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16. Abstract

A closed course nighttime legibility study measured legibility distance for 6 inch letters using Highway Series D and two experimental fonts, Clearview Condensed Road and a D-Modified font. The Clearview font has a thinner stroke width than Series D and was used for white-on-green signs. The D-Modified font has a thicker stroke width than Series D and was used for black letters on white, yellow, and orange backgrounds. Three types of retroreflective sheeting were tested: ASTM Types III, VIII, and IX. Forty-eight signs were used; all sign blanks were 12 inch x 30 inch with a border. Twenty-four participants, aged 55 - 75, drove a passenger sedan around a closed course at 30 mph while attempting to read ground-mounted signs on the right shoulder. Results showed no difference between drivers aged 55 - 64 and those aged 65 - 75. Overall legibility distances ranged from 143 ft to 206 ft, producing legibility indexes in the range of 24 - 34 ft of legibility per inch of letter height. Color was found to be a significant factor in legibility with yellow and white producing the longest legibility distances followed by green and then orange. Across all colors, retroreflective sheeting type was a significant factor with specific differences among sheetings dependent on color. The font results were surprising in that Highway Series D was better than or equivalent to both alternatives tested and the version of Clearview tested performed slightly worse than the standard font.

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NIGHTTIME LEGIBILITY OF GROUND-MOUNTED TRAFFIC SIGNS AS A FUNCTION OF FONT, COLOR, AND RETROREFLECTIVE SHEETING TYPE

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CHAPTER 1: BACKGROUND AND ORGANIZATION OF REPORT

BACKGROUND

The last 50 years have seen continual improvements in retroreflective sign sheeting materials. Today's sign materials have better color and brightness than previous generations. The basic sign designs and typefaces used on highway signs have not changed much in those 50 years. The Highway Series font is still the only approved typeface in the Manual on Uniform Traffic Control Devices (MUTCD) (*1*). All the fonts in this series share the same basic letter shape but vary in the interletter spacing, stroke width, and the height:width ratio. The MUTCD, and the accompanying Standard Highway Signs book (*2*), specify which series font is to be used on which signs. So, for instance, a large freeway guide sign may require Highway Series E(Modified), which has a broad height:width ratio, a thick stroke width and ample interletter spacing. A destination sign on a low-speed secondary road may require a Highway Series C that has a more condensed letter form, a thinner stroke, and tighter spacing. These font recommendations do not take into account the type of retroreflective sheeting, the presence of ambient lighting, or the color of a specific sign.

In addition to examining the effect of fonts, the goals of this project included an evaluation of the relative performance of various types of retroreflective sheeting for small, ground-mounted signs. In practical use, a traffic engineer typically is setting policy for a specific series of signs. The results of this project can be used in practice by examining the results for a specific color and selecting the font and sheeting type that produced the greatest legibility distances for that color.

ORGANIZATION OF THE REPORT

The research project described herein was conducted by the Texas Transportation Institute (TTI) from September 1, 1999 to August 31, 2002. The activities that were completed, as well as the report organization, are described below.

- *Literature Review*. The research team reviewed previous research on sign legibility, color recognition, and sign retroreflectivity. In addition, basic concepts of visibility, reflectivity, and legibility are explained in Chapter 2.

- *Experimental Sign Development.* The design of the experimental signs, in terms of font selection and material choice are described in Chapter 3.
- *Nighttime Field Study Method.* The details of the data collection procedures for the nighttime closed course driving study are explained in Chapter 4.
- *Results and Data Analysis.* The legibility distance results and comments from drivers, as well as a detailed data analysis, are presented in Chapter 5.
- *Discussion and Recommendations.* Chapter 6 contains a discussion of the results and recommendations for TxDOT practice

CHAPTER 2. LITERATURE REVIEW

HIGHWAY FONTS AND LEGIBILITY STUDIES

Recent developments in sign fabrication and font design make it possible to design a font specifically for retroreflective sheeting of a certain color. Garvey et al. (*3*) report on the development and testing of the Clearview font for positive contrast highway signs. Like the Highway Series fonts, there are several versions of Clearview varying in stroke width, interletter spacing, and height:width ratio. In general, this font has thinner stroke width than corresponding Highway Series fonts. The lettershapes are more refined than the simple block letters of the Highway Series. With these two improvements, the designer found that interletter spacing could be reduced. Reducing spacing allows signs either to be smaller or letter size could be increased 12 percent without increasing the physical size or cost of the sign. This font was designed for positive contrast signs (white letters on green, brown, or blue backgrounds) using mixed upper- and lower-case legends. Most of the design work went into refining the lower-case letters of the alphabet.

The first edition of the Clearview fonts were evaluated for day and night legibility by the Pennsylvania Transportation Institute (*4*). Five-inch letters were used, and all signs were white-on-green Type III and Type IX sheeting (*5*). Participants were all over the age of 65 and were passengers in the test vehicle. The studies used two distinct methodologies that produced different results. One was a legibility task where subjects were to simply read a single unknown word. In another study, subjects completed a recognition task where they were asked to identify a target word on a three-line sign. Two sizes (100 and 112 percent of the capital letter height) of each of two series of Clearview were tested. The series named Clearview was similar in height:width ratio as Highway Series E(Modified). The one named Clearview Condensed was closer in proportion to Highway Series D. They found that the Clearview Condensed mixed-case performed worse than Highway Series D when letter sizes were equal, and when the larger version of Clearview was used, legibility was about the same as Series D all upper-case. For recognition of words, Clearview Condensed mixed-case performed better than the all upper-case Series D. For the E(Modified) comparison, there were no daytime differences but at night the Clearview 112 performed better on both the legibility and recognition tasks. There was no difference between E(Modified) and Clearview when the letter size was the same. No differences between type of retroreflective sheeting were noted in the report.

Development of the Clearview font continued and a second edition was tested by the Texas Transportation Institute (*6*). In 1999, Hawkins et al. studied the daytime and nighttime performance (both recognition and legibility) of the Clearview alphabet, comparing it to Series E(Modified) and British Transport Medium. They also considered the difference between shoulder-mounted signs and overhead signs. The study used Type III sheeting exclusively. Full-scale freeway signs were used with 16 inch upper-case letters and appropriately sized lower-case letters. A total of 54 subjects (with an emphasis on older drivers) participated in both the day and night trials. Three test subjects rode together in a passenger car during the study.

For both the daytime and nighttime overhead recognition results, Clearview consistently outperformed Series E(Modified). Although the improvement was as much as 8 percent in some cases, the only statistical difference was for the daytime overhead position. For the shoulder-mounted signs, no recognition statistical differences were found, although a general decrease in performance was associated with Clearview.

There were no statistically significant differences found in the legibility studies. However, for the overhead position during both daytime and nighttime conditions, Clearview consistently outperformed Series E(Modified) by 0.6 to 3.3 percent. The daytime ground position results show a consistent decrease in performance with Clearview, while the nighttime data slightly favor Clearview.

In 2001, Carlson reported on a study to determine the nighttime legibility of the Clearview alphabet on freeway guide signs constructed with microprismatic retroreflective sheeting (*7*). Full-scale shoulder-mounted and overhead guide signs were studied. The signs were made with either Type VIII or Type IX sheeting. A total of 60 subjects divided into three age groups participated in this nighttime study. The subjects were asked to drive while performing the legibility tasks. The findings indicate that the Clearview alphabet provides statistically longer legibility distances than the Series E(Modified) alphabet. The largest 50th percentile differences were 58 ft for shoulder-mounted signs and 54 ft for overhead signs.

The City of Toronto has sponsored research evaluating the Clearview font for its mast arm street name signs in downtown and suburban areas (*8*). They evaluated an unspecified version of the Clearview font for white letters on blue background using Type IX microprismatic sheeting. They compared letter sizes of 4, 6, and 8 inches for mast arm signs and 5- and 8-inch letters for ground-mount advance street name signs. They had participants over the age of 50 drive a passenger car in live traffic in non-rush hour periods in the daytime and the evening following a predetermined route. They were told to turn at specified intersections and the measure of effectiveness was the distance at which they activated their turn indicator. The results of this study led to a recommendation of use of 8 inch Clearview mixed-case for these types of signs.

Review of the literature revealed experimentation with improving fonts for negative contrast signs (black letters on light-colored background). Shepard (*9*) recommended using a thicker stroke width for construction work zone signs made with high-intensity sheeting. Mace, et al. (*10*) examined different stroke widths of Highway Series fonts. They found no effects of stroke width in the daytime and only a slight improvement at night for orange signs of Type I material. This idea of increased stroke width was further tested by Kuemmel (*11*) who compared Series B, C, and E with versions with an 18 percent increased stroke width. This study showed no benefit, and in some cases a detriment, to increasing stroke width for negative contrast signs. It should be noted that in this study, each experimental sign with the thicker stroke width had an unusual legend and was being compared to the standard fonts with typical work zone sign legends. This confound in the experimental design may explain the results. Several states have been informally experimenting with a version of Series D that has a thicker stroke width on the interior of the letters. The interletter spacing, overall width of each letter, and overall size of the sign is the same as if Highway Series D were used. The version tested in the present project was obtained through a sign software vendor who had prepared it for the Alabama DOT.

In two major studies, Forbes performed pioneering work on the legibility of traffic signs. His 1939 research with Holmes established legibility indices for the Series B and D alphabets (*12*). His 1951 research with Moskowitz and Morgan established the legibility of the lower-case Series E(Modified) alphabet (*13*).

In his 1939 study, Forbes evaluated the Series B and D block letter alphabets and found a legibility index of 33 ft/inch for Series B and 50 ft/inch for Series D. These are 80th percentile values from observations by 412 different people representing normal (20/20) vision. Letter size ranged from 6 to 24 inches, with 6-letter place names. Letters were black paint on a white board. Floodlighted signs at night gave a legibility distance 10 to 20 percent less than daytime values.

Glass ball reflectors were also evaluated with headlights, and results were similar up to about 300 ft. The measurements represented "pure" legibility (test subjects were given an unlimited response time). The visual acuity of the test subjects was measured for only 52 of the 412 subjects. The results of the visual acuity test indicated that the median legibility distances represented better than 20/20 vision, the 80th percentile distances represented 20/20 vision, and the 95th percentile distance represented 20/30 vision.

Forbes (*12)* also showed a nonlinear relationship between letter size and legibility distance, and showed that wider letters are more effective than narrow ones. The practical importance of a curvilinear relationship between letter size and legibility distance is that experimental relationships among alphabet styles, letter spacing, etc. for small test letters may not be directly applicable for large-scale letters.

Forbes' 1951 research *(13*) is the basis for the modern Series E(Modified) alphabet and laid the groundwork for the adoption of the lower-case alphabet for freeway guide signs. The purpose of this experiment was to determine the distances at which lower-case signs could be read as compared to rounded capital letters on overhead mounted signs. Experiments on ordinary printed pages with type forms have shown that lower-case printing gives more rapid reading than solid block printing with capital letters. This advantage has been attributed to more definite pattern characteristics of the lower-case words. However, the factors that produce the rapid reading at a close range may not be the same as the factors that allow the reading of large signs at a maximum distance.

The letters used in Forbes' study were 5 to 18 inches in height. The letters were white, standard Series E rounded letters, with the stroke widened to correspond to that deemed most satisfactory from experience of the California Highway Division. They were placed on a black background. The lower-case letters were approximately the same average height:width ratio. When an initial upper-case letter was used with the lower-case letters, it was Series D of 1.5 times the loop height of lower-case. The letters were placed on an experimental sign bridge that had a background 24 ft X 6 ft high. The bottom edge of the sign was 17 ft above the ground. Letters and sign background were both non-retroreflectorized. Nighttime conditions had illumination levels of 41.1 to 61.7 cd/m^2 (candelas per square meter) from fluorescent lighting.

To obtain the best control possible and still obtain a comparison of familiar and unfamiliar words created from upper/lower-case letters and capital letters, observations of three types were used:

- Six nonsense scrambled-letter combinations (upper-case not used with lower-case),
- 12 place names (6- to 9-letter California cities and counties) “without knowledge” (lower-case had initial upper-case), and
- 12 place names (6- to 9-letter California cities and counties) “with knowledge” (lower-case had initial upper-case).

Each of the words was presented in both capital letter and lower-case letter (with upper-case letters as indicated above) formats. A total of 3939 observations were made by an average of 55 observers for each condition. Each observer made six observation trips “reading” six different signs on each trip during a given afternoon or evening. These observations were carried out during two afternoon and evening sessions in July 1950. The observers consisted of both males and females between the ages of 18 to 70 years and consisted of office staff from departments other than the traffic department. The 85th percentile acuity was 20/20. The observers would start from a distance where no one could identify the six test words. They then walked toward the sign boards until they could read each word and the exact spelling of each word. Once a word was “read,” they would record the next distance marker ahead. The observers also faced in an easterly direction so that the afternoon observations could be made with the sun directly on the sign boards and out of the direct field of vision.

In general, the researchers found that the 85th percentile daytime legibility distance (representing 20/20 vision) was 32 ft/inch of letter height for lower-case scrambled letters and 48 ft/inch for lower-case place names “without prior knowledge.” The nighttime legibility index was found to be 33 ft/inch for scrambled lower-case letters and 53 ft/inch for lower-case place names “without prior knowledge.” Both day and night legibility indices are calculated using the upper-case letter height appropriate to the lower-case letter. Table 1 summarizes legibility results for the 85th percentile “without knowledge” words. The Forbes researchers recommended that these values be used for design purposes.

