBER POLE	*1.708*	1.500	1.423	1.682
BARBER POLE AND	1.125	1.174	1.269	*1.364*
VEHICLE IN BLIND SPOT	1.111	1.290	1.015	*1.293*
PRECRIPTIVE ARROW	1.049	*1.217*	1.062	1.164
DESCRIPTIVE CAR CRASH	1.140	*1.190*	1.047	1.077
TONE 1 & DESCRIPTION	1.000	1.000	1.000	*1.045*
TONE 1	1.000	1.000	1.000	1.000
TONE 2	1.000	1.000	1.000	1.000
MUTH MIRROR	1.000	--	--	1.000

The results associated with required alert presentations should be interpreted cautiously for several reasons. First, driver- or passenger-side location for the SODS alert might serve to encourage consistent use of the side view mirrors, yet drivers have no experience with alerts being presented at these locations. Also, these findings might be different if drivers were on-the road under representative driving conditions making lane change decisions. The current study, however, employed a somewhat simple, almost impoverished, set of visual stimuli to the subjects. Thus, it was somewhat surprising that there were any meaningful differences associated with this variable; i.e., subjects really had nothing else to do except wait for the icons to be presented.

Effects of Dynamic Properties of the Alerts

Responses to Multiple Choice Questions

Tables 23,24,25, and 26 show the distribution of responses to the multiple choice questions as a function of driving scenario, with each of the four tables corresponding to a different display location.

Table 23. Percentage of responses as a function of display location by dynamic, driver side only.

DISPLAY LOCATION	DYNAMIC	QUESTION NUMBER	SUBJECT RESPONSE				
			A	**B**	**C**	**D**	**E**
DRIVER SIDE	**STATIC**	1	7.1	22.2	*34.3*	33.8	2.5
		2	16.2	21.2	10.6	10.1	*41.9*
		3	5.1	1.5	11.1	*44.4*	37.9
		4	17.7	6.6	20.2	13.6	*41.9*
		5	8.1	32.3	4.5	22.7	*32.3*
		6	2.5	13.7	14.2	22.3	*47.2*
	FLASHING	1	6.2	21.5	*44.4*	27.8	0.0
		2	13.2	20.1	13.2	13.9	*39.6*
		3	2.8	0.0	11.8	*46.5*	38.9
		4	19.4	4.2	19.4	11.8	*45.1*
		5	9.0	31.3	6.2	20.1	*33.3*
		6	4.9	12.5	20.1	19.4	*43.1*
	MOVING	1	9.3	27.8	*42.6*	16.7	3.7
		2	9.3	*25.9*	13.0	13.0	38.9
		3	1.9	0.0	11.1	*46.3*	40.7
		4	13.0	7.4	13.0	13.0	*53.7*
		5	11.1	22.2	7.4	20.4	*38.9*
		6	5.6	13.0	11.1	25.9	*44.4*
	SIZE INCREASE	1	6.7	25.0	33.3	*35.0*	0.0
		2	8.3	8.3	13.3	10.0	*60.0*
		3	5.0	0.0	10.0	40.0	*45.0*
		4	15.0	6.7	25.0	13.3	*40.0*
		5	5.0	33.3	10.0	*26.7*	25.0
		6	8.3	15.0	15.0	25.0	*36.7*

Table 24. Percentage of responses as a function of display location by dynamic, rear view mirror only.

DISPLAY LOCATION	DYNAMIC	QUESTION NUMBER	SUBJECT RESPONSE				
			A	B	C	D	E
DRIVER SIDE	STATIC	1	7.4	28.6	*33.7*	23.4	6.9
		2	7.4	24.0	20.6	16.0	*32.0*
		3	6.9	3.4	9.1	*42.9*	37.7
		4	21.1	1.7	16.6	16.6	*44.0*
		5	10.9	24.0	16.0	*27.4*	21.7
		6	10.9	8.0	16.0	28.6	*36.6*
	FLASHING	1	2.8	27.8	*45.8*	22.9	0.7
		2	4.9	21.5	*26.4*	23.6	23.6
		3	2.8	6.2	11.8	37.5	*41.7*
		4	19.4	2.1	19.4	16.0	*43.1*
		5	5.6	*34.7*	16.0	23.6	20.1
		6	8.3	13.9	17.4	27.8	32.6
	MOVING	1	3.8	37.7	*43.4*	15.1	0.0
		2	7.5	20.8	18.9	22.6	*30.2*
		3	1.9	1.9	0.0	47.2	*49.1*
		4	18.9	1.9	17.0	24.5	*37.7*
		5	9.4	20.8	15.1	*30.2*	24.5
		6	9.4	5.7	13.2	32.1	*39.6*
	SIZE INCREASE	1	1.7	23.3	*53.3*	20.0	1.7
		2	3.3	6.7	28.3	*31.7*	30.0
		3	3.3	3.3	11.7	38.3	*43.3*
		4	23.3	5.0	23.3	16.7	*31.7*
		5	3.3	*41.7*	15.0	28.3	11.7
		6	6.7	11.7	25.0	*28.3*	*28.3*

Table 25. Percentage of responses as a function of display location by dynamic, dash panel only.

DISPLAY LOCATION	DYNAMIC	QUESTION NUMBER	SUBJECT RESPONSE				
			A	B	C	D	E
DRIVER SIDE	STATIC	1	4.8	21.4	28.3	*36.9*	8.6
		2	9.6	23.0	15.5	18.2	*33.7*
		3	7.0	4.8	12.8	*39.6*	35.8
		4	21.4	5.9	26.2	10.2	*36.4*
		5	12.3	*34.2*	11.2	11.2	31.0
		6	13.9	10.2	12.8	11.2	*51.9*
	FLASHING	1	1.3	16.0	37.2	*40.4*	5.1
		2	5.8	21.2	17.3	22.4	*33.3*
		3	5.8	3.2	9.6	*44.2*	37.2
		4	21.8	6.4	24.4	9.6	*37.8*
		5	11.5	*36.5*	8.3	10.9	32.7
		6	10.9	5.8	20.5	12.2	*50.6*
	MOVING	1	8.3	16.7	*33.3*	31.7	10.0
		2	6.7	20.0	18.3	20.0	*35.0*
		3	6.7	5.0	6.7	25.0	*56.7*
		4	16.7	5.0	25.0	16.7	*36.7*
		5	6.7	*36.7*	15.0	15.0	26.7
		6	11.7	3.3	23.3	13.3	*48.3*
	SIZE INCREASE	1	0.0	18.5	30.8	*44.6*	6.2
		2	3.1	6.2	20.0	26.2	*44.6*
		3	4.6	6.2	7.7	32.3	*49.2*
		4	26.2	7.7	20.0	9.2	*36.9*
		5	13.8	*36.9*	7.7	13.8	27.7
		6	24.6	4.6	13.8	9.2	*47.7*

Table 26. Percentage of responses as a function of display location by dynamic, passenger side only.

