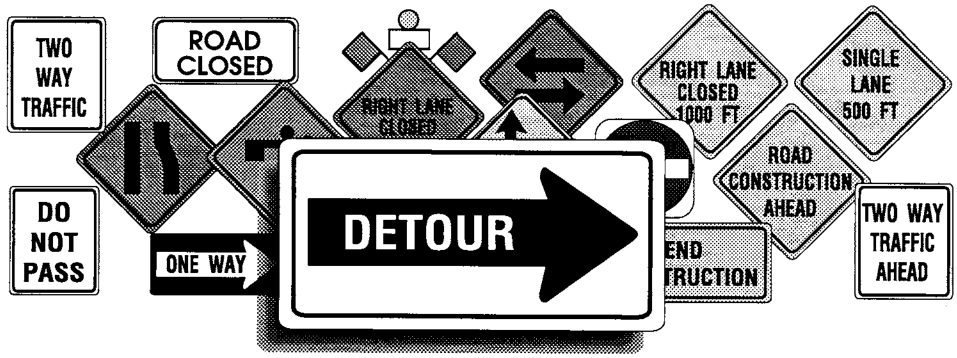
FINAL
CONTRACT REPORT

IMPROVING THE CONSPICUITY OF TRAILBLAZING SIGNS FOR INCIDENT MANAGEMENT



JULIE A. BARKER
Graduate Research Assistant

VICKI L. NEALE, Ph.D.
Research Scientist
Center for Transportation Research
Virginia Polytechnic Institute & State University

THOMAS A. DINGUS, Ph.D.
Director
Center for Transportation Research
Virginia Polytechnic Institute & State University

V · I · R · G · I · N · I · A
VTRC
TRANSPORTATION RESEARCH COUNCIL

VIRGINIA TRANSPORTATION RESEARCH COUNCIL

Standard Title Page - Report on State Project

<table>
<tr><td>Report No.

VTRC 98-CR36</td><td>Report Date

March 1998</td><td>No. Pages

47</td><td>Type Report:
Final
Period Covered:
10/1/96-3/31/98</td><td>Project No.:
9815-030-940
Contract No.
97-0100-07</td></tr>
<tr><td colspan="4">Title and Subtitle:
Improving the Conspicuity of Trailblazing Signs for Incident Management</td><td rowspan="3">Key Words:
Incident Management
Conspicuity
Signage
MUTCD
Reserved Sign Colors
Older Drivers</td></tr>
<tr><td colspan="4">Authors:
Julie A. Barker, Vicki L. Neale, Thomas A. Dingus</td></tr>
<tr><td colspan="4">Performing Organization Name and Address:

Virginia Transportation Research Council
530 Edgemont Road
Charlottesville, VA 22903</td></tr>
<tr><td colspan="5">Sponsoring Agencies' Name and Address

Virginia Department of Transportation
1401 E. Broad Street
Richmond, VA 23219</td></tr>
<tr><td colspan="5">Supplementary Notes</td></tr>
</table>

Abstract

This report represents efforts to design and evaluate a new sign design for emergency route trailblazing in a two-part series. Study 1 was an off-road field experiment conducted to determine the best sign color combination, letter stroke width, and letter size for the emergency sign. Based upon the results of that first study, three color combinations were chosen for testing (black on coral, black on light blue, and yellow on purple) against a baseline color combination of black on orange. The test signs to be further tested featured D series, 125-mm (5 in) height letters.

Study 2 was conducted using an instrumented vehicle and survey questionnaire through a construction zone-related detour. The independent variables of interest were sign color combination, age, and visibility condition. The findings of Study 2 indicated that use of a color combination other than the traditional orange background with a black legend will improve driver performance and safety when used for trailblazing during critical incidents.

Based on the conclusions and other anecdotal evidence, the following recommendations were made:

1. Do not use a black on orange sign for trailblazing around a critical incident if an existing detour/construction zone is in place.
2. Do not use a black on coral sign for trailblazing around a critical incident.
3. A black on light blue sign is recommended due to its generally favorable subjective ratings and for minimization of the number of turn errors made by drivers in an overlapping detour.
4. Despite recommendation 3, it is important to note that the black on light blue sign fades to take on the appearance of a regulatory sign when headlights reflect onto it.
5. If the black on light blue sign is deemed inappropriate due to its appearance as a regulatory sign at night, consider using the yellow on purple color combination. In this study, the yellow on purple sign color combination resulted in fewer turn errors than black on orange and it was generally rated favorably by drivers, especially younger drivers.

FINAL CONTRACT REPORT

IMPROVING THE CONSPICUITY OF TRAILBLAZING SIGNS FOR INCIDENT MANAGEMENT

Julia A. Barker, Vicki L. Neale, Ph.D. and Thomas A. Dingus, Ph.D.
Center for Transportation Research
Virginia Polytechnic and State University
Blacksburg, Virginia 24061-0404

(The opinions, findings, and conclusions expressed in this report are those of the authors and not necessarily those of the sponsoring agency).

Project Monitors
Stephen C. Brich, Virginia Transportation Research Council
Amy A. O'Leary, Ph.D., Virginia Transportation Research Council
Michael A. Perfater, Virginia Transportation Research Council

Contract Research Sponsored by
Virginia Transportation Research Council

Virginia Transportation Research Council
(A Cooperative Organization Sponsored Jointly by the
Virginia Department of Transportation and
the University of Virginia)

Charlottesville, Virginia
March 1998
VTRC 98-CR36

NOTICE

The project that is the subject of this report was done under contract for the Virginia Department of Transportation, Virginia Transportation Research Council. The opinions and conclusions expressed or implied are those of the contractors, and, although they have been accepted as appropriate by the project monitors, they are not necessarily those of the Virginia Transportation Research Council or the Virginia Department of Transportation.

Each contract report is peer reviewed and accepted for publication by Research Council staff with expertise in related technical areas. Final editing and proofreading of the report are performed by the contractor.

Copyright 1998, Virginia Department of Transportation

ABSTRACT

This report represents efforts to design and evaluate a new sign design for emergency route trailblazing in a two-part series. Study 1 was an off-road field experiment conducted to determine the best sign color combination, letter stroke width, and letter size for the emergency sign. Based upon the results of that first study, three color combinations were chosen for testing (black on coral, black on light blue, and yellow on purple) against a baseline color combination of black on orange. The test signs to be further tested featured D series, 125-mm (5 in) height letters.

Study 2 was conducted using an instrumented vehicle and survey questionnaire through a construction zone-related detour. The independent variables of interest were sign color combination, age, and visibility condition. The findings of Study 2 indicated that use of a color combination other than the traditional orange background with a black legend will improve driver performance and safety when used for trailblazing during critical incidents. The following conclusions were made:

1. A yellow on purple sign or black on light blue sign will likely result in fewer late braking maneuvers if the road geometry has many tight curves.
2. A black on light blue sign will result in the fewest number of turn errors in both rural and urban settings.
3. A black on orange sign will result in more turn errors, especially during the day and particularly when it is overlapped with existing detour/construction zone signs.
4. A black on coral sign is least preferred by older and younger drivers when compared to the other sign colors tested in this study.
5. Younger drivers tend to have a preference for a yellow on purple sign, and older drivers tend to have a preference for a black on light blue sign.

Based on the conclusions and other anecdotal evidence, the following recommendations were made:

1. Do not use a black on orange sign for trailblazing around a critical incident if an existing detour/construction zone is in place.
2. Do not use a black on coral sign for trailblazing around a critical incident.
3. A black on light blue sign is recommended due to its generally favorable subjective ratings and for minimization of the number of turn errors made by drivers in an overlapping detour.
4. Despite recommendation 3, it is important to note that the black on light blue sign fades to take on the appearance of a regulatory sign when headlights reflect onto it.
5. If the black on light blue sign is deemed inappropriate due to its appearance as a regulatory sign at night, consider using the yellow on purple color combination. In this study, the yellow on purple sign color combination resulted in fewer turn errors than black on orange and it was generally rated favorably by drivers, especially younger drivers

FINAL CONTRACT REPORT

IMPROVEMENT OF CONSPICUITY FOR TRAILBLAZING SIGNS FOR INCIDENT MANAGEMENT

Julie A. Barker
Graduate Research Assistant

Vicki L. Neale, Ph.D.
Research Scientist, Virginia Tech Center for Transportation Research

Thomas A. Dingus, Ph.D.
Director, Virginia Tech Center for Transportation Research

INTRODUCTION

Traffic incidents block roadways, forcing traffic to be diverted from the primary route onto a secondary street system, and then back to the primary route. When placed in a work zone with other black on orange signs competing for visual attention, the black on orange "EMERGENCY DETOUR" sign that is currently in use may be ineffective for trailblazing. Diversion routes need to be marked, or "trailblazed," in a conspicuous manner so that motorists unfamiliar with the area can navigate the alternate route. Furthermore, traffic signs must be recognized and understood quickly to allow sufficient time for decision making and appropriate action relative to the changing combination of driving conditions. For these reasons, there is a need to identify the most conspicuous sign color, the best contrast colors for the legend and border, and other sign design factors so that motorists can effectively navigate through an unfamiliar route, even when that route traverses through work zones.

There are a host of issues that affect the design of a trailblazing sign. Increased driver workload associated with navigating through a trailblazed area may affect the driver, who must attend to the vehicle path, identify trailblazing signs, read the message, understand it, and decide what action to take. A contributing factor to this problem may be that the "EMERGENCY DETOUR" sign currently used for trailblazing employs the black on orange color scheme that is associated with construction activities. Research results (e.g., Pietrucha, 1993) indicate that there should be a separate category of traffic signs (i.e., independent of construction signs) to control traffic in an emergency situation.

Other issues when designing a trailblazing sign are driver characteristics and individual differences. For example, the age range of the driving population is of primary concern. Elderly drivers experience more stress than drivers of other age groups, which reduces the amount of attention they can devote to detecting, reading, and responding to traffic signs and other traffic identify and discriminate real-world targets, including traffic signs (Owsley and Sloane, 1987). These characteristics require that a traffic control device provide older drivers with more information and more time to respond than younger drivers (Mortimer and Fell, 1989). Similarly, younger drivers may also need more time to respond to traffic control devices, although for other reasons. Younger drivers tend to have a lower risk perception than older drivers (Finn and Bragg, 1986), which, when coupled with their driving inexperience, leads to a higher probability of a crash.