The fonts designed and tested in the Forbes' research have been used since that time as the standard typeface and spacing for all signs in the MUTCD. Only recently has their use with modern retroreflective sheeting been examined. Efforts to improve legibility for older drivers, in particular, have been the impetus for most of the examinations of font improvement.

Table 1. Legibility Index for Place Names "Without Knowledge."

	85th Percentile Legibility Index (feet of legibility distance / inch of letter height)			
	Daytime		**Nighttime**	
Letter Height (inches)	**Upper-case**	**Lower-case**	**Upper-case**	**Lower-case**
6	74	45	60	65
8	76	48	64	53
12	79	50	67	53

Source: Reference (13)

DRIVER AGE

The U.S. Census Bureau predicts that the number of older drivers will increase over the next six decades, both in number and as a proportion of the population (*14*). It is also known that older drivers are more likely to have impaired vision, which is of great concern when addressing nighttime driving. Consequently, to increase motorist safety, the design of roadway signs should consider the nighttime visual needs of this growing population of drivers.

Age is an important factor in sign legibility due to the expected growth in elderly drivers over the next 20 years and the higher accident rate among older drivers (*15*). Mace (*16*) studied the characteristics of guide sign legibility regarding luminance, contrast, and the age of the motorist and found that:

- Older drivers require more contrast between legend and background to achieve the same level of recognition as younger drivers.
- Legibility losses with age are greater at low levels of background luminance.
- Legibility losses with age increase when luminance increases beyond the optimum level on partially reflectorized signs.

In other words, older drivers are less sensitive to contrast, but are more sensitive to the degrading effects of brightness extremes than younger drivers. In addition, the aging process diminishes depth perception, glare recovery (the ability of the eye to readapt to low light levels after exposure to high light levels), and the ability of the eye to focus. While the legibility index of Series E lettering 50 ft/inch is a generally accepted minimum legibility index for guide signs within the professional community, Mace contends that safety engineers should not expect a legibility index of more than 40 ft/inch for older drivers (*16*).

A report from the University of Michigan (*17*) found that with partially retroreflectorized signs, irradiation is particularly serious for older drivers. Irradiation is an effect where the edges of bright objects become blurred; it is also called overglow, blooming, and halation. The authors recommend that at high levels of luminance, the stroke width of white letters on dark backgrounds (as is the case with freeway guide signs) be decreased to offset the effects of irradiation. With regard to the effect of driver age on sign legibility, the report noted the following generalizations (*17*):

- Older drivers require more contrast between the legend and the background of a sign than younger drivers to achieve the same level of legibility.
- Legibility losses with age are greater at low levels of background luminance. A reduction in legibility distance of between 10 to 20 percent should be assumed when signs are not fully reflectorized.
- Signs are more likely to suffer a loss in legibility for older drivers when luminance is increased beyond the optimum level on a partially reflectorized sign.
- Higher surround luminance improved the legibility of signs more for older drivers and reduced the negative effects of excessive contrast.

Increasing luminance extends legibility up to a point, after which irradiation begins to degrade legibility. The loss of legibility is difficult to document with any confidence since conflicting results have been found in the literature. Some researchers report a small loss, only occurring with very high levels of luminance (*18*). Others have shown irradiation to be a more pervasive problem, particularly for older drivers (*19*).

A 1979 paper suggested that older drivers should not be expected to achieve a legibility index of 50 ft/inch under most nighttime circumstances (*20*). The data provided by this report give some expectation that 40 ft/inch is a reasonable goal under most conditions. Their data compared younger and older drivers on luminance and contrast requirements for different legibility criteria, different colors, background, and surrounding luminance. A 40 ft/inch index can generally be achieved by older drivers with contrast ratios greater than 5:1 (slightly higher for guide signs) and luminance greater than 10 cd/m^2 for partially retroreflectorized signs.

The current MUTCD guideline for legibility index is 40 ft/inch. Other work on older driver sign legibility (16) recommends a value of 33 ft/inch be used for design and sign placement. In the proposed revision to the MUTCD (Section 2A-12) 40 ft/inch is listed in the Guidance section as a "should statement" while in the Support section it states that "33 ft/inch could be beneficial.".

COLOR RECOGNITION AND LEGIBILITY

The impact color has on sign legibility is mostly related to luminance. A white sign has much higher luminance than a blue sign. In fact, several studies have shown that color, by itself, has no measurable impact on legibility but can add to conspicuity, especially with the fluorescent sign sheetings (*21*,*22*).

Olson examined several possibilities in hopes to explain the conspicuity differences associated with color (*22*). One promising possibility is usually referred to as heterochromatic brightness matching. A typical approach to research in this area requires subjects to adjust the luminance of a white surface until it appears to be the same brightness as an adjacent colored surface. When a subject determines a match, the samples are photometrically measured. The luminance ratio of the white to colored surface (B/T) is generally greater than one. The ratio increases with increasing saturation of the test surface. However, and most interestingly, yellow is a color that has been cited as an exception to this rule. Data show that the luminance ratio remains near one even as the saturation of a yellow surface approaches maximum.

In an attempt to account for the color findings of the field study, Olson conducted a laboratory brightness evaluation. In general, the results are in accord with those from heterochromatic brightness matching studies. However, although colors such as red, green, and blue were judged brighter than would be indicated on the basis of their photometric properties, they were not judged brighter than white or yellow from the same family of materials. The results of this study indicate that colors such as red, orange, green, and blue have inherently greater conspicuity per unit retroreflectivity than yellow and white in the context of road signs. Lacking more definitive data on the effect of color, recommendations were based on the assumption that orange, red, green, and blue have conspicuity equal to that provided by yellow in the same family of materials. However, further work on color effects should be tried out to better define the relationship.

In terms of age effects, Olson found 85th percentile detection distance differences of about 150 and 200 ft for high and low surrounding complexities, respectively (for yellow enclosed lens sign panel). These detection differences were generally equal throughout a range starting at the 99th percentile and continuing to the 25th percentile.

In a study of sign legibility with participants as passengers in a vehicle driven on a closed course, Chrysler et al. (*23*) found white-on-green signs had slightly longer legibility distances than black-on-white signs. These signs were all engineering grade (Type I) material with an 8-inch Landolt Ring as the legibility target. They also found that aged white material had a significantly shorter legibility distance than all other conditions. They hypothesized that as the white material aged, the retroreflectivity decreased, thus also decreasing the contrast ratio between the black letters and the background material. This effect was seen in both younger and older driver groups.

RETROREFLECTIVE SHEETING

The last 10 years have seen a proliferation of types of retroreflective sheetings, especially those using microprismatic optics. Each type of sheeting identified in the ASTM (American Society for Testing and Materials*, 5*) specification has unique characteristics in terms of retroreflection measured in the laboratory. On the road, drivers see the luminance of a sign, which is controlled by the vehicle headlamps and the retroreflective characteristics of the sign material. Sivak and Olson (*24*) provide a review of the literature on driver needs for luminance. The sign materials available today meet those needs to varying extents. Part of this project was to quantify the differences among sheeting types in terms of sign legibility for small signs. Sign brightness helps not just legibility, but also detection, color and shape recognition, and locating the sign along the roadway. While the focus of the current project is on legibility, it is important to note that retroreflective characteristics may affect other visual processing in addition to legibility.

Probably the most referenced research effort related to recommended luminance requirements for highway signs was conducted by Sivak and Olson and published in 1985 (*24*). Computing the geometric mean of 18 previous research efforts' findings, Sivak and Olson recommended optimal and minimal sign luminance values for low-beam U.S. and European headlamps. For optimal values, they used the crest of the derived inverted U-shaped luminance functions shown in the research findings. To determine the minimum sign luminance needed, Sivak and Olson used legibility indices of 50 and 40 ft/inch for younger and older drivers, respectively. Their recommended values are shown in Table 2. The replacement values apply to signs in dark environments.

Table 2. Replacement Luminance Values.

Replacement Level	**Sign Luminance (cd/m^2)**	**Estimated Retroreflectivity ($cd/lx/m^2$) at 0.2° observation and -4° entrance angle**	
		U.S. headlamp	**European headlamp**
Optimal	75	3547	7252
85th percentile	16.8	798	1624
75th percentile	7.2	342	696
50th percentile	2.4	114	232
Note: These values apply to various types of signs including the legends of fully reflectorized signs with background complexity luminance of up to 0.4 cd/m^2 and a maintained internal contrast ratio of 12:1			

Source: Reference 25.

In 1987, Morales published work related to retroreflectivity requirements for stop signs (*25*). Morales developed a process where the overall retroreflectivity is the criterion and is dependent on the approach speed and size of the sign. To determine the overall retroreflectivity, Morales recommends multiplying the red retroreflectivity value by 0.76 and the white retroreflectivity value by 0.24 and summing the two values. For a 30-inch stop sign on roads with approach speeds greater than 50 mph, 40 $cd/lx/m^2$ is recommended as the minimum retroreflectivity value. Other values are reported for different speeds and sizes of stop signs.

In 1985, Mace et al. investigated visual complexity and its impact on sign luminance (*26*). The researchers used warning signs at three different luminance levels to determine detection and recognition distances. The major finding was that increases in visual complexity had detrimental impacts on recognition and no effect on legibility, but brightness improved both recognition and legibility. Based on their findings, the researchers recommended warning sign retroreflectivity values of 18 cd/lx/m^2 for low complexity and 36 cd/lx/m^2 for high complexity areas.

Brekke and Jenssen (*27*) tested the legibility of 7.8-inch letters on ASTM Types I, III, VII, and IX in yellow and orange. The mean nighttime legibility distances for their older participants were 187 ft for orange Type III compared to 216 ft for Fluorescent Orange Type VII and 213 ft for orange Type III compared to 233 ft for Yellow Type IX. It should be noted that in the present project, a fluorescent orange version of Type IX was used that was not available at the time of the Brekke and Jenssen research. One explanation of these results is that the Type III orange signs were below luminance threshold for some participants and the shift to the microprismatic material raised the sign brightness above threshold. For the yellow signs, Type III may have been above threshold due to the lighter color, so the difference between that and the microprismatic was lessened.

Another study (*10)* showed that Type VII microprismatic increased nighttime legibility distances compared to Type III orange signs with Series D letters. They did not see the same effect of sheeting with Series C letters. This study had subjects seated in a static car with signs containing individual letters which were exposed for 10 seconds.

The majority of studies on legibility are conducted with participants who are not driving a vehicle. In some studies, the subjects remain static and signs are moved toward them (*11*,*28*) and in others groups of subjects are moved toward the sign (*3*,*27*). Most studies done on closed courses have the subject seated in the front passenger seat. While each of these methods has advantages in terms of experimental control and repeatability, they are not very challenging to participants. There have been a few studies where the subject was the driver of the experimental vehicle on a closed course (*24,28).* Chrysler et al. (*29*) examined the effects of sheeting type on sign legibility using older drivers in real traffic. They found that as intersection complexity increased from a dark residential neighborhood to a complex urban intersection, the differences between the types of retroreflective sheeting became more apparent. They tested 6 inch white letters on green background (Series C font) on ASTM Types I, III, VII, and IX. The results showed the two microprismatic types to be statistically equivalent and both microprismatics to be better than Type III. Across the three intersection types and across test positions on both sides of the street, the mean legibility distances were 142 for Type III, 170 for Type VII, and 172 for Type IX. The Toronto study (*8)* also had research participants driving in actual traffic.

The present project sought to provide information on nighttime sign legibility distances using participants aged 55 - 75 who were actively driving a passenger sedan on a closed course. The signs were all actual road-related words in 6-inch letters mounted on the right shoulder of the road. The parameters varied in the fabrication of the test signs were retroreflective sheeting type, font, and color.

CHAPTER 3. EXPERIMENTAL SIGN DEVELOPMENT

The researchers conducted a nighttime legibility experiment to determine the best font and sheeting for small ground-mount signs. This chapter describes the details of the preparation of the signs. The coefficient of retroreflection is reported as R_A.

MATERIALS

This project used a mixed design with age group as a between-subjects variable and with font, sheeting type, and color as within-subjects variables. Three types of retroreflective sheeting were tested:

- ASTM Type III: high-intensity encapsulated lens glass bead material (minimum new R_A at 0.2^o observation angle and -4^o entrance angle for white material of 250 cd/lx/m^2 and 95 cd/lx/m^2 at 0.5^o observation angle and -4^o entrance angle). Material was purchased from the 3M Company.
- ASTM Type VIII: super-high-intensity microprismatic material (minimum new R_A at 0.2^o observation angle and -4^o entrance angle for white material of 700 cd/lx/m^2 and 250 cd/lx/m^2 at 0.5^o observation angle and -4^o entrance angle). Material was purchased from the Avery-Denison Company.
- ASTM Type IX: very-high-intensity microprismatic material (minimum new R_A at 0.2^o observation angle and -4^o entrance angle for white material of 380 cd/lx/m^2 and 240 cd/lx/m^2 at 0.5^o observation angle and -4^o entrance angle). Material was purchased from the 3M Company.

Four colors of signs were tested: green, yellow, orange, and white. For the microprismatic materials, a fluorescent version of orange was used since this is the material typically used when microprismatic retroreflective performance is selected. All material was purchased from a third-party sign fabricator (Interstate Signs, Little Rock, Arkansas), with the exception of fluorescent orange Type IX, which was obtained directly from the manufacturer.