DISPLAY LOCATION	DYNAMIC	QUESTION NUMBER	SUBJECT RESPONSE				
			A	B	C	D	E
DRIVER SIDE	STATIC	1	5.5	28.0	*35.2*	25.8	5.5
		2	14.3	22.5	11.0	*28.6*	23.6
		3	5.5	1.6	26.9	32.4	*33.5*
		4	22.5	9.3	12.6	19.2	*36.3*
		5	15.9	*24.7*	12.6	23.6	23.1
		6	11.5	5.5	20.9	*33.0*	29.1
	FLASHING	1	3.0	22.0	*45.5*	26.5	3.0
		2	9.1	22.7	12.1	*31.8*	24.2
		3	2.3	4.5	26.5	29.5	*37.1*
		4	19.7	6.8	20.5	15.9	*37.1*
		5	12.1	*29.5*	9.1	22.0	27.3
		6	9.8	7.6	20.5	*37.1*	25.0
	MOVING	1	6.1	30.6	*40.8*	16.3	6.1
		2	8.2	18.4	12.2	*38.8*	22.4
		3	4.1	2.0	22.4	32.7	*38.8*
		4	12.2	14.3	24.5	18.4	*30.6*
		5	10.2	*28.6*	12.2	24.5	24.5
		6	10.2	8.2	18.4	*34.7*	28.6
	SIZE INCREASE	1	1.8	20.0	*47.3*	23.6	7.3
		2	3.6	14.5	16.4	*40.0*	25.5
		3	5.5	5.5	21.8	*36.4*	30.9
		4	18.2	10.9	27.3	14.5	*29.1*
		5	7.3	*36.4*	12.7	25.5	18.2
		6	5.5	0.0	27.3	*36.4*	30.9

Across the four display locations, there appears to be no clear advantage associated with any of the dynamic property conditions with respect to: getting the subjects' attention (question #l), in the level of annoyance associated with the alerts (question #3), in the degree to which the alert communicates the nature of the situation (question #5), or in the extent to which the alert might be confused with something else (question #6). The lack of differences, particularly for questions #l and #3, may well reflect the relative simplicity of the experimental environment. That is, in the absence of multiple external stimuli (real people and cars) and the simplicity of the subjects' task (no control inputs required), all of the alerts were well above threshold in terms of their ability to get the subjects attention and below threshold in terms of being an annoyance to the subjects.

For question X2, ***"To what extent does this alert communicate a sense of urgency to you?,"*** there seems to be a pattern of results favoring the use of increasing the alert size. Specifically, across all four display locations, the distribution of responses to this questions shows a consistently higher level of perceived urgency associated with increasing the size of the alert. For question #4, ***"To what extent does this alert communicate the location of the potential***

danger?" there appears to be an advantage to the moving alert, when presented on the driver's side of the vehicle.

Stated Preferences for Alert Designs

Table 27 shows subject preferences for the dynamic properties of visual alerts. As seen in the table, 75 percent of subjects in the 'intent to turn' scenario and 60 percent of subjects in the 'no intent to turn' scenario did not state a preference.

Table 27. Stated preferences for dynamic properties as a function of driving scenario.

DYNAMIC PROPERTY	INTENT	NO INTENT
None specified	75.00%	60.42%
Moving	16.67%	4.17%
No data	4.17%	8.33%
Size increase	2.08%	2.08%
Static	2.08%	**NR**
Flashing	**NR**	14.58%
Would not have 'no intent' alert	**NA**	10.42%

Number of Required Alert Presentations

Table 28 shows the number of presentations required as a function of both dynamic properties and display location. On the whole, these data do not suggest any strong advantage for any of the four types of dynamic properties investigated in this study; however, slightly more presentations were required for moving alerts, while slightly fewer presentations were required for the flashing alerts.

Table 28. Number of presentations as a function of display location by dynamic property.

		DRIVER SIDE	REAR VIEW MIRROR	DASH PANEL	PASSENGER SIDE
STATIC	**Mean**	1.119	1.178	1.064	1.233
	SD	0.517	0.603	0.282	0.693
	Minimum	1.0	1.0	1.0	1.0
	Maximum	6.0	4.0	3.0	5.0
FLASHING	**Mean**	1.132	1.187	1.051	1.152
	SD	0.517	0.697	0.048	0.531
	Minimum	1.0	1.0	0.048	1.0
	Maximum	4.0	5.0	3.0	5.0
MOVING	**Mean**	1.407	1.404	1.317	*1.469*
	SD	1.011	0.927	0.886	1.129
	Minimum	1.0	1.0	1.0	1.0
	Maximum	6.0	5.0	5.0	6.0
SIZE INCREASE	**Mean**	1.167	*1.267*	1.077	*1.182*
	SD	0.611	0.855	0.319	0.766
	Minimum	1.0	1.0	1.0	1.0
	Maximum	5.0	5.0	3.0	6.0

Effects of Driving Scenario

Responses to Multiple Choice Questions

Tables 29,30,3 1, and 32 show the distribution of responses to the multiple choice questions as a function of driving scenario, with each of the four tables corresponding to a different display location. Across all four display locations, different responses were obtained to the question ***"To what extent does this alert communicate a sense of urgency to you?"*** as a function of driving scenario. Specifically, alerts presented in the 'no intent to turn' scenario were associated (as one would expe.ct) with a lower sense of urgency. Also, as shown in table 31, subjects answered question 4, ***"To what extent does this alert communicate the location of the potential danger?"*** in a different way depending on the expressed driving scenario. Specifically, in the 'intent to turn' condition, the most frequent response was "I would know immediately which side the potential danger was on;" in the 'no intent to turn' condition, the most frequent response was "I would understand that there was an object in my path. I would check for vehicles in front, to the rear, to my left, and to my right."

Table 29. Percentage of responses as a function of display location by scenario, driver side only.

DISPLAY LOCATION	SCENARIO	QUESTION NUMBER	SUBJECT RESPONSE				
			A	**B**	**C**	**D**	**E**
DRIVER SIDE	INTENT	1	8.0	22.6	28.1	*37.5*	3.8
		2	4.9	8.0	12.5	12.5	*62.2*
		3	4.5	1.4	5.2	38.5	*50.3*
		4	14.9	6.2	21.5	13.2	*44.1*
		5	6.6	*33.7*	6.2	21.5	31.9
		6	6.6	13.9	15.0	20.2	*44.3*
	NO INTENT	1	4.2	18.5	*43.5*	30.1	3.7
		2	23.1	*35.6*	11.1	8.8	21.3
		3	7.4	0.9	21.3	*46.3*	24.1
		4	22.7	6.9	19.9	13.9	*36.6*
		5	9.3	*35.6*	6.9	18.1	30.1
		6	3.2	14.8	17.1	22.7	*42.1*

Table 30. Percentage of responses as a function of display location by scenario, rear view mirror only.

