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16. Abstract

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SI CONVERSION FACTORS

To Convert From	To	Multiply By
Length:		
in	cm	2.54
in	m	0.025 4
ft	m	0.304 8
yd	m	0.914 4
mi	km	1 . 609 344
Area:		
in^2	cm^2	6.451 600 E+00
ft^2	m^2	9.290 304 E-02
yd^2	m^2	8.361 274 E-01
mi^2	Hectares	2.589 988 E+02
acre (a)	Hectares	4.046 856 E-01
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pt	m^3	4.731 765 E-04
qt	m^3	9.463 529 E-04
gal	m^3	3.785 412 E-03
in^3	m^3	1.638 706 E-05
ft^3	m^3	2.831 685 E-02
yd^3	m^3	7.645 549 E-01

NOTE: $1m^3 = 1,000$ L

To Convert From	To	Multiply By
Volume per Unit Time:		
ft^3/min	m^3/sec	4.719 474 E-04
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gal/min	m^3/sec	6.309 020 E-05
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dwt	kg	1.555 174 E-03
lb	kg	4.535 924 E-01
ton (2000 lb)	kg	9.071 847 E+02
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Velocity: (Includes Speed)		
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mi/h	m/s	4.470 400 E-01
knot	m/s	5.144 444 E-01
mi/h	km/h	1.609 344 E+00
Force Per Unit Area:		
lbf/in^2 or psi	Pa	6.894 757 E+03
lbf/ft^2	Pa	4.788 026 E+01
Viscosity:		
cS_t	m^2/s	1.000 000 E-06
P	Pa·s	1.000 000 E-01

Temperature: $(°F-32)^5/9 = °C$

FINAL REPORT

SIGN LEGIBILITY FOR MODIFIED MESSAGES

by

Frank D. Shepard
Research Scientist

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

Virginia Transportation Research Council
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In Cooperation with the U.S. Department of Transportation
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ABSTRACT

This study was conducted to investigate ways of increasing the legibility of signs with high background brightness. Research was limited to silver, yellow, and orange encapsulated lens sheeting materials, and modifications were made within the standards for highway signs as specified in the Manual on Uniform Traffic Control Devices. The results of the study show that in Virginia the legibility of selected signs with high background brightness can be increased by modifying the letter design.

SIGN LEGIBILITY FOR MODIFIED MESSAGES

by

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INTRODUCTION

The conventional highway sign is the primary means of transmitting information to the highway user, and it is necessary that those factors that influence legibility be optimized. Much research related to legibility has resulted in the standardization of many factors that contribute to an increase in legibility. One factor, however, that can have a significant influence on legibility -- namely, sign brightness -- is quite variable. Allen and Straub studied the effect of different levels of brightness on legibility and came up with the plots shown in Figure 1(1). These plots show two important relationships: the legibility distance as a function of letter series, and the legibility distance as a function of sign brightness.

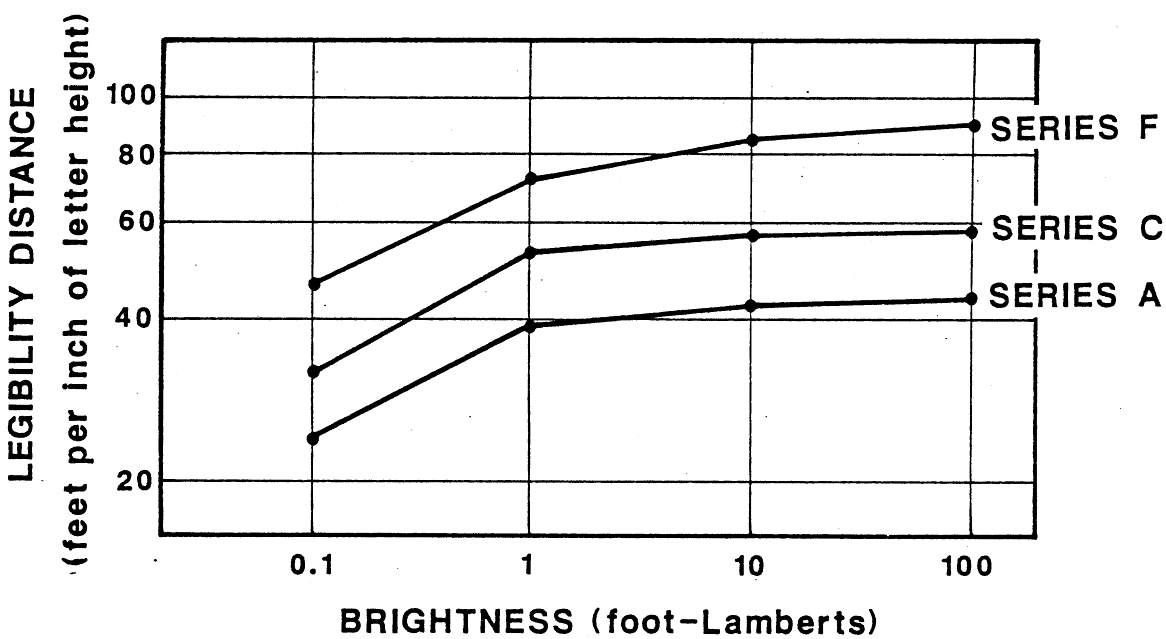

Figure 1. Brightness vs. legibility for different letter series.

Source: Sign Brightness and Legibility

As the size of the letters increase (Series A to F), the legibility distance increases for each brightness level observed. The primary reason for this increase is that the size of the letter increases in width and stroke width as the series advances from A to F.

Another factor that has a significant influence on legibility is sign brightness. As the sign brightness increases from 0.1 to 100 foot-lamberts, the legibility distance increases. For the most part, Virginia presently uses encapsulated lens sign sheeting, which is one of the brightest materials being used and falls within the upper limits of the brightness as shown. However, irradiation also influences legibility, especially for the higher levels of brightness. Irradiation is the overglow or spreading of the bright background material over the black letters, causing them to appear narrower; it occurs at night when a driver whose eyes are adapted to a fairly low level of brightness encounters a sign of very high brightness.

Virginia uses a bright encapsulated lens sheeting for most signs, and there have been some questions concerning the effects of irradiation and the resulting detrimental influence on sign legibility.

It is known that sign legibility can be increased for bright sign materials by modifying the letter design. Letter modifications are permissible through the Manual on Uniform Traffic Control Devices (MUTCD), especially if standardized MUTCD designs are used. Providing good legibility for signs necessary to warn drivers of existing or potentially hazardous conditions is certainly desirable, and if sign modification can help the traffic engineer achieve this goal, it should be considered.