FONTS AND SIGN DESIGN

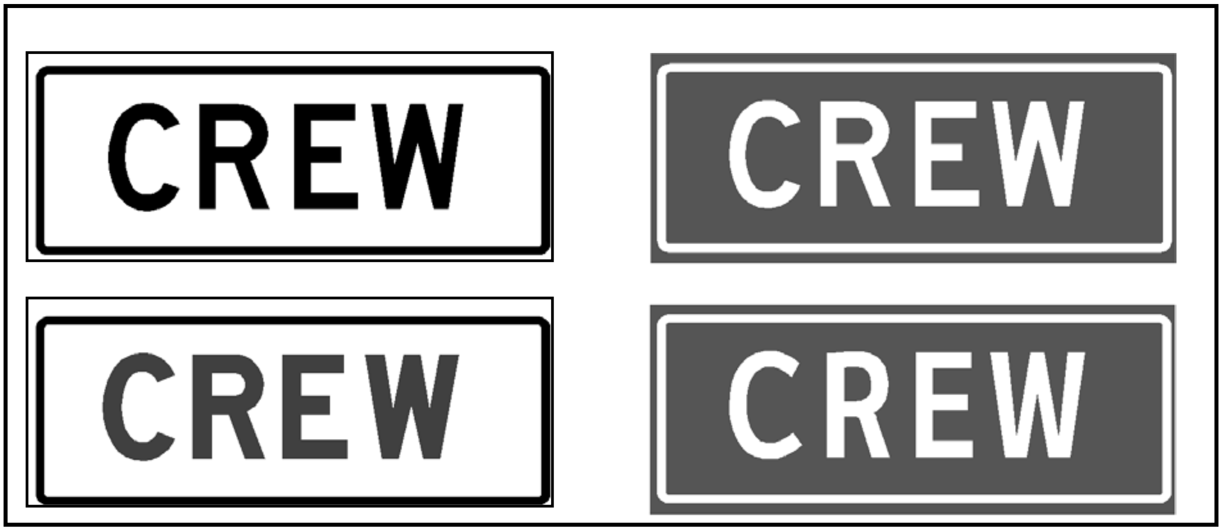
The focus of this project was on conventional road guide signs that would be shoulder mounted, such as distance/destination signs. In addition, warning, regulatory, and post-mounted regulatory sign positions were of interest as well. To simplify the experimental design, it was advantageous to have a single font represent the standard current practice for all these varied sign types. A thorough review of the TxDOT Standards and Specifications Sheets and the Texas Standard Highway reference material revealed a variety of fonts used on these signs. The specific font depended mostly on message length, with more condensed fonts being used on longer messages. Appendix A shows the results of this analysis. Based on this review, the research team decided to use Highway Series D as the baseline font, as it is used on signs of all four colors. In addition to the font identification, this analysis revealed that the most common letter height was 6 inches. Thus, all words used in the nighttime legibility project were 6 inch letters in all upper-case. All of the sign layouts were created by TTI staff using the TrafficCad software. These files were transmitted electronically to the fabricator.

For positive contrast signs (white letters on green background), the experimental font was Clearview Condensed Road. This font is very similar to Highway Series D in its height:width ratio, but has a thinner stroke width. At the time of the study, the ClearviewOne Highway ™ series of fonts was undergoing additional revisions by its creator. The research team felt that instead of testing a new version, it would be best to test a version from the same edition of the typeface that was used in earlier TTI research (*7*). The Clearview Road Condensed, particularly for upper-case letters, does not represent a radical change (see Figure 1). Refinements can be seen in the opening in the R where the loop has been made larger and more elongated. The letter W also illustrates the changes to reduce areas where the bright white reflective material may create halation.

For the negative contrast signs (black letters on white, orange, and yellow backgrounds), a font called D-Modified was used. This font was created for the Alabama DOT for use on its work zone signs. The font was the same height:width ratio and interletter spacing as Highway Series D, but has a thicker stroke width. The lettershapes for this font were obtained electronically from the SignCad software. The spacing for this typeface was not functioning properly, so the letters were placed by hand in TrafficCad using the default spacing for Highway Series D as a guide.

Table 3. Independent Variable Summary.

Age Group	Background Color	Sheeting Type	Font
55 – 64	Green	ASTM Type III	Highway Series D
65 -75	White	ASTM Type VIII	D-Modified
	Yellow	ASTM Type IX	Clearview Condensed Road
	Orange		



Key: ***Series D*** ***Series D***

D-Modified ***Clearview Condensed Road***

Figure 1. Example of the Fonts Tested in the Project.

CHAPTER 4. NIGHTTIME FIELD STUDY METHOD

The research team created a driving course containing the test signs at the Riverside Campus of Texas A&M University. A group of participants between the ages of 55 - 75 drove the course at night while attempting to read the signs. This chapter describes the study method.

SUBJECTS

Twenty-four licensed drivers were recruited for the project through personal contacts and past research participants lists. Subjects were evenly split between two age groups: 55 - 64 and 65 - 74. Gender was evenly split among each of the age groups. Subjects were paid $20 for their participation. When subjects arrived they were briefed on the purpose of the project, but no details of the font or sheeting type manipulations were revealed. After reading and signing an informed consent form (see Appendix C), the subject's vision was tested. Binocular acuity was assessed using a standard Snellen eye chart under room illumination. Contrast sensitivity was measured using the VisTech ™ Vision contrast test system (*30*). This test asks subjects to identify the orientation of a series of sine wave gratings that vary in their contrast. Results of the vision test are given in Appendix B. Color vision was tested by using a simplified Ishihara color plate. Participants completed a short questionnaire about their driving habits.

EXPERIMENTAL VEHICLE

All testing took place after sunset with low-beam headlamps. The test vehicle was a 1998 Chevy Lumina sedan with HB4 halogen headlamps equipped with a Numetrics Nitestar distance measuring instrument (DMI). The windshield and headlamps were cleaned at the start of each night's testing. The test vehicle is shown in Figure 2.

Figure 2. Test Vehicle 1998 Chevrolet Lumina Sedan.

EXPERIMENTAL DESIGN

Word selection is another crucial aspect to any legibility study. All of the signs contained words that could be expected to be found on real traffic signs, with all signs containing words that were four letters in length. Short words were selected for several reasons. One is that the time to articulate short words may be more uniform than longer words, thus reducing variability. The other consideration was cost of sign fabrication and ease of installation on the closed course. A list of 65 four-letter words was generated based on signs in the MUTCD. The final 48 words were selected based on a small pilot test where the 65 candidate words were flashed on a projection screen briefly and subjects were asked to identify each word. Any candidate word that produced errors in four out of five subjects was rejected. The goal of this prescreening was to weed out any word that may be extraordinarily easy or difficult to read.

For the field study, each word was randomly assigned to a font-color-sheeting sign condition. Each word occurred only once. Table 4 shows the experimental design and the words used in the project.

Table 4. Experimental Design and Words Used in the Project.

Sheeting	Background Color	Legend Color	Font	Word 1	Word 2
Type III	Green	White	Clearview Cond. Road	REST	SLOW
			Highway Series D	LEFT	WORK
	Orange	Black	D-Modified	CREW	WITH
			Highway Series D	ENDS	NEXT
	White	Black	D-Modified	PASS	TURN
			Highway Series D	EAST	LOOP
	Yellow	Black	D-Modified	CARE	ONLY
			Highway Series D	MILE	RAMP
Type VIII	Green	White	Clearview Cond. Road	FINE	TONS
			Highway Series D	GEAR	TEST
	Orange	Black	D-Modified	TIRE	WHEN
			Highway Series D	ZONE	HERE
	White	Black	D-Modified	FROM	PATH
			Highway Series D	CURB	LANE
	Yellow	Black	D-Modified	DEAD	WALK
			Highway Series D	EXIT	FARM
Type IX	Green	White	Clearview Cond. Road	OVER	RAIL
			Highway Series D	AREA	CITY
	Orange	Black	D-Modified	BIKE	BOAT
			Highway Series D	LINE	WEST
	White	Black	D-Modified	DEER	ROAD
			Highway Series D	PARK	ROCK
	Yellow	Black	D-Modified	DRAW	LOAD
			Highway Series D	FOOT	KEEP

***Note: Words were randomly assigned to treatment condition*.**

DATA COLLECTION PROCEDURE

A test course with 48 sign positions was laid out on a closed-course facility (see Figure 3). All signs were offset 14 ft from the right edge line with a height of 8 ft to the center of the sign. The driving path was clearly delineated through the use of retroreflective raised pavement markers.

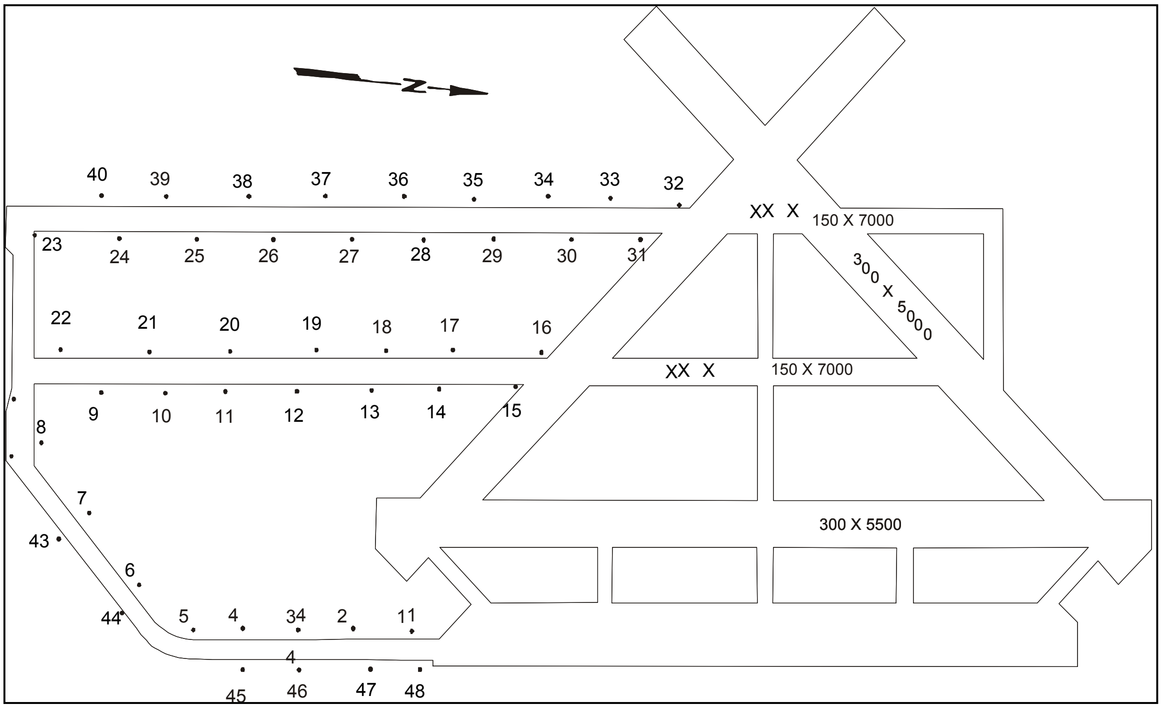


Figure 3. Driving Course and Sign Positions.

The sign positions were 500 ft apart at a minimum. The research team had some concerns that the specific sign locations may affect legibility distance. While the test course is generally very dark, there are a few outdoor lights and other objects visible that may have posed a slight distraction to the driver. In addition, some locations were preceded by more complicated driving maneuvers that may also have distracted participants from the legibility task. One would expect some learning to take place, so the initial sign positions may be at a disadvantage as well. In order to minimize any systematic effects of sign position, the placement of the signs along the course was randomly determined. This was accomplished by treating each sign position as an independent location and numbering the locations sequentially according to the driving path. Then each sign was randomly assigned a number and placed in that location. Due to the labor involved in rearranging the signs, it was not feasible to change them after every subject or even after every night of testing. Instead, a compromise was reached to create three sign orders and change the signs after every set of eight subjects.

The subject sat in the driver's seat and was in control of the vehicle at all times during the experiment. The experimenter sat in the front passenger seat. Subjects were told that they would be driving on a closed-course roadway simulating roads typically encountered in Texas. They were instructed to drive with prudence at speeds not to exceed 30 mph. Subjects were told to say the word as soon as they could correctly identify it, but were also told that there was no penalty for being wrong and that it was alright to guess. The researcher provided verbal directions to the subject about where to drive and the maximum speed allowed on the course segment. The course was clearly marked on the roadway through the use of retroreflective raised pavement markers. At the start of each straight segment of road, there was a pair of traffic cones to mark the "starting gate." This served to notify the subject that a sign was coming soon and it also gave the experimenter a chance to clear the DMI. Errors in measurements can be introduced following the hard corners and U-turns necessitated by the test course.

Subjects drove for approximately three minutes on approach roads prior to beginning the study trials. The driving course took approximately 20 minutes to complete. If participants made any comments during the legibility portion of the task, these were noted on the response form.

CHAPTER 5. RESULTS AND DATA ANALYSIS

The researchers analyzed the data from the field study using standard statistical procedures from engineering and the behavioral sciences. This chapter presents the results and the details of the statistical analysis.

RESULTS

The legibility distance data were obtained through a subtractive procedure. The actual distances recorded during the experiment were cumulative distances since the last zeroing of the instrument. Without subjects present, the research team drove the course multiple times to ascertain the actual distance between the starting points and the sign positions. These calibrated distances were used to calculate the actual distance from the sign where subjects correctly identified the word. The experimental design of 48 signs viewed by 24 subjects produces a total of 1152 data points. Due to equipment errors, seven observations were lost. All data are legibility distance, in feet, for correct word identification. Table 5 shows the mean legibility distance for each of the treatment conditions along with the corresponding standard deviation.