Visibility conditions, especially differences due to daytime versus nighttime driving, must also be considered when designing a trailblazing sign or other traffic control device. The visibility (conspicuousness) of road signs decreases significantly at night, with the problem being more pronounced for older drivers and drivers with color vision deficiencies (Collins, 1989; Verriest, 1963). Glare from headlights on a road sign, glare in the driver's eyes due to oncoming traffic lights, and reduced visibility due to weather conditions are also of concern.

There are also several design issues concerning the legibility distance and reaction time that are associated with a traffic sign (e.g., Dewar, 1988, 1989, 1993; Mace, 1988; U. S. Department of Transportation, 1983). These include:

shape coding and sign size	letter fonts and size
color coding and color combinations	uniformity of design
understandability of symbols	sign positioning
proximity of borders	luminance of the sign
illumination	retroreflectivity
stroke width	legend
spacing between letters	contrast

This list, although not comprehensive, demonstrates that there are many design issues that impact the effectiveness of a traffic sign, even under the most ideal of viewing conditions. With this information in mind, a research initiative was proposed.

Summary of Study 1

A two-part experiment was initiated by the Virginia Department of Transportation's (VDOT) Statewide Incident Management (SIM) Committee and the Virginia Transportation Research Council due to problems experienced when an incident detour marked with black on orange detour signs overlapped with a construction detour that was also marked with black on orange detour signs. It was felt by members of the SIM Committee that the inability of the motorist to determine which sign to follow prompted the need for a unique sign color to trailblaze motorists around an incident. It was further thought that a unique sign color for an incident detour would reduce motorist confusion, give the driver a "level of comfort" while navigating an unfamiliar area, and improve operational safety and efficiency by reducing sudden stops and erratic maneuvers.

Study 1 was an off-road field experiment conducted to evaluate the four sign background colors that are currently reserved by the Manual on Uniform Traffic Control Devices (MUTCD) (coral, light blue, purple, and strong yellow-green), with a host of legend colors. Also evaluated were the current standard black on orange sign, and a red, white, and blue sign. The legend colors chosen were based on analyses of luminance contrast and color contrast with the background colors. In total, 13 color combinations were evaluated. The combinations were:

1. black on orange
2. black on coral
3. blue on coral
4. white on coral
5. black on light blue
6. blue on light blue
7. yellow on light blue
8. black on purple
9. white on purple
10. yellow on purple
11. black on fluorescent yellow-green
12. strong yellow-green on purple
13. red on white and white on blue on the same sign

This last color combination represents the red, white, and blue sign currently being considered for use during emergency detour routing through a construction work zone in Northern Virginia.

The independent variables in Study 1 were sign color combination, letter stroke width, and letter size. The 13 color combinations listed above were evaluated using two letter series, C and D (which were used to investigate letter stroke width ratio values of 0.14 and 0.16, respectively), and two letter sizes, including 100 mm (4 in) and 125 mm (5 in). Other independent variables included driver age (young and older) and visibility conditions (daytime or nighttime). Factors that were experimentally controlled were: 1) gender; 2) color vision; 3) daytime cloud conditions (clear versus cloudy); and 4) time of day. Furthermore, presentation of the signs was varied systematically to account for the position of the sun in reference to the sign. The dependent variable of interest was legibility distance of the sign (the distance required to read) including determination of the sign arrow direction.

Test signs were manufactured using 3M's Scotchlite™ Transparent Process Color and Scotchlite™ Diamond Grade Reflective sheeting. The background colors were fabricated by traditional silk screening. Text legends, arrow icons, and sign borders were applied either by silk screening, non-reflective black tape, yellow Scotchlite™ Diamond Grade Reflective sheeting tape, or Scotchlite™ Type III High Intensity Grade sheeting tape, depending on the legend color used. Test signs measured 0.610 m (24 in) by 0.762 m (30 in).

Sixteen drivers participated in this off-road field experiment. Nine of the drivers were ages 18 to 28, one driver was age 42, and six drivers were ages 67 to 75. A 1995 Oldsmobile Aurora was used as the observation vehicle. The study was conducted on an isolated test strip at the Virginia Tech airport in Blacksburg, Virginia. Twenty-seven test signs featuring the 13 color combinations, combinations of the letter heights and letter series, and directional arrows were posted at alternate ends of the 296.7 m (970 ft) test strip. Participants were driven toward the test signs until they were able to read each line of text and determine the arrow direction; each legend or arrow reading was considered a unique measurement. Following each sign presentation, participants were asked to give a subjective rating of the sign's legibility.

Study 1 revealed that several of the sign color combinations resulted in legibility distances that were superior to black on orange. Of these, three color combinations were chosen for an on-road test of conspicuity: black on coral, black on light blue, and yellow on purple. Furthermore, the results indicated improved legibility distances for signs employing the D series, 125-mm (5 in) (stroke width ratio = 0.16) letters. Based on the results of Study 1, an on-road test and evaluation of the traffic signs was employed to determine conspicuity of the new sign designs (Barker, Neale, and Dingus, 1997). The remainder of this report documents Study 2.

STUDY 2 – PURPOSE AND SCOPE

As previously explained, Study 1 found that black on coral, black on light blue, and yellow on purple color combinations with 125-mm (5 in) letter height, D series letters resulted in the best legibility distances. These were selected for further testing. Study 2 tested these three sign color combinations in addition to the standard black on orange sign color combination currently used for construction detours and emergency incident-related detours. The purpose of Study 2 was to quantitatively evaluate the conspicuity of the experimental signs when overlayed with an existing construction detour. During Study 2, as in actual scenarios, regular detour signs and the experimental emergency detour signs were posted along some of the same stretches of roadway, but marking two distinct routes.

The driver response to the stated design parameters was examined in terms of the following:

1. The conspicuity of the experimental sign color combinations relative to the standard highway black on orange traffic control sign under normal traffic conditions, with respect to driver age and day and night driving conditions.
2. The legibility and understandability of the experimental sign color combinations relative to the standard black on orange sign colors under normal traffic conditions, with respect to driver age and day and night driving conditions.

The primary goal of this research was to identify the sign legend and background color combination and other design parameters that are most effective for emergency detour routes (i.e., alternate routes), including detours through work zones, during incident management situations. The modified sign design would provide a means for conveying conspicuous emergency detour information to motorists regardless of other traffic sign information.

The expected benefits of a modified detour sign design for incident management include improved safety as better signs will increase driver awareness of traffic direction information or more timely awareness of such information, especially during incident management situations. In addition, it is expected that driver comfort will be increased due to earlier detection, color recognition and better sign legibility. Finally, it is expected that older drivers will benefit due to the age-related need for enhanced color contrast and brightness in traffic control signs. As a result, it is envisioned that this report's recommendation for a sign color combination and related sign design parameters for incident management will ultimately become a state and national standard.

METHODS AND MATERIALS

Experimental Design

A 4 X 2 X 2 (Sign color x Age x Visibility Conditions) between factor design was utilized for this study. The general assignment of participants is shown in Table 1. Male and female participants were randomly assigned between daytime and nighttime conditions. Participants with varying levels of color vision deficiency were also randomly assigned between daytime and nighttime conditions. Daytime viewing conditions included both clear conditions and cloudy or partly cloudy conditions. Each participant was shown one test sign configuration and was exposed to one viewing condition, as indicated in Table 1. The same experimental detour route, located alongside an existing work zone detour in Mecklenburg County, Virginia, was used for all participants (see Appendix A for a map of the route).

Table 1. Experimental assignment of participants

Sign Color Combination	Younger Drivers		Older Drivers		Totals
	Daytime	Nighttime	Daytime	Nighttime	
Black on Orange - Baseline	5	4	4	2	15
Yellow on Purple	4	6	4	5	19
Black on Light Blue	4	5	6	2	17
Black on Coral	6	5	6	2	19
Totals	19	20	20	11	
	39		31		70

Independent Variables

- *Sign Color Combination.* The three experimental sign color combinations included yellow on purple, black on light blue, and black on coral. These color combinations were chosen based on the results of Study 1. Black on orange was tested as a baseline.
- *Age.* Two age groups of drivers were used: younger drivers (18-34 years) and older drivers (54-75 years). Note that, as with other on-road driving studies, there was difficulty recruiting older drivers to participate in the night driving condition.
- *Visibility Condition.* Participants drove either during the day or night. Thirty-nine of the participants observed the test signs during daytime sessions. Daytime test sessions began no sooner than one hour after sunrise and no later than one hour before sunset. During the course of the study, all signs were observed under both clear skies and cloudy/partly cloudy conditions. Thirty-one of the participants observed the test signs during nighttime sessions, with only the low-beam headlights of the test vehicle to illuminate the test signs. Nighttime test sessions began no sooner than one-half hour after sunset. All data collection occurred in fair weather, i.e. no precipitation was falling.

Controlled Variables

- *Gender.* Gender was controlled such that an approximately equal number of male and female drivers were assigned and tested under daytime and nighttime conditions, respectively.
- *Color Vision Deficiency.* Visual ability was controlled such that at least one participant for each sign color combination demonstrated some level of color vision deficiency. Eight participants demonstrated normal color vision using the Titmus® II vision tester, 33 participants demonstrated a mild level of deficiency, and 29 participants failed the color vision screening. The fact that a majority of the participants demonstrated some level of color vision deficiency may be due to the use of an older motorized vision tester whose test slides may be beginning to show signs of aging. All participants who volunteered and met all of the other screening criteria (general health, hearing, valid license, and so on) were asked to participate since this criteria was not used as a basis to determine eligibility to participate.

Dependent Variables

The in-vehicle data collection system provided the capability to store data on a computer in the form of one line of numerical data every 0.1 seconds during a data run. The videotape record provided by the cameras' views was time-stamped and synchronized with the computer data stream so that post-test data reduction and data set merging could be performed in the laboratory. All vehicle data collection records were time-stamped to an accuracy of +/- 0.1 seconds. The specific measures collected were as follows:

- *Average Vehicle Velocity/Velocity Variance.* Research indicates velocity maintenance to be a sensitive measure of changes in the amount of attention demanded by secondary driving tasks (Monty, 1984). A change in vehicle velocity can also be used to indicate the point where a driver receives information about a detour or a change in speed limit.
- *Late Braking Reaction.* Braking behavior can also provide a sensitive measure of performance (Monty, 1984). If drivers are inattentive, the brake must be depressed harder and the resulting deceleration is greater than in a normal attention situation. In addition, an abrupt maneuver can be indicative of a driver receiving or processing information late about an upcoming maneuver. A late reaction was operationally defined by a brake position found to be more than two standard deviations from the mean brake position during the course of a sign event. A sign event began when a sign came into view and ended when the experimental vehicle passed the sign.
- *Longitudinal Acceleration/Deceleration Measures and Braking Data.* The pattern of acceleration and braking data is an indication of driver inattention to the forward roadway.
- *Lateral Acceleration Measures.* Abrupt lateral maneuvers, such as large steering reversals, are indicative of a vehicle that is off the center lane track due to driver inattention. Lateral acceleration measures are highly correlated with driver steering input and are therefore used to highlight large magnitude corrections.
- *Steering Wheel Position Variance.* Research has shown that changes in driver steering behavior occur when driver attention changes (Wierwille and Gutman, 1978). In normal,

low-attention circumstances, drivers make continuous, small steering corrections to correct for roadway variance and driving conditions. These corrections typically range from two to six degrees. As attention or workload demands increase, the number of these corrections decreases, requiring a larger input to correct the vehicle's position. Therefore, an increase in the variance of steering wheel position indicates high attention or workload requirements.