DISPLAY LOCATION	ALERT DESIGN	QUESTION NUMBER	SUBJECT RESPONSE				
			A	B	C	D	E
REAR VIEW MIRROR	INTENT	1	3.6	25.4	*40.6*	24.3	6.2
		2	1.8	7.2	23.6	28.3	*39.1*
		3	5.8	5.4	9.8	38.0	*40.9*
		4	20.7	2.5	21.4	15.6	*39.9*
		5	5.1	*34.8*	13.8	26.1	20.3
		6	8.0	12.0	19.9	25.7	*34.4*
	NO INTENT	1	4.9	26.5	*33.3*	16.5	8.8
		2	10.8	*35.8*	21.6	14.2	17.6
		3	7.8	3.9	11.8	37.7	*38.7*
		4	21.1	6.4	16.7	22.1	*33.8*
		5	10.3	*31.4*	20.6	22.5	15.2
		6	9.8	13.7	14.2	28.4	*33.8*

Table 31. Percentage of responses as a function of display location by scenario, dash panel only.

DISPLAY LOCATION	SCENARIO	QUESTION NUMBER	SUBJECT RESPONSE				
			A	B	C	D	E
DASH PANEL	INTENT	1	2.0	18.1	30.8	*40.8*	8.4
		2	3.3	7.7	18.7	20.1	*50.2*
		3	6.4	5.4	11.0	30.1	*47.2*
		4	23.1	7.7	20.4	9.7	*39.1*
		5	11.0	*37.1*	7.4	13.4	31.1
		6	16.7	7.0	16.7	9.0	*50.5*
	NO INTENT	1	4.5	14.9	26.7	*43.4*	10.4
		2	11.8	*35.7*	13.1	20.4	19.0
		3	8.6	3.2	16.7	*42.5*	29.0
		4	22.2	4.1	*33.5*	14.0	26.2
		5	12.7	*41.2*	14.9	7.7	23.5
		6	10.0	10.9	17.2	16.3	*45.7*

Table 30. Percentage of responses as a function of display location by scenario, passenger side only.

DISPLAY LOCATION	ALERT DESIGN	QUESTION NUMBER	SUBJECT RESPONSE				
			A	B	C	D	E
PASSENGER SIDE	INTENT	1	2.7	22.3	*38.3*	27.3	9.5
		2	6.4	9.8	14.4	*39.4*	29.9
		3	5.3	5.3	24.2	30.7	*34.5*
		4	19.7	11.4	19.3	16.7	*33.0*
		5	12.9	*31.1*	11.0	23.1	22.0
		6	11.4	6.8	20.1	*35.6*	26.1
	NO INTENT	1	5.6	24.7	*35.4*	28.8	5.6
		2	14.1	*26.9*	9.1	21.2	18.7
		3	4.0	1.5	31.8	29.3	*33.3*
		4	22.7	7.6	17.2	21.7	*30.8*
		5	13.1	*31.8*	13.1	19.7	22.2
		6	8.6	10.6	21.7	*29.8*	29.3

Number of Required Alert Presentations

Table 33 provides the number of alert presentations required as a function of both driving scenario and display location; there appear to be no meaningful differences between the two scenarios.

Table 33. Number of presentations as a function of display locations by scenario.

		DRIVER SIDE	REAR VIEW MIRROR	DASH PANEL	PASSENGER SIDE
INTENT	Mean	1.18	*1.25*	1.12	1.23
	SD	0.61	0.80	0.48	0.73
	Minimum	1.00	1.00	1.00	1.00
	Maximum	6.00	5.00	5.00	6.00
NO INTENT	Mean	1.12	1.13	1.04	*1.20*
	SD	0.56	0.51	0.24	0.69
	Minimum	1.00	1.00	1.00	1.00
	Maximum	6.00	4.00	3.00	6.00

Effects of Age and Gender

Responses to Multiple Choice Questions

Tables 34, 35, 36, and 37 show the distribution of responses to the multiple choice questions as a function of subject age, with each of the four tables corresponding to a different display location.

Table 34. Percentage of responses as a function of display location by age group, driver side only.

DISPLAY LOCATION	AGE GROUP	QUESTION NUMBER	SUBJECT RESPONSE				
			A	B	C	D	E
DRIVER SIDE	YOUNG	1	13.1	*31.5*	29.8	22.0	3.6
		2	16.7	*31.0*	11.3	12.5	28.6
		3	10.7	3.0	18.5	*38.1*	29.8
		4	22.0	17.9	*7.7*	20.8	*31.5*
		5	13.1	31.0	3.0	20.2	*32.7*
		6	11.3	*26.2*	17.3	23.8	21.4
	MIDDLE	1	3.6	13.7	26.2	*50.6*	6.0
		2	20.2	12.5	23.8	15.5	*28.0*
		3	6.5	0.6	10.1	*64.9*	17.9
		4	17.9	1.2	32.1	16.1	*32.7*
		5	8.3	*33.9*	16.1	16.1	25.6
		6	3.0	4.2	19.0	23.8	*50.0*
	OLDER	1	2.4	17.3	*48.2*	30.4	1.8
		2	1.2	16.1	0.6	4.8	*77.4*
		3	0.0	0.0	7.7	22.6	*69.6*
		4	14.9	0.6	22.6	3.6	*58.3*
		5	1.8	*38.7*	0.6	23.8	35.1
		6	1.2	12.6	11.4	16.2	*58.7*

Table 35. Percentage of responses as a function of display location by age group, rear view mirror only.

DISPLAY LOCATION	AGE GROUP	QUESTION NUMBER	SUBJECT RESPONSE				
			A	B	C	D	E
REAR VIEW MIRROR	YOUNG	1	10.0	*39.4*	26.9	15.0	8.8
		2	12.5	21.9	*32.5*	15.0	18.1
		3	5.0	5.6	10.0	*54.4*	25.0
		4	28.8	3.7	17.5	6.2	*43.7*
		5	10.0	*41.9*	1.9	26.9	19.4
		6	18.8	22.5	13.8	18.1	*26.9*
	MIDDLE	1	1.3	35.0	*35.6*	17.5	10.6
		2	1.3	15.6	23.8	*31.3*	28.1
		3	12.5	2.5	15.6	*44.4*	25.0
		4	25.0	7.5	28.1	5.0	*34.4*
		5	5.6	*31.3*	23.1	20.0	20.0
		6	3.1	10.6	20.6	*45.0*	20.6
	OLDER	1	1.3	3.1	*50.0*	43.1	2.5
		2	3.1	20.6	11.9	20.6	*43.7*
		3	2.5	6.2	6.2	15.0	*70.0*
		4	8.8	1.3	12.5	*43.7*	33.7
		5	6.2	*26.9*	25.0	*26.9*	15.0
		6	4.4	5.0	18.1	17.5	*55.0*

Table 36. Percentage of responses as a function of display location by age group, dash panel only.

DISPLAY LOCATION	AGE GROUP	QUESTION NUMBER	SUBJECT RESPONSE				
			A	B	C	D	E
DRIVER SIDE	YOUNG	1	5.6	30.0	*32.5*	23.1	8.8
		2	8.8	20.6	25.0	15.6	*30.0*
		3	3.1	0.0	18.8	*40.6*	37.5
		4	8.8	5.0	20.6	21.3	*44.4*
		5	2.5	31.3	20.6	13.8	*31.9*
		6	6.2	8.1	16.3	10.0	*59.4*
	MIDDLE	1	3.5	13.0	*34.0*	32.5	17.0
		2	10.5	*29.0*	11.5	24.0	25.0
		3	16.5	6.0	11.5	31.0	*35.0*
		4	33.5	3.0	24.0	3.5	*36.0*
		5	16.5	*38.5*	1.5	12.0	31.5
		6	21.0	7.5	14.5	17.0	*40.0*
	OLDER	1	0.0	8.1	19.4	*72.5*	0.0
		2	0.6	6.9	13.8	20.0	*58.7*
		3	0.0	6.9	10.6	35.6	*46.9*
		4	23.1	11.3	*33.7*	11.9	20.0
		5	15.0	*46.9*	11.9	6.9	19.4
		6	12.5	10.6	20.6	8.1	*48.1*

Table 37. Percentage of responses as a function of display location by age group, passenger side only.