DATA ANALYSIS

First, a test of sign position was conducted to assure that there were no systematic errors introduced into the data due to position on the test course. This analysis, which simply regressed legibility distance onto sign position, showed a non-significant effect ($F_{47, 1097} = 0.79, p = 0.85$). Sign position was thus dropped from further analysis. Whatever error was introduced by the individual sign positions was spread across the three counter-balancing groups.

A mixed-model Analysis of Variance (ANOVA) with Age Group as a between-subjects factor and Font, Sheeting, and Color as within-subjects factors was performed. This overall ANOVA 2 X 3 X 3 X 4 model with 24 subjects produced an R^2 value of 0.88 ($F_{574, 1144} = 7.25, p < 0.0001$). This means that the 88 percent of the variance in the legibility data can be explained by the factors varied in the experiment.

The main effect of Age Group was not significant ($F_{1,22} = 2.47, p = 0.13$). Age Group did produce a significant interaction with Color, but otherwise was never a significant factor.

Table 5. Mean Legibility Distances (ft) for Each Treatment Condition.

Color	Sheeting Type	Font	Mean	Standard Deviation
Green	III	Clvw Cond Road	167	61
		Hwy D	179	68
	VIII	Clvw Cond Road	171	71
		Hwy D	180	70
	IX	Clvw Cond Road	176	69
		Hwy D	200	71
Orange	III	D-Modified	153	61
		Hwy D	143	61
	VIII	D-Modified	166	59
		Hwy D	185	62
	IX	D-Modified	163	71
		Hwy D	175	70
White	III	D-Modified	203	75
		Hwy D	180	66
	VIII	D-Modified	184	76
		Hwy D	181	68
	IX	D-Modified	198	67
		Hwy D	184	65
Yellow	III	D-Modified	179	73
		Hwy D	186	74
	VIII	D-Modified	206	72
		Hwy D	192	75
	IX	D-Modified	181	79
		Hwy D	194	69

Note: Each cell represents the average of two different words per condition viewed by 24 subjects.

Color was a significant main effect ($F_{3, 66} = 25.25$, $p < 0.0001$). A Bonferroni post hoc *t*-test reveals that yellow and white signs are equivalent at means of 190 and 188 ft respectively. White was not different from green (mean of 179 ft), but yellow was. Orange signs performed worst at 164 ft and were significantly different than all other colors. The interaction between Color and Age group seemed to be due to the poor performance of orange signs for the younger age group compared to the other colors. For the older group, orange was worst, but not by quite as large a factor.

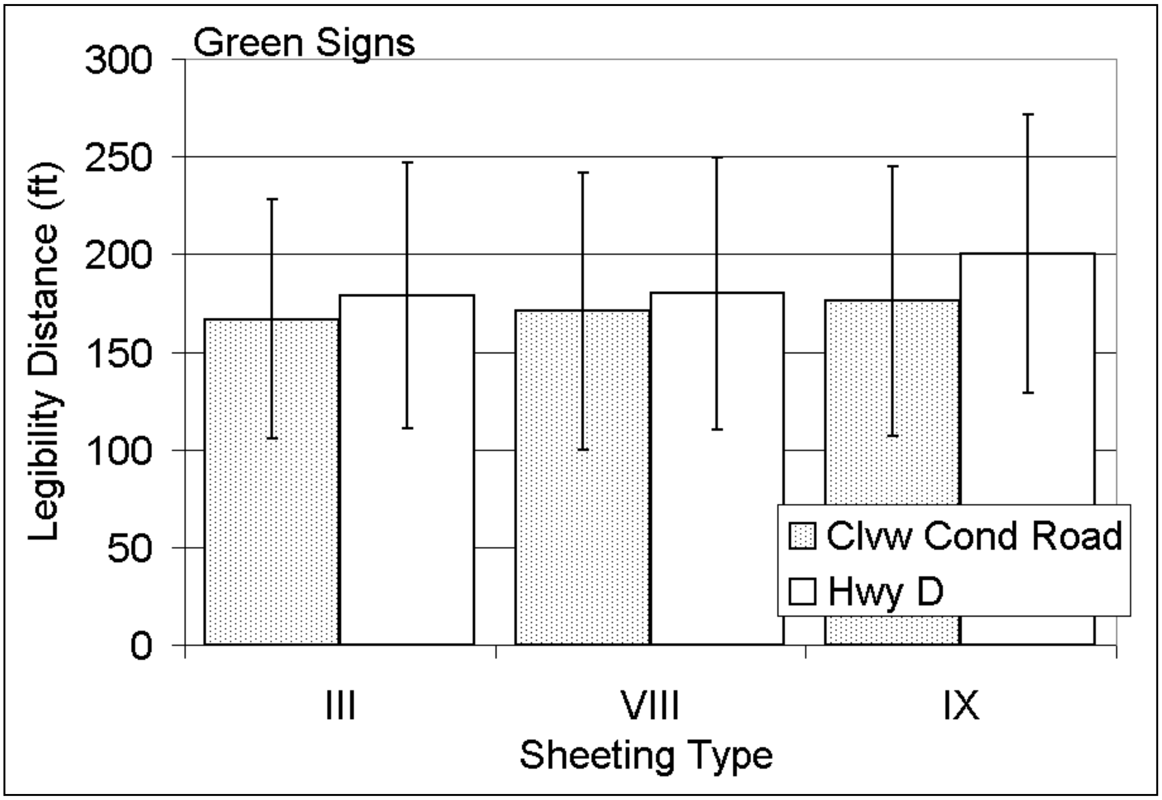
The main effect of Sheeting was significant ($F_{2, 44} = 10.84$, $p < 0.0001$). Across all fonts and colors, post hoc tests show that the two microprismatic types were not significantly different (Type IX mean = 184, Type VIII mean = 183) and both were better than Type III (mean = 174). Note that the Sheeting X Color interaction was significant ($F_{6, 132} = 6.38$, $p < 0.0001$). The relative performance of the three sheeting types changed depending on the color as detailed below. Likewise, because Font and Color were not fully crossed, subsequent ANOVAs were performed for each color separately to examine the Font main effect and interactions with Age or Sheeting. The effects of Font and Sheeting are different for each color, so further results will be reported for each color separately.

For the overall test of Series D compared to D modified, an ANOVA was performed on data from the three colors used for the negative contrast signs. The Bonferroni *t*-tests from subsequent ANOVAs on each individual color show mixed results as detailed in the following sections.

Green Signs

For the comparison between Series D and Clearview Condensed Road, the legibility distances for only the green signs were evaluated. The results for green signs by font and sheeting type are shown in Figure 4. The difference between the two fonts was significant ($F_{1,22} = 9.31$, $p = 0.006$) with the Series D mean at 187 ft and the Clearview Condensed Road mean at 171 ft. This result is opposite of what was predicted based on previous research that shows the Clearview font producing modest gains in legibility distance.

Retroreflective sheeting type was a significant main effect ($F_{2,44} = 4.80$, $p = 0.013$). Post hoc tests using a Bonferroni t (degrees of freedom (df) = 44, Minimum Significant Difference = 13.30) show that the differences between the two microprismatics is not statistically significant (Type VIII mean = 175 and Type IX mean = 188). Likewise, Types VIII and Type III (mean = 173) were not statistically different, but Type IX was different than Type III.



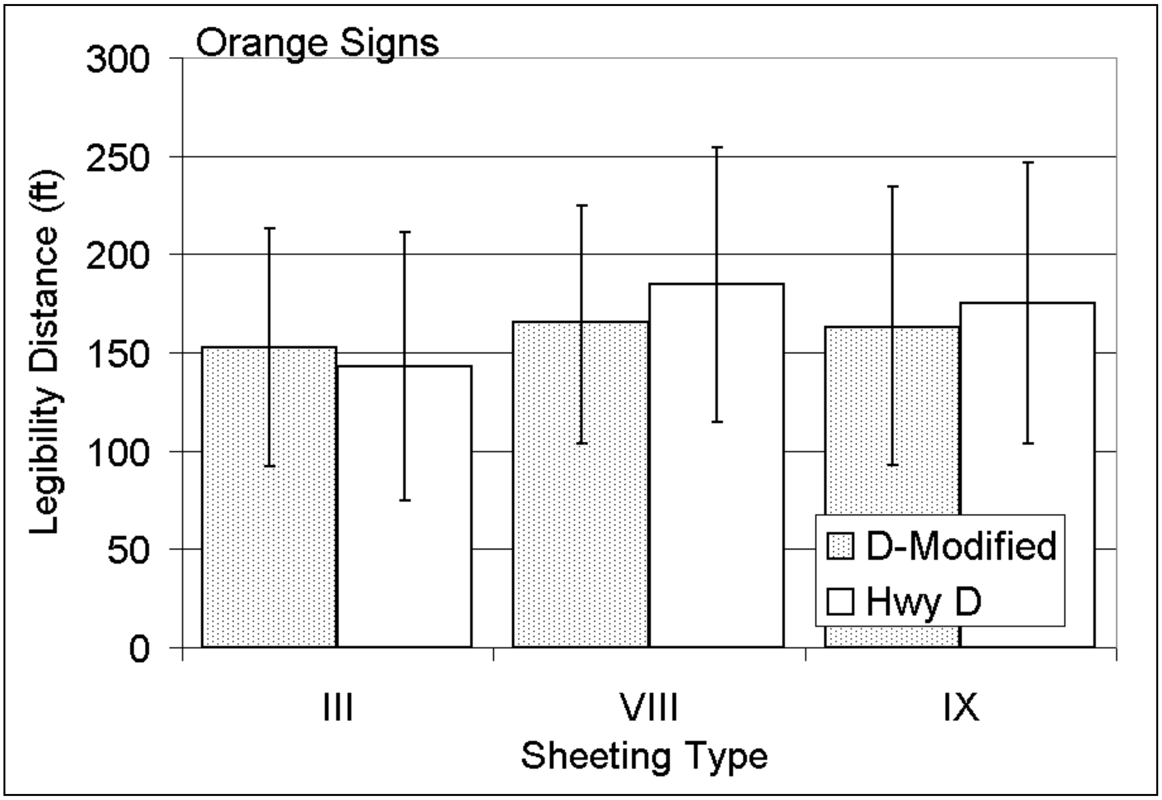
Note: Error bars indicate + / - one standard deviation unit for that condition mean

Figure 4. Legibility Distances as a Function of Sheeting Type and Font for Green Signs.

Orange Signs

The results for orange signs by font and sheeting type are shown in Figure 5. In this analysis, the font main effect was not significant, but font did interact significantly with color ($F_{2, 66} = 7.39$, $p = 0.002$).

For orange signs, the two fonts were not significantly different with D-Modified having a mean of 160 and Series D at 167. Retroreflective sheeting type was a significant main effect ($F_{2, 44} = 10.99$, $p = 0.0001$). Post hoc tests using Bonferroni t (df = 44, Minimum Significant Difference = 15.31) showed that the differences between the two microprismatics is not statistically significant (Type VIII mean = 175 and Type IX mean = 169). Both microprismatic materials were significantly different than Type III (mean = 148).

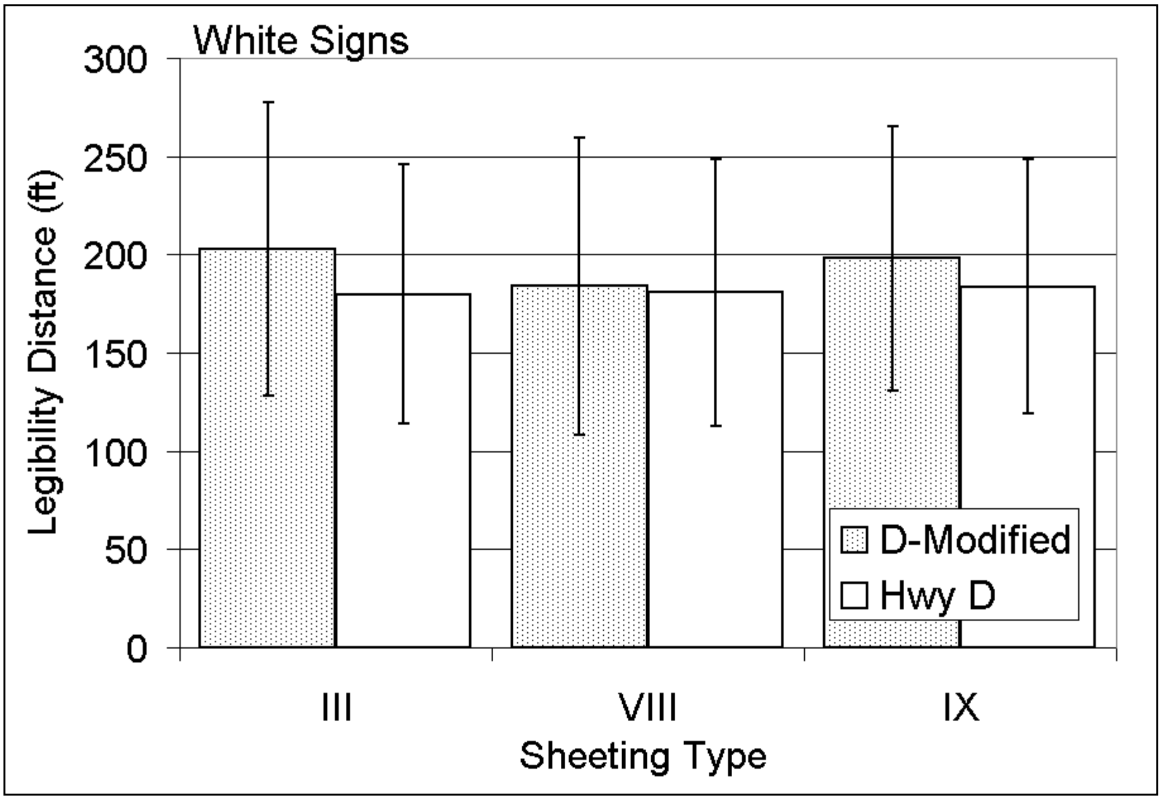


Note: Error bars indicate + / - one standard deviation unit for that condition mean

Figure 5. Legibility Distances as a Function of Sheeting Type and Font for Orange Signs.