- *Number of Wrong and Missed Turns*. The number of wrong turns is an indication of whether the signs are being detected, recognized, and understood by the driver. A wrong turn event was defined as a turn taken when no directional information was provided to indicate a required turn. A missed turn event was defined as a required turn that was not taken when indicated by a sign. In the event that a wrong turn and a missed turn occurred for the same sign site, only one error was counted. This data was collected by the experimenter.
- *Subjective Acceptance and Preference Measures*. This data was collected via a subjective questionnaire to assess the driver's impressions and preferences about the TEST DETOUR signs.

Participants

Ninety-six drivers were to have participated in this study in order to have six subjects per experimental cell. However, due to (1) a limited test period of one month associated with the impending removal of the work zone detour, and (2) recruitment limitations in the test area, 70 drivers actually participated in this study. Thirty-nine participants were between the ages of 18 and 34 (younger drivers), and 31 participants were between the ages of 54 and 75 (older drivers). Drivers were recruited through advertisements in local newspapers and flyers posted at local merchants in the Mecklenburg County area. Participants received $25 for participating in this study for approximately one hour of experiment time.

Each participant was required to: (1) be a licensed driver; (2) drive a minimum of twice a week in Mecklenburg County, Virginia, or the surrounding area; (3) pass a health screening questionnaire; and (4) have a minimum of 20/40 visual acuity, wearing corrective lenses if necessary. In addition, participants were screened for color vision deficiencies, and participants were randomly assigned to each sign color combination based on a demonstrated deficiency.

Apparatus

The primary apparatus used in the study were: (1) an illuminance meter; (2) a vision tester; (3) an automobile; (4) the test signs located along the test route; and (5) a post-test questionnaire. These are described in the following sections.

Illuminance Meter

An Extech Instruments Digital Light Meter was used to obtain illuminance measurements of the ambient lighting conditions during the data collection sessions. The measuring range for this device is 0.0 to 50,000 lux (0.0 to 5,000 foot-candelas).

Titmus® II Vision Tester

This device was used to screen participants for visual acuity and color discrimination (i.e., color vision) at a far distance. The device included a Landholt broken ring test for visual acuity. The level of visual acuity was determined by the participant's ability to locate and identify the unbroken ring in each of the numbered targets. The color vision test consisted of six accurately reproduced Ishihara Pseudo-Isochromatic Plates. This test was used to identify the presence of a color deficiency, however, it was not able to classify type of deficiency.

Automobile

A 1995 Oldsmobile Aurora was used as the experimental vehicle for all participants. The instrumentation in the vehicle provided the means to unobtrusively collect, record, and reduce a number of data items, including measures of attention demand, measures of navigation performance, safety-related incidents, and subjective opinions of the participants. The system consisted of video cameras to record pertinent data events, an experimenter control panel to record time and duration of events and information on an MS display, sensors for the detection of variations in driving performance and behavior, and a custom analog-to-digital interface and computer to log the data in the required form for analysis. A detailed description of the vehicle's components is in Appendix B.

Experimental Sign Design

There were three experimental sign design configurations in addition to the orange with black legend baseline for a total of four color combinations were used. The signs read "TEST" on the first line and "DETOUR" on the second line. The overall dimensions for each sign were 0.609 m (24 in) tall by 0.762 m (30 in) wide, as is the standard for the black on orange EMERGENCY DETOUR signs currently used. Remaining specifications are shown in Figure 1.

A photograph of the experimental sign color combinations is shown in Figure 2. The actual Commission International d'Eclairge (CIE) Notations for the background and legend colors are shown in Table 2 as specified in the *Standard Highway Color Specifications* (U. S. Department of Transportation, 1969). Note that the coral color used is not the same as that specified in the *Standard Highway Color Specifications* (U. S. Department of Transportation, 1969), although it is extremely close. The reason for the discrepancy is that the specified coral ink is not being mass manufactured and therefore was not readily available for the study. The inks had to be specially formulated for the study. Note that neither the test colors nor the colors used on the existing detour signs along the test route were fluorescent. At the time of testing, the test colors were not all available in fluorescent versions. Due to this fact, testing was only conducted for colors that could be produced in similar materials.

Table 2. CIE Notation for experimental sign colors (from U. S. Department of Transportation, 1969)

Color	CIE Y (%)	CIE x	CIE y
Black	9.43	0.3101	0.3163
Light blue	43.06	0.2410	0.2854
Orange	24.58	0.5609	0.3950
Purple	12.00	0.3056	0.2060
Yellow	50.68	0.5007	0.4555
*Coral	49.52	0.3943	0.3251

* The FHWA-specified coral ink is Y%=51.08, x=0.3815, y=0.3169

The background colors for all of the test signs, as well as the existing orange and black detour signs, were fabricated by traditional silk screening. All black legends and borders were applied using non-reflective black tape. The highway yellow legends and borders were applied using yellow-colored Scotchlite™ Diamond Grade Reflective sheeting tape. The colored inks(3M's Scotchlite™ Transparent Process Color) for both test signs and existing detour signs were applied to aluminum sheeting via the 3M Company's Scotchlite™ Diamond Grade Reflective sheeting material. The diamond grade sheeting material, which can be distinguished by the diamond-shaped lattice separating the sheeting layers, reflects back to the driver a maximum amount of light from vehicle headlights at a wide angle. The benefit of using diamond grade sheeting is two-fold: 1) it improves the conspicuity of the sign for both daytime and nighttime conditions, and 2) it improves the conspicuity of signs that are slightly off angle, which is often the case in realistic work-zone situations.

Eighteen experimental signs were posted along the route. Each sign panel was supported on a standard sign post, and oriented approximately perpendicular to the direction of travel, facing the observation vehicle, as is normal practice. The signs were mounted 2.13 m (7 ft) from the ground to the bottom edge of the sign with the exception of a few cases in which two traffic signs were on the same post. Sign supports were located on the right shoulder of the road, approximately 3.66 m (12 ft) from the edge of the travel lane, as specified by the MUTCD.

Post-test Questionnaire

The post-test questionnaire to gather subjective opinion data is shown in Appendix C. The first three questions on the survey asked the driver to *rate* the sign they had just seen on the test route in terms of visibility, ease of identifying and understanding the directional information, and usefulness of the sign information. It is important to note that these questions asked the driver to make a relative judgement of the sign they saw; that is, the drivers had only seen one sign color to this point and could not judge the sign color as it compared to the other sign colors.

Questions 4, 5, and 6 on the survey asked the drivers to *rank* the four sign colors based on two redundant information sources. The first source was a 7.5 cm x 12.5 cm sample of the background sign color (without contrasting legend color) on Scotchlite Type 3 high intensity grade sheeting (described as having a "honeycomb" appearance). The second source was four 8 cm x 8 cm Polaroid photographs (taken with the flash on), one of each of the four sign colors. Drivers were asked to rank the signs in terms of visibility, readability, and overall preference. The pictures were taken during the daylight hours (late afternoon) at a distance of approximately one meter. It is important to note that the drivers did not have the opportunity to see the signs with varying levels of daytime light, such as might occur with a changing sun position, or during nighttime viewing conditions, in which case the effect of headlights could dramatically change the appearance of the signs. However, Questions 4, 5, and 6 did allow for an absolute judgement of sign colors; that is, the drivers could look at the four sign colors together and decide which they most and least preferred.

Procedure

The study was conducted in Mecklenburg County, Virginia, along routes 92, 688, 701, and 698 (see Appendix A). Participants were initially screened over the telephone regarding age, gender, driving frequency, and general health. If participants were eligible, times were scheduled for testing. Participants were instructed to meet experimenters at the Chase City Police Department, in Chase City, Virginia. Upon arrival, the participant was given an overview of the study, and he or she was asked to review and complete the informed consent form (Appendix D). Next, he or she was asked to complete a health screening questionnaire (Appendix E). In addition, he or she was given a simple vision test and a color vision test using the Titmus® II vision tester. After these tasks were completed, the participant was escorted to the test vehicle.

The vehicle's windshield was cleaned prior to each testing session. While the car was in park, the experimenter reviewed general information concerning the operation of the test vehicle (e.g., lights, seat adjustment, mirrors, and windshield wipers). The participant was then asked to operate each control and set it for his/her driving comfort. When the participant felt comfortable with the controls, the experimenter briefly described the driving task. To allow the participant to become familiar with the handling of the vehicle, the drivers maneuvered the vehicle along a practice route. No test signs were mounted along the practice route. Once the driver completed the practice session, he/she was asked if he/she felt comfortable with the car. If the answer was "no," the practice run was repeated. Drivers were allowed as many practice runs as desired in order to feel comfortable with the vehicle. When the driver indicated that he/she felt comfortable with the car, the test run began.

The experimental protocol required two experimenters as well as the participant to be in the vehicle. The experimenter seated in the front passenger seat gave initial navigational instructions, served as the safety officer using the emergency brake as needed, flagged events in the data set using the event flagger, and recorded the events corresponding to the flagged data on a data sheet. Only unplanned external events, such as a preceding car slowing suddenly or pedestrians or animals on or crossing the roadway, were flagged during the data collection session; the "planned" sign events were marked manually during later data analysis. The second experimenter was seated in the back seat and monitored the data collection computer. The low-beam halogen headlights were used during nighttime driving conditions.

At the beginning of the test route, the participant was instructed to look for and follow the signs that read "TEST DETOUR" (the sign color was not mentioned). The participant was told that these signs marked a predetermined route of approximately 12 miles in length. The participant was also instructed that all test signs would contain the same text legend, and that each sign would contain a directional arrow to indicate the route to be taken. While following the directions provided by the signs, the participant was instructed to obey the traffic laws and to drive safely. If a wrong turn was made, the experimenter allowed the driver to complete the turn and then immediately directed him/her back to the prescribed route.