DISPLAY LOCATION	AGE GROUP	QUESTION NUMBER	SUBJECT RESPONSE				
			A	B	C	D	E
REAR VIEW MIRROR	YOUNG	1	2.4	33.9	*45.2*	13.1	5.4
		2	13.1	*23.2*	9.5	31.5	22.6
		3	0.6	2.4	22.6	*37.5*	36.9
		4	22.0	0.0	28.0	18.5	*31.5*
		5	13.1	*29.2*	17.9	23.2	16.7
		6	9.5	9.5	20.2	20.8	*39.9*
	MIDDLE	1	0.8	9.5	*59.5*	23.8	6.3
		2	4.8	24.6	12.7	*31.0*	27.0
		3	3.2	0.8	38.9	*48.4*	8.7
		4	9.5	4.0	9.5	27.0	*50.0*
		5	3.2	38.1	6.3	*34.9*	17.5
		6	1.6	4.0	4.0	*73.8*	16.7
	OLDER	1	7.7	23.2	11.9	*45.8*	11.3
		2	10.1	17.3	14.3	*32.1*	26.2
		3	10.1	7.1	23.8	8.9	*50.0*
		4	*28.6*	23.8	15.5	13.1	19.0
		5	20.2	28.6	10.1	10.1	*31.0*
		6	17.3	10.7	*33.9*	14.9	23.2

A number of differences in alert perception as a function of age are evident. Responses to question #l, ***"To what extent would this alert be effective at getting your attention?," suggest*** that, for the passenger side, rear view, and dash panel locations, older subjects generally felt that the alerts were more noticeable than did the middle aged and younger drivers.

Responses to question #2, ***"To what extent does this alert communicate a sense of urgency to you?,"*** suggest that for the rear view, dash panel, and driver side locations, older subjects assigned more urgency to the alerts than did the middle aged and younger drivers. Responses to other questions are not quite as consistent across display locations. For example, in response to question #4, ***"To what extent does this alert communicate the location of the potential danger?,"*** older subjects generally felt that the alerts communicated less information regarding the location of the potential danger to them when presented from the passenger side and dash panel locations, but that they communicated more such information when presented from the driver side and rear view mirror locations.

Responses to question # 6, ***" To what extent would you confuse this alert with something else?"*** indicate that, when presented on the passenger side of the vehicle, middle aged subjects reported a much greater impression of the alerts being different from other alerts than did either the younger or older subjects.

Appendix G provides tables showing the distribution of responses to the multiple choice questions as a function of subject gender and display location.

Number of Required Alert Presentations

Table 38 provides the mean number of alert presentations required as a function of both gender and display location. As seen in the table, female subjects required more presentations (mean = 1.347) than did the male subjects (mean = 1.050). No other gender differences are present.

Table 38. Number of presentations as a function of display locations by gender.

		DRIVER SIDE	**REAR VIEW MIRROR**	**DASH PANEL**	**PASSENGER SIDE**
MALE	Mean	*1.17*	1.05	1.12	1.14
	SD	0.62	0.27	0.49	0.58
	Minimum	1.00	1.00	1.00	1.00
	Maximum	6.00	3.00	5.00	6.00
FEMALE	Mean	1.12	*1.35*	1.05	1.27
	SD	0.55	0.91	0.25	0.79
	Minimum	1.00	1.00	1.00	1.00
	Maximum	6.00	5.00	3.00	6.00

Table 39 provides the mean number of alert presentations required as a function of age, display location, and alert. With a few exceptions, older subjects consistently required more alert presentations than did either younger or middle aged subjects.

Table 39. Mean number of presentations as a function of display location by age and alert design.

ALERT DESIGN	DISPLAY LOCATION	YOUNG	MIDDLE	OLDER
INVERTED TRIANGLE	Driver Side	1.00	1.10	*1.58*
	Rear View Mirror	1.02	1.20	*1.65*
	Dash Panel	*1.05*	1.00	*1.05*
	Passenger Side	1.00	1.27	*1.55*
FIVE HORIZONTAL LEDS	Driver Side	1.10	1.15	*1.30*
	Rear View Mirror	1.00	1.10	*1.35*
	Dash Panel	1.00	1.08	*1.15*
	Passenger Side	1.05	1.20	*1.55*
FIVE VERTICAL LEDS	Driver Side	1.10	1.05	*1.55*
	Rear View Mirror	1.05	1.05	*1.60*
	Dash Panel	1.05	*1.27*	1.20
	Passenger Side	1.00	1.27	*1.50*
BARBER POLE	Driver Side	1.13	1.38	*2.63*
	Rear View Mirror	1.00	1.38	*2.13*
	Dash Panel	1.00	1.50	*1.75*
	Passenger Side	1.63	*1.83*	1.63
BARBER POLE & CAUTION	Driver Side	1.00	1.00	*1.38*
	Rear View Mirror	1.00	1.14	*1.38*
	Dash Panel	1.13	*1.40*	1.25
	Passenger Side	1.25	1.00	*1.75*
VEHICLE IN BLIND SPOT	Driver Side	1.10	1.05	*1.18*
	Rear View Mirror	1.00	1.09	*1.80*
	Dash Panel	1.00	*1.04*	1.00
	Passenger Side	1.10	1.00	*1.68*
PRESRCIPTIVE ARROW	Driver Side	1.05	1.00	*1.10*
	Rear View Mirror	1.00	1.00	*1.65*
	Dash Panel	1.00	*1.13*	1.05
	Passenger Side	1.00	1.13	*1.35*
DESCRIPTIVE CAR CRASH	Driver Side	1.16	1.05	*1.22*
	Rear View Mirror	1.00	1.00	*1.55*
	Dash Panel	1.00	*1.13*	1.00
	Passenger Side	1.00	1.07	*1.17*
TONE 1 & DESCRIPTIVE CAR CRASH	Driver Side	1.00	1.00	1.00
	Rear View Mirror	1.00	1.00	1.00
	Dash Panel	1.00	1.00	1.00
	Passenger Side	1.00	1.00	*1.13*
TONE 1	Driver Side	1.00	1.00	1.00
	Rear View Mirror	1.00	1.00	1.00
	Dash Panel	1.00	1.00	1.00
	Passenger Side	1.00	1.00	1.00
TONE 2	Driver Side	1.00	1.00	1.00
	Rear View Mirror	1.00	1.00	1.00
	Dash Panel	1.00	1.00	1.00
	Passenger Side	1.00	1.00	1.00

Table 39. Mean number of presentations as a function of display location By age and alert design (continued).