PURPOSE AND SCOPE

It is, therefore, the purpose of this study to investigate ways of increasing the legibility of signs with high background brightness levels. The modifications believed to increase legibility and considered for this study include: (1) an increase in letter series, (2) an increase in letter height, and (3) an increase in letter stroke width. The modifications found to be appropriate for signs in Virginia (considering legibility, cost, convenience, etc.) were identified. Research was limited to silver, yellow, and orange encapsulated lens sheeting materials.

Modifications were made within the standards for highway signs as specified in the MUTCD.

PROCEDURE

The procedure for conducting the project consisted of the following tasks:

1. A review of current literature (along with contact with various state agencies) was made for the purpose of investigating how various factors influence sign legibility for bright sign backgrounds. Such factors as visual complexity, glare, the age of the driver, sign color, along with design features including letter height, letter stroke width, and letter series were reviewed.

2. Using the information obtained in the literature survey, the feasibility of increasing the legibility of signs in Virginia was investigated. This was accomplished by considering the factors influencing legibility and investigating whether these could be incorporated into the standard design and fabrication procedures of signs in Virginia.

3. A small number of test panels incorporating some of the modifications were fabricated for observation. It was not, however, the intent of this research to investigate sign legibility through subject testing. Therefore, the signs were fabricated for the purpose of observation.

APPLICATION OF RESULTS

Providing good sign legibility is important, especially when signs are placed for the purpose of warning drivers of existing or potentially hazardous conditions. Studies have shown that because of overglow, or irradiation, at night, the lettering of signs fabricated with encapsulated lens sheeting appears to be narrower; consequently, it loses some of its legibility. Observations throughout the state confirm that some signs are not providing optimum legibility at night, especially those placed for work zone protection.

FACTORS INFLUENCING LEGIBILITY

The legibility of highway signs at night involves a complex relationship between the highway, vehicle, observer, and sign. This study is primarily concerned with increasing the legibility of encapsulated lens signs (bright background) on Virginia's highways. Prior to concentrating on specific problems and solutions, various factors that influence legibility will be discussed to better understand legibility, why Virginia has a problem, and what can be done about the problem.

Sign Brightness

The widespread use of retroreflective sign materials has resulted in signs that have excellent potential nighttime brightness. The degree of brightness depends on the type of retroreflective material, the environment (placement and surrounding luminance), car (position and headlight characteristics) and the observer (visual characteristics of the observer). Whatever the conditions, a certain amount of light is available for reading the sign.

Two research efforts(2,3) indicate that legibility is an inverted U-shaped function of luminance; however, one study(1) showed that for a black legend on a white background, optimal legibility was not reached at a luminance of 343.0 cd/m^2. Sivak went so far as to average all the luminance values for various studies using black legends on light backgrounds and came up with an average of 75 cd/m^2(4).

Olson presented data describing the relationship between sign luminance characteristics and legibility(5). Table 1 shows legibility distances as a function of background specific luminance for roadside signs having black legends in four different situations. No background luminance level is associated with optimum legibility in all cases. This research suggested that sign backgrounds have a substantial effect on sign legibility: there are gains in legibility associated with highly reflective backgrounds. It was also noted that for yellow and orange words, conspicuity was very important; therefore, high luminance may be favored.

Table 1

Legibility Distances (ft/in letter height) as a Function of Background Specific Luminance for Signs Having Black Legends in Four Different Situations

	Figure Number			
Background Specific Luminance (cd/ft-c/ft^2)	3 Roadside Low Beams	4 Roadside High Beams	7 Roadside Left Curve Low Beams	8 Roadside Right Curve Low Beams
5	37	44	33	32
10	41	47	37	35
30	45	48	42	40
50	47	47	45	43
100	48	43	48	45
150	48	--	49	47
250	48	--	49	48
500	46	--	49	49
1000	--	--	44	48

Source: Determine the Luminous Requirements of Retroreflective Highway Signing

Although there is variability among studies, this is understandable given all the possible variables associated with questions of the relationship between luminance and legibility. There is an optimum luminance; however, it can vary depending on which combination of variables is given or is available.

Since Virginia uses encapsulated lens sheeting, this study is limited to the combination of encapsulated lens sheeting and black legends. The encapsulated lens sheeting is considered highly reflective and generally provides good legibility.

Case reported in 1952 that for relatively bright sign materials, there is a spreading of light (called "irradiation") causing an apparent decrease in the spacing between letters(6). Allen and Straub illustrated in 1955 how high sign brightness can reduce legibility by showing a message of the same size and same letter series at optimum and high brightness(1). Figure 2 shows this reproduction. Irradiation is thought to be at least partially responsible for the problems with legibility in Virginia.

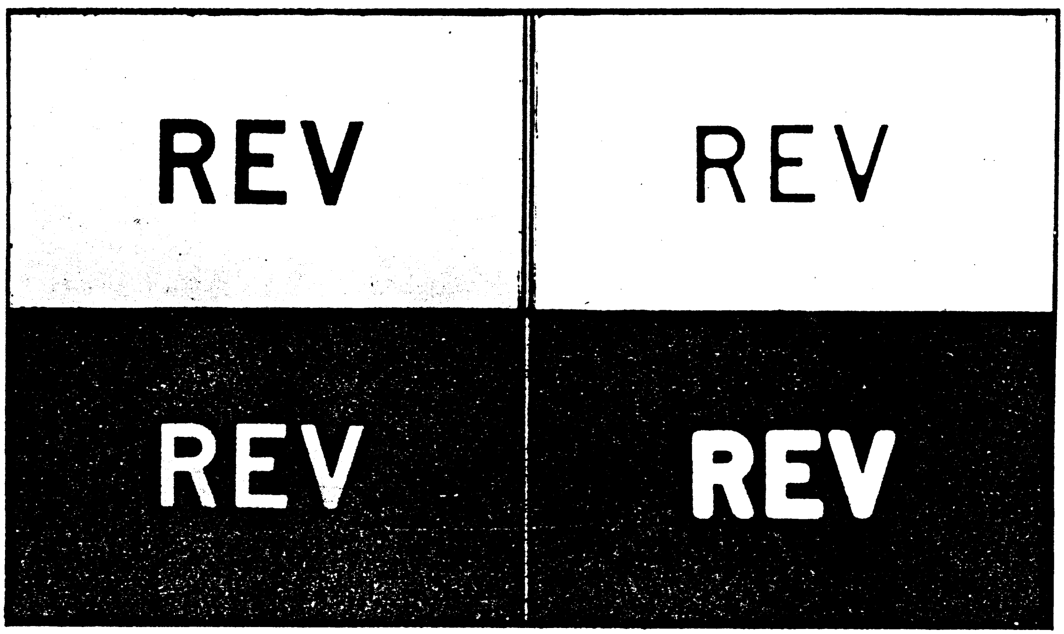

Figure 2. Appearance of signs of optimum and high brightness. Reference 1

Source: Sign Brightness and Legibility

Irradiation occurs at night when a driver whose eyes are adapted to relatively low levels of brightness encounters a sign of very high brightness. This could very well explain the problems witnessed around the state with sign messages being "washed out." When signs are close to the highway, as may be the case, for example, for warning signs or signs placed in conjunction with work zones, the amount of light striking the face of the sign from passing vehicles can reach levels that result in very high background luminance, thereby causing irradiation and a consequent decrease in legibility.