The test route and data collection began in Chase City, Virginia, on Route 92 and ended at the rural intersection of state Route 698 and Route 49 (see Appendix A). The test route was approximately 19.3 km (12 mi) long and overlapped with an existing detour for a construction work zone located on Route 49. The roadways along the entire test route were two-lane roads, some portions with marked lanes and some without, and with few sources of illumination other than occasional private homes or businesses once outside of the business section of Chase City.

The first 2 km (1.25 mi) of the test route overlapped the existing car and truck detour route. The next 10.07 km (6.25 mi) of the test route overlapped the existing car detour route. The remaining 7.24 km (4.5 mi) of the test route employed only the experimental signs. The number of experimental signs matched the number of existing detour signs per unit of distance.

Signs were posted in both urban and rural settings. The first three sign posts were placed in a business section of Chase City, Virginia. All other sign posts were placed in rural settings in Mecklenburg County. A total of 23 sign post locations were used to post the existing detour signs and the experimental signs along the 19.3-km test route.

Following completion of the test run, participants were driven back to the meeting place, i.e., the Chase City Police Department, where an experimenter administered the post-test questionnaire (see Appendix C). Drivers were then debriefed and paid for their time. The total time for the experiment was approximately one hour.

RESULTS AND DISCUSSION

All statistical analyses were conducted using the SAS® 6.12 software package. Due to missing or unbalanced experimental cells (typical of field experiments), all analyses of variance (ANOVAs) were conducted using the general linear model (GLM) procedure (Littell, Freund, and Spector, 1991). For this experiment, a 0.05 significance level was used (95% probability that the results reported reflect actual differences). Non-parametric tests were performed where appropriate.

Driving Performance Variables

Late Braking Maneuvers

A late braking maneuver was operationally defined as an incident requiring a brake position more than two standard deviations from the mean brake position to slow to make a turn during the course of a sign event. A sign event began when a sign came into view and ended when the experimental vehicle passed the sign.

Only one sign event had enough late braking maneuvers to evaluate (three other sign events resulted in one late braking maneuver each). In that event, shown in Appendix A as site 20, the road geometry was such that the driver would have to detect the sign quickly in order to avoid a late braking maneuver. The sign was posted at an intersection that occurred after a curve in the road. In order to make the turn indicated by the sign, the driver had to perceive and read the sign immediately upon coming out of the curve and brake for the turn. Sixteen of 70 participants demonstrated late reactions. A chi-square test was conducted on the braking data using the 4 x 2 matrix shown in Table 3. Although this difference was not significant, it does show a trend toward a higher level of conspicuity for the black on light blue and the yellow on purple signs for this event. It is plausible that if time were available to have more drivers participate, a significant difference may have been shown. Late braking maneuvers did not approach significance as analyzed by age or visibility condition.

Table 3. Frequency of late braking maneuvers at site 20

Sign Color Combination	No Late Reaction Observed	Late Reaction Observed	Significance Level
Black on Orange	10	5	$X^2(3,N=70) = 5.866$, $p = 0.118$
Yellow on Purple	17	2	
Black on Light Blue	15	2	
Black on Coral	12	7	

Other Driving Performance Variables

Data analysis performed on the other driver performance variables measured (average vehicle velocity/velocity variance, longitudinal acceleration/deceleration measures and braking data, lateral acceleration measures, steering wheel position variance) showed no significant differences for an analysis by sign color, age, or visibility condition. This outcome may be a result of a relatively small effect size combined with the high variability in driving performance measures that occur in field data.

Analysis of Wrong and Missed Turns

Assessment for Sign Color

Wrong and missed turns were analyzed together as turn errors. Table 4 shows the frequency of correct turns and turn errors analyzed by sign color. A wrong turn event was defined as a turn taken when no directional information was provided to indicate a required turn. A missed turn event was defined as a required turn that was not taken when indicated by a sign. In the event that a wrong turn and a missed turn occurred for the same sign site, only one error was counted. Note that there were no incorrect turn events (wrong or missed turns) for the light blue with black legend test detour sign.

Table 4. Overall frequency of turn errors by sign color combination

Sign Color Combination	CORRECT TURNS	Incorrect Turns	Significance Level
Black on Orange	336	9	$X^2(3,N=1610) = 9.759$, $p = 0.021$
Yellow on Purple	431	6	
Black on Light Blue	391	0	
Black on Coral	431	6	

The locations at which the turn errors occurred were reviewed in an effort to determine any underlying cause for the turn errors other than an effect of sign color. No pattern could be resolved – the turn errors occurred at five different sign locations (three rural and two urban) that were not distinct in terms of road geometry, sight distance, or visual noise.

A 4 x 2 chi-square test was conducted on the data contained in Table 4 to determine if there was a difference between the number of correct and incorrect turns for each sign color. There was a significant difference between sign colors. A series of pairwise chi-square tests revealed that the black on light blue sign was the only sign color combination to result in significantly fewer turn errors (see Appendix Table F-1). This indicates that the light blue and black sign resulted in significantly fewer incorrect turns, and that the black on light blue sign is more conspicuous than the other sign colors.

Assessment for Age

A chi-square test was conducted on the incorrect turn data contained in Table 5 to determine if there was a significant difference for each sign color in the number of incorrect turns by younger and older drivers. The results show that there was not a difference between the age groups, indicating that younger and older drivers made a similar number of incorrect turns for each sign color.

Table 5. Frequency of turn errors by driver age and sign color combination

Sign Colors	Younger Drivers	Older Drivers	Significance Level for Analysis by Age
Black on Orange	4	5	$X^2(1,N=1610) = 0.096, p = 0.757$
Yellow on Purple	4	2	
Black on Light Blue	0	0	
Black on Coral	3	3	

Assessment for Visibility Conditions

A chi-square test was conducted on the data in the 4 x 2 matrix in Table 6 to determine if there was a difference between the daytime and nighttime driving conditions for each sign color. The results indicate that there is a significant difference between daytime and nighttime drivers.

Table 6. Frequency of turn errors by visibility condition and sign color combination

Sign Colors	Daytime	Nighttime	Significance Level for Analysis by Visibility Condition
Black on Orange	5	4	$X^2(1,N=1610) = 4.320, p = 0.038$
Yellow on Purple	1	5	
Black on Light Blue	0	0	
Black on Coral	1	5	

To test for differences in daytime turn data by sign color, a chi-square test was performed on the 4 x 2 matrix in Table 7, and it revealed a significant difference. A paired comparison of the four sign color combinations for daytime drivers revealed significant differences between the light blue sign and the traditional orange sign (see Appendix Table F-2). Since the light blue sign resulted in proportionately more correct turns and fewer incorrect turns, this result indicates that the orange and black color combination is inappropriate for daytime drivers when it is overlayed with existing detour signs.

To test for differences in nighttime turn data by sign color, a chi-square test was performed on the 4 x 2 matrix in Table 8. No significant differences were found between the sign colors.

Table 7. Frequency of correct turns and incorrect turns for daytime drivers

Sign Colors	Correct Turns	Incorrect Turns	Significance Level for Analysis by Visibility Condition
Black on Orange	202	5	$X^2(3,N=897) = 9.713$, $p = 0.021$
Yellow on Purple	183	1	
Black on Light Blue	230	0	
Black on Coral	275	1	

Table 8. Frequency of correct turns and incorrect turns for nighttime drivers

Sign Colors	Correct Turns	Incorrect Turns	Significance Level for Analysis by Visibility Condition
Black on Orange	134	4	$X^2(3,N=713) = 4.942$, $p = 0.176$
Yellow on Purple	248	5	
Black on Light Blue	161	0	
Black on Coral	156	5	

Driver Preference Data

For survey questions 1, 2, and 3, the drivers only rated the sign they saw while driving (refer to the section "Post-test Questionnaire" and Appendix C). Since the number of participants who viewed each sign color was unequal, the number of drivers rating each sign was unequal. Therefore, the number of drivers making each rating is specified in the tables as "N = *number.* " Means and standard deviations are also specified.

Survey Question #1: How Visible was the Test Detour Sign Relative to the Environment?

This question asked drivers to rate the visibility of the experimental TEST DETOUR sign that they saw on the test route on a Likert-type scale of one to five, with one meaning not visible and five meaning extremely visible (see Appendix C). ANOVAs were performed on the mean ratings for this question.

For the assessment by sign color, the mean scores are shown in Table 9. An analysis for sign color (see Appendix Table F-3) revealed that the ratings were not significantly different from one another. Based on the mean ratings, this result indicates that the drivers in each group thought the experimental sign they saw was moderately to very visible.

For the assessment by age, the mean ratings for older and younger drivers are shown in Table 10. An analysis (see Appendix Table F-3) revealed that the ratings by younger and older drivers were not significantly different for each sign color. Based on the mean ratings for each group, younger and older drivers did not rate the visibility of the signs differently; that is, both younger and older drivers thought that the experimental sign they saw was moderately to very visible.

Table 9. Survey question 1 mean ratings for assessment by sign color

Sign Colors	Mean*/STD (Number)	Overall Significance Level for Sign Color
Black on Orange	3.73/1.0328 (N=15)	F (3,54) = 1.55, p = 0.2121
Yellow on Purple	4.05/0.7799 (N=19)	
Black on Light Blue	4.06/0.8269 (N=17)	
Black on Coral	3.74/0.6534 (N=19)	

* 1 = not visible, 5 = extremely visible

Table 10. Survey question 1 mean ratings for assessment by age

Sign Colors	Younger MEAN/STD (Number)	Older Mean/STD (Number)	Significance Level for Analysis by Age
Black on Orange	3.33/1.0000 (N=9)	4.33/0.8165 (N=6)	F(1,54) = 1.78, p = 0.1879
Yellow on Purple	4.10/0.8756 (N=10)	4.00/0.7071 (N=9)	
Black on Light Blue	3.78/0.6667 (N=9)	4.34/0.9161 (N=8)	
Black on Coral	3.73/0.4671 (N=11)	3.75/0.8864 (N=8)	

* 1 = not visible, 5 = extremely visible

For the assessment by visibility condition, the mean ratings for daytime and nighttime drivers are shown in Table 11. An analysis for differences in ratings between daytime versus nighttime drivers (see Appendix Table F-3) revealed that daytime drivers ranked the signs they saw as significantly more visible (4.18) than the nighttime drivers (3.55). This indicates that, not surprisingly, the signs were generally more visible during the daytime than at night.

