Sign Legibility

The Impact Of Color And Illumination

UNITED STATES SIGN COUNCIL

RESEARCH CONCLUSIONS / PENNSYLVANIA STATE UNIVERSITY

SIGN LEGIBILITY

IMPACT OF
COLOR AND ILLUMINATION
ON TYPICAL ON-PREMISE
SIGN FONT LEGIBILITY

A Research Project of the

UNITED STATES SIGN COUNCIL

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EXECUTIVE SUMMARY

OBJECTIVES

This study assessed the performance of four nighttime illumination technologies commonly used by on-premise sign advertisers. These illumination technologies were field tested at night and during the day with different combinations of text and background color. The primary research objective was to determine the impact of the technologies and sign colors on legibility distance. The rationale for this is that poorly visible advertising signs can overload a driver's cognitive and perceptual resources, which can result in erratic driving maneuvers such as inappropriate rates of deceleration and untimely lane changes. Two commonly used on-premise sign letter styles were used on the test signs. The study goal was met by (1) determining recognition and legibility distances for each font, color, and illumination technology combination under investigation during day and night conditions; and (2) by using the recognition and legibility distances to determine the time available for a driver to read a sign's message at various traffic approach speeds.

The overall goal of this study is to provide useful information to sign design practitioners, land use planners, and highway engineers. Such information includes desired legibility distances that provide adequate reading time for a driver, and the effects of various sign characteristics (e.g., illumination technology and color) on sign legibility. Thus, the results can be immediately applied to on-premise sign design.

The study revealed that for both recognition and legibility distances, younger subjects (ages 30-45) outperformed older subjects (ages 65 and older). These findings were expected based on the fact that the average (mean) visual acuity for younger subjects was significantly better than that for older subjects. No significant differences were found in average recognition and legibility distances based on gender.

Research findings also indicated that the test signs performed significantly better during daytime viewing than during nighttime viewing. This finding held for both recognition and legibility distances. Further, the performance difference was not a function of subject visual acuity as the average acuity for daytime subjects was not significantly different from that for nighttime subjects.

Under investigation were four illumination technologies:

- External illumination,
- Internal illumination with only text illuminated on an otherwise opaque background,
- Internal illumination with both text and background illuminated, and
- Neon.

Complete comparisons of illumination technology effects were not possible because of the presence of different stroke width-to-height ratios for sign text. In general, external illumination performed the poorest. Internal illumination with opaque and translucent backgrounds outperformed external illumination for both daytime and nighttime viewing. Also, neon illumination outperformed external illumination during nighttime viewing, though not during daytime viewing.

Four text and background color combinations were utilized in the study:

- black text/white background,
- yellow text/green background,
- white text/black background, and
- red text/black background.

Certain comparisons of color effects on sign legibility were confounded because of varying stroke width-to-height ratios in the sign text. Further, not every color combination was used with each illumination technology. However, despite these restrictions, some key information was gleaned from the study results. In general, positive contrast signs outperformed negative contrast signs for both recognition and legibility distance, especially during nighttime viewing. Further, when considering neon illumination, white text outperformed red during daytime viewing, but no significant difference in performance was found during nighttime viewing.

Two font styles, Helvetica and Clarendon, were selected for use in this research study. Both of these fonts are typically used in the on-premise sign industry. No significant difference in font performance was observed in the study. Unconfounded comparisons were impossible because of the variety of stroke width-to-height ratios and kernings. In general, the Clarendon font had a lower stroke width to height ratio than that for a companion Helvetica font in numerous comparisons. This difference in ratio could possibly account for the lack of performance difference.

The secondary research objective of this study was to determine the time available for a driver to read a sign message at various approach speeds. These available times were based on the measured recognition and legibility distances and were calculated for the average and 15th percentile distance for each test sign. Speeds considered ranged from 25 mph to 55 mph in 5 mph increments. Calculations were made for overall viewing, daytime, and nighttime viewing conditions, and were then compared to a 5.5 sec minimum required reading time to determine adequacy. The results from the available reading time analyses concur with the previous findings from the study. In general, external illumination performs poorly and most often failed to provide adequate reading time at speeds of 30 mph or higher. Those signs which performed the best were internally illuminated signs with positive contrast designs. Neon also performed well at night. Also, assuming a 15th percentile distance significantly reduces the number of signs that can provide sufficient reading time at various speeds. All signs tested in this study had a 6-inch letter height.

Many factors contribute to sign legibility and detectibility, most of which interact with each other. As with similar research, this sign legibility study made various basic assumptions regarding on-premise signs. These assumptions included:

1. The sign is perpendicular to the observer's line of sight.
2. The sign has five or fewer critical elements.
3. The observer is alert and looking for the sign.
4. The observer is not familiar with the sign.
5. The observer has 20/40 or better visual acuity.
6. Sign copy is alphanumeric.
7. Sign copy is displayed in lower case.
8. Copy is not abbreviated.