Target Value and Visual Complexity

Before reading a sign, the driver must be able to select the sign over the other sources competing for his attention at the particular time. The ability to select a sign, therefore, depends on the characteristics of the surroundings within which a sign is located.

In 1985, Mace(7) studied the luminance levels for conspicuity of yellow diamond warning signs for different levels of scene complexity at night. Figures 3 and 4 show the recognition and legibility performance, respectively, for different visual complexities and sign brightness. Data indicated that sign brightness increased the distance of both recognition and legibility. Although, low brightness signs might be acceptable in low complexity sites (based on predicted driver requirements), it was suggested that high intensity sheeting (or larger signs) may be needed in high complexity locations, particularly when speed limits are high and speed reduction or lane change maneuvers are required.

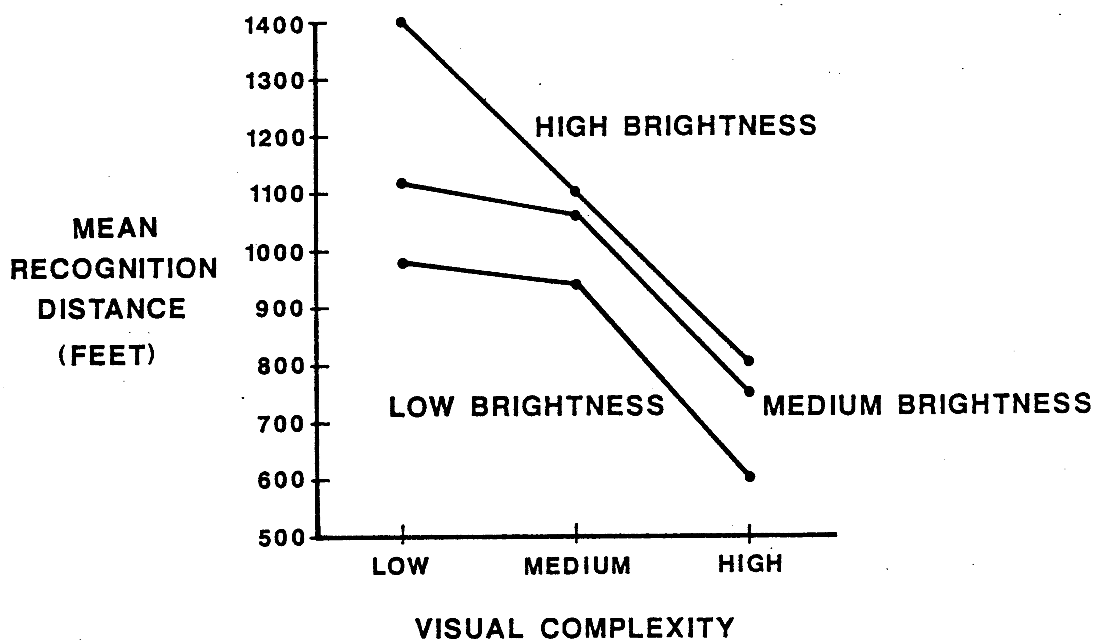

Figure 3. Recognition performance by visual complexity and sign brightness.

Source: Sign Luminance Requirements for Various Background Complexities.

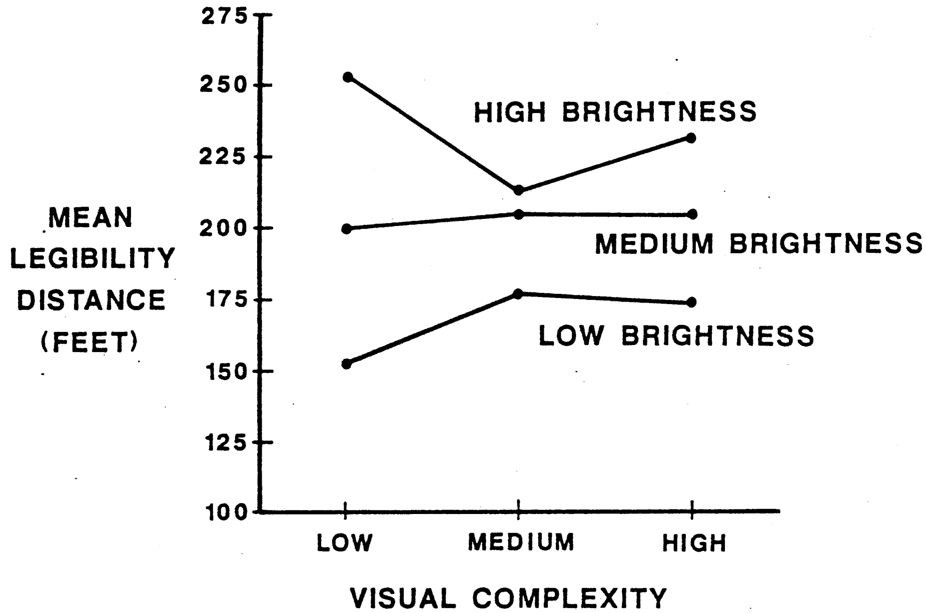

Figure 4. Legibility performance by visual complexity and sign brightness.

Source: Significance Requirements for Various Background Complexities.

Glare

Olson reported that environmental glare appears not to be a serious problem in terms of sign legibility(2). If significant sources of glare are located near the sign, the losses in legibility can be compensated for by increases in background luminance, which also increases conspecuity.

In addition to environmental glare, the sign itself can function as a glare source. Often construction zone warning signs are placed close to the roadway so that the vehicle lights shining on the bright sign materials can result in high luminance levels. The above study also suggested that highway signs at the highest luminance levels typically found normally, do not constitute a significant source of glare to drivers even in dark surroundings and that luminance levels could be substantially increased in many cases with no harm done.