White Signs

For white signs, the D-Modified font (mean distance = 195 ft) did produce significantly longer legibility distances than Series D (mean distance = 181 ft). The main effect of sheeting was not significant in the analysis of the subset of white signs ($F_{2, 44} = 2.32$, $p = 0.11$). The means were 191, 182, and 191 for Types III, VIII, and IX, respectively. The results for white signs by font and sheeting type are shown in Figure 6.

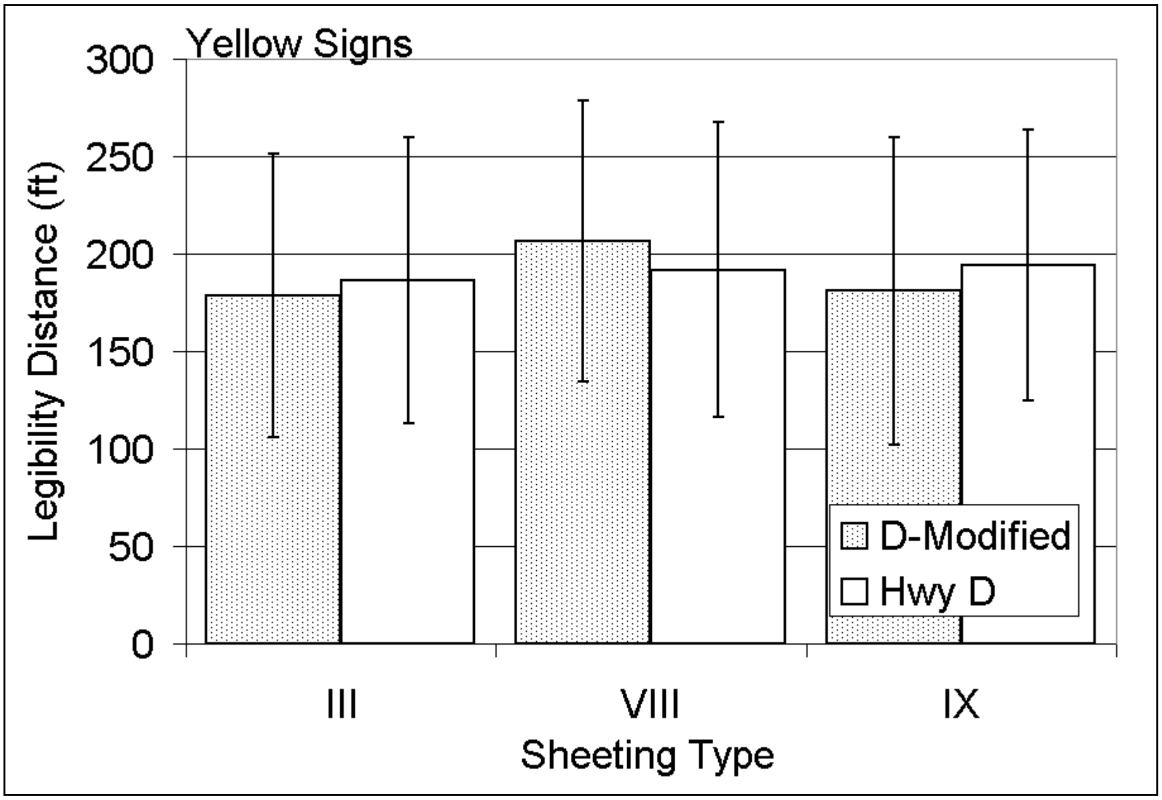


Note: Error bars indicate + / - one standard deviation unit for that condition mean

Figure 6. Legibility Distances as a Function of Sheeting Type and Font for White Signs.

Yellow Signs

For yellow signs, the differences were not significant with D-Modified having a mean of 189 and Series D at 191. The results for yellow signs by font and sheeting type are shown in Figure 7. The main effect of sheeting was significant in the analysis of the subset of yellow signs ($F_{2, 44} = 6.84$, $p = 0.0026$). The post hoc Bonferroni t (df = 44, Minimum Significant Difference = 11.43) showed that the Type VIII (mean = 200) was statistically different than both the other microprismatic, Type IX (mean = 188) and the encapsulated lens, Type III (mean = 183). Legibility for Type III and Type IX were not statistically different for yellow signs.



Note: Error bars indicate + / - one standard deviation unit for that condition mean

Figure 7. Legibility Distances as a Function of Sheeting Type and Font for Yellow Signs.

CHAPTER 6. DISCUSSION AND RECOMMENDATIONS

DISCUSSION

Overall, yellow and white signs provided the greatest legibility distances, followed by green, and then orange. This order follows closely the relative brightness of the different materials, thus illustrating the role of sign luminance in legibility.

The comparisons among the three types of retroreflective sheeting (Types III, VIII, and IX) were quite mixed, depending on color. With the exception of orange signs, the three materials produced legibility distances within 17 ft of each other. Given the measurement procedure which relied on the experimenter reacting to the subject's verbal response, 17 ft may well be within the error range of the procedure. This distance is not much greater than the 11-15 ft difference needed to establish statistical significance between two averages given the standard deviations of this data. In a practical sense, as well, 17 ft represents just 0.2 of a second when traveling at 60 mph. This small performance gain in legibility may not justify the cost difference. As mentioned in the introduction, previous studies (*11*) have shown large performance gains in detection and color and shape recognition when moving from encapsulated lens to microprismatic sheeting. And one study (*7*) that compared legibility for large guide signs did show an advantage for microprismatic materials. When selecting sign material, all visual performance factors must be considered: detection, color recognition, shape recognition, and legibility. This performance should be evaluated for all lighting and weather conditions. In addition, durability, ease of fabrication, and cost must be weighed against the benefits of each product. The current project only examined nighttime legibility in clear conditions for signs with 6-inch legends, so it provides only part of the answer.

The results of this project demonstrate that it is not practical to identify one combination of font, sheeting, and color that optimizes sign performance in all conditions. The lack of font effects was surprising based on informal viewings prior to the project. Given the particular experimental design, it is impossible to separate out what effect word difficulty may have had on the results. Each word was used in only one experimental treatment. So, if two particularly easy words happened to have been assigned to a particular treatment, the results may favor that treatment unfairly. The experimental design was largely driven by the cost of fabricating signs and testing additional participants so that any one driver would not see the same word repeatedly.

Word difficulty could be assessed in a separate, non-driving test, similar to the small prescreening study done here. This could be the focus of additional research.

The finding that the all upper-case Clearview Condensed Road was not as legible as the Standard Highway Series D was surprising in light of past research. All previous research on Clearview has used mixed-case (upper and lower) case legends. Other than the initial Clearview evaluation, there has not been any legibility evaluations of words presented in all upper-case Clearview. As such, the current upper-case letters of Clearview have not been refined through field evaluation to the extent of the lower-case letters. FHWA is currently considering adopting the latest edition of the Clearview Highway font as an approved alternative for highway signs, but the version to be adopted by the FHWA is a refinement of the version evaluated in this experiment. Given the limited number of Clearview signs evaluated in this experiment (two words each for three sheeting types) and the subsequent refinements to Clearview, additional evaluations may be appropriate to assess the legibility impacts of using Clearview on post-mounted signs.

COMPARISONS TO PREVIOUS STUDIES

This project provides a chance to compare actual legibility distances to other nighttime studies. A comparison can be made by converting the results of all studies to a legibility index of mean legibility distance per inch of letter height. The effect of having the subject actually drive the car becomes clear immediately. Chrysler, et al. (*23*) report on a study in which older persons actually drove a car in real, uncontrolled traffic at night while reading experimental street name signs. These signs were mixed-case Highway Series C with a 6 inch initial upper-case and 4.5 inch lower-case letter. All signs were white letter on green background but four different types of retroreflective sheeting were tested. This study found an overall legibility index of 29 ft/inch averaged across Types III, VII and IX. The second TTI project examining the Clearview font for large guide signs did have the subject drive (*7*). For microprismatic ground-mounted green signs (Types VIII and IX) viewed by drivers aged 55 and over, the legibility index averaged across the Highway Series E(Modified) and Clearview Expressway font used by Carlson (*7*) is 32 ft/inch of letter height. The corresponding value from the current project for green microprismatic signs (Types VII and IX) averaged across Clearview Condensed Road and

Highway Series D is 30 ft/inch. It is worth noting that these legibility indices are very close to each other in spite of the fact that the current project used all upper-case letters and the other two studies used mixed-case letters.

Two previous studies tested older drivers at night with white-on-green signs. As described earlier, Garvey et al. (4) tested several subjects at a time in a van. The legibility index for Types III, VII, and IX across the Clearview Condensed, Clearview, Highway Series D, and Highway Series E(Modified) fonts was 38 ft/inch. Hawkins, et al. (*6*) tested only Type III sheeting with multiple subjects as passengers in a moving car. They found a legibility index of 40 ft/inch. Clearly, as the subject's task becomes more difficult, legibility index decreases.

RECOMMENDATIONS

The key results of the project are listed below. This list contains the results that were statistically significant and that the research team felt had practical significance as well.

- For small signs with white, yellow, or green backgrounds in unlighted areas, microprismatic retroreflective sheeting is not consistently better than encapsulated lens high intensity. TxDOT should not change the current standard of Type III material on all ground-mounted signs.
- For work-zone signs with orange background, microprismatic materials did provide for greater legibility distance than high intensity. TxDOT should continue with its recent change to use fluorescent microprismatic sheeting for work zone signs.
- The D-Modified font with a thicker stroke width did not improve legibility compared to Highway Series D for white, yellow, and orange signs. The Clearview Condensed Road font (with a thinner stroke) in all upper-case letters did not improve when compared to Highway Series D for white-on-green signs. TxDOT should not change the current standard of Highway Series D for ground-mounted signs with upper-case legends.
- The legibility index used for design and sign placement should be 40 feet of sign legibility per inch of letter height at a maximum. A more conservative value, supported by the current project, is 33 feet/inch.

Ground-mounted Signs Retroreflective Sheeting Type

TxDOT should continue to evaluate the necessity of specifying microprismatic material for ground-mounted signs. These signs include regulatory, warning, and distance / destination signs. This project, conducted with a particular passenger sedan, did not show a significant difference between the currently specified Type III sheeting and either Type VIII or Type IX microprismatics. This finding may not hold true across a variety of vehicle and headlamp types. Different vehicles can provide vastly different amounts of illumination to ground-mounted sign positions. The sign luminance provided by the combination of the Chevy Lumina and Type III sheeting produced sufficient luminance for legibility for the subjects in this project. Those same drivers placed in a vehicle with a larger observation angle or a sharper cut-off on the headlamps may find that the luminance of a Type III sign is not sufficient for legibility. Future research efforts in this area may want to consider the use of a variety of vehicle types. Another recent project by TTI (Project 0-4269) did conduct a study in which the same participant read signs both from a Chevy Lumina and from a heavy truck. Interested readers are referred to Report 4269-1.

Work Zone Signs Retroreflective Sheeting Type

This project confirms the wisdom of TxDOT's recent decision to specify microprismatic materials for work zone applications. Some practitioners have expressed concern over the legibility of these materials while acknowledging their superior conspicuity and detection performance. This project demonstrates that the microprismatic fluorescent orange materials perform better than the Type III that was formerly specified.

Font Type

This research project did not find an advantage for either of the alternative fonts. The all upper-case Highway Series D that is currently specified for the majority of ground-mounted signs performed equal to or better than both the Clearview Condensed Road and the D-Modified. Past research with Clearview suggests that this font may show a benefit only when used in mixed-case messages.

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APPENDIX A: FONT AND LETTER SERIES FREQUENCY ANALYSIS

In order to identify the most common font series and letter size, an analysis of the Texas Standard Highway Signs book was conducted. The following tables illustrate the letter series and size for each class of signs. They also indicate any changes suggested to the standard inter-letter spacing. Some legends, due to their size, call for a reduction in spacing in order to fit the words on the standard sized sign blank. Changes to spacing are indicated as negative percentages of the standard spacing. So, for instance, the standard spacing table may call for a two inch space between a particular pair of letters for Series C in general, but for a specific sign the indication is -40 percent spacing. This means that the letters should be spaced an inch and a quarter apart, which is a 40 percent reduction of the standard 2 inches. Where no spacing column is listed, no adjustments to letter spacing are recommended.

For lines with optional multiple lines of text, additional columns are shown.

Separate tables are provided for signing in the following categories:

- School and civil defense,
- construction work-zone,
- regulatory, and
- warning

The distribution of letter series for each sign type is given at the end of each table (Tables A1-A4).