The report discusses each assumption, additional sign variables, and provides design recommendations based on the study results.

1. BACKGROUND

On-premise commercial signs play an important role in the driver way-finding task. Well-placed and well-designed, properly sized, commercial signs can guide a driver toward a selected destination with minimal attentional demand. However, poorly visible advertising signs can overload a driver's cognitive and perceptual resources, which can result in erratic driving maneuvers such as inappropriate rates of deceleration and untimely lane changes.

As an integral part of the navigation task, on-premise commercial signs are a necessary traveler aid (King and Lunenfeld, 1971), often as important as highway guide signs for conventional road navigation. This relationship between signing for highways and signing for businesses is accepted by the highway signing community, as indicated by the recent addition of tourist-oriented directional signs (TOD's) and logotype signing to the roadway environment. However, the visibility of advertising signs is frequently determined not by human-factors researchers, visibility experts, or traffic engineers, but by local planning and zoning officials without specialized training in these relevant fields. Regulations governing advertising sign visibility characteristics are often based on arguments for improved aesthetic appeal and vague safety claims. Such characteristics include means of illumination, lateral and vertical offset, typeface style, color, and sign size. A need clearly exists to determine the effects these characteristics have on on-premise sign visibility and traffic safety from a scientific perspective.

For an on-premise sign to be visually effective, it must be first, detectable and second, readable. For an on-premise sign to be maximally efficient in terms of visibility, it needs to be readable at a minimum distance at which a driver can process the sign's content and respond to the sign's information in a safe manner. This distance is the minimum required legibility distance (MRLD). However, a driver must first detect a sign before he can read it. This sign detection is directly associated with sign conspicuity, which is a function of a driver's ability to detect a sign, regardless of its placement within the visual field (Mace, Garvey, and Heckard, 1994). However, from a visibility standpoint, a sign does not need to be detected at a distance greater than MRLD. A common argument is that it is pointless for a driver to be able to see a sign but not read it, and such a situation might result in a driver disregarding the sign before he can read its message. Therefore, MRLD drives the minimum required detection distance (MRDD).

Many factors contribute to sign legibility distance. One major factor is letter style or font. Most research on font legibility distance has been funded by state and federal sources. Thus, assessing letter styles' effects on sign legibility has been limited by the government's desire to keep the font simple and unembellished, such as with sans-serif alphabets. However, font choice in the commercial signing community is not limited to these alphabets. While an extensive font choice allows for creative sign designs, it also creates problems for sign designers, sign purchasers, and ordinance writers, as they have no information of the impact of font size on sign legibility. Virtually no legibility distance data exist for the vast range of fonts used in commercial signing.

Other important factors that affect sign visibility are sign color, color contrast, and nighttime illumination techniques. Nighttime illumination assists sign visibility, but no research has addressed the impacts of the unique illumination technologies used by the commercial sign industry and how these lighting techniques interact with font and sign color. Thus, it is not known how these technologies impact the legibility of on-premise signs. This project focuses on determining the impact of illumination and color on the legibility of typical on-premise sign fonts.

2. RESEARCH OBJECTIVES

This study assesses the performance of four nighttime illumination technologies commonly used by on-premise sign advertisers. These illumination technologies were field tested at night and during the day with different combinations of text and background color. The goal was to determine the impact of the technologies and sign colors on legibility distance. Two commonly used on-premise sign letter styles were used on the test signs. The study goal was met by completing the following two objectives:

- Determine recognition and legibility distances for each font, color, and illumination technology combination under day and night conditions; and
- Given these recognition and legibility distances, determine the time available for a driver to read a sign's message at various traffic approach speeds.

The overall goal of this study is to provide useful information to sign design practitioners, land use planners, and highway engineers. Such information includes desired legibility distances that provide adequate reading time for a driver, and the effects of various sign characteristics (e.g., illumination technology and color) on sign legibility. Thus, the results can be immediately applied to on-premise sign design.

3. FIELD RESEARCH

OVERVIEW

As noted previously, this study investigates the performance of illumination technologies commonly used with on-premise advertisement signs. Specifically, the study addresses how four typical illumination technologies impact sign legibility under various conditions. The test conditions include four combinations of text and background color and two typical text styles commonly used in the on-premise sign industry.

The study was a daytime and nighttime field investigation where the subjects were driven around a 1-mile test track. Five signs capable of displaying all available illumination, color, and font combinations were located at five separate stations along the track. Each sign had three words. The subjects were first asked to find the lower-case target word "blythe" as soon as it became readable. This target word, chosen because of its unique footprint or pattern, appeared on each sign. Subjects were then asked to read one of the two lower-case distractor words as soon as one became readable. Each of the two distractor words on each sign had a footprint different from that of "blythe". The measures of effectiveness were: (1) the threshold recognition distance for the target word, or the furthest distance at which a subject was able to correctly identify the target word's location on the sign (e.g., top, middle, or bottom); and (2) the threshold legibility distance for one of the distractor words, or the longest distance at which a distractor word could be read correctly.