It is noted that various comments heard from field personnel give the impression that there may be a problem with glare and that this can be reduced if the sign is positioned at a larger angle to the roadway alignment.

Age

Much is being said about the visibility needs of the old driver, especially since the percent of older drivers on our highway system is increasing.

Blackwell reported in 1980 that older drivers will generally be penalized in terms of visual performance potential if they are provided the same levels of task luminance as their younger counterparts(8). Furthermore, they will be additionally penalized whenever the method of providing task luminance is of lower "quality" in the sense that it involves luminance nonuniformities from point to point within the visual field surrounding the task. The relation between age and the relative effective overall light transmittance of the human eye is shown in Table 2. These values suggest that "if no allowance was made for observer age except to equate photons of luminous energy falling upon the retinal photoreceptors, levels of illuminance would have to be approximately doubled by observer age 55, and quadrupled by observer age 75 with respect to values which might be deemed appropriate for observers within the 20-30 year age range"(8).

Table 2

Relationship Between Age and Light Transmittance of the Human Eye

Age	Transmittance
25	1.000 (baseline)
35	.886
45	.691
55	.507
65	.369
75	.247

A study was conducted by Olson(2) that compared the recognition performance of younger and older subjects for white, yellow, and orange backgrounds of varying luminance with black legends (see Figures 5 through 7). Legend sizes correspond to a viewing distance of 6.0 m/cm (50 ft/in letter height).

These data indicate that much higher background luminance levels are required by the older subjects to achieve performance comparable to the younger subjects. In some instances, background luminance levels that result in improved legibility for older subjects are excessive for younger subjects. It was pointed out that legibility at high luminance levels may be limited by irradiation. Also, for older subjects, increases in sign background luminance mitigate environmental glare effects somewhat, as do increases in surround luminance.

Color

For white, yellow, and orange reflectorized backgrounds, Olson treated the legibility distance as a function of background luminance(2). The curves plotted in Figure 8 show that a white background required the lowest luminance in order to achieve a given performance level, followed by orange and yellow, but the differences are not very great. Forbes reported similar results, however, he found yellow better than orange(9). Forbes also reported that the effects of luminance on color recognition at five ambient levels showed the need to increase luminance and contrast as ambient levels increase.

Environmental Effects

Environmental effects on signs may be categorized as short term and long term. The effect of rain, dew, and frost are short term, whereas the deterioration caused by sun and weather are long term. Road dirt, exhaust residuals, water spray, etc., from vehicles can also degrade reflective properties.

Louisiana observed that the performance of encapsulated lens sheeting is not as adversely affected by dew, rain, or fog as compared to the enclosed lens sheeting(10).

Discussion of Factors Influencing Legibility

The above information gives a good overview of the factors affecting the legibility of highway signs made with white, yellow, and orange reflectorized sheeting materials. Most of these factors point to the advantages of increasing the luminance for improved legibility; however, there are situations where high luminance is detrimental to legibility because of irradiation.

At present, the design and placement of signs with background reflectorized sheeting materials is regulated by the MUTCD and state specifications. There are many instances in which a sign may not be positioned for optimum legibility because of the many variables. Theoretically, if a sign were designed for specific locations using information relative to roadway geometrics, light reaching the sign, driver characteristics, etc., it could be better designed and placed to help optimize legibility. However, this information, although available, cannot be realistically assembled and applied.

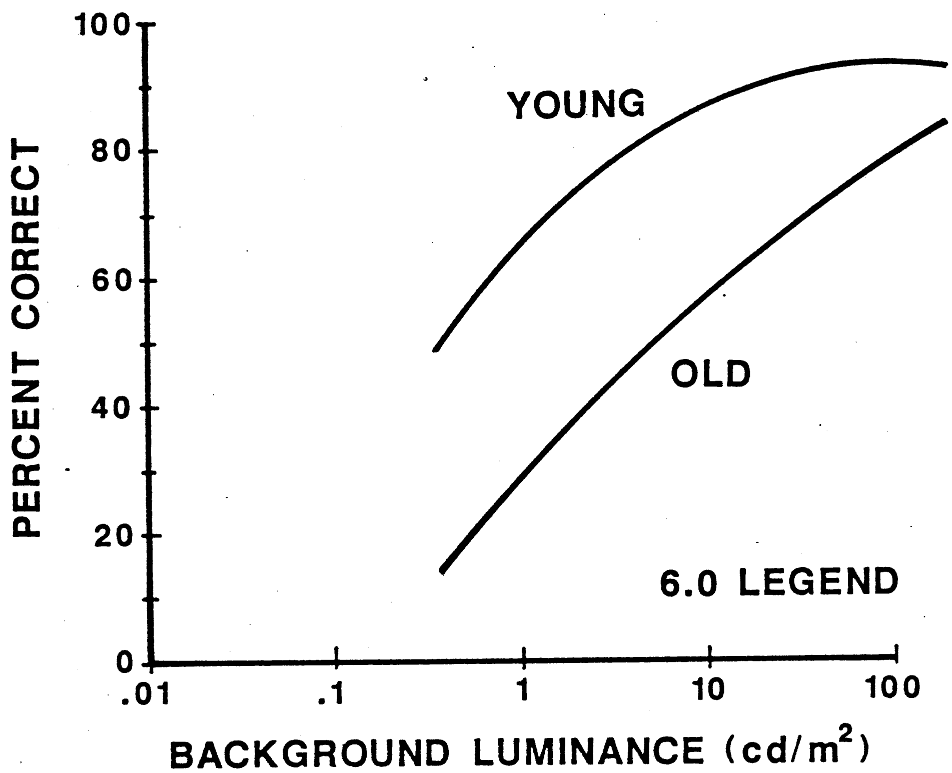

Figure 5. Percent correct responses as a function of background luminance and legend size for older as compared with younger subjects. White background, dark surround (0.034 cd/m²).

Source: Variables Influencing the Nighttime Legibility of Highway Signs.