Table 11. Survey question 1 mean ratings for assessment by visibility condition

Sign Colors	Daytime Mean/STD (Number)	Nighttime Mean/STD (Number)	Significance Level for Analysis by Visibility Condition
Black on Orange	4.00/0.8660 (N=9)	3.33/1.2111 (N=6)	F(1, 54) = 11.23, p = 0.0015
Yellow on Purple	4.63/0.5175 (N=8)	3.64/0.6742 (N=11)	
Black on Light Blue	4.30/0.8233 (N=10)	3.710.7559 (N=7)	
Black on Coral	3.92/0.5149 (N=12)	3.43/0.7868 (N=7)	

* 1 = not visible, 5 = extremely visible

Survey Question #2: How Easy was it to Identify, or Understand, the Directional Information Provided by the Test Signs?

This question asked drivers to rate the directional information on the experimental TEST DETOUR sign that they saw while driving. The Likert-type rating scale ranged from one to five, with one meaning not easy and five meaning extremely easy (see Appendix C). ANOVAs were performed on the mean ratings for this question.

The overall mean scores for question 2 are shown in Table 12. An analysis for sign color (see Appendix Table F-4) revealed that the ratings were not significantly different from one another. Based on the mean ratings, this result indicates that drivers thought the directional information on the sign they saw was very easy to identify or understand.

Table 12. Survey question 2 mean ratings for assessment by sign color

Sign Colors	Mean*/STD (Number)	Overall Significance Level for Sign Color
Black on Orange	4.07/1.0328 (N=15)	F (3,54) = 1.11, p = 0.3532
Yellow on Purple	4.11/0.8753 (N=19)	
Black on Light Blue	4.24/0.7524 (N=17)	
Black on Coral	4.00/0.8165 (N=19)	

* 1 = not easy, 5 = extremely easy

An analysis for age differences (Table 13 and Appendix Table F-4) revealed that the ratings by younger and older drivers were not significantly different for each sign color. Based on the mean ratings by each group, both younger and older drivers thought that the experimental sign they saw was moderately to very easy to identify.

An analysis for visibility condition (see Table14 and Appendix Table F-4)) revealed that the daytime drivers rated the directional information on the signs they saw as significantly easier to identify and understand (4.49) as compared to nighttime drivers (3.61). This outcome is not surprising since road signs are generally easier to identify during the daytime.

Table 13. Survey question 2 mean ratings for assessment by age

Sign Colors	Younger Mean/STD (Number)	Older Mean/STD (Number)	Significance Level for Analysis by Age
Black on Orange	4.00/1.0000 (N=9)	4.17/1.1690 (N=6)	F(1,54) = 1.44, p = 0. 2361
Yellow on Purple	3.90/1.1005 (N=10)	4.33/0.5000 (N=9)	
Black on Light Blue	3.89/0.7817 (N=9)	4.63/0.5175 (N=8)	
Black on Coral	3.91/0.7006 (N=11)	4.13/0.9910 (N=8)	

* 1 = not easy, 5 = extremely easy

Table 14. Survey question 2 mean ratings for assessment by visibility condition

Sign Colors	Daytime Mean/STD (Number)	Nighttime Mean/STD (Number)	Significance Level for Analysis by Visibility Condition
Black on Orange	4.67/0.5000 (N=9)	3.17/0.9832 (N=6)	F(1,54) = 22.47, p = 0.0001
Yellow on Purple	4.63/0.7440 (N=8)	3.73/0.7862 (N=11)	
Black on Light Blue	4.40/0.6992 (N=10)	4.00/0.8165 (N=7)	
Black on Coral	4.33/0.4924 (N=12)	3.43/0.9759 (N=7)	

* 1 = not easy, 5 = extremely easy

Survey Question #3: How Useful Would You Find this Type of Sign Design for Providing Temporary Directional/Detour Information While Driving?

This question referred to the experimental TEST DETOUR sign that drivers saw on the driving route. Drivers were asked to rate the sign they saw on a Likert-type scale of one to five, with one meaning the information was not useful and five meaning the information was extremely useful. ANOVAs were performed on the mean ratings for this question (see Appendix C).

An analysis for sign color (see Table 15 and Appendix Table F-5) revealed that the ratings were not significantly different from one another. Based on the mean ratings, this result indicates that drivers thought the experimental sign they saw was very useful for providing detour information.

Table 15. Survey question 3 mean ratings for assessment by sign color

Sign Colors	Mean*/STD (Number)	Overall Significance Level for Sign Color
Black on Orange	3.93/0.7988 (N=15)	F (3,54) = 1.05, p = 0.3779
Yellow on Purple	3.89/0.8753 (N=19)	
Black on Light Blue	3.94/0.8993 (N=17)	
Black on Coral	3.63/1.0116 (N=19)	

* 1 = not useful, 5 = extremely useful

An analysis by age group (see Table 16 and Appendix Table F-5) revealed that the ratings by younger and older drivers were not significantly different for each sign color. Based on the mean ratings by each group, both younger and older drivers thought that the experimental sign they saw was moderately to very useful for providing detour information.

Table 16. Survey question 3 mean ratings for assessment by age

Sign Colors	Younger MEAN/STD (Number)	Older Mean/STD (Number)	Significance Level for Analysis by Age
Black on Orange	3.67/0.8660 (N=9)	4.33/0.5164 (N=6)	F(1, 54) = 1.92, p = 0.1718
Yellow on Purple	3.90/0.9944 (N=10)	3.89/0.7817 (N=9)	
Black on Light Blue	3.56/0.7265 (N=9)	4.38/0.9161 (N=8)	
Black on Coral	3.73/0.7862 (N=11)	3.50/1.3093 (N=8)	

- 1 = not useful, 5 = extremely useful

An analysis by visibility condition (see Table 17 and Appendix Table F-5) revealed that the ratings were not significantly different for daytime drivers as compared to nighttime drivers. Both daytime and nighttime drivers found the signs to be moderately to very useful for detour information.

Table 17. Survey question 3 mean ratings for assessment by visibility condition

Sign Colors	Daytime Mean/STD (Number)	Nighttime Mean/STD (Number)	Significance Level for Analysis by Visibility Condition
Black on Orange	4.11/0.6009 (N=9)	3.66/1.0328 (N=6)	$F(1,54) = 1.36$, $p = 0.2483$
Yellow on Purple	4.25/0.7071 (N=8)	3.64/0.9244 (N=11)	
Black on Light Blue	4.00/0.9428 (N=10)	3.86/0.8997 (N=7)	
Black on Coral	3.75/0.9653 (N=12)	3.43/1.1339 (N=7)	

* 1 = not useful, 5 = extremely useful

Survey Question #4: Rank the Sample Signs in Order of Preference for Visibility Along the Roadway, by Sign Color.

For question 4 on the post-test questionnaire (see Appendix C), drivers were shown sign color samples and photos of all four TEST DETOUR sign color combinations taken during daylight viewing conditions and asked to rank them in order of preference for visibility along the roadway. For the purposes of analysis, the most preferred sign for visibility was equated to a numerical value of one, and the least preferred sign was equated to a numerical value of 4. A Friedman two-way analysis of variance by ranks was used to analyze the data. Note that for this question, data from four younger subjects and one older subject were discarded because the subjects did not answer the questions correctly (e.g., skipped a number when ranking), leaving a total N of 65.

An analysis to determine if the drivers ranked the sign colors differently was significant (Table 18). Pairwise comparisons (Appendix Table F-6) revealed that the orange, purple, and light blue signs were ranked significantly more visible than the coral sign.

Table 18. Survey question 4 mean rankings for assessment by sign color

Sign Colors	Rank Sum	Statistical Results for Analysis by Sign Color
Black on Orange	140	$F_r(3,N=65)=38.15>F_{tab}(alpha=0.05,df=3)=7.82$
Yellow on Purple	133	
Black on Light Blue	162	
Black on Coral	215	

*1 = most visible, 4 = least visible

An analysis by age group was conducted to determine if there was a significant difference in rankings of visibility between the younger and older drivers (Table 19). The result was not significant, indicating that younger and older drivers did not rank the visibility of each sign color in the photos differently.

Table 19. Survey question 4 mean rankings for assessment by age

Sign Colors	Younger	Older	Statistical Results for Analysis by Sign Color
Black on Orange	2.0	2.4	$F_r(3,N=2)=4.2<F_{tab}(alpha=0.05,df=3)=7.82$
Yellow on Purple	2.1	2.0	
Black on Light Blue	2.8	2.1	
Black on Coral	3.2	3.5	

*1 = most visible, 4 = least visible

Survey Question #5: Rank the Sample Signs in Order of Preference Based on How Easy You Feel the Signs are to Read.

As with question 4, drivers were shown sign color samples and photos of the four TEST DETOUR sign color combinations taken during daylight conditions and asked to rank them in order of preference based on how easy they were to read (see Appendix C). Again, the most preferred sign was equated to a numerical value of one, and the least preferred sign was equated to a numerical value of 4. A Friedman two-way analysis of variance by ranks was used to analyze the data. Note that for this question, data from four younger subjects and two older subjects were discarded because the subjects did not answer the questions correctly (e.g., skipped a number when ranking), leaving a total N of 64.

An analysis by sign color and pairwise comparisons (see Table 20 and Appendix Table F-7) revealed that the purple and light blue signs were ranked significantly easier to read than the coral signs. There were no significant differences between the orange sign and the other sign colors.

Table 20. Survey question 5 mean rankings for assessment by sign color

Sign Colors	Rank Sum	Statistical Results for Analysis by Sign Color
Black on Orange	168	$F_r(3,N=64)=24.08>F_{tab}(alpha=0.05,df=3)=7.82$
Yellow on Purple	138	
Black on Light Blue	136	
Black on Coral	198	

*1 = most easy to read, 4 = least easy to read

An analysis was conducted to determine if there was a difference between rankings given by younger and older drivers (Table 21). The result was not significant, indicating that younger and older drivers did not rank the readability of each sign color in the photos differently.

Table 21. Survey question 5 mean rankings for assessment by age

Sign Colors	Younger	Older	Statistical Results for Analysis by Sign Color
Black on Orange	2.4	2.9	$F_r(3,N=2)=4.2<F_{tab}(alpha=0.05,df=3)=7.82$
Yellow on Purple	2.0	2.4	
Black on Light Blue	2.6	1.5	
Black on Coral	3.0	3.2	

*1 = most easy to read, 4 = least easy to read

Survey Question #6: Rank the Sample Signs in Order of Overall Preference for Use on Signs Providing Temporary Directional/Detour Information.