The use of a recognition task is based on research that has shown that legibility distance increases with the degree of familiarity (Forbes, Moscowitz, and Morgan, 1950). Thus, the target word affords the collection of primed legibility distance for the target word as well as true legibility distance for the unfamiliar distractor words. All words used consisted of lower-case letters to reduce the likelihood of word recognition based solely on the larger initial capital. Also, the use of varying footprints reinforces the fact that recognition of word patterns is a key component of word recognition (Forbes, et al., 1950).

In each sign, the distractor words had footprints different from each other and from the target word so that the subject had to detect the footprint of the target word from three separate footprints.

SUBJECT RECRUITMENT AND SCREENING

Ninety-two subjects were recruited for research participation. All subjects were required to hold valid Pennsylvania driver's licenses. Forty subjects were from age 30 to 45, another thirty-two of the subjects were from 65 to 74, and the final twenty were 75 years of age and older. Of these 92 subjects, 53 were female and 39 were male. There are two reasons that the proportion of older subjects in this study is greater than that found in the driving population. First, older people exhibit a greater degree of between-subject variability in performance measures. Therefore, to obtain adequate statistical power in the study, a larger group of older subjects is needed. Second, because on average their vision is poorer, a larger proportion of older observers provides a more conservative (i.e., safer) estimate of sign visibility.

There is in this research, as always, a concern about a self-selection bias in the recruitment of older participants. This concern is manifested in a general fear that only the "best" older drivers will participate, providing an older subject sample biased toward good vision and unrepresentative of the older driver populations. To avoid this, older subjects were recruited from local senior groups. The groups were encouraged to enlist a high percentage of their membership. In past studies (Garvey and Mace, 1995; Mace, et al., 1994) the proposed researchers found this technique resulted in a representative test sample.

Prior to the field data collection, subjects were briefed on the procedures, foreseeable risks, benefits, and confidentiality of the study. They were then asked to sign an Informed Consent Form required by Penn State's Office for Regulatory Compliance. Subjects were also asked to undergo two vision tests. The tests included a standard Snellen Wall Chart for high-contrast, high-luminance visual acuity and a Vistech Contrast Testing System for high luminance contrast sensitivity. The results from these vision tests were recorded on a subject data sheet along with the conditions of the subject's viewing. The average vision test scores are shown in Table 1.

Table 1. Average field study vision test scores.

Testing Time	Group	Age	Standard Acuity	Vistech Contrast Testing System High Luminance				
Daytime (n=46)	1 (n=20)	39	20/18	61	115	125	67	22
	2 (n=16)	70	20/26	48	83	69	36	9
	3 (n-10)	78	20/30	42	71	47	22	11
Nighttime (n=46)	1 (n=20)	39	20/21	57	119	110	66	17
	2 (n=16)	70	20/28	49	71	50	16	6
	3 (n=10)	78	20/30	40	65	39	9	3

The subjects were asked to indicate if their vision was corrected and the type of correction, if applicable. Of the 92 subjects, 9 wore contact lenses, 65 wore glasses, and 18 had no visual correction. The breakdown of subject gender and visual correction by group and time of testing is provided in Appendix A. Also, the breakdown of subject visual acuity and contrast sensitivity by gender, visual correction, viewing order, and subject group is also provided in Appendix A.

VARIABLES

The first dependent variable, or measure of effectiveness (MOE), is the threshold distance for recognition of the target word. Threshold distance for word recognition is defined as the maximum distance at which a subject is able to correctly identify the target word's location on the sign: top, middle, or bottom. The second dependent variable is legibility distance threshold for the distractor words. Legibility distance is defined as the maximum distance at which a subject is able to begin correctly reading a sign message. The independent, or controlled, variables are font type (i.e., Helvetica medium, Clarendon), text and background color (sign-type dependent), and nighttime illumination technology (i.e., externally illuminated, internally illuminated [translucent and opaque background], and neon). This design results in 16 possible testing combinations. Table 2 illustrates the color schemes for each of the illumination technologies. The three color schemes for the externally illuminated sign allow for comparisons with each of the two color schemes for the other illumination technologies with the exception of neon.

Table 2. Sign color schemes.