Table A-1. Civil Defense and School Signs.

Sign	Std Size	Legend	Spacing	Primary or All Legend		Secondary Legend		Tertiary Legend		Quaternary Legend	
				Alphabet	Height	Alphabet	Height	Alphabet	Height	Alphabet	Height
CD-1	18	Evacuation Route		D	1.5"						
CD-1a	24	Evacuation Route		C	3"						
CD-2	30x24	Area Closed		C	6"						
CD-3	30x24	Traffic Regulation Post		C	4"						
CD-4	24x30	Maintain Top Safe Speed		C	4"	F	5"	E	4"		
CD-5	24x30	Road Use Permit Required…		C	4"	C	3"				
CD-6	30x24	Decontamination Center		C	3"	C	4"				
CD-7	30x24	Fallout Shelter		D	3"	D	5"				
S3-1	30x30	School Bus Stop Ahead	-25%	C	5"						
S4-1	24x10	8:30 AM to 5:30 PM		D	2.5"						
S4-1a	24x10	7:30 - 8:15 AM….		D	2"						
S4-2	24x10	When Children Are Present		D	2"						
S4-3	24x8	School		D	4"						
S4-4	24x10	When Flashing		D	2.5"						
S5-1	24x48	School Speed Limit		D	4"	E	4"	E	14"	D	2.5"
S5-2	24x30	End School Zone	-30%	C	5"						
Subtotals		# B		0		0		0		0	
		# C		8		2		0		0	
		# D		8		1		0		1	
		# E		0		1		2		0	
		# E(m)		0		0		0		0	
		# F		0		1		0		0	

Grand Total		Sum	Percent Occurrence
	# B	0	0%
	# C	10	63%
	# D	10	63%
	# E	3	19%
	# E(m)	0	0%
	# F	1	6%

Table A-2 Construction Work-zone Signs.

Sign	Std Size	Legend	Spacing	Primary or All Legend		Spacing	Secondary Legend		Tertiary Legend	
				Alphabet	Ht.		Alphabet	Ht.	Alphabet	Ht.
CW9-3	48x48	Center Lane Closed		C	7"					
CW20-1D	48x48	Road Work Ahead		D	7"		C	6"		
CW20-2D	48x48	Detour Ahead	-40%	D	8"		C	8"		
CW20-3A	48x48	Road Closed 1500 FT		D	7"		C	7"		
CW20-4A	48x48	One Lane Road 1500 FT		C	7"					
CW20-5R	48x48	Right Lane Closed		D	8"					
Plaque	30x12	1/2 Mile		C	6"					
CW20-5aR	48x48	Right Two Lanes Closed		C	8"		C	6"		
CW20-6	54x48	Lane Blocked 1 2 3 4 X		D	7"		D	6"		
CW20-7a	48x48	Flagger 1500 FT	-40%	C	7"					
CW20-7b	36x36	Be Prepared To Stop		D	5"					
CW20-8	48x48	Narrow Lanes Ahead		C	6"		D	6"	E	12"
CW21-1b	30x30	Workers Ahead		C	5"					
CW21-1t	48x48	Give Us a BRAKE		C	8"					
CW21-2	30x30	Fresh Oil	-20%	D	6"	-50%				
CW21-3d	36x36	Road Machinery Ahead	-40%	D	5"					
CW21-5	30x30	Shoulder Work	-25%	C	5"					
CW21-5aR	48x48	Right (Left) Shoulder Closed		C	8"					
Plaque	30x12	500 FT		D	5"		C	6"		
CW21-6	30x30	Survey Crew Ahead		D	5"					
CW21-6D	30x30	Survey Crew Ahead		C	5"					
CW21-7d	48x48	Utility Work Ahead		D	7"					
CW21-9	30x30	Mowers Ahead		D	5"					
CW21-10	48x48	Work Convoy		D	8"					
CW21-16	18x24	Next 14 Miles		C	4"		D	5"		
CW21-17	36x36	Guardrail Damage Ahead		C	5"					
CW21-18	36x36	Bridge Rail Damage Ahead		C	5"					

Table A-2 Construction Work-zone Signs (continued).

Sign	Std Size	Legend	Spacing	Primary or All Legend		Spacing	Secondary Legend		Tertiary Legend	
				Alphabet	Ht.		Alphabet	Ht.	Alphabet	Ht.
CW22-1b	48x48	Blasting Zone 1000 FT	-40%	C	7"					
CW22-2a	60x36	Turn Off Two-Way Radios and Telephones		C	6"					
CW22-3	42x36	End Blasting Zone		C	7"					
CW23-1	48x48	Shoulder Lane Ahead	-40%	C	7"					
CW23-2	48x48	Begin Shoulder Lane		C	8"					
CW23-3	48x48	End Shoulder Lane		C	8"					
CW25-1	48x48	Use Next Ramp		D	8"					
CW26-1t	96x24	Exit Closed		E	10"					
G20-1	60x24	Road Work Next 5 Miles		D	6"		C	6"		
G20-1a	72x36	Road Work Next 15 Miles		D	6"		C	6"		
G20-1bl	72x24	Road Work Next 5 Miles		D	6"		C	6"		
G20-2a	48x24	End Road Work		C	6"					
G20-4	36x18	Pilot Car Follow Me	-40%	C	5"					
G20-6	60x42	Contractor Info sign		D	4"					
G20-7	96x48	Working For You Give Us a BRAKE		D	5"		E(m)	8"		
G20-8	72x72	Highway Project Sign		C	5"					
G20-9	24x18	Work Zone		D	5"					
E5-2	48x48	Exit Open		E	10"					
CW2-6B	48x48	Highway Intersection 1000 FT		C	6"					
CW2-8	36x36	Traffic Islands Ahead		C	5"					
CW3-1	36x36	Stop Ahead	-20%	D	7"		C	7"		
Plaque	24x18	Stop Ahead		D	4"					
CW3-2	36x36	Yield Ahead		C	7"					
Plaque	24x18	Yield Ahead		D	4"					
CW3-3a	36x36	Signal Ahead		D	6"					
CW4-1aR	36x36	Thru Traffic Merge Right (Left)		D	4"		E	4"		

Table A-2 Construction Work-zone Signs (continued).

Sign	Std Size	Legend	Spacing	Primary or All Legend		Spacing	Secondary Legend		Tertiary Legend	
				Alphabet	Ht.		Alphabet	Ht.	Alphabet	Ht.
CW5-1	36x36	Road Narrows	-25%	D	6"					
CW5-2	30x30	Narrow Bridge	-25%	D	5"	-30%				
CW5-3	36x36	One Lane Bridge		C	6"					
CW6-1a	36x36	Divided Highway		D	5"					
CW6-2a	36x36	End Freeway 1/2 Mile		D	5"					
CW6-4	48x48	Hill		E	6"					
CW7-1a	30x30	Use 2nd Gear		E	8"					
CW7-2	24x18	Use Low Gear		C	4"				E	6"
CW7-2a	24x18	Trucks Use Lower Gear		C	4"				E	6"
CW7-2b	24x18	9% Grade	25%	C	3"					
CW7-3	24x18	Next 7 miles	75%	D	4"					
CW7-3a	24x18	9% Grade 7 Miles		C	4"					
CW7-4	78x48	Runaway Truck Ramp 1 Mile		E	6"					
CW7-4a	78x60	Runaway Truck Ramp		C	8"					
CW8-1	30x30	Bump		D	8"				D	4"
CW8-2	30x30	Dip	50%	E	8"					
CW8-3	30x30	Pavement Ends		C	5"					
CW8-4	30x30	Soft Shoulder	-25%	C	5"					
CW8-6	30x30	Truck Crossing		C	5"					
CW8-7	30x30	Loose Gravel	-40%	D	5"					
CW8-8	30x30	Rough Road		D	5"					
CW8-8T	30x30	Grooved Pavement Ahead		C	5"					
CW8-9	30x30	Low Shoulder		C	5"					
CW8-9a	36x36	Shoulder Drop-Off		C	6"					
CW8-11	36x36	Uneven Lanes		D	6"					
CW8-12	36x36	No Center Stripe		C	6"				0	
CW8-13	30x30	Water Crossing		D	4"				0	
CW8-14	30x30	Water Over Road		C	5"				1	

Table A-2 Construction Work-zone Signs (continued).

Sign	Std Size	Legend	Spacing	Primary or All Legend		Spacing	Secondary Legend		Tertiary Legend	
				Alphabet	Ht.		Alphabet	Ht.	Alphabet	Ht.
CW8-15	36x36	Watch for Water on Road		C	6"		C	4"	3	
CW9-1r	36x36	Right (Left) Lane Ends		D	6"				0	
CW9-2l	36x36	Lane Ends Merge Left (Right)		C	4"		D	6"		
CW10-1a	24x12	Exempt								
CW10-5	30x30	Uneven Tracks		C	5"					
CW12-2p	24x18	Low Clearance		D	5"		C	3"		
CW12-4	Varx36	Low Clearance 10 miles ahead Loads over 12 ft high detour by way of Austin		D	5"		D	3"		
CW12-5	36x36	Load Zoned Bridge		D	5"					
CW13-1	18x18	35 M.P.H		D	8"	100%	E	3"		
CW13-2	48x60	Exit 25 M.P.H.		E	8"		E	16"		
CW13-3	48x60	Ramp 25 M.P.H.		E	8"		E	16"		
CW13-4	18x18	On Ramp		D	4"					
CW14-1	30x30	Dead End		D	6"					
CW14-2	30x30	No Outlet		C	6"					
CW14-3	36x48x48	No Passing Zone	-20%	D	5"	-35%	C	5"		
CW19-1	30x30	Draw Bridge Ahead		C	5"					
CW19-2	36x36	Watch for ICE on Bridges		C	5"		D	7":	D	4"
CW19-3	36x36	Ramp Metered When Flashing		D	4"					
CW19-4	36x36	Ramp Signal Ahead		D	5"					
CW19-5	30x30	Loose Sand		D	5"					
CW19-6T	30x30	Cattle Guard		D	5"					
CW19-10	30x30	Falling Rock	-50%	D	5"					
CW19-11	30x30	Rock Slides		D	5"					
CW19-12	30x30	Earth Slides		D	5"					
CW19-14	36x36	Watch for SMOKE on Road		D	4"		E	5"		
CW19-15	36x36	Watch for MUD on Road		D	4"		E	6"		

Table A-2 Construction Work-zone Signs (continued).

Sign	Std Size	Legend	Spacing	Primary or All Legend		Spacing	Secondary Legend		Tertiary Legend	
				Alphabet	Ht.		Alphabet	Ht.	Alphabet	Ht.
		# B		0			0		0	
		# C		46			12		0	
		# D		52			6		1	
		# E		8			6		3	
		# E(m)		0			1		0	
		# with Spacing Change	24							
		Max	100%							
		Min	-50%							

	Sum	Percent Occurrence
# B	0	0%
# C	58	43%
# D	59	44%
# E	17	13%
# E(m)	1	1%

Table A-3 Regulatory Signs.

Sign	Std Size	Legend	Spacing	Primary or All Legend		Spacing	Secondary Legend		Tertiary Legend	
				Alphabet	Ht.		Alphabet	Ht.	Alphabet	Ht
R1-2a	21x15	To Ramp		D	4"					
MR1-2b	36x24	To Oncoming Traffic		D	6"		E	6"		
R1-5R	36x18	Cross Traffic Does Not Stop	-15%	D	3"					
R2-1	24x30	Speed Limit 50		E	4"		E	10"		
R2-2	24x24	Trucks 40	-32%	D	4"		E	10"		
R2-2a	24x36	Truck Speed Limit 50		E	4"		E	10"		
R2-3	24x24	Night 45	50%	F	3"		E	10"		
R2-4	24x30	Minimum Speed 40		C	4"		D	10"		
R2-4a	24x48	Speed Limit 50 Minimum 30		E	4"		E	10"	C	4"
R2-4t	138x42	Maximum Legal Speeds….		D	6"					
FR2-4TA	318x96	Maximum Legal Speeds….		D	10"					
FR2-4Tb	318x80	Maximum Legal Speeds….		D	10"					
R2-5a	24x30	Reduced Speed Ahead	-50%	B	6"		C	6"		
R2-5b	24x30	Reduced Speed 30		C	4"		E	10"		
R2-5c	24x30	Speed Zone Ahead	-40%	C	6"					
R3-3	24x24	No Turns		D	6"	-35%	D	5"		
R3-4a	24x30	No U Turn		D	5"		F	8"		
R3-5l	30x36	Only		D	6"					
R3-7R	30x30	Right Lane MUST Turn Right		C	4"		C	5"		
Plaque	30x8	500 FT		C	4"					
R3-8L	30x30	Only	-50%	D	4"					
R3-8u	24x30	Only		D	4"					
R3-9a	30x36	Only		D	6"					
R3-9b	24x36	Center Lane Only		E	3"					
R3-10	30x42	Restricted Lane Ahead		B	4"	100%	C	4"		
R3-11	30x42	Buses and Car Pools Only…		C	3"	-25%	C	4"	D	2"
R3-12	30x42	Restricted Lane Ends		B	4"	100%	C	4"		

Table A-3. Regulatory Signs (continued).