For this question (see Appendix C), drivers were shown sign color samples and photos of the four TEST DETOUR sign color combinations taken during daylight conditions. The subjects were then asked to rank the signs in order of overall preference for providing temporary directional/detour information. Again, the most preferred sign was equated to a numerical value of one, and the least preferred sign was equated to a numerical value of four. A Friedman two-way analysis of variance by ranks was used to analyze the data. Note that for this question, data from three older subjects were discarded because the subjects did not answer the questions correctly (e.g., skipped a number when ranking), leaving a total N of 67.

An analysis to determine if the drivers ranked the sign colors differently was significant (Table 22). Pairwise comparisons (Appendix Table F-8) revealed that the orange, purple, and light blue signs were ranked significantly more visible than the coral sign.

Table 22. Survey question 6 mean rankings for assessment by sign color

Sign Colors	Rank Sum	Statistical Results for Analysis by Sign Color
Black on Orange	152	$F_r(3,N=67)=35.47>F_{tab}(alpha=0.05,df=3)=7.82$
Yellow on Purple	135	
Black on Light Blue	164	
Black on Coral	219	

*1 = most preferred, 4 = least preferred

An analysis was also conducted to determine if there was a difference between rankings given by younger and older drivers (Table 23). The result was not significant, indicating that there was not a difference between younger and older drivers for sign preference.

Table 23. Survey question 6 mean rankings for assessment by age

Sign Colors	Younger	Older	Statistical Results for Analysis by Sign Color
Black on Orange	2.2	2.4	$F_r(3,N=2)=4.2<F_{tab}(alpha=0.05,df=3)=7.82$
Yellow on Purple	1.9	2.2	
Black on Light Blue	2.8	2.0	
Black on Coral	3.2	3.4	

*1 = most preferred, 4 = least preferred

Trends in the Post-test Questionnaire Data

Recall that questions 1, 2, and 3 requested that the drivers rate the sign that they used while navigating along the test route. Note that ratings were made without having seen the other experimental sign colors. For the assessment by sign color across the three ratings, black on coral was rated consistently low. The younger drivers who used the yellow on purple sign to navigate tended to rate that sign higher than younger drivers who used the other sign colors. The older drivers who used the black on light blue sign tended to rate that sign higher than older drivers who used the other sign color combinations. The older drivers' preference for black on light blue may result from a high contrast for this sign, especially at night. This explanation seems especially plausible since the nighttime drivers who used the black on light blue sign rated it consistently higher than nighttime drivers who used the other sign colors. The higher level of contrast at night may be a result of the fact that the light blue background fades to appear white when headlights reflect on the sign at night. This high contrast effect, especially at night, may partially explain the high ratings.

The results from the first three survey questions should be interpreted with caution. There were fewer nighttime-older drivers (11) than nighttime-younger drivers (20), daytime older drivers (20), or daytime younger drivers (19), which may have impacted the results. Specifically, with more nighttime older drivers, it is plausible that the ratings for the black on light blue sign would have been stronger in the assessments by sign color since the older and nighttime drivers appear to favor this sign more. Finally, the range of mean ratings is not large. Across every mean rating for all analyses, the lowest rating was a 3.17 and the highest was a 4.67, with most ratings falling between 3.70 to 4.40. This means that the signs were generally rated very visible, identifiable, and useful.

To answer questions 4, 5, and 6 on the post-test questionnaire, drivers looked at color samples of the background sign colors and pictures of the signs taken under daylight viewing conditions. They were then asked to rank the four colors in terms of visibility, readability, and overall preference from highest to lowest. Note that these questions were not analyzed by visibility condition since survey respondents could not make comparisons for daytime versus nighttime conditions.

Reviewing the results, it can be seen that the black on coral sign was consistently ranked the least visible across questions four, five, and six by both younger and older drivers. While completing the last three questions on the survey, the drivers would often comment that the coral sign looked like a faded orange sign, which is likely the reason for the poor rankings. The younger drivers tended to favor the purple sign, and they consistently ranked the black on light blue sign as third in order of preference. The older drivers tended to favor the light blue sign and ranked the orange sign as third in order of preference. However, based on the statistical results of these three questions, the only significant finding is that the black on coral sign is least preferred by all drivers tested.

CONCLUSIONS

1. A yellow on purple sign or black on light blue sign will likely result in fewer late braking maneuvers if the road geometry has many tight curves.
2. A black on light blue sign will likely result in the fewest number of turn errors in both rural and urban settings.
3. A black on orange sign will likely result in more turn errors, especially during the day and particularly when it is overlapped with existing detour/construction zone signs.
4. A black on coral sign is least preferred by older and younger drivers when compared to the other sign colors tested in this study.
5. Younger drivers tend to have a preference for a yellow on purple sign and older drivers tend to have a preference for a black on light blue sign.

Limitations of this Research and Directions of Future Research

1. Time did not permit recruitment of more test participants. Seventy drivers participated in this study as compared to the 96 drivers planned. More drivers would have bolstered the statistical power of the analyses conducted, which may have resulted in more significant differences between groups.
2. It was difficult to recruit older nighttime drivers. Considering that the older age group is the fastest growing segment of the population, it is imperative that their needs for conspicuous and readable road signs be met. Currently, many older individuals will not drive at night because road signs are difficult to see (see Introduction). Future research should carefully consider how best to meet the signing needs of the older drivers.
3. This study did not evaluate the use of fluorescent colors. Anecdotal evidence suggests that the use of fluorescent colors on signs improves their conspicuity.

RECOMMENDATIONS

1. Do not use a black on orange sign for trailblazing around a critical incident if an existing detour/construction zone is in place.
2. Do not use a black on coral sign for trailblazing around a critical incident.
3. A black on light blue sign is recommended due to its generally favorable subjective ratings and for minimization of the number of turn errors made by drivers in an overlapping detour.
4. Despite the recommendation in 3, it is important to note that the black on light blue sign fades to take on the appearance of a regulatory sign when headlights illuminate it at night.
5. If the black on light blue sign is deemed inappropriate due to its appearance as a regulatory sign at night, the yellow on purple color combination should be considered for use. In this study, the yellow on purple sign color combination resulted in fewer turn errors than black on orange, and it was generally rated favorably by drivers, especially younger drivers.

REFERENCES

Barker, J., Neale, V. L., and Dingus, T. A. 1997. Improvement of conspicuity for trailblazing signs: Study 1, evaluation of sign design parameters to determine improvements of conspicuity for traffic signs (CTR Report No. CTR-97-01). Blacksburg, VA: Virginia Tech Center for Transportation Research.

Collins, B. L. (1989). Color appearance of traffic control devices under different illuminants. *Transportation Research Record 1247*. Washington, D. C.: Transportation Research Board.

Dewar, R. E. (1988). Criteria for the design and evaluation of traffic sign symbols. *Transportation Research Record 1160* (pp. 1-6). Washington, D. C.: Transportation Research Board.

Dewar, R. E. (1989). Traffic Signs. In *International Review of Ergonomics, 2:65-86.*

Dewar, R. E. (1993). Traffic control devices, highway safety, and human factors. *Transportation Research Circular Number 414*. Washington, D. C.: Transportation Research Board.

Finn, P., and Bragg, B. W. E. (1986). Perception of risk of an accident by young and older drivers. *Accident Analysis and Prevention*, *18:* 289-298.

Hiatt, L. G. (1987). Designing for the vision and hearing impairments of the elderly. As cited in Pirkl, J. J. (1994). *Transgenerational Design: Products for an Aging Population*. New York, NY: Van Nostrand Reinhold.

Littell, R. C., Freund, R. J., and Spector, P. C. (1991*). SAS system for linear models (3rd. Ed.).* Cary, NC: SAS Institute, Inc.

Mace, D. (1988). Sign legibility and conspicuity. In *Transportation in an Aging Society, Vol. 2.* Transportation Research Board Special Report #218, pp. 270-290. Washington, D. C.: Transportation Research Board. As cited in Dewar, R. E. 1989. Traffic Signs. In *International Review of Ergonomics*, *2:65-86.*

Monty, R. W. (1984). Eye movements and driver performance with electronic automotive displays. Unpublished master's thesis, Virginia Polytechnic Institute and State University, Blacksburg, VA.

Mortimer, R. G., and Fell, J. C. (1989). Older drivers: their night fatal crash involvement and risk. *Accident Analysis and Prevention, 21*(3): 273-282.

Owsley, C. E., and Sloane, M. E. (1987). Contrast sensitivity, acuity, and the perception of "real-world" targets. *British Journal of Ophthalmology, 71:* 791-796.

Pietrucha, M. T. (1993). Development of an emergency zone sign. *Transportation Research Record 1421*. Washington, D. C.: Transportation Research Board.

Titmus® Optical, Inc. (1985). *Titmus® II Vision Tester Occupational Model Training Manual.* Petersburg, VA.