Lighting Technology	External		Internal Opaque		Internal Translucent		Neon	
Text/Background	**T**	**B**	**T**	**B**	**T**	**B**	**T**	**B**
Color Scheme A	Black	White			Black	White		
Color Scheme B	Yellow	Green	Yellow	Green	Yellow	Green		
Color Scheme C	White	Black	White	Black			White	Black
Color Scheme D							Red	Black

SITE AND APPARATUS

The test site was the Pennsylvania Transportation Institute's (PTI) Bus Research and Testing Facility. This facility was designed and built in 1989 on the site of PTI's Transportation Research Facilities with funding provided by the Federal Transit Administration. The 5,042-ft-long, 15-ft-wide oval track is located 4 miles from PTI's offices. The track is equipped with seven overhead luminaires. To avoid artificially truncating legibility distances, the signs were placed along the two long tangent sections of the test track allowing for at least 1,200 ft of sign visibility for each sign. The overhead luminaires were illuminated during nighttime testing to simulate real-world viewing conditions.

The observation vehicle, a 1994 Ford Crown Victoria, was obtained from Penn State's Fleet Operations. It was equipped with a distance measuring instrument (DMI) to record observation distances throughout the research effort. The model used was the Nu-Metrics Roadstar 40. The DMI was interfaced with a laptop computer on which the data were stored for analysis. A button box containing three buttons was interfaced with the DMI and the laptop for use in recording distance data for analysis.

The signs were obtained from manufacturers and designers with the help of the United States Sign Council (USSC). A total of five signs were used, consisting of one each of the four different sign illumination types and an additional externally illuminated sign. Each sign was constructed of aluminum sheeting with a matte black finish. With the exception of the neon, each of the signs was capable of displaying the two letter styles and two or three color treatments, depending on the technology. The neon sign only displayed the Helvetica medium letter style. Each sign was bolted to 4-inch-by-4-inch posts and mounted at one of the five sign sites, at a 25-ft horizontal offset and a 5-ft vertical offset, both characteristic of on-premise signs. Each offset was measured to the edge of the sign structure. The locations of the test signs are illustrated in Figure 1.

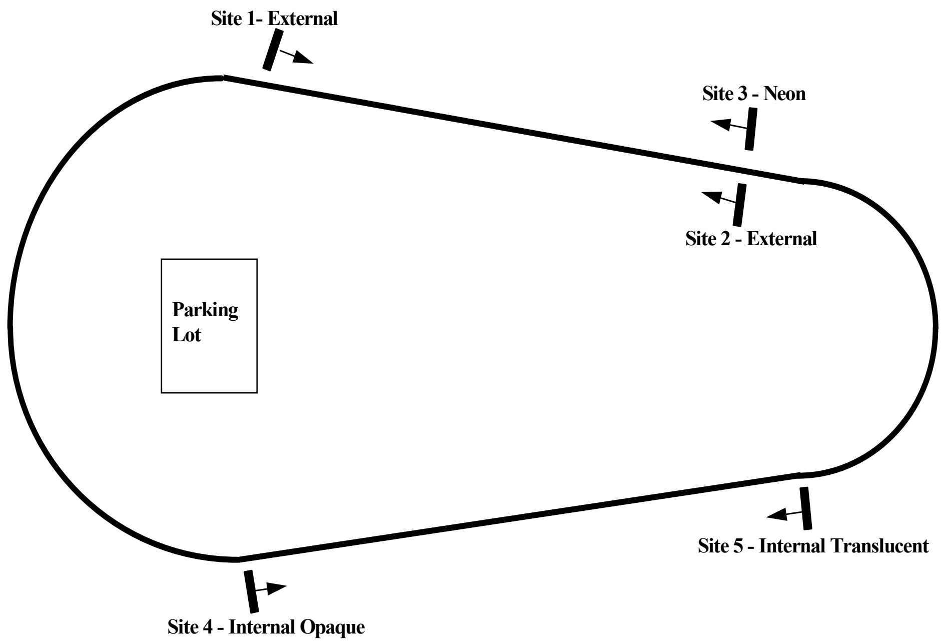


Figure 1. PTI test track and test sign locations.

SIGN DESIGN

Positive contrast signs have a light text on a darker background. Negative contrast signs have a dark text on a lighter background. The experimental design allowed for comparison of legibility distances between illumination technology types as well as between positive and negative contrast signs. With respect to color, the positive contrast signs had yellow text on a green background, white text on a black background, or red text on a black background. The negative contrast signs had black text on a white background.

The externally illuminated signs were lit with two 150-watt flood lamps placed at ground level, 7 feet from the base of the sign, and aimed at the center of the sign. The internally illuminated signs were lit with four 40-watt fluorescent lamps. The luminance of all materials was to manufacturer's optimum standards. Letter and background luminance levels were measured in the field using a Minolta LS-110 luminance meter with a 20-minute-of-arc aperture. The measurements were taken from a tripod set in front of each sign. Table 3 summarizes the text and background luminance levels of each sign type.

Table 3. Field photometric results.

Lighting Technology	External (cd/m^2)		Internal Opaque (cd/m^2)		Internal Translucent (cd/m^2)		Neon (cd/m^2)	
Text/Background	**T**	**B**	**T**	**B**	**T**	**B**	**T**	**B**
Color Scheme A	1.9	35.6			12.5	842.5		
Color Scheme B	7.3	1.1	437.2	0.98	447.6	145.5		
Color Scheme C	16.2	0.17	447.8	0.96			1534.4	3.32
Color Scheme D							1436.2	2.64

Each sign consisted of a 48-inch square panel with three six-letter lower-case words stacked one above the other in a 6-inch Helvetica medium or Clarendon font with a 4.25-inch loop-height lower case. A 6-inch border was around all text, and the vertical space between words was 10.5 inches to avoid crowding of words, minimizing the effect of location on word recognition and legibility. Upon inspection of the test signs, several letter stroke widths and kernings were observed. Table 4 provides a summary of font characteristics for each sign. These values were used in comparisons of recognition and legibility distances. The varying stroke width-to-height ratios restricted the number of direct comparisons that could be made in the research. These comparisons will be discussed along with other findings in a later section.

Table 4. Characteristics of test fonts.

Lighting Technology	Test Font	Text Color	Sign Number	Letter Height (in)	Stroke Width (in)	Stroke Width to Height Ratio	Kerning (in)
External	Helvetica	Black Yellow White	9 15 17	6/4.25 6/4.25 6/4.25	1.00 1.625 1.00	1:6.00 1:3.69 1:6.00	0.75 1.00 0.75
	Clarendon	Black Yellow White	1 7 18	6/4.25 6/4.25 6/4.25	1.25 1.50 1.25	1:4.80 1:4.00 1:4.80	0.75 1.50 0.75
Internal Opaque	Helvetica	Yellow White	2 11	6/4.25 6/4.25	1.625 1.625	1:3.69 1:3.69	1.00 1.00
	Clarendon	Yellow White	12 8	6/4.25 6/4.25	1.50 1.50	1:4.00 1:4.00	1.50 1.50
Internal Translucent	Helvetica	Black Yellow	3 16	6/4.25 6/4.25	1.00 1.625	1:6.00 1:3.69	0.75 1.00
	Clarendon	Black Yellow	14 5	6/4.25 6/4.25	1.25 1.50	1:4.80 1:4.00	0.75 1.50
Neon	Helvetica	White Red	13 6	6/4.25 6/4.25	0.50 0.50	1:12.00 1:12.00	2.00 2.00

Each subject saw 15 of the 16 sign combinations, each only seeing one of the neon signs (i.e., white or red). Within these 15 combinations, the target word, “blythe,” appeared in the each of the top, middle, and bottom locations five times. The distractor words used on each sign are from one of five categories based on the word footprint, each having an initial ascender. These categories are middle ascender, middle descender, ending ascender, ending descender, and no ascenders or descenders. Each type of word category appeared six times throughout the experiment. The sign design procedure, including samples of each sign, is provided in Appendix D. The signs for the study are shown in Table 5.

Table 5. Stimuli for field research.

Lighting Technology	Test Font	Scheme A	Scheme B	Scheme C	Scheme D
External	Helvetica	dorsey blythe helena	frazee larned blythe	blythe borger linsey	
	Clarendon	blythe fulton lompoc	harper blythe lowery	dassel lisman blythe	
Internal Opaque	Helvetica		blythe hosper dorset	dundee forney blythe	
	Clarendon		dupree lavaca blythe	lanark blythe donora	
Internal Translucent	Helvetica	blythe dunnel luning	hamlin blythe lorman		
	Clarendon	harney forgan blythe	blythe lamson delano		
Neon	Helvetica			hobson blythe durant	hobson blythe durant

PROCEDURE

According to availability, subjects were tested under daytime or nighttime viewing conditions. At night, the headlamps were set on low beam. The general procedure consisted of an experimenter driving each subject around the track, one at a time, at approximately 5 mph. To avoid the possible confounding effects of fatigue and/or learning, each subject viewed the signs in one of four sign orders, which are provided in Appendix C. Table 6 summarizes the number of subjects in each group that viewed each order, broken down by time of viewing (i.e., day or night) and the neon color they viewed (i.e., white or red).

Table 6. Summary of number of subjects by viewing conditions.

Viewing Time	Subject Group	Viewing Order by Neon Color							
		A		B		C		D	
		W	R	W	R	W	R	W	R
Daytime (n=46)	1 (n=20)	2	3	3	2	2	3	3	2
	2 (n=16)	2	2	2	3	2	2	0	3
	3 (n=10)	1	3	3	0	1	2	0	0
Nighttime (n=46)	1 (n=20)	3	2	2	3	3	2	2	3
	2 (n=16)	2	4	3	0	2	1	2	2
	3 (n=10)	1	1	2	2	1	1	1	1
Total Subjects	92	11	15	15	10	11	11	8	11
		26		25		22		19	

From the initial start point, the experimenter drove around the 1-mile track in a clockwise direction. When the first sign became visible, the subject was instructed to find the target word and identify its location on the sign. At the end of a correct reading, the experimenter pressed the button on the button box connected to the DMI which corresponded with the location of the target word (i.e., button 1 = top, button 2 = middle, button 3 = bottom). The experimenter then asked the subject to select and read one of the distractor words located on the sign. Having the subjects choose one of the distractor words to read reduced the likelihood of word or letter superiority influencing legibility distance. At the end of a correct reading, the experimenter pressed the button on the button box connected to the DMI which corresponded with the location of the distractor word the subject read (i.e., button 1 = top, button 2 = middle, button 3 = bottom). A correct reading consisted of the subject reading the word with at least four of the six letters correct. The experimenter pressed the first button on the button box when the vehicle was parallel with that sign. The difference between the first and third button pushes provided a threshold recognition distance measurement for that trial. The difference between the second and third button pushes provided a threshold legibility distance measurement for that test trial.

The dynamic measurement procedure used in the experiment gives relative performance data of the signs rather than absolute recognition and legibility distances. For instance, each test trial included the reaction times of the subject and the experimenter, both of which should be a constant of approximately 1 sec across all conditions. Hence, the distance traveled during these reaction times was included in the measurements. This procedure was used because it is a more realistic approximation of the driver's visual task. A static procedure involving discrete steps allows the subject too much time to stare or squint at the signs, adjust their focal length, or adapt to pupil dilation or constriction.

This procedure was repeated for each sign. One sign was visible at a time at each of the sign sites. Two signs were viewed for each loop around the track. During clockwise loops the test signs were shown at sites two, three, and four; during counterclockwise loops sites one and five were used (see Figure 1). A total of four clockwise and four counterclockwise loops were required to view all 15 conditions. The entire session took no longer than 45 minutes to one hour, including vision testing and debriefing.

ANALYSES AND RESULTS

The multiple-observer technique used in this study resulted in very little lost data. Of the 2,760 distance measurements collected during the course of this experiment, only 36 measurements, 1.3 percent of the data points, were lost. A statistical analysis of the pattern of these lost points indicated that their loss was random. Hence, imputation was used to fill in the missing data. With the assistance of the Statistical Consulting Center at Penn State, the missing data points were imputed using a program developed by Dr. Joseph L. Schafer of the Department of Statistics designed for this specific purpose (Schafer, 1996). The statistical analyses were then conducted on the imputed data. Appendix F contains the output from the field study statistical analyses.

Descriptive Statistics

The averages, standard deviations, and 15th percentiles for recognition and legibility distances were calculated for all signs for all viewing conditions. The 15th percentiles were calculated to establish the distance at which 85 percent of the subjects could read an individual sign. These distances are provided in Table 7.

Table 7. Average distances, standard deviations, and 15th percentiles.

Sign	Lighting	Text Color	Font	Recognition Distance (ft)			Legibility Distance (ft)		
				Average	SD	15th	Average	SD	15th
1	External	Black	Clarendon	413	150	229	263	84	169
2	Opaque	Yellow	Helvetica	558	170	363	320	97	221
3	Translucent	Black	Helvetica	433	139	278	247	78	172
5	Translucent	Yellow	Clarendon	536	166	351	311	87	219
6	Neon	Red	Helvetica	439	176	283	272	102	172
7	External	Yellow	Clarendon	433	145	286	290	101	184
8	Opaque	White	Clarendon	533	156	373	289	85	213
9	External	Black	Helvetica	398	134	233	252	79	173
11	Opaque	White	Helvetica	533	169	329	300	85	204
12	Opaque	Yellow	Clarendon	536	176	321	291	85	196
13	Neon	White	Helvetica	510	123	359	308	68	226
14	Translucent	Black	Clarendon	441	139	286	280	80	186
15	External	Yellow	Helvetica	437	144	282	260	85	158
16	Translucent	Yellow	Helvetica	556	159	380	314	90	221
17	External	White	Helvetica	397	162	230	248	79	158
18	External	White	Clarendon	448	139	285	220	68	141

The averages and 15th percentiles for legibility indexes were then calculated for all signs for all viewing conditions from the average and 15th percentile legibility distances. Legibility index is defined as the distance in feet at which a sign can be read for every inch of letter height; for example, a sign with a legibility index of 50 ft/inch (ft/in) would be legible at 50 ft with 1-inch letters, 300 ft with 6-inch letters, and 500 ft with 10-inch letters. As with the distances, the 15th percentile legibility indexes were calculated to establish the index at which 85 percent of the subjects could read a sign. These indexes are provided in Table 8.

Table 8. Average legibility indices and 15th percentiles.

Sign	Lighting	Text Color	Font	Legibility Index (ft/in)	
				Average	15th
1	External	Black	Clarendon	44	28
2	Opaque	Yellow	Helvetica	53	37
3	Translucent	Black	Helvetica	41	29
5	Translucent	Yellow	Clarendon	52	37
6	Neon	Red	Helvetica	45	29
7	External	Yellow	Clarendon	48	31
8	Opaque	White	Clarendon	48	36
9	External	Black	Helvetica	42	29
11	Opaque	White	Helvetica	50	34
12	Opaque	Yellow	Clarendon	49	33
13	Neon	White	Helvetica	51	38
14	Translucent	Black	Clarendon	47	31
15	External	Yellow	Helvetica	43	26
16	Translucent	Yellow	Helvetica	52	37
17	External	White	Helvetica	41	26
18	External	White	Clarendon	37	24

The following sections discuss the effects of various factors on recognition and legibility distances when analyzed across viewing conditions and when analyzed by viewing time.

Group Effects. A multivariate analysis of variance (ANOVA) revealed a significant main effect of subject group for recognition and legibility distances, respectively ($F=22.75$, $p<0.001$, and $F=21.49$, $p<0.001$) and no interaction between subject group and time-of-viewing for both measures ($F=1.22$, $p=0.300$, and $F=0.82$, $p=0.442$). All recognition and legibility distances were collapsed across signs and viewing times and subjected to independent sample one-tailed t-tests. For both recognition and legibility distances, respectively, Subject Group 1 [ages 30-45] outperformed both Subject Group 2 [ages 65-74] ($t=4.82$, $p<0.001$, and $t=4.65$, $p<0.001$) and Subject Group 3 [ages 75+] ($t=5.99$, $p<0.001$, and $t=6.02$, $p<0.001$). Subject Group 2 did not significantly outperform Subject Group 3 ($t=1.45$, $p=0.077$, and $t=1.54$, $p=0.065$) in both measurements, respectively. These findings were expected based on the differences in the average visual acuity of the subject groups. The average acuity of Subject Group 1 was significantly lower than that of Subject Group 2 ($t=-5.32$, $p<0.001$) and Subject Group 3 ($t=-6.15$, $p<0.001$), while the average visual acuity of Subject Group 2 was not significantly different from that of Subject Group 3 ($t=-1.47$, $p=0.074$). Average recognition and legibility distances for each subject group are plotted in Figure 2.

Time Effects. A multivariate ANOVA revealed a significant main effect of viewing time for recognition and legibility distances, respectively ($F=8.90$, $p=0.004$, and $F=8.08$, $p=0.006$). All recognition and legibility distances were collapsed across viewing time and subjected to independent sample one-tailed t-tests. For both recognition and legibility distances, respectively, the signs performed better during daytime viewing than during nighttime viewing ($t=2.91$, $p=0.003$, and $t=2.75$, $p=0.004$). This performance difference was not a function of subject visual acuity as the average acuity for the daytime subject group was not significantly different from the nighttime subject group (t=-1.01, p=0.316). Average recognition and legibility distances for each viewing time are plotted in Figure 3.

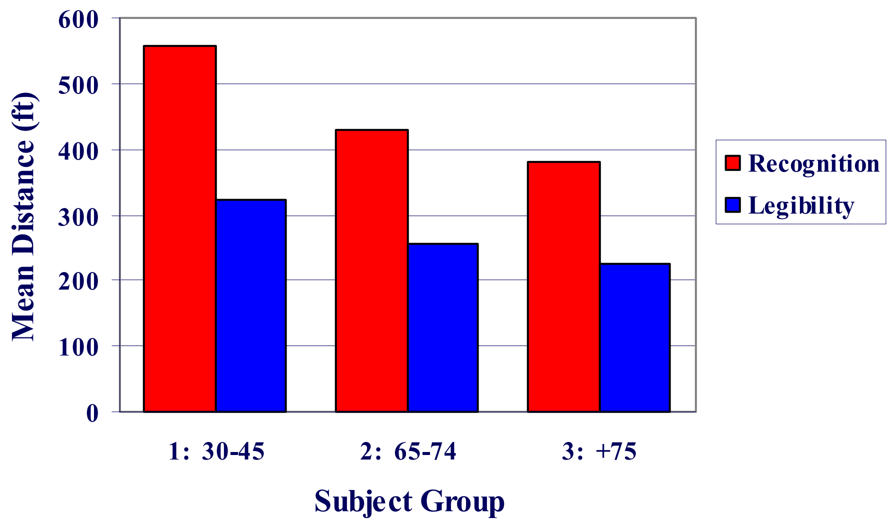


Figure 2. Average recognition and legibility distances by subject group.

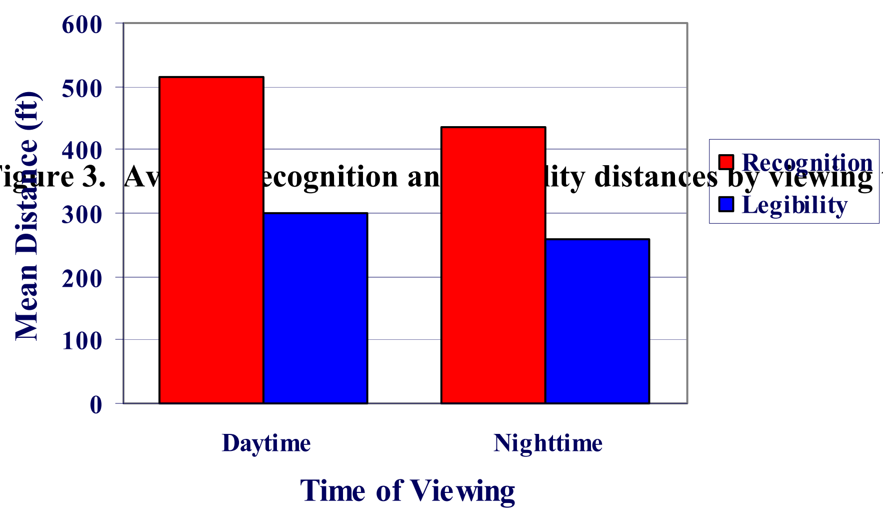


Figure 3. Average recognition and legibility distances by viewing time.

To further investigate the impact of time of viewing, the recognition and legibility distances were collapsed across signs but separated by time of viewing and subject group. One-tailed independent sample t-tests indicated that for recognition and legibility distances, daytime subjects outperformed nighttime subjects for Subject Group 1 (t=3.07 p=0.002, and t=2.85, 0.004) and Subject Group 2 (t=2.58, p=0.008, and t=2.26, p=0.016). For Subject Group 3, neither daytime nor nighttime subjects outperformed the other for both recognition distance (t=0.25, p=0.402) and legibility distance (t=0.39, p=0.348). The significant differences were not a function of subject visual acuity as one-tailed independent sample t-tests indicated that the average visual acuity between daytime and nighttime subjects of Subject Group 1 (t=-1.30, p=0.102), Subject Group 2 (t=-0.79, p=0.219), and Subject Group 3 (t=0, p=0.50) were not significantly different. The average recognition and legibility distances for each subject group by time of viewing are shown in Figure 4.

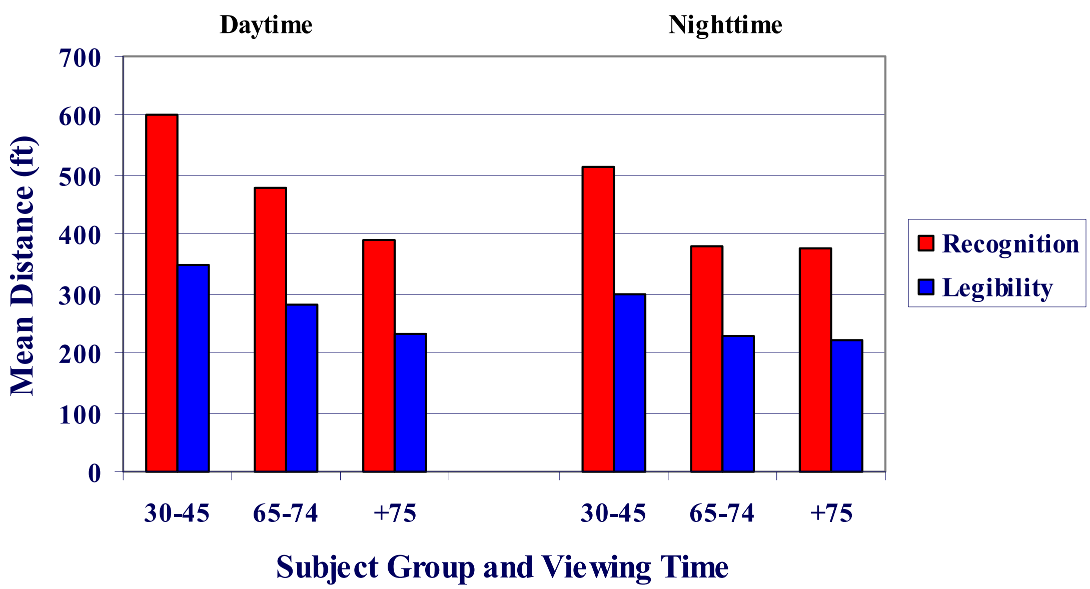


Figure 4. Average recognition and legibility distances by subject group, viewing time.

Color Effects. Because of the experimental design and the varying font characteristics discussed previously, complete within-subject comparisons of color effects were not possible without confounding the effects of font and illumination. The potential unconfounded color comparisons are provided in Table 9. The following sections discuss these individual comparisons in detail.

Table 9. Unconfounded color effect comparisons.

Font	Illumination	Text Color Comparison
Helvetica