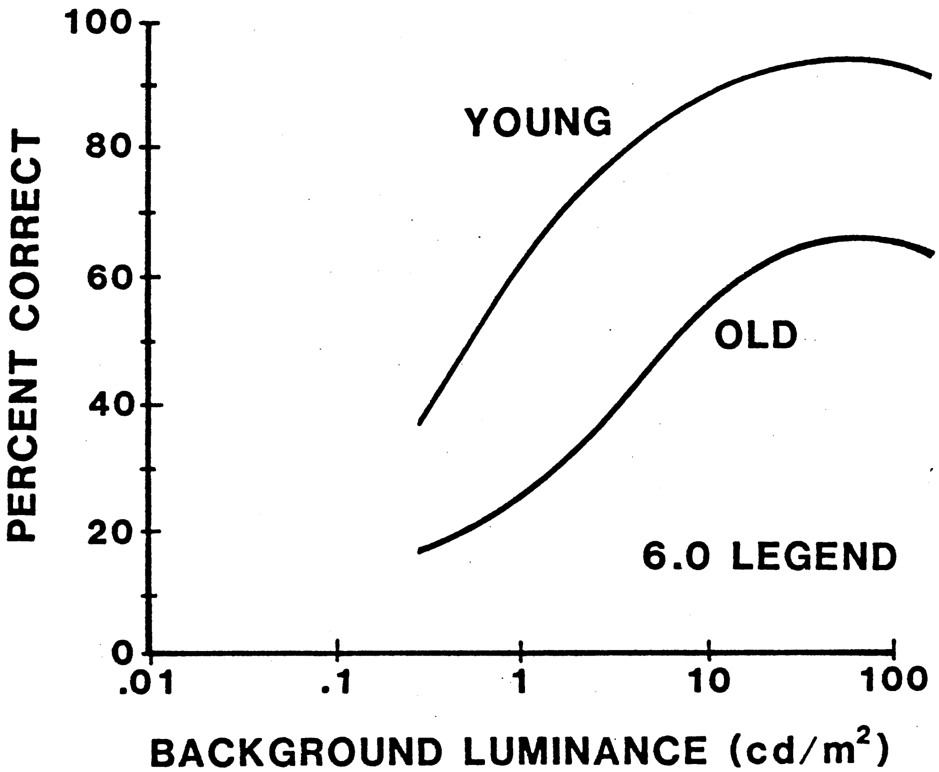

Figure 6. Percent correct responses as a function of background luminance and legend size for older as compared with younger subjects. Yellow background, dark surround (0.034 cd/cm²).

Source: Variables Influencing the Nighttime Legibility of Highway Signs.

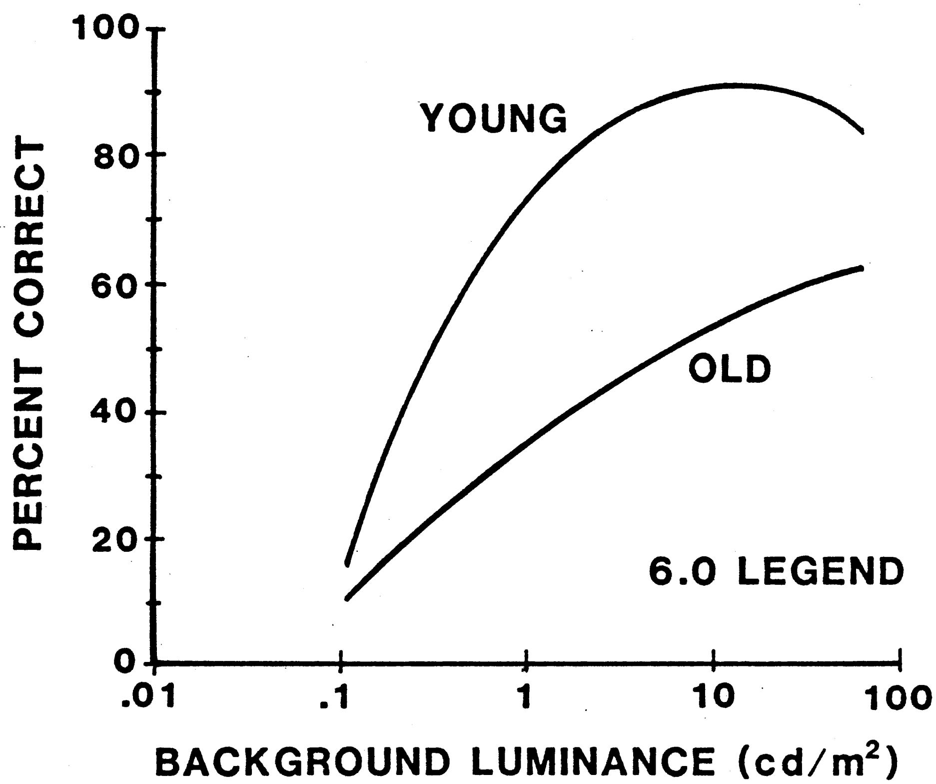

Figure 7. Percent correct responses as a function of background luminance and legend size for older as compared with younger subjects. Orange background, dark surround (0.034 cd/m²).

Source: Variables Influencing the Nighttime Legibility of Highway Signs.

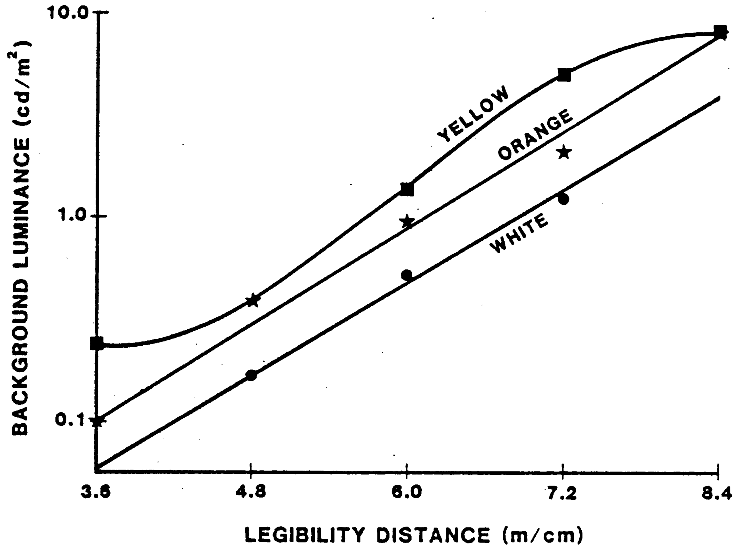

Figure 8. Background luminance required for 85% performance by young, normal subjects. Black legend on various backgrounds.

Source: <u>The Nighttime Legibility of Highway Signs as a Function of Their Luminance Characteristics</u>.

Given the Department's standard design procedures and the highway environment (which includes the vehicle, driver, etc.), apparently very little can be done to enhance legibility relative to sign design and placement. Therefore, the remaining factor available for possibly increasing legibility for bright sign background materials is sign message design, which I will now discuss.

DESIGN

Outside of sign background sheeting materials, the main components of sign design involve the overall size and design of the message. Although the larger a sign, the more legible it becomes, the overall dimensions are generally standardized for different highway types and will not be discussed here. Message design consists in trying to optimize the message size within the given sign dimensions to achieve the greatest legibility. In an attempt to investigate the different possibilities, changes in letter series, letter height, message placement, and letter stroke width were tried. The following discussions explain the rationale and procedures used to determine the feasibility of various modifications.