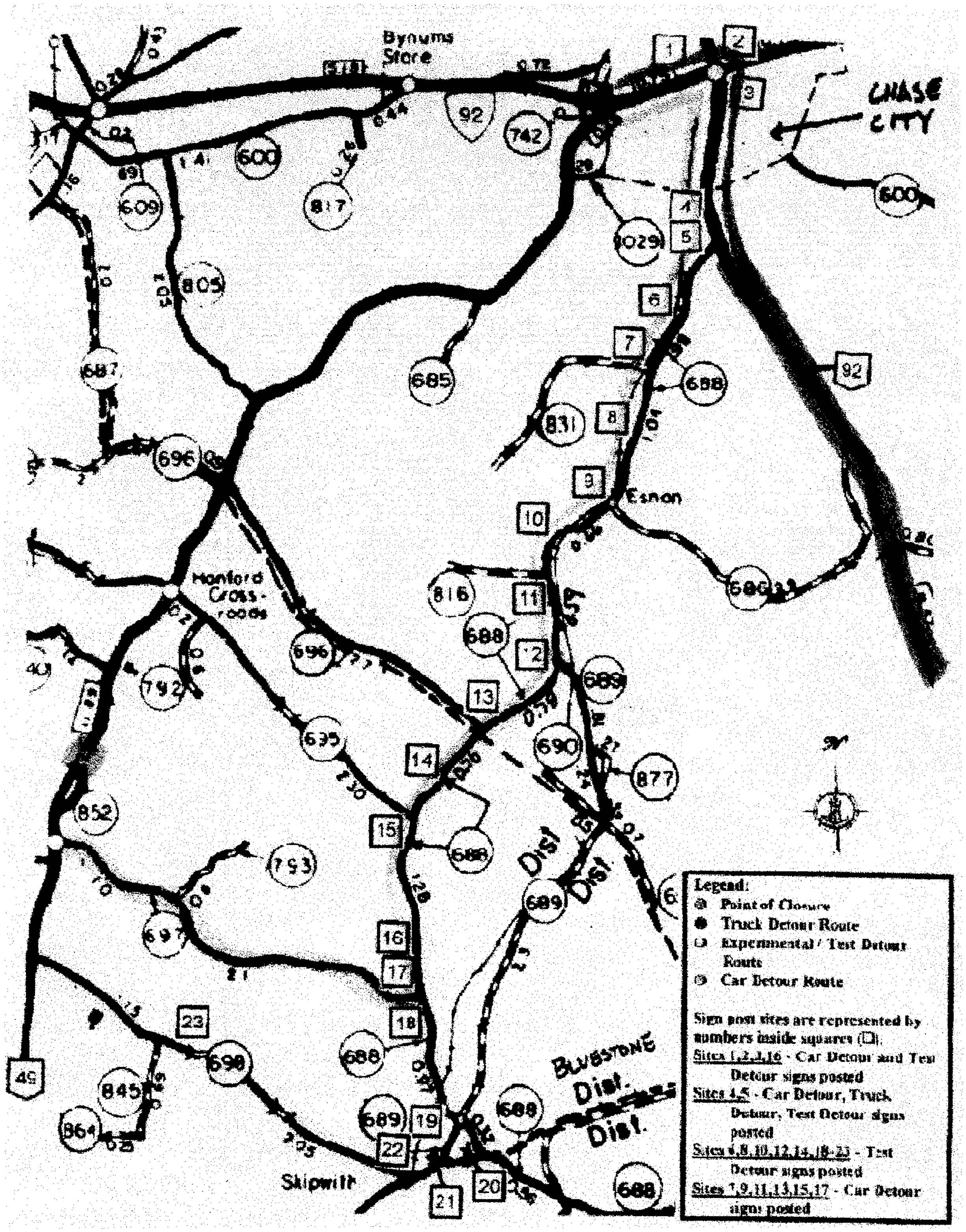
Federal Highway Administration. (1969). *Standard Highway Color Specifications*. Washington, D. C.: USGPO.

Federal Highway Administration. (1983). *Traffic Control Devices Handbook.* Washington, D. C.: USGPO.

Verriest, G. (1963). Further studies on acquired deficiency of color discrimination. *Journal of the Optical Society of America, 53:* 185-195. As cited in Boff, K. R., and Lincoln, J. E. (Ed.). (1986). *Engineering Data Compendium, Human Perception and Performance.* Wright-Patterson Air Force Base,: Harry G. Armstrong Aerospace Medical Research Laboratory.

Wierwille, W. W., and Gutman. (1978). Comparison of primary and secondary task measurements as a function of simulated vehicle dynamics and driving conditions. *Human Factors*: 20:233-244.

APPENDIX A: MAP OF TEST AREA WITH ROUTE HIGHLIGHTED



APPENDIX B: DESCRIPTION OF THE INSTRUMENTED VEHICLE

A 1995 Oldsmobile Aurora was used as the experimental vehicle for all participants. The instrumentation in the vehicle provided the means to unobtrusively collect, record, and reduce a number of data items, including measures of attention demand, measures of navigation performance, safety-related incidents, and subjective opinions of the participants.

Forward-View Camera

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

Multiplexer and PC-VCR

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

Data Collection Computer

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

Sensors

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

Experimenter Control Panel and Event Flagger

A custom experimenter control panel was located in the vehicle and allowed the experimenter to record the occurrence of test sign events or other unplanned events in the data set by push-button input.

Video/Sensor/Experimenter Control Panel Interface

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

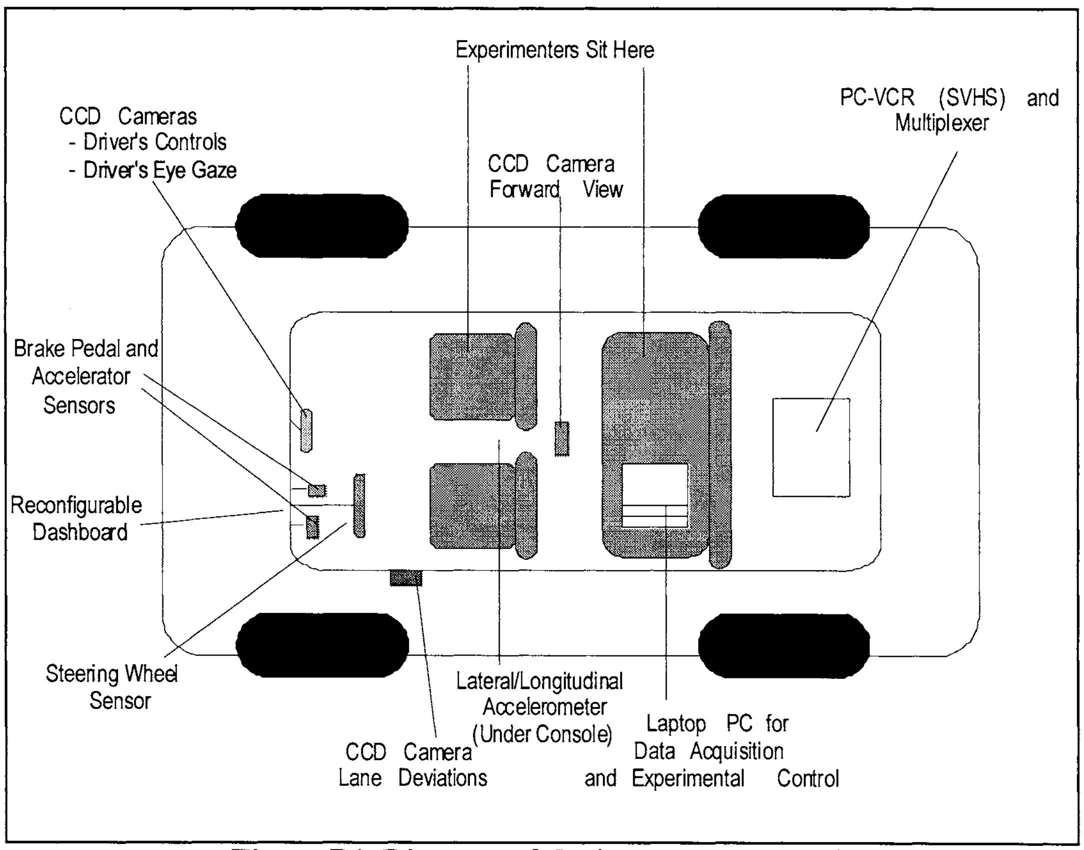


Figure B1. Diagram of the instrumented vehicle

Safety Apparatus

The test vehicle had the following safety apparatus provided as part of the instrumented vehicle system:

- All data collection equipment was mounted such that no hazard was posed to the driver.
- Participants were required to wear the lap and shoulder belt restraint system. The vehicle was equipped with a driver-side and passenger-side airbag supplemental restraint system.
- The vehicle had an experimenter's brake pedal mounted in the front passenger side.
- The vehicle had a fire extinguisher, first aid kit, and cellular phone, for emergency use.
- None of the data collection equipment interfered with the driver's normal field-of-view.
- Emergency protocol was established prior to testing.

APPENDIX C. POST-TEST QUESTIONNAIRE

VIRGINIA TECH CENTER FOR TRANSPORTATION RESEARCH
SIGN CONSPICUITY STUDY

User Survey

Participant ID: ______________	Date: __________

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

1. How visible was the test detour sign relative to the environment?

1	2	3	4	5
Not visible	Somewhat Visible	Moderately visible	Very visible	Extremely visible

2. How easy was it to identify, or understand, the directional information provided by the test signs?

1	2	3	4	5
Not easy	Somewhat easy	Moderately easy	Very easy	Extremely easy

3. How useful would you find this type of sign design for providing temporary directional/detour information while driving?

1	2	3	4	5
Not useful	Somewhat useful	Moderately useful	Very useful	Extremely useful

User Survey (continued, Page 2)

Participant ID: ______________	Date: __________

4. Please answer the following questions using the sign samples shown on the following pages.

Example. Suppose you are shown the following sign sample colors:
1) red and white, 2) green and yellow, and 3) brown and blue.
Rank in order of preference:

Most preferred	*brown and blue*
Somewhat Preferred	*red and white*
Least Preferred	*green and yellow*

Please use the color definitions provided with the sign samples.

a. Please rank the signs in order of preference for visibility along the roadway, or how well you feel the signs would stand out from the environment and other signs along the roadway. Use the following definitions of visibility to rank the sign samples:

Most visible ______________________________
More visible ______________________________
Somewhat visible ______________________________
Least visible ______________________________

b. Please rank the signs in order of preference based on how easy you feel the signs are to read. Use the following definitions of readability to rank the sign samples.

Most readable ______________________________
More readable ______________________________
Somewhat readable ______________________________
Least readable ______________________________

c. Please rank the signs in order of overall preference for use on signs providing temporary directional/detour information. Use the following definitions of preference to rank the sign samples.

Most preferred ______________________________
More preferred ______________________________
Somewhat preferred ______________________________
Least preferred ______________________________

APPENDIX D. INFORMED CONSENT FORM.
VIRGINIA POLYTECHNIC INSTITUTE & STATE UNIVERSITY
Informed Consent for Participants of Investigative Projects

Title of the Project: *On-Road Evaluation of Sign Design Parameters to Determine Improvements of Conspicuity for Traffic Signs*
Investigators: *Julie A. Barker, Dr. Vicki L. Neale, and Dr. Thomas A. Dingus*

I. THE PURPOSE OF THIS RESEARCH

The purpose of this research project is to evaluate how drivers perform when navigating a route. Participants will drive an instrumented vehicle along a predetermined route in a normal traffic situation, and will follow the directional information provided by test signs. For safety considerations, data collection will occur when on dry pavement, and an experimenter will be present in the car during the data collection session. The results of this study will help traffic engineers to design more visible and conspicuous traffic control devices. The study involves 96 observers of varying age and gender.

II. PROCEDURES

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

1. Complete a short demographic survey (over the phone).
2. Read and sign an Informed Consent Form.
3. Complete a simple vision test and color vision test.
4. Complete a brief health screening questionnaire.
5. Listen to the instructions regarding the task that you will be performing.
6. Read general information about the operation of the experimental vehicle.
7. Participate in a training session in which you will learn about specific features of the experimental vehicle and perform a test drive of the experimental vehicle until you are comfortable with the vehicle and the tasks that you will perform as part of this experiment.
8. Perform one experimental drive with the vehicle over a pre-determined route in which data will be collected.
9. Answer questions regarding your subjective assessment of the navigation devices provided during your drive.