ALERT DESIGN	DISPLAY LOCATION	YOUNG	MIDDLE	OLDER
MUTH MIRROR	Driver Side	1.00	1.00	1.00
	Rear View Mirror	--	--	--
	Dash Panel	--	--	--
	Passenger Side	1.00	1.00	1.00

This finding is seen even more clearly in table 40, which shows the mean number of alert presentations required as a function of only age and display location. With the exception of the dash panel display location, the number of alert presentations required by older subjects is consistently greater than the number of presentations required by either younger or middle aged subjects.

Table 40. Number of presentations as a function of display location by age.

		DRIVER SIDE	REAR VIEW MIRROR	DASH PANEL	PASSENGER SIDE
YOUNG	**Mean**	1.06	1.01	1.02	1.06
	SD	0.31	0.09	0.13	0.44
	Minimum	1.00	1.00	1.00	1.00
	Maximum	4.00	2.00	2.00	6.00
MIDDLE	**Mean**	1.06	1.08	1.12	*1.15*
	SD	0.29	0.31	0.48	0.52
	Minimum	1.00	1.00	1.00	1.00
	Maximum	3.00	3.00	5.00	4.00
OLDER	**Mean**	1.31	*1.51*	1.10	*1.40*
	SD	0.90	1.08	0.44	0.95
	Minimum	1.00	1.00	1.00	1.00
	Maximum	6.00	5.00	4.00	6.00

SODS STATUS INDICATOR PHASE

Effects of Status Indicator Design

Responses to Multiple Choice Questions

Table 41 shows the distribution of responses to the multiple choice questions as a function of the status indicator design; six design alternatives were evaluated. The data show clearcut reactions to the different status indicator designs. Specifically, in response to the question ***"How recognizable is this as a system status indicator?,"*** the simple green and red circle symbols were not perceived as being effective status indicators by 60.4 percent and 39.6 percent of the subjects, respectively. The green checkmark and the red 'X' fared somewhat better, but were still rated as ineffective by approximately 30 percent of the subjects. The clear 'winners', with respect to the SODS status indicator, are the symbol + text combinations. With respect to the green circle with the 'System OK' text status indicator design, 52.1 percent of subjects responded with "I would know immediately that the system was/was not working." With respect to the and the red circle with the 'System Malfunction' text status indicator design, 62.5 percent of subjects responded with "I would know immediately that the system was/was not working."

Table 41. Percentage of responses as a function of status indicator.

STATUS INDICATOR	QUESTION NUMBER	SUBJECT RESPONSE				
		A	B	C	D	E
GREEN CIRCLE	7	60.4	6.2	12.5	4.2	16.7
RED CIRCLE	7	39.6	12.5	20.8	4.2	22.9
GREEN CIRCLE + SYSTEM OK	7	10.4	10.4	10.4	16.7	52.1
RED CIRCLE + SYSTEM MALFUNCTION	7	12.5	4.2	6.2	14.6	62.5
GREEN CHECKMARK	7	29.2	10.4	16.7	12.5	31.3
RED X	7	33.3	6.2	12.5	8.3	39.6

Stated Preferences for Status Indicator Design

Table 42 provides the stated preferences from subjects for the location of the status indicator design. For both the 'System OK' and the 'System Malfunctioning' conditions, there was a strong consensus (approximately 67% and approximately 70%, respectively) to locate the status indicator on or near the dash panel; i.e., in front of the driver.

Table 42. Stated preference for the location of a SODS status indicator.

DISPLAY LOCATION	SYSTEM OK	SYSTEM MALFUNCTIONING
Dashboard behind wheel	37.50%	41.67%
General dash area	14.58%	16.67%
Top dash, left of wheel	8.33%	6.25%
Top dash, center of wheel	6.25%	6.25%
Both driver and passenger mirrors	6.25%	6.25%
Other	6.25%	6.25%
Would not have indicator if system was OK	6.25%	4.17%
Top dash, right of wheel	4.17%	2.08%
Center console	4.17%	4.17%
Rear mirror	2.08%	2.08%
HUD on windshield	2.08%	2.08%
Passenger mirror	2.08%	2.08%

Table 43 provides the stated preferences from subjects for the color of the status indicator design. There was a strong consensus (70%) for the 'System OK' indicator to be green and a strong consensus (93%) for the 'System Malfunctioning' indicator to be red.

Table 43. Stated preference for the color of a SODS status indicator.

COLOR	SYSTEM OK	SYSTEM MALFUNCTIONING
Green	70.83%	NR
Red	15.48%	93.75%
Wouldn't have indicator for OK	6.25%	4.17%
Yellow (Amber)	4.17%	NR
White	2.08%	NR
Blue	2.08%	NR
Black	NR	2.08%

Table 44 provides the stated preferences from subjects for the basic design of the status indicator. For both the 'System OK' and the 'System Malfunctioning' conditions, the data are somewhat mixed. In both conditions, approximately 30 percent of the subjects wanted either just text such as 'System OK' or 'System Malfunctioning' or these text messages plus a green or red circle. For the 'System OK' indicator 27 percent of the subjects preferred some "other" design; for the 'System Malfunctioning' indicator 35 percent preferred some "other" design. The next most frequent responses were a green check (16%, for the 'System OK' condition) and a red 'X' (14%, for the 'System Malfunctioning' condition).

Table 44. Stated preference for the basic design of a SODS status indicator.

STATUS INDICATOR	SYSTEM OK	SYSTEM MALFUNCTIONING
Other	27.08%	35.42%
Text like 'system OK' only	22.92%	NA
Text like 'system malfunction' only	NA	25.00%
Green check	16.67%	NA
Red X	NA	14.58%
Green circle	10.42%	NA
Red circle	NA	10.42%
Green circle and 'system OK'	8.33%	NA
Red circle and 'system malfunction'	NA	6.25%
Would not have indicator for system	6.25%	4.17%
Vehicle in blind spot	6.25%	NA
Prescriptive Arrow	2.08%	2.08%
None Specified	NA	2.08%

CHAPTER 4: CONCLUSIONS

CONCLUSION

As noted earlier, our objectives for this study were to identify general characteristics of the SODS DVI that enhance driver performance, driver acceptance, and overall system effectiveness. This study was intended primarily as a screening study for candidate SODS DVI solutions, and was not intended to provide definitive design recommendations. In the Introduction section of this report, we listed a series of key SODS DVI research questions that would be addressed by this study. These questions are listed below and will serve to organize our conclusions from this exploratory research.

What Is the Preferred Location for the SODS Display?

For the SODS alerts, the results suggest an advantage for the dash panel location with respect to the alert's ability to get the drivers' attention and to convey urgency. In addition, subjects stated a consistent preference for a forward, i.e. around the dash panel, location for both the SODS alert and the SODS status indicator. Also, with the exception of the dash panel display location, the number of alert presentations required by older subjects was consistently greater than the number of presentations required by either younger or middle-aged subjects. This suggests an advantage to the dash panel location for older drivers in particular. However, there were no other meaningful differences in the number of presentations associated with display location. The driver and passenger side locations did not appear to provide any advantage to the subjects in terms of identifying either the left or right side of the vehicle as containing a potential danger. As noted above, these findings may well reflect our subjects' previous experience with, and expectations for, automobile alerts. The study did not assess driver performance and preferences to non-dash panel alerts in a more realistic, on-the-road environment. The results suggest that drivers may accept dash panel alerts, but they do not rule out other locations for the SODS alert; and there is a need to evaluate the effects of display location on driver performance,

For the SODS status indicator, there was a strong consensus to locate the visual display on or near the dash panel; i.e., in front of the driver.