The state of Virginia uses encapsulated lens sheeting material; because of its high brightness, irradiation is thought to be primarily responsible for problems with legibility. Since irradiation causes black letters to appear smaller, it was believed that larger or wider letters would help legibility. Decreasing the influence of irradiation involved two procedures: increasing letter size by increasing the letter series and/or letter height, and increasing the letter stroke widths.

Increase in Letter/Message Size

The feasibility of increasing the size of sign messages was determined by going through the MUTCD and taking all the warning, work zone, and selected regulatory signs with word messages and determining if an increase in letter size was possible. Few of the messages could be increased in size using the MUTCD recommended letter series and heights since the letter dimensions and spacings have been optimized for the particular sign dimensions. However, keeping in mind that irradiation causes black letters to appear smaller and the MUTCD recommended designs do not take this into consideration, it was believed that the spacing between letters could possibly be decreased which would allow a larger letter to be used.

Case(6) found that black letters on white background are most legible when the letters are closely spaced. He noted that irradiation might be the explanation for this. Subsequent research by Anderton(11) on Australian Standards of letter spacing for "series D" alphabet and high intensity reflective sheeting showed that although narrow letter spacing does significantly reduce legibility distances, the effect is not large enough to be of great practical importance. A "narrow" letter spacing was approximately 98 mm wide for a 640 mm letter height. If the Australian series D letter is the same as our MUTCD series D, narrow spacing is approximately equal to the letter stroke width.

For the purpose of investigating the feasibility of increasing the letter/message size on signs by decreasing the spacings, the following assumptions were made:

- Average spacing between letters and letters and the border was equal to the stroke width. It is estimated that for the signs investigated, the average MUTCD recommended spacing between letters was approximately 25% wider than the stroke width.
- Spacing between messages on the same line was twice the stroke width.
- Vertical spacing between lines was 80% of the MUTCD recommended spacing.

An increase in letter height and letter series was tried for 17 signs (it is noted that the MUTCD had recommended a reduction of spacing for 10 of the warning- and work-zone signs; therefore, these were not considered) by determining whether the modified message would fit into the available area. Of the 27 signs reviewed, only 3 or 4 could possibly be modified by increasing the letter series and/or letter height.

Because of the lack of information concerning the effect of different letter/message spacing on legibility for black letters on high brightness sheeting, it is not believed that the few possible modifications noted above would warrant any recommendations.

Many questions arise when considering letter/message spacings. For example, what is the consequence of decreasing the spacing from 20% to 40% between letters as recommended by the MUTCD on legibility? Also, how does irradiation influence the MUTCD recommended spacing between letters and messages?

Modification of Letter Stroke Width

The modification of letter stroke width seems to hold promise for increasing sign legibility. For high levels of luminance, irradiation causes black letters to appear smaller, and this problem may be helped by altering the letter stroke width.

In 1950, Kuntz conducted a study to establish an optimal ratio between height and stroke width(12). Figure 9 shows the average legible distance for black numerals on white background. As noted, the curve peaks at a ratio 5.0:1. The legibility as related to brightness for different H/S.W. is shown in Figure 10. There is a trend for the average legibility distance to increase with an increase in illumination from 3 to 31 footlamberts. Also, optimal H/S.W. is approximately 5.0.

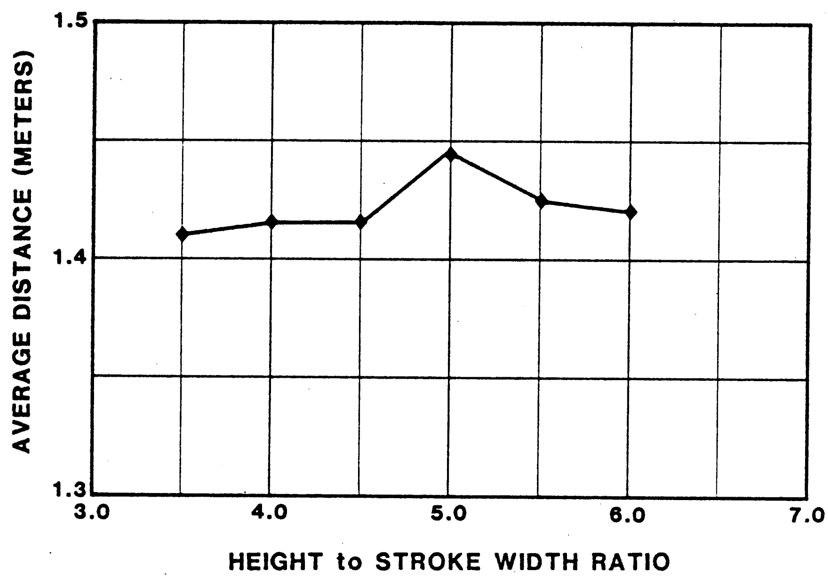

Figure 9. Average legibility distance for numerals as a function of height/stroke-width ratio and background.