Sign	Std Size	Legend	Spacing	Primary or All Legend		Spacing	Secondary Legend		Tertiary Legend	
				Alphabet	Ht.		Alphabet	Ht.	Alphabet	Ht
R3-13	66x36	Restricted Lane Ahead	-50%	C	6"		D	6"		
R3-14	72x60	Buses and 4 Rider…		D	6"		C	6"	C	3"
R3-15	66x36	Restricted Lane Ends	-50%	C	6"		D	6"		
R3-16	24x30	Lane Ahead	100%	C	3"					
R3-17	24x30	Right Lane Only		D	3"		C	5"		
R3-20	48x48	Left Lane MUST Enter Ramp		C	6"		D	8"		
R3-21R	48x48	Right Lane Must Exit		C	6"		D	10"		
R3-22	48x60	All Traffic Must Exit		C	8"		D	10"		
R4-1	24x30	Do Not Pass	-40%	D	6"					
R4-2	24x30	Pass with Care		C	6"					
R4-2a	24x36	Left Lane for Passing Only	-25%	D	4"					
R4-3	24x30	Slower Traffic Keep Right	-25%	D	4"					
R4-3a	36x30	Do Not Drive on Shoulder		C	5"					
R4-3b	36x36	Do Not Cross Double White Line		C	4"					
R4-3c	36x36	Do Not Change Lanes		C	6"					
R4-3c	48x32	Shoulder Lane Use OK		C	6"					
R4-4	36x30	Begin Right Turn Lane Yield to Bikes	-20%	C	4"		B	4"		
R4-5	24x30	Trucks Use Right Lane	-32%	D	4"					
R4-6	24x30	Truck Lane 500 FT		E	4"					
R4-7a	24x30	Keep Right	-30%	D	5"					
R4-7b	24x30	Keep Right	-30%	D	5"					
R4-8a	24x30	Keep Left		D	5"					
R4-8b	24x30	Keep Left		D	5"					
R5-1T	48x18	Ramp		D	9"					
R5-2a	24x24	No Trucks		D	6"		C	5"		
R5-3	24x24	No Motor Vehicles		C	4"		B	4"		
R5-3T	30x18	Motor-Driven Cycles Prohibited		C	3"					

Table A-3. Regulatory Signs (continued).

Sign	Std Size	Legend	Spacing	Primary or All Legend		Spacing	Secondary Legend		Tertiary Legend	
				Alphabet	Ht.		Alphabet	Ht.	Alphabet	Ht
R5-4	24x30	Commercial Vehicles Excluded	-50%	B	4"					
R5-5	24x30	Vehicles with Lugs Prohibited	-20%	B	4"					
R5-6T	30x18	Nonmotorized Traffic Prohibited		C	3"					
R5-10a	30x36	Pedestrians Bicycles Motor Drive….		B	4"					
R5-10b	24x12	Pedestrians and Bicycles Prohibited		C	3"					
R5-10c	24x12	Pedestrians Prohibited		C	3"					
R5-11	30x30	For Official or Emergency Vehicle Use ONLY		C	3"		C	6"		
R6-1l	36x12	One Way		D	4"					
R6-2R	18x24	One Way		D	5"					
R6-3	24x18	Divided Highway		E	2"					
R6-3a	24x18	Divided Highway		E	2"					
R8-1	24x30	No Parking on Pavement		D	5"	-50%	C	5"	D	3"
R8-1T	24x30	No Parking on Bridge		D	5"	-50%	C	5"	D	3"
R8-2	24x30	No Parking Except on Shoulder		D	5"	-0.5	C	5"	C	3"
R8-2T	24x30	No Parking Within 10 Feet of Pavement		C	4"		C	3"		
R8-3	24x30	No Parking	80%	D	6"	-50%	C	5"		
R8-3R	24x30	No Parking	80%	D	5"	-50%	C	5"		
R8-5	24x30	NO Stopping on Pavement		D	5"	-25%	B	5"	D	3"
R8-6	24x30	No Stopping Except on Shoulder		D	5"	-25%	B	5"	C	3"
R8-8	24x30	Do Not Stop on Tracks		D	4"					
R8-9	24x24	Tracks Out of Service		C	4"					

Table A-3. Regulatory Signs (continued).

Sign	Std Size	Legend	Spacing	Primary or All Legend		Spacing	Secondary Legend		Tertiary Legend	
				Alphabet	Ht.		Alphabet	Ht.	Alphabet	Ht
R9-1	18x24	WALK on Left Facing Traffic		D	4"		D	3"	D	2"
R9-4	18x24	NO Hitchhiking		C	6"					
R9-5	12x18	Use Ped Signal		C	2"					
R9-6	12x18	Yield to Peds		C	2"					
R9-7	12x18	KEEP Left/Right		B	4"	-50%	B	2"		
R10-5	24x30	Left on Green Arrow Only		C	3"		D	3"		
R10-6	24x36	Stop Here on Red		D	5"		D	3"		
R10-6a	24x30	Stop Here on Red		D	5"		D	3"		
R10-7	24x30	Do Not Block Intersection	-55%	C	6"	-50%	B	4"		
R10-8	24x30	Use Lane with Green Arrow		E	3"					
R10-9	18x12	Protected Left on Green Arrow	-20%	C	2"					
R10-10L	24x30	Left Turn Signal		C	5"					
R10-11a	24x30	NO Turn on Red		E	5"		D	5"		
R10-11b	24x30	NO Turn on Red		E	4"		D	4"		
R10-11c	24x30	No Right Turn on Red		E	5"		D	4"		
R10-12	30x36	Left Turn Yield on Green		C	3"		C	4"		
R10-15	24x18	Emergency Signal		D	2.5"		D	3"		
R11-1	24x30	Keep Off Median	50%	C	5"	-20%				
R11-2	48x30	Road Closed		D	8"					
R11-3a	60x30	Road Closed 10 Miles Ahead…		C	6"		C	5"	C	4"
R11-3b	60x30	Bridge Out 10 Miles Ahead…		C	6"		C	5"	C	4"
R11-4	60x30	Road Closed to Thru Traffic		C	6"		C	5"		
R12-1	24x30	Weight Limit 10 Tons		D	4"		E	5"	D	5"
R12-1T	24x36	Weight Limit Gross 58420 LBS		C	3"		C	4"		
R12-2	24x30	Axle Weight Limit 5 Tons		D	4"	-0.5	D	5"		

Table A-3. Regulatory Signs (continued).

Sign	Std Size	Legend	Spacing	Primary or All Legend		Spacing	Secondary Legend		Tertiary Legend	
				Alphabet	Ht.		Alphabet	Ht.	Alphabet	Ht
R12-2Ta	24x36	Weight Limit Axle 15000 LBS		C	3"		C	4"		
R12-2Tb	24x36	Weight Limit Axle or Tandem 17500 Lbs		C	3"		C	4"	B	3"
R12-2Tc	24x36	Weight Limit Tandem Axle 28000 LBS		C	3"		C	4"	B	3"
R12-3	24x36	NO TRUCKS Over 7000 LBS Empty WT		D	6"		C	5"	D	3"
R12-4	36x24	Weight Limit 2 Tons Per Axle…	-60%	C	4"	-55%				
R12-4Ta	24x36	Weight Limits Gross 25000 LBS…		C	3"		B	3"		
R12-4Tb	24x42	Weight Limits Gross 23000 LBS…		C	3"		B	3"		
R12-4Tc	24x42	Weight Limits Gross 60000 LBS…		C	3"		B	3"		
R12-5	30x36	Weight Limit		E	4"		D	4"		
R12-6Ta	VARx36	Load Zoned Bridge		D	5"		D	3"		
R12-6Tb	VARx30	Load Zoned Road		D	5"		D	3"		
R12-7Ta	VARx36	Load Zoned Road		D	5"		D	3"		
R12-7Tb	VARx30	Load Zoned Road		D	5"		D	3"		
R12-8a	78x36	Weight Limit…		C	4"					
R12-8b	78x24	Weight Limit…		C	4"					
R12-8c	78x24	Weight Limit…		C	4"					
R12-9	24x36	Width Limit 8 FEET		D	4"		E	9"	E	3"
R12-9a	48x60	Width Limit 8 ft 6 in		E	8"		C	18"		
R13-1	72x48	All Trucks Commercial Vehicles Next Right		E	6"					

Table A-3. Regulatory Signs (continued).

Sign	Std Size	Legend	Spacing	Primary or All Legend		Spacing	Secondary Legend		Tertiary Legend	
				Alphabet	Ht.		Alphabet	Ht.	Alphabet	Ht
R13-1a	48x48	All Trucks Stop Ahead When Flashing		C	6"					
R13-1T	72x30	All Trucks Next Exit		D	7"					
R13-1Ta	48x36	All Trucks MUST Stop Ahead		C	6"		D	8"	C	5"
R14-1	24x18	Truck Route		D	5"					
R14-2	24x24	HC		C	10"					
R14-3	24x24	No HC		C	10"					
R14-6	18x18	HC Must Follow Routes		E	12"					
R15-1	48x9	Rail Road Crossing		D	5.5"					
R15-2	9x9 and 27x9	3 Tracks		D	5.5"		D	4"		
R15-3	24x12	Exempt		D	4"					
R15-4	24x12	To Report Malfunction…		C	1"					
R19-1	48x60	STOP for School Bus Loading…		D	8"		D	5"		
R19-2	60x30	STOP Ask Flagger for Road Information		E	8"		D	4"		
R19-3	36x18	Damaging Trees or Plants….		D	2"					
R19-4	30x18	Unlawful to Write on or Mar…		D	1.5"					
R19-5	24x30	NO Dumping Allowed		D	6"		C	4"		
R19-6	48x30	Littering Prohibited		E	4"		D	4"	D	2.5"
R19-6a	48x30	Don't Mess with Texas		E(m)	4"		C	3"		
R19-7	24x30	No Fishing from Bridge		D	4"		C	4"		
R19-8	30x30	Fasten Safety Belts State Law		D	4"		D	2.5"		
R20-1	24x18	Next X Miles		C	4"					
R20-2R	48x60	Form One Line Right (Left)		E	8"					
R20-3	48x42	Observe Warning Signs State Law		D	4"		C	6"		

Table A-3. Regulatory Signs (continued).

Sign	Std Size	Legend	Spacing	Primary or All Legend		Spacing	Secondary Legend		Tertiary Legend	
				Alphabet	Ht.		Alphabet	Ht.	Alphabet	Ht
R20-4	48x42	2 Miles Ahead		D	6"					
R20-5	24x30	Traffic Fines Double		C	5"		C	3"		

# B		7			9		2
# C		47			24		6
# D		47			21		7
# E		12			8		0
# E(m)		0			0		0
# F		1			1		0
# with Spacing Change	40						
Max	100%						
Min	-60%						

	Sum	Percent Occurrence
# B	11	8%
# C	30	22%
# D	28	21%
# E	8	6%
# E(m)	0	0%
# F	1	1%

Table A-4. Warning Signs

Sign	Std Size	Legend	Spacing	Primary or All Legend		Spacing	Secondary Legend		Tertiary Legend	
				Alphabet	Ht.		Alphabet	Ht.	Alphabet	Ht.
W2-6B	48x48	Highway Intersection 1500 FT		C	6"					
W2-8	36x36	Traffic Islands Ahead		C	5"					
W3-1	36x36	Stop Ahead	-20%	D	7"		C	7"		
Plaque	24x18	Stop Ahead		D	4"					
W3-2	36x36	Yield Ahead		C	7"					
Plaque	24x18	Yield Ahead		D	4"					
W3-3a	36x36	Signal Ahead		D	6"					
W4-1aR(L)	36x36	Thru Traffic Merge Right (Left)		D	4"		E	4"		
W5-1	36x36	Road Narrows	-25%	D	6"					
W5-2	30x30	Narrow Bridge	-25%	D	5"	-30%				
W5-3	36x36	One Lane Bridge		C	6"					
BW5-4	18x18	Bikeway Narrows	-50%	C	3"					
W6-1a	36x36	Divided Highway		D	5"					
W6-2a	36x36	Divided Highway Ends		D	5"					
W6-4	48x48	End Freeway 1/2 MI		E	6"					
W7-1a	30x30	Hill		E	8"					
W7-2	24x18	Use 2nd Gear		C	4"					
W7-2a	24x18	Use Low Gear		C	4"					
W7-2b	24x18	Trucks Use Lower Gear		C	3"					
W7-3	24x18	9 % Grade	25%	D	4"					
W7-3a	24x18	Next 7 Miles	75%	C	4"					
W7-3b	24x18	9 % Grade 7 Miles		C	3"					
W7-4	78x48	Runaway Truck Ramp 1 Mile		E	6"					
W7-4a	78x60	Runaway Truck Ramp		C	8"					
W8-1	30x30	Bump		D	8"					
W8-2	30x30	Dip	50%	E	8"					
W8-3	30x30	Pavement Ends		C	5"					
W8-4	30x30	Soft Shoulder	-25%	C	5"					
W8-6	30x30	Truck Crossing		C	5"					
W8-7	30x30	Loose Gravel	-40%	D	5"					

Table A-4. Warning Signs (continued).