What Is the Preferred Symbology for the SODS Display?

Several alerts, the Vehicle in Blind Spot, Prescriptive Arrow, Descriptive Car Crash, Descriptive Car Crash + Tone, the two tones, and the Muth Mirror alert, were consistently associated with conveying urgency. Each of these alerts except for the Muth Mirror alert were also perceived as being effective at communicating both the location of the potential danger as well as the nature of the situation. In addition, none of these alerts were perceived as being annoying or as being confusable with other displays. The Vehicle in Blind Spot and Prescriptive Arrow in particular were also rated highly by subjects with regard to stated preference. Overall, the results support a SODS alert design that is simple, yet is able to convey the nature of the situation to drivers. Also, the use of directional alerts that directly provide information on the location of a potential threat vehicle seems to provide some benefits in terms of conveying urgency and communicating the location of the potential changes and the nature of the situation. Several alerts, such as the Inverted Triangle, Horizontal and Vertical LEDs, and Barber Pole alerts did not convey either urgency or information about the situation to the subjects. For two alerts, the Barber Pole with Caution, and the Muth Mirror, the results were somewhat inconclusive.

The dynamic properties variable requires further study. Standard human factors design practice would suggest that flashing or moving alerts would improve a driver's ability to detect the alerts. However, in the current study, no consistent advantages were associated with alerts that flashed, moved, or increased in size. As noted earlier, this may have been due to the relative simplicity of the test environment. In the absence of competing stimuli and continued control requirements, all alerts were able to get the subjects' attention quickly.

For the SODS status indicators, the results were mixed. However, displays such as 'System OK' or 'System Malfunctioning,' or these text messages plus a green or red circle were the most commonly preferred designs. Other candidates for the status indicators include a green check (for the 'System OK' condition) and a red 'X' (for the 'System Malfunctioning' condition).

What Is the Preferred Color for the SODS Display?

The results strongly support the use of red as the alert color during situations where the driver is intending to merge or make a lane change. In cases where no merge or lane change is taking place, the results were mixed and do not support a clear conclusion; there was still a preference for red, but some of the subjects preferred yellow (amber). For the SODS status indicator, the results strongly support the use of green for the 'System OK' indicator and red for the 'System Malfunctioning.'

What is the Preferred Form of Auditory Alerts?

Although auditory alerts were superior to visual alerts in their ability to gain the subjects' attention and their effectiveness at conveying urgency, the preference data suggest that the use of auditory alerts should be limited to situations where the driver is intending to merge or make a lane change. The majority of the subjects preferred a tone in the 'intent to turn' scenario and did not want a tone in the 'no intent to turn' scenario. Also, three alerts, the Descriptive Car Crash + Tone, plus the individual tones were rated highly for both their ability to get the subjects' attention as well as to annoy the subjects. This provides further support to the conclusion that tones should be limited to driving conditions in which getting the drivers' attention is critical, such as 'intent to turn' situations.

In general, the tones used in the study seemed appropriate for use in a SODS device. When stating a preference for the type of auditory alert to use subjects were evenly split between using a human voice and using a beeping tone.

What Information Should SODS Present to Drivers?

The results support a SODS design that presents three types of information to drivers: (1) an status indication at vehicle start-up to inform the driver whether the system is OK or malfunctioning, (2) a caution alert indicating that a vehicle has been detected under conditions in which the driver ***is not*** intending to merge or make a lane change, and (3) a hazard alert indicating that a vehicle has been detected under conditions in which the driver ***is*** intending to merge or make a lane change.

Are There Any Age or Gender Differences Associated with Preferences for the SODS DVI Design?

While there were not any consistent differences in DVI design requirements as a function of age or gender, there was striking inconsistency between older subjects's subjective reporting of the alerts' urgency and attention-getting abilities and the number of presentations required before the older subjects noticed that the alerts been activated. Specifically, older subjects associated all of the alerts with greater attention-getting abilities and a higher sense of urgency than did younger and middle-aged subjects. However, the number of alert presentations required by older subjects was consistently greater than the number of presentations required by either younger or middle aged subjects in all display locations except for the dash panel location. The design implications of these findings are unclear, yet they suggest that future SODS research should continue to assess older drivers particular needs and preferences for alert information.

SUMMARY

As noted above, this study was intended as a screening study, and not as a definitive experiment to determine a precise SODS DVI. The goal has been to identify clear "winners" and "losers" with respect to SODS DVI options through an assessment of driver preferences.

What were the clear "winners" in this study? With respect to the information provided to drivers by a SODS device, three types of information are perceived as valuable: (1) a status indication at vehicle start-up, (2) a caution alert under 'no intent to turn' situations, and (3) a hazard alert under 'intent to turn' situations. With respect to alert design for an 'intent to turn' situation, the Vehicle in Blind Spot, Prescriptive Arrow, and Descriptive Car Crash designs (all in red), accompanied by a tone seem to meet basic requirements of a SODS alert in terms of driver preference, perhaps because they provide directional information about the location of a potential threat vehicle. These alerts should be investigated further under more representative conditions in future research. For the 'no intent to turn' situation, these same alerts (in yellow or amber) without the accompanying tone are recommended for future research. The dash panel location would also seem to be a winner, perhaps due to drivers' familiarity with this location.

What were the clear "losers" in this study? With respect to the information provided to drivers by a SODS device, the use of a tone under 'no intent to turn' situations was not perceived as valuable by subjects. For individual alert designs, several alerts, the Inverted Triangle, Horizontal and Vertical LEDs, and Barber Pole alerts conveyed lower levels of urgency and less information about the situation than the alerts listed above. These alerts should be given lower priority during future SODS DVI research projects.

Some of the issues investigated in this study remain unresolved and should be studied further as SODS devices move towards maturity and implementation in automobiles. While preliminary information regarding the preferred display location for a SODS device was obtained, future on-the-road research should continue to study this important design parameter. The driver and passenger side locations, including the Muth mirror locations, while not the most preferred locations, were not consistently associated with poor results or negative findings. Results associated with these non-dash panel display locations should be interpreted within the context of the current study, as well as with respect to driver expectations for warning displays. As noted earlier, subjects' responses in the study reflected their immediate impressions of the alerts, as opposed to the preferences that they might state after several weeks of use of and exposure to a SODS device. With extended use of a SODS, simple alerts presented on the side view mirror may be acceptable. Also, there were a number of obvious differences between the experimental environment and real-world conditions. Subjects were not interacting with the simulator, nor were they checking side-view mirrors as they might during lane change or merge driving maneuvers. We can certainly expect a more detailed and precise set of finding when SODS DVI candidates are studied for longer periods of time under more realistic conditions. Future research should also continue to investigate the unique performance and preference requirements of older drivers.