Source: Legibility of numerals: the optimal ratio of height to width of stroke

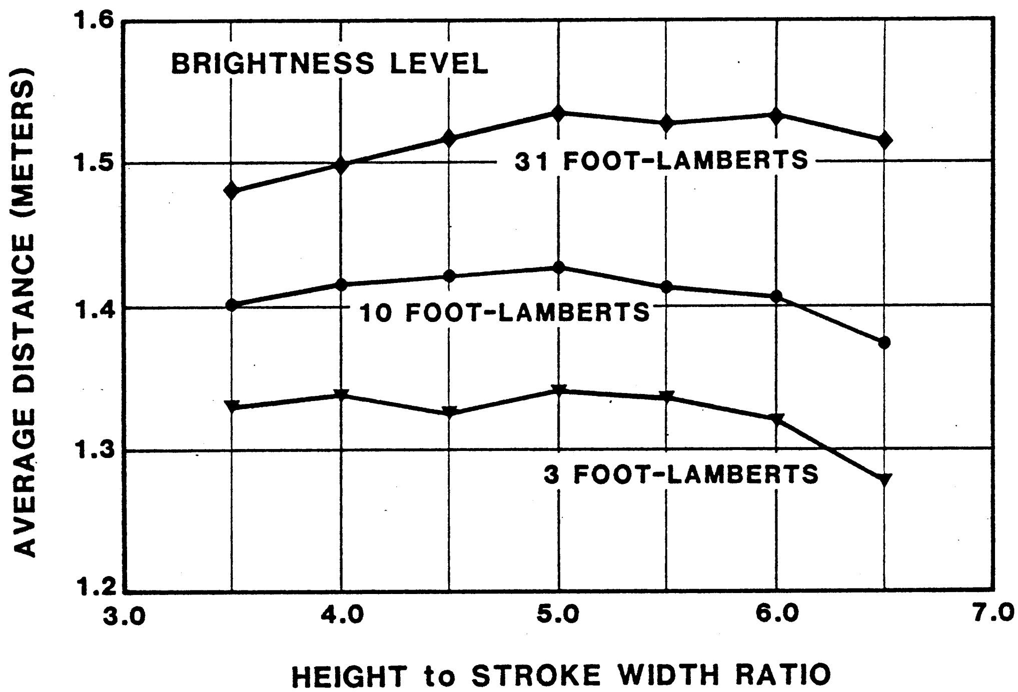

Figure 10. Average legibility distance for numerals as a function of height stroke-width ratio and brightness.

Source: Legibility of numerals: the optimal ratio of height to width of stroke

Hind studied five stroke widths, five levels of luminance, five numeral sets, and four distances and concluded that "for black numerals the strokewidth/height (SW/H) interacts with the visual angle and the greatest legibility is for SW/H = 0.167"(13). Figure 11 shows the effects of distance, luminance, and SW/H ratio on recognition of black numerals. Although it was concluded that optimum legibility was obtained when SW/H ratios are less than 0.167, it is interesting to note that the percent recognized is generally the highest for the highest luminance and that for D_3 (distance), the percent recognized is still increasing at the 0.167 SW/H level.

Figure 12 shows the effect of font and SW/H on the percentage of black numerals recognized. The percent generally increased for each numeral type as the SW/H increased and was still on the increase at the 0.167 level.

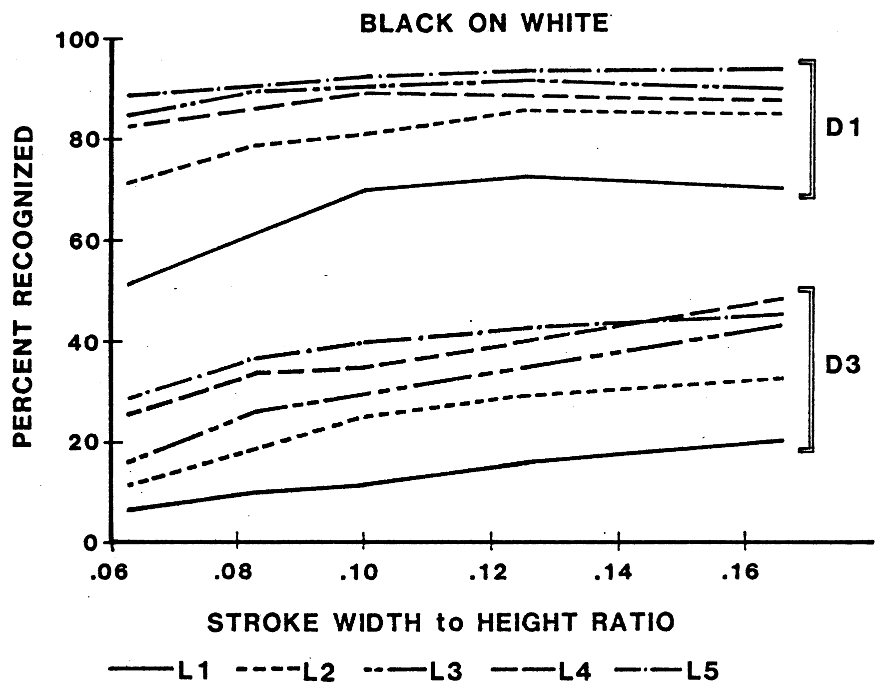

Figure 11. Illustration of the effects of distance, luminance and strokewidth/height ratio on recognition of black numerals.

Source: <u>Effects of level of illumination, strokewidth, visual angle and contrast on the legibility of numerals of various factors</u>.

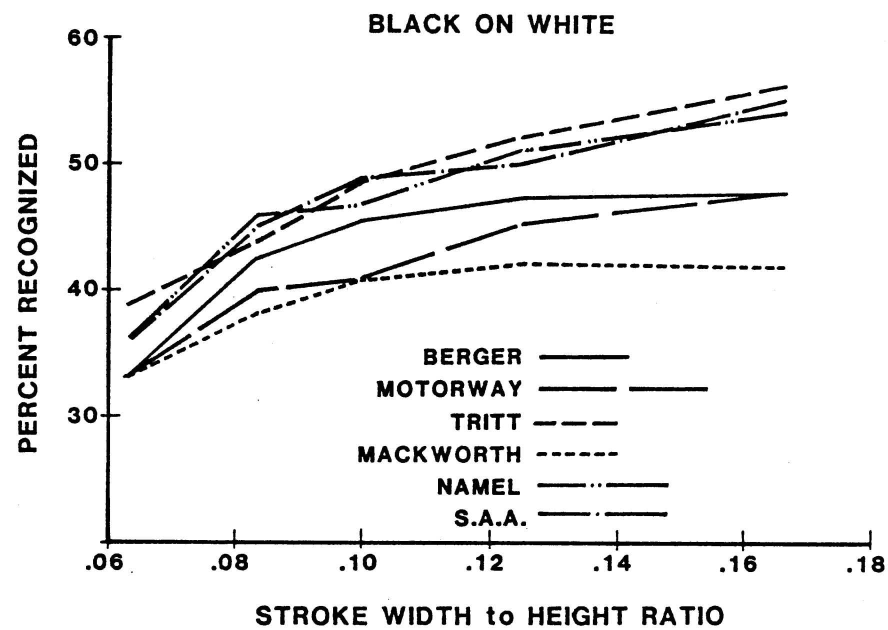

Figure 12. The effect of font and strokewidth/height ratio on the percentage of black numerals recognized.

Source: <u>Effects of level of illumination, strokewidth, visual angle and contrast on the legibility of numerals of various factors</u>.

The above research shows that for black lettering on bright reflective sheeting, increases in letter stroke widths have given better legibility.

The actual field use of sign messages with wide stroke letters goes back to tests run in California in 1950, whereas a standard series "E" letter alphabet with strokes widened (12-18% increase to correspond to that deemed most satisfactory from experience of the Highway Division) was used on the highway. Approximately 12 years ago, Nebraska changed from enclosed to encapsulated lens sheeting. They used a modified D series letter because the more reflective background of the sheeting produced a halation effect on the message. The decision was made to compensate for the loss of legibility by increasing the stroke width approximately 20% but not the letter width or letter spacing.