Sign	Std Size	Legend	Spacing	Primary or All Legend		Spacing	Secondary Legend		Tertiary Legend	
				Alphabet	Ht.		Alphabet	Ht.	Alphabet	Ht.
W8-8	30x30	Rough Road		D	5"					
W8-8T	36x36	Grooved Pavement Ahead		C	5"					
W8-9	30x30	Low Shoulder	-25%	C	5"					
W8-9a	36x36	Shoulder Drop-off		C	6"					
W8-11	36x36	Uneven Lanes		D	6"					
W8-12	36x36	No Center Stripe		C	6"					
W8-13	30x30	Water Crossing		D	4"					
W8-14	30x30	Water Over Road		C	5"					
W8-15	36x36	Watch for Water on Road		C	6"		C	4"		
W9-1R	36x36	Right Lane Ends		D	6"					
W9-2L	36x36	Lane Ends Merge Left		C	4"		D	6"		
W10-1a	24x12	Exempt								
W10-6	30x30	Uneven Tracks		C	5"					
W11-11	36x36	Watch for Emergency Vehicles		D	4"					
W12-2P	24x18	LOW Clearance		D	5"		C	3"		
W12-4	Varx36	Low Clearance 10 Miles Ahead Loads over 12 FT High Detour by Way of Austin		D	5"		D	3"		
W12-5	36x36	Load Zoned Bridge		D	5"					
W13-1	18x18	35 M.P.H.		D	8"	100%	E	3"		
W13-2	48x60	Exit 25 M.P.H.		E	8"		E	16"	E	6"
W13-3	48x60	Ramp 25 M.P.H.		E	8"		E	16"	E	6"
W13-4	18x18	On Ramp		D	4"					
W14-1	30x30	Dead End		D	6"					
W14-1P	36x8	Dead End		C	4"					
W14-2	30x30	No Outlet		C	6"					
W14-2P	36x8	No Outlet		C	4"					
W14-3	36x48x48	No Passing Zone	-20%	D	5"	-35%	C	5"		
W19-1	30x30	Draw Bridge Ahead		C	5"					
W19-2	36x36	Watch for Ice on Bridges		C	5"		D	7"	D	4"
W19-3	36x36	Ramp Metered When Flashing		D	4"					

Table A-4. Warning Signs (continued).

Sign	Std Size	Legend	Spacing	Primary or All Legend		Spacing	Secondary Legend		Tertiary Legend	
				Alphabet	Ht.		Alphabet	Ht.	Alphabet	Ht.
W19-4	36x36	Ramp Signal Ahead		D	5"					
W19-5	30x30	Loose Sand		D	5"					
W19-6	30x30	Loose Livestock		D	4"					
W19-6T	30x30	Cattle Guard		D	5"					
W19-7	30x30	Hospital		D	5"					
W19-8	30x30	Church		D	6"					
W19-9	30x30	Military Entrance		C	5"		B	5"		
W19-10	30x30	Falling Rock	-50%	D	5"					
W19-11	30x30	Rock Slides		D	5"					
W19-12	30x30	Earth Slides		D	5"					
W19-14	36x36	Watch for SMOKE on Road		D	4"		E	5"		
W19-15	36x36	Watch for MUD on Road		D	4"		E	6"		
W20-1	36x36	Weigh Station 1 Mile		C	6"					
W20-2	36x36	Weigh Station 1/2 Mile		C	5"					
W20-DPA	24x18	Next 1500 Feet		C	5"					

#B		0			1		0	
#C		31			4		0	
#D		36			3		1	
#E		6			6		2	

	Sum	Percent Occurrence
#B	1	1.4
#C	35	48.6
#D	40	55.6
#E	14	19.4

# with Spacing Change	17
Max	100%
Min	-50%

APPENDIX B: RESULTS OF VISION TESTING

High luminance binocular acuity was measured at a distance of 20 feet. Table B-5 lists the frequency distribution for the twenty-four participants.

Table B-5 Distribution of Snellen Acuity scores.

Acuity Score	Frequency
20 / 15	3
20 / 20	9
20 / 25	9
20 / 30	1
20 / 40	1
20 /50	1

The contrast sensitivity test is reported in terms of the ordered number of the column the subject was last able to correctly identify. The manufacturers of the test provide a range of normal performance in these terms. Table B-2 shows the range of scores for the participants in the current study. Note that on the higher spatial frequency, one subject performed below the normal vision range.

Table B-2 Raw scores and normal ranges for contrast sensitivity test.

Spatial Frequency (cycles per degree)					
	1.5	**3**	**6**	**12**	**18**
Minimum	5	4	4	0	0
Maximum	6	7	7	6	6
Median	5	6	5.5	5	3
Normal Range	4.5 - 6.75	5 - 7.1	4.2 - 7.1	3 – 7	1.2 – 6.6

Another way to present these data is in terms of percent contrast threshold. This is, in essence, an expression of how much contrast is necessary in order for the subject to see that there are lines present in the stimulus. A score of 2.5 would mean that the luminance of the white portion of the striped stimulus would have to be 2.5 times brighter than the gray portion in order for the stripes to be detected. This scoring is included in this project for the benefit of visual performance researchers. Table B-3 shows the percent contrast scores.

Table B-3 Percent contrast scores for contrast sensitivity test.

Spatial Frequency (cycles per degree)					
	1.5	**3**	**6**	**12**	**18**
Minimum	1.43	0.59	0.54	1.14	2.5
Maximum	2.86	33.33	2.22	33.33	33.33
Median	2.86	1.13	1.115	1.82	10

APPENDIX C: INSTRUCTIONS, INFORMED CONSENT, AND SUBJECT INFORMATION FORMS

Prior to Study - Verbal Instructions to Subjects

My name is ________________________________; I work for the Texas Transportation Institute, which is part of the Texas A&M University System. I would first like to thank you for volunteering to participate in this study. The study is being sponsored by the Texas Department of Transportation. The purpose of this study is to determine how well drivers can see and read highway signs. Before I tell you about the study, I need to get a little information from you.

First, we need to confirm that you are 55 or older, and you currently have a Texas driver's license.

NOTE: The above questions should have been asked when they were recruited. They are repeated at this time for added assurance.

Now, we're going to give you a simple visual screening test:

Snellen acuity "eye chart" (visual acuity screening test):
Binocular only. Record acuity (e.g., 20/20, 20/50) based on last line of which participant reads all letters correctly. If participant misses only one or two letters, have them try to read the next larger line. If they get all the letters correct, continue to the next line down. If they can't read it, go back to the previous line. If they still make errors, use last all correct line to determine acuity.

Vistech (contrast sensitivity screening test)
Binocular only. First point out the sample patches at the bottom of the chart with the three possible responses (left, right, or straight up). Start with Row A and ask the participant to identify the last patch in which lines can be seen and tell you which direction they tilt. If a response is incorrect, have them describe the preceding patch. Once the participant has correctly identified a patch, have them guess which way the lines tilt in the next patch to the right. Record the last patch the patient correctly identifies in each row by marking the corresponding dot on the Evaluation Form. Record the lowest acuity (e.g., 20/20, 20/50-highest number is lowest acuity) that the line falls through.

Do Color Vision test

Now, let me tell you a little about your task tonight.

You will be driving a state-owned passenger vehicle on a closed course we've set up on the runway system here at the Riverside Campus. The vehicle is specially equipped to record and measure various driving characteristics, but drive just like normal vehicles. While driving through the selected route, you will encounter various signs. For each sign you encounter you are to say the word out loud as soon as you feel you can correctly identify it. I will press a button in the car which will record the distance. This button makes a little beeping sound. It's alright to guess and then correct yourself. There's no penalty for being wrong. Some signs will be easier to read than others, so don't feel bad if there's one or two that you can't make out.

There will be two cones for you to line up with prior to the study area to assist you in your driving path. There will be about 48 signs to evaluate. After you have completed the study course, a researcher will ask you a series of questions about what you have seen.

You will be driving through a number of different areas. Parts of the course will look very much like rural Texas roads you have driven on in the past. Other areas may not look much like roadways at all and may be confusing, but a researcher will always be in the car with you and will direct you where to drive. You are to drive 30 mph. It is important that you follow the researchers instructions very carefully when we're out on the test course.

An ID number will identify you during the data collection part of the study. The only information I will collect that identifies you by name is the Consent Form, and the disbursement log that I will ask you to sign. Nothing that identified you will be included in any data collected or reports written about this study.

There will be a cellular telephone and/or two-way radio available at all times during the study. In case of an accident or medical emergency, appropriate emergency medical services will be called. However, neither TTI nor Texas A&M University will assume financial responsibility for any medical costs incurred due to your participation in this study. Continuing medical care and/or hospitalization for research-related injury will not be provided free of charge nor will financial compensation be available, or be provided by TAMU or the investigator.

As you were told, the complete study will take about one hour. Upon completion of the study, you will be compensated $20.00 for your participation. If you are uncomfortable during any part of the study or have any questions, please let me know. I will try to answer any questions you have, except those that may affect the results of the study. If for any reason you choose not to continue to participate in the research study, you are free to quit at any time. If you do quit before the end of the study, you will receive compensation based on the portion of time you participated. Unforeseen circumstances such as equipment breakdown may cause the study to stop before it is completed. In that event, you will be compensated $10.00.

This study has been reviewed and approved by the Texas A&M's Institutional Review Board for the use of human subjects in research. Before, we can begin you will need to read, understand, and sign this document *(hand the subject the consent form).* It's an informed consent document that confirms that you are volunteering to participate in this study and that you understand what is being asked of you. It summarizes the things that I've just gone over with you. *Allow the participant to read the consent form, ask questions, sign form, and then give a copy of a signed form to the subject.*

Now, unless you have some questions, we are ready to go. Once in the study vehicle, the researcher will give you more specific instructions on the study procedures.

(Offer restroom opportunity before leaving).

Verbal Instructions to Participants in Test Vehicle

Make sure participants fasten their seat belt. Make sure the participant is wearing glasses if required on drivers license. Direct subject to the first study location.

NOTE: Make sure low beam headlights are on.

Okay, a few things we need to go over are:

- Drive 30 mph.
- There will be two cones for you to line up with prior to each study area to assist you in your driving path.
- There will be RPMs on your left to help guide you through the study area.

We are approaching our first study area.

INFORMED CONSENT

This research study is being conducted by the Texas Transportation Institute (TTI), which is part of the Texas A&M University System (TAMU). It is sponsored by the Texas Department of Transportation. The study is being conducted to determine how well drivers can see and read highway signs. Approximately 24 subjects will be participating in the study.

I have been selected because I have a current Texas drivers license and am 55 years old or older.

The study will take approximately one hour to complete. At the end of my participation in the study I will be compensated $20.00. If I am uncomfortable with any part of the procedure, I will not hesitate to make it known to the researcher. If I choose not to continue to participate in the research for any reason, I am free to quit at any time. If I do quit before the end of the study, I will receive compensation based on the portion of time I participated. Unforeseen circumstances such as equipment breakdown may cause the researcher to excuse me from further participation on the project. In that event, I will be compensated at least $10.00. Other than the compensation, I understand that there are no special benefits to me for participating.

I understand that if I accept payment for participating in this study, the fact that I participated in this study may be obtained under the Texas Open Records Act, even though any information that I give to the investigator is confidential.

Records that identify me by name or in any other way will be kept in locked storage in Room 410 of the CE/TTI Building on the Texas A&M University campus.

I understand that I may incur travel costs to the Texas A&M Riverside campus, and that these expenses will not be reimbursed.

I will be asked to drive a state-owned passenger vehicle. This vehicle is specially equipped to record and measure various driving characteristics, but drive just like normal vehicles. The study will be done at night on a simulated highway set up at the Texas A&M Riverside Campus of Texas A&M University. Upon traveling through the selected route, I will encounter various signs, I am to say the word displayed out loud as soon as I feel I can correctly identify it. There will be approximately 48 different types of signs to evaluate. I will not be asked to exceed 30 mph at the Riverside Campus during the study.

A cellular telephone or two way radio will be available to the researcher at all times. *In case of an accident or medical emergency, appropriate emergency medical services will be called. However, neither TTI nor Texas A&M University will assume financial responsibility for any medical costs incurred due to my participation in this study. Continuing medical care and/or hospitalization for research-related injury will not be provided free of charge nor will financial compensation be available, or be provided by TAMU or the investigator.*

I understand that this research study has been reviewed and approved by the Institutional Review Board - Human Subjects in Research, Texas A&M University. For research-related problems or questions regarding subjects' rights, the Institutional Review Board may be contacted through

Dr. Michael W. Buckley, IRB Coordinator, Office of the Vice President for Research and Associate Provost for Graduate Studies at (979) 845-1811 (e-mail: mwbuckley@tamu.edu).

I have read and understand the explanation provided me. I have had all my questions answered to my satisfaction, and I voluntarily agree to participate in this research project. I have been provided a copy of this consent form.

____

Research Participant ***Date***

____

Researcher ***Date***

Principal Investigator:
Dr. Susan Chrysler
Associate Research Scientist
Operations and Design Division
Texas Transportation Institute
The Texas A&M University System
(979) 862-3928

Project # 1796　　　　　　　　　　　　　　　　Date ____________

SUBJECT INFORMATION

Name: ____

Address: ____

City: ____________　State: __________________　Zip Code: ______________

Phone (Home): ______________________　Phone (Work): __________________________

Date of Birth: ___________　Age: _______　Gender: ______________________

Do you have a current Texas driver's license (Yes/No)? ________________________________

Does your driver's license have any restrictions, such as corrective lenses or no nighttime driving (Yes/No)? ________ If yes, please explain. ____
____

Approximately how many miles per year do you drive in Texas? _________________________

Do you have any visual problems, such as cataracts (Yes/No)? _______ If yes, please explain.
____

Have you ever had eye surgery, such as cataracts or laser (Yes/No)? ________ If yes, please explain. ____

Are you colorblind (Yes/No)? _________

Would you be interested in participating in any future surveys (Yes/No)? __________________

Visual Acuity Test: _______________

Contrast Sensitivity Test:
____

Color Vision Test:
____