APPENDIX A: MULTIPLE CHOICE QUESTIONS- SODS ALERTS

1) To what extent would this alert be effective at getting your attention?
A) I would probably not see/hear it.
B) I would notice it when I needed the information.
C) I would probably notice it sooner or later, even if I wasn't expecting it.
D) I would notice it right away, even if I wasn't expecting it.
E) It is so noticeable, it would distract me from my driving.

2) To what extent does this alert communicate a sense of urgency to you?
A) I would likely just ignore it.
B) I would be in no hurry to respond to it.
C) I would proceed changing lanes with an increased awareness of other traffic.
D) I would double check my mirrors to see if I missed a vehicle before I changed lanes.
E) I would immediately stop changing lanes until I was certain the side was clear.

3) To what extent would this alert be annoying to you?
A) I would disconnect the display/alarm.
B) I would limit my turn signal use if the display/alarm was activated by the use of my signal.
C) I would be somewhat annoyed if the alarm went on in this situation.
D) I would not be annoyed if the display/alarm went on frequently.
E) I would appreciate having this display/alarm warn me of other vehicles.

4) To what extent does this alert communicate the location of the potential danger?
A) I would not understand what the alert is trying to communicate.
B) I would understand that there was an object close to my vehicle. I would check first for vehicles immediately in front of me.
C) I would understand that there was an object in my path. I would check for vehicles in front, to the rear, to my left, and to my right.
D) I would know immediately that the display/alert was warning of a vehicle either on my left or right, but not specifically which side.
E) I would know immediately which side the potential danger was on.

5) To what extent does this display/alert communicate the nature of the situation?
A) I would not know that there was a potential danger.
B) I would know that there was a danger, BUT I would not know where or what the hazard was.
C) I would know what the hazard was BUT I would not know exactly where it was.
D) I would know where the hazard was BUT I would not know exactly what it was.
E) I would know where the hazard was AND what it was.

6) To what extent would you confuse this alert with something else?
A) Even after looking/listening for a long time, I would not be certain that the alert was a side object detection system.
B) I would need to look/listen for a second or two to make sure it was not some other light or sound from in the car.
C) At first glance/listen I wouldn't be certain whether this was a side object detection system or some other warning display/alarm.
D) This is different than most other displays/alarms that I have ever se en/heard.
E) This is a distinct display. It cannot be confused with any existing displays I know of.

7) How recognizable is this as a system status indicator?
A) This is not an effective status indicator light. I would have no idea what it's purpose was.
B) I would have to look at it for a second or two to determine that it was a status indicator.
C) I would know that this was a status indicator, but I would not know the status of the system.
D) I would have to look at it for a second or two to determine the status of the system.
E) I would know immediately that the system was/was not working.

APPENDIX B: PHONE QUESTIONNAIRE

Subject Selection Phone Questionnaire

Subject Name____________________________________

Phone Number____________________________

Age___________

Gender_______________

1) Do you have an active driver's license? __________Yes __________ No
[Exclude subject if answer is NO]

2) How many times per week do you drive? ______<1X ______ 1x ______ 2 or more
[Exclude subject if answer is <1X]

3) Are you color blind? __________Yes __________ No
[Exclude subject if answer is YES]

APPENDIX C: CONSENT FORM

NHTSA RESEARCH PARTICIPATION CONSENT FORM
Task 1 Laboratory Study
(G478108-01)

You have been recruited to participate in a study that will examine the effects that Side-Object Detection Systems (SODS) have on driver attitudes and performance. SODS provide drivers with information to help prevent lane change crashes by detecting nearby vehicles and providing a warning to the driver. During this study, you will see and hear examples of these systems. There are no risks associated with this experiment other than those of everyday life.

The information gathered in this study will permit us to better understand how collision warning systems effect driver performance. All data obtained is for research purposes only and will remain confidential. The information will be reviewed by Battelle and National Highway Traffic Safety Administration (NHTSA) scientists, and the data will reside at Battelle and NHTSA. It is your privilege to withdraw from this study at any time. If you withdraw, you will be paid for the time you have participated without the loss of benefits. For your participation in this study, we will compensate you at the rate of $5.00 per hour.

If you have any questions or desire further information about this study, please contact John Campbell or Becky Hooey at Battelle, (206)528-3265. If you have concerns about the treatment of subjects you may call the Chair of Battelle's Human Subject Committee, Mr. David Snediker (614)424-4633.

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

Signature of Participant ____________ **Date of Birth** ____________ **Today's Date** ____________

Signature of Investigator ____________ **Today's Date** ____________

Record of Payment

Please Print Name ____________ **Social Security Number** ____________

________ hours @ $______ per hour = $________

TOTAL = $ ___________

Signature of Participant ____________ **Today's Date** ____________

Signature of Investigator ____________ **Today's Date** ____________

APPENDIX D: PROTOCOL AND INSTRUCTIONS

Overview of SODS Task 1 Laboratory Study

(To Be Read by the Experimenter)

Purpose of the Study

The purpose of this study is to determine drivers' preferences for various Side-Object Detection Systems or SODS. SODS provide the driver with information about vehicles in the "blind spot", or the visual area to the driver's side where neither the forward view, rear-view, or side-view mirrors can detect a vehicle. Having information about vehicles in the blind spot could help prevent lane change and merge type crashes.

In this study, you will be seated in our driving simulator, watching the road scene as if you were driving your own car down the road. You will see and hear different examples of what the Side Object Detection System might look like and you will be asked to provide your opinion regarding each of the alerts.

The experiment should last approximately 2 hours. As you have read on your consent form, you may choose to stop at any time. If you should stop prior to completion, you will be compensated at the rate of $5.00 per hour for the time that you were here. If you complete the experiment, you will earn $5.00 per hour, but you will also have the possibility of earning bonus money of up to $10.00. I will explain the bonus to you in a minute. You will be paid at the end of the session today.

What are SODS?

As mentioned earlier, SODS provide the driver with information about vehicles in the blind spot. You may be wondering, how they do this? Without getting into the technical details, there are a number of concepts and system designs which provide the driver with information about side vehicles in a timely manner and are easy to understand and react to. For example, some designs might be visual and flash a light when there is a vehicle in the blind spot. Others may be auditory and sound a tone when a side vehicle has been detected. Still others might be a combination of the visual and auditory alerts described above.

Today, you will be giving your opinion regarding several different designs and letting us know which ones you like and which ones you don't like. It is important in your assessment of these systems that you are as accurate and honest as possible. Your opinion will help us better determine what characteristics or features drivers like. Because these systems are just now being developed, you have a terrific opportunity to "put in your two-cents worth" and help make decisions about their design.

SODS Driving Conditions

An alert may be useful to drivers in a number of different situation. For today, I want you to consider two different driving conditions in which you might be alerted by SODS. The first condition or scenario we want you to consider is that you are driving down an interstate, you have activated your turn signal and you intend to change lanes. The alert may be activated if there is another vehicle in your path. The second scenario we want you to consider is that you are driving down an interstate, you do not intend to change lanes, and the alert activates to tell you that there is a vehicle in your blindspot. As you might expect, the type of alert that you might want or need may be different for each of these situations.