At the end of the experimental run, you will drive back to the original location, be paid for your time and debriefed about the research. The total experiment time will be approximately 1 hour.

It is important for you to understand that we are evaluating the navigation materials, not you. Therefore, we ask that you perform to the best of your abilities. If you ever feel frustrated in attempting complete the task, just remember that this is the type of thing that we need you to comment on. The information and feedback that you provide is very important to this project.

III. RISKS

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

(1) The risk of an accident normally associated with driving an automobile in light or moderate traffic, as well as on straight and curved roadways.
(2) Possible fatigue due to the length of the experiment. However, you will be given rest breaks during the experimental session.
(3) While you are driving the vehicle, you will be videotaped by cameras. Due to this fact, we will ask that you not wear sunglasses. If this at any time during the course of the experiment impairs your ability to drive the vehicle safely, you should to notify the experimenter.

The following precautions will be taken to ensure minimal risk to the you.

(1) An experimenter will monitor your driving and will ask you to stop if she feels the risks are too great to continue. However, as long as the you are driving the research vehicle, it remains you responsibility to drive in a safe, legal manner.
(2) You are required to wear the lap and shoulder belt restraint system while in the car. The vehicle is also equipped with a driver's side and passenger's side airbag supplemental restraint system.
(3) The vehicle is equipped with an experimenter brake pedal if a situation should warrant braking and the test participant fails to brake.
(4) The vehicle is equipped with a fire extinguisher, first-aid kit, and a cellular phone, which may be used in an emergency.
(5) If an accident does occur, the experimenters will arrange medical transportation to a nearby hospital emergency room. In that event, you will be required to undergo examination by medical personnel in the emergency room.
(6) All data collection equipment is mounted such that, to the greatest extent possible, it does not pose a hazard to you, the driver, in any foreseeable case.
(7) None of the data collection equipment interferes with any part of your normal field of view present in the automobile.

IV. BENEFITS OF THIS RESEARCH

There are no direct benefits to you from this research other than payment for participation. No promise or guarantee of benefits is made to encourage you to participate. Your participation will provide baseline data for visibility and conspicuousness of highway traffic control devices composed of various design parameters and colors. This may have a significant impact on highway traffic sign effectiveness, as well as on driving safety, when these color combinations and design parameters are employed. Ultimately, the results of these data may significantly affect highway traffic signing as specified by the Virginia Department of Transportation and the Federal Highway Administration.

V. EXTENT OF ANONYMITY AND CONFIDENTIALITY

The data gathered in this experiment will be treated with confidentiality. Shortly after participation, your name will be separated from your data. A coding scheme will be employed to identify the data by participant number only (e.g., Participant No. 1). You will be allowed to see your data and withdraw the data from the study if you so desire, but you must inform the experimenters immediately of this decision so that the data may be promptly removed. At no time will the researchers release the results of this study to anyone other than individuals working on the project without your written consent.

VI. COMPENSATION

You will receive $25.00 total for your participation in this study. This payment will be made to you at the end of your voluntary participation in this study for the portion of the study that you complete.

VII. FREEDOM TO WITHDRAW

As a participant in this research, you are free to withdraw at any time for any reason. If you choose to withdraw, you will be compensated for the portion of time of the study for which you participated. Furthermore, you are free not to answer any questions or respond to any research situations without penalty.

VIII. APPROVAL OF RESEARCH

This research has been approved, as required, by the Institutional Review Board for Research Involving Human Subjects at Virginia Polytechnic Institute and State University and by the Virginia Tech Center for Transportation Research.

IX. PARTICIPANT'S RESPONSIBILITIES

If you voluntarily agree to participate in the study, you will have the following responsibilities: To be physically free from any illegal substances (alcohol, drugs, etc.) for 24 hours prior to the experiment, and to conform to the laws and regulations of driving or public roadways.

X. PARTICIPANT'S PERMISSION

I have read and understand the Informed Consent and conditions of this project. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent for participation in this project. If I participate, I may withdraw at any time without penalty. I agree to abide by the rule of this project.

____

Participant's Signature   Date

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

Julie A. Barker, Investigator	(540) 961-7441
Vicki L. Neale, Project Manager	(540) 231-5578
Thomas A. Dingus, Principal Investigator	(540) 231-8831
H. T. Hurd, Chair, IRB	**(540) 231-5281**

APPENDIX E. HEALTH SCREENING QUESTIONNAIRE

Health Screening Questionnaire

Participant ID: __________

1. Are you in good general health? Yes No

   If no, please list any health-related conditions you are experiencing or have experienced recently.

   ____

   ____

2. Have you experienced any of the following conditions on a regular basis?

Inadequate sleep	Yes	No
Unusual hunger	Yes	No
Hangover	Yes	No
Headache	Yes	No
Cold symptoms	Yes	No
Depression	Yes	No
Allergies	Yes	No
Emotional upset	Yes	No

3. Do you have a history of any of the following?

   Visual Impairment Yes No
   (If yes, please describe.)

   ____

   ____

   Hearing Impairment Yes No
   (If yes, please describe.)

   ____

   ____

   Seizures or other lapses of consciousness Yes No
   (If yes, please describe.)

   ____

   ____

   Any disorders similar to the above or that would impair your driving ability Yes No
   (If yes, please describe.)

   ____

   ____

4. If you are female, are you pregnant? Yes No

5. List any prescription or non-prescription drugs you have taken in the last 24 hours.

____

____

____

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

____

____

7. List the approximate amount of caffeine (coffee, tea, soft drinks, etc.) you have consumed in the last 6 hours.

____

____

8. Are you taking any drugs of any kind other than those listed in questions 5 or 6?

Yes No

____________________ ____________________

Signature Date

APPENDIX F: STATISTICAL TABLES FOR SURVEY QUESTIONS

Significant p, z or χ^2 values are indicated by an asterisk in the right hand column.

Table F-1. Statistical results for pairwise comparisons for frequency of turn errors, assessment by sign color

Sign Color Background	Significance Level
Orange vs Purple	χ^2(1, N=782) = 1.565, p = 0.211
Orange vs Light Blue	χ^2(1, N=736) = 10.326, p = 0.001*
Orange vs Coral	χ^2(1, N=782) = 1.565, p = 0.211
Purple vs Light Blue	χ^2(1, N=828) = 5.408, p = 0.020*
Purple vs Coral	χ^2(1, N=874) = 0.000, p = 1.000
Light Blue vs Coral	χ^2(1, N=828) = 5.408, p = 0.020*

Table F-2. Statistical results for pairwise comparisons for frequency of turn errors for daytime drivers

Sign Color Background	Significance Level
Orange vs Purple	x^2(1,N=391) = 2.259, p = 0.133
Orange vs Light Blue	x^2(1,N=437) = 5.620, p = 0.018*
Orange vs Coral	x^2(1,N=483) = 4.064, p = 0.144
Purple vs Light Blue	x^2(1,N=414) = 1.253, p = 0.263
Purple vs Coral	x^2(1,N=460) = 0.084, p = 0.772
Light Blue vs Coral	x^2(1,N=506) = 0.835, p = 0.361

Table F-3. Analysis of variance table for survey question #1

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Sign Color	3	2.6889	0.8963	1.55	0.2121
Age	1	1.0283	1.0283	1.78	0.1879
Visibility Condition	1	6.4912	6.4912	11.23	0.0015*
Sign Color X Age	3	3.3175	1.1058	1.91	0.1384
Sign Color X Visibility Condition	3	0.7175	0.2392	0.41	0.7438
Visibility Condition X Age	1	0.0804	0.0804	0.14	0.7107
Sign Color X Age X Visibility Cond	3	0.5501	0.1834	0.32	0.8129
SNUM(Sign Color, Age, Visibility)	54	31.2167	0.5781		

Table F-4. Analysis of variance table for survey question #2

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Sign Color	3	1.8569	0.6190	1.11	0.3532
Age	1	0.8006	0.8006	1.44	0.2361
Visibility Condition	1	12.5330	12.5330	22.47	0.0001*
Sign Color X Age	3	1.5580	0.5193	0.93	0.4320
Sign Color X Visibility Condition	3	3.3147	1.1049	1.98	0.1277
Visibility Condition X Age	1	0.2543	0.2543	0.46	0.5024
Sign Color X Age X Visibility Cond	3	0.8305	0.2768	0.50	0.6863
SNUM(Sign Color, Age, Visibility)	54	30.1167	0.5577		

Table F-5. Analysis of variance table for survey question #3

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Sign Color	3	2.5353	0.8451	1.05	0.3779
Age	1	1.5428	1.5428	1.92	0.1718
Visibility Condition	1	1.0959	1.0959	1.36	0.2483
Sign Color X Age	3	4.8306	1.6102	2.00	0.1247
Sign Color X Visibility Condition	3	1.4959	0.4986	0.62	0.6053
Visibility Condition X Age	1	1.5320	1.5320	1.90	0.1733
Sign Color X Age X Visibility Cond	3	1.5156	0.5052	0.63	0.6002
SNUM(Sign Color, Age, Visibility)	54	43.4500	0.8046		

Table F-6. Pairwise comparisons for survey question 4, assessment by sign color

Sign Color Background	Difference between Rank Sums z(alpha=0.05, #c=6)=2.638, $z_{critical}$ = 39.42
Orange vs Purple	17
Orange vs Light Blue	12
Orange vs Coral	67*
Purple vs Light Blue	29
Purple vs Coral	84*
Light Blue vs Coral	55*

Table F-7. Pairwise comparisons for survey question 5, assessment by sign color

Sign Color Background	Difference between Rank Sums z(alpha=0.05, #c=6)=2.638, $z_{critical}$ = 38.53
Orange vs Purple	30
Orange vs Light Blue	32
Orange vs Coral	30
Purple vs Light Blue	2
Purple vs Coral	60*
Light Blue vs Coral	62*

Table F-8. Pairwise comparisons for survey question 6, assessment by sign color

Sign Color Background	Difference between Rank Sums z(alpha=0.05, #c=6)=2.638, $z_{critical}$ = 39.42
Orange vs Purple	17
Orange vs Light Blue	12
Orange vs Coral	67*
Purple vs Light Blue	29
Purple vs Coral	84*
Light Blue vs Coral	55*