Since the MUTCD design standards have already optimized the letter/ message size and spacing to fit most signs, any modification of letter stroke width would involve widening the stroke width without altering the letter width or height. This would require that the stroke width be widened to the inside of the letter as was done in California and Nebraska.

Modifying the letter stroke width without changing the letter width or height could improve the legibility of signs. This strategy should be implemented in Virginia. An increase of approximately 18% is recommended. This corresponds to a SW/H of 0.167 for "C" series and 0.184 for "D" series.

Cost of Modification

Modification of a letter increases the stroke width to the inside only so that the letters occupy the same rectangle of space. The primary cost is for the fabrication of the modified letters, which are then positioned to form the desired message. Once the layout is complete, a transparency is made of the sign. The transparency is then used to make a silk screen and sign. Artwork for producing the modified letters is available, and allowing an hour to produce the modified sign layout and transparency, the cost would be approximately $50 per sign transparency.

There are approximately 20 warning and worksite protection signs which could be modified, and with the different sizes recommended by the MUTCD for standard, expressway, and freeway designs, this number increases to about 45. Most signs are either series C or D with letter heights ranging from 5 in to 8 in.

Once the transparencies are available to the district sign shops, signs with modified messages could be fabricated as needed and would replace the signs in the field according to normal replacement procedures (i.e., when the sign no longer serves its intended function).

OBSERVATION OF TEST SIGNS

The potential benefit in terms of added legibility resulting from letter modification by increasing the stroke width is not known, and it is not within the scope of this study to conduct experiments for this purpose. However, as stated in the procedure, a small number of test signs were fabricated for general observations.

Various signs were made to observe some of the modifications discussed above. A list of the modified signs is in Table 3.

Table 3

Signs Observed

	Test Panel	Color	Modification
I.	Right Lane Closed Ahead	Orange	6C standard SW/H = 0.14
	Right Lane Closed Ahead	Orange	6C modified SW/H = 0.20
	Right Lane Closed Ahead	Orange	6D standard SW/H = 0.14, spacing reduced to accommodate message
II.	Road Closed	White	8D standard SW/H = 0.14
	Road Closed	White	8D modified SW/H = 0.20
III.	Right	Orange	8D standard SW/H = 0.14
	Right	Orange	8D modified SW/H = 0.20
	Right	Orange	8D standard SW/H = 0.14, spacing reduced 40%
	Right	Orange	8D modified SW/H = 0.20, spacing reduced 40%
	Right	Orange	8D modified SW/H = 0.20, spacing = stroke width

The test signs were erected on an unopened portion of interstate highway and were positioned 5 ft above the road surface. Observations were made from two distances (in an automobile) during the day and at night. At night, the signs were viewed under two light conditions: (1) no surrounding or vehicle lights and (2) opposing vehicle lights adjacent to the signs. High and low headlight beams were used.

Each of six observers were asked to designate which sign was the most legible for the different viewing conditions. The subjects were members of the Virginia Department of Transportation and ranged in age from 28 to 55 years. Two age groups were selected: 28-32 years (3 subjects) and 48-55 years (3 subjects).

These signs were fabricated and viewed to allow casual observations of various modifications, and the results are not statistically significant. The review did reveal several observations, which are listed below.

Right Lane Closed Ahead (black/orange): Both age groups preferred the modified sign for all conditions for nighttime. Daylight performance was split between the standard and modified signs.

Right/Right/Right (Black/Orange): The younger group liked the standard lettering, whereas the older group preferred the modified lettering (spacing equal SW). Observations were made in daylight and at night. There were some instances where the choice was influenced by the distance from the sign for the younger group. The older group was consistent in its choice.

Road Closed (black/white): The younger group preferred the standard sign, whereas the older group leaned toward the modified for both day and night.

It is not known if the observations simulated or were indicative of the problems noted with sign legibility relative to irradiation. For example, it seems that irradiation is a function of sign luminance, which is influenced by many factors that may not have existed in the test (e.g., influence of other headlights in the traffic stream, both traveling in the same direction and opposing the motorist).

The many variables that influence the choice and legibility of signs would require a more controlled test, including the light conditions, geometrics, etc., and the number, age, etc., of subjects.

The demonstration generally indicated that the younger observers were comfortable with the standard design, whereas the older group mostly preferred the modified letters. It is the author's opinion that the modified design was best since it provided better target value and legibility because of the bolder message.

CONCLUSIONS AND RECOMMENDATIONS

There are numerous variables that influence the legibility of signs; however, many of these are set as a result of the highway environment in which the sign is placed, and very little can be done to enhance legibility for these given conditions. There are some factors, however, that pertain to sign fabrication and message design that can be changed to influence legibility. The literature indicted that it was generally advantageous to increase luminance for increased legibility; however, in some instances, high luminance causes sign irradiation, which is detrimental to legibility. Since Virginia uses high intensity reflective sheeting, it is believed that irradiation is one of the primary causes of problems observed in the field with legibility. Various means of combating irradiation include changing the letter stroke width, increasing the letter series and/or letter height, and changing the message placement.

If the MUTCD standards are adhered to, the most feasible change is a modification of the letter stroke width (increased to the inside only) so the letter has a wider stroke width yet occupies the same rectangle of space. This tends to offset the detrimental effects of irradiation, which causes an apparent decrease in letter stroke width.

It is recommended that the state modify the letter design for selected signs by increasing the stroke width (inside only) for series C and D letters by approximately 18%. It is estimated that 40 to 50 warning, construction, and maintenance signs should be modified. The cost of providing transparencies of the modified designs to the district regional sign shops is $6,000 to $8,000. Because of the potential benefit of enhancing the legibility of signs in critical areas, this is a worthwhile investment for the Department.

ISSUES FOR FURTHER CONSIDERATION

During the course of this study, various questions arose relative to legibility as a function of letter/message design. There seems to be a lack of information relative to the effect of different letter/message spacings on legibility for black letters on bright reflective sheeting. Also, what is the consequence of decreasing the letter spacing from 20% to 40% for many of the warning/work zone signs as specified in the MUTCD? How do the different letter stroke widths and spacings along with the spacing between words (horizontally and vertically) influence the sign legibility for older drivers?

Because of the problems associated with the legibility of word messages, especially those with small letters and orange/yellow background sheeting, further thought should be given to the possibility of using symbol signs for some of our present word message signs. Jacobs concluded that the average 50% threshold legibility distance for symbolic signs is about twice that for alphabetic signs for all levels of visual acuity(14).

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