For the experiment today, I am going to begin by describing one of the above scenarios to you. It is important that you keep that scenario in mind throughout the entire trial, imagining yourself in the situation I describe. You will be watching the view as you drive down the road. You will not be required to actually steer or use the gas or brake pedals. The simulator will do all of that for you. Simply watch the vehicle as it drives down the road, and imagine yourself in the situation.

As you watch the view, an alert will come on, either visual or auditory, which will warn you of an object beside your car. The visual alerts will always be presented here <show ***display*** location>. Following each alert, you will be given six questions about this display. Remember to answer the questions by considering the driving situation that was assigned to you. ***<Experimenter show subjects the six questions, in the order assigned. Read each question and allow enough time for subjects to read all alternatives.>***

After each alert, I will present these six questions to you, and ask you to choose the response that mostly closely reflects your opinion. I will record your response for you, so please state out loud the letter associated with your response. ***<Experimenter provide example from first question>*** When you have finished answering the last of the six questions, return your attention to the driving view, and prepare for the next alert.

SODS Target Presentation

Throughout the drive, it is important that you remain as attentive to the driving environment as you possibly can. In addition to watching for the alerts, your job is to identify some “targets” throughout the drive. The targets that you are looking for are red cars. Cars may be approaching you in oncoming traffic, or they may be approaching from behind, in which case you would see them in your rear-view mirror.

As you will see, there are two buttons on the steering wheel, You will use these to report when you see the red cars. When ever you see a red car approaching you in oncoming traffic, you should press the right button on the steering wheel. As you see, this button is marked “FRONT”. When ever you see the red car approaching from behind you, press the left button that is marked “REAR”. You will earn 50 cents for each correctly identified red car. So, it is to your advantage to press the button as quickly as you can when you see one. If, however, the red cars happen to appear while you are reading and answering the questions, I will pay you for them, even if you don't notice them. So you do not need to monitor the roadway when you are answering the questions.

Do you have any questions about this? The specifics associated with this task will certainly become clearer as you move through them.

APPENDIX E: INSTRUCTIONS FOR DRAWING SODS

Designing The Ideal SODS Alert

If you were to design your own SODS alert, what would it look like?

1. What would your SODS alert look like if a car was in your blind spot AND you intended to turn?

What color would it be?	
Would it have sound?	
What would it look like?	
Where would it be located?	

2. What would your SODS alert look like if a car was in your blind spot but you did NOT intend to turn?

What color would it be?	
Would it have sound?	
What would it look like?	
Where would it be located?	

APPENDIX F: INSTRUCTIONS FOR DRAWING STATUS INDICATORS

Designing the Ideal Status Indicator

If you were to design your own status indicator, what would it look like?

1. First of all, think about what your status indicator would look like if the system were operating OK?

What color would it be?	
What would it look like?	
Where would it be located?	

2. Now, think about what your status indicator would look like if the system was **NOT** operating OK?

What color would it be?	
What would it look like?	
Where would it be located?	

APPENDIX G: THE DISTRIBUTION OF RESPONSES TO THE MULTIPLE CHOICE QUESTIONS AS A FUNCTION OF SUBJECT GENDER AND DISPLAY LOCATION.

Table 45. Percentage of responses as a function of display location by gender, driver side only.

DISPLAY LOCATION	GENDER	QUESTION NUMBER	SUBJECT RESPONSE				
			A	B	C	D	E
DRIVER SIDE	MALE	1	7.9	7.5	38.5	*43.7*	2.4
		2	13.9	17.9	19.8	10.3	*38.1*
		3	7.1	0.4	9.9	37.7	*44.8*
		4	17.1	7.9	22.2	3.6	*49.2*
		5	13.9	27.4	3.6	*28.6*	26.6
		6	6.3	15.9	19.4	15.9	*42.5*
	FEMALE	1	4.8	*34.1*	31.0	25.0	5.2
		2	11.5	21.8	4.0	11.5	*51.2*
		3	4.4	2.0	14.3	*46.0*	33.3
		4	19.4	5.2	19.4	23.4	*32.5*
		5	1.6	*41.7*	9.5	11.5	35.7
		6	4.0	12.7	12.4	26.7	*44.2*

Table 46. Percentage of responses as a function of display location by gender, rear view mirror only.

DISPLAY LOCATION	GENDER	QUESTION NUMBER	SUBJECT RESPONSE				
			A	B	C	D	E
DRIVER SIDE	MALE	1	2.9	21.3	39.2	30.8	5.8
		2	2.1	13.8	30.4	24.2	29.6
		3	4.2	5.4	16.7	49.2	24.6
		4	24.6	7.5	14.2	20.4	33.3
		5	6.7	37.9	17.9	12.9	24.6
		6	11.3	10.0	19.6	23.8	35.4
	FEMALE	1	5.4	30.4	35.8	19.6	8.8
		2	9.2	25.0	15.0	20.4	30.4
		3	9.2	4.2	4.6	26.7	55.4
		4	17.1	0.8	24.6	16.3	*41.2*
		5	7.9	28.8	15.4	36.2	11.7
		6	6.2	15.4	15.4	30.0	32.9

Table 47. Percentage of responses as a function of display location by gender, dash panel only.

DISPLAY LOCATION	GENDER	QUESTION NUMBER	SUBJECT RESPONSE				
			A	B	C	D	E
DRIVER SIDE	MALE	1	3.9	12.5	29.3	*41.1*	13.2
		2	9.3	13.9	13.6	27.9	*35.4*
		3	13.6	5.4	17.5	30.7	*32.9*
		4	20.7	8.2	23.6	11.4	*36.1*
		5	7.1	*40.7*	12.1	10.7	29.3
		6	12.9	11.8	20.7	11.4	*43.2*
	FEMALE	1	2.1	21.7	28.8	*42.9*	4.6
		2	4.2	26.3	19.6	11.3	*38.7*
		3	0.0	3.3	8.8	40.8	*47.1*
		4	25.0	3.7	28.8	11.7	*30.8*
		5	17.1	*36.7*	8.8	11.3	26.3
		6	15.0	5.0	12.5	12.9	*54.6*

Table 46. Percentage of responses as a function of display location by gender, passenger side only.

DISPLAY LOCATION	GENDER	QUESTION NUMBER	SUBJECT RESPONSE				
			A	B	C	D	E
DRIVER SIDE	MALE	1	4.3	25.7	35.7	30.5	3.8
		2	9.0	18.6	11.9	*35.2*	25.2
		3	1.0	3.8	32.4	19.5	*43.3*
		4	16.7	9.5	13.3	19.0	*41.4*
		5	10.5	22.9	16.7	*26.2*	23.8
		6	9.5	7.6	16.2	30.5	*36.2*
	FEMALE	1	3.6	21.4	*38.1*	25.8	11.1
		2	10.3	23.8	12.3	28.6	25.0
		3	7.9	3.6	23.4	38.9	26.2
		4	*24.6*	9.9	22.6	18.7	24.2
		5	15.1	38.5	7.9	17.9	20.6
		6	10.7	9.1	24.6	35.3	20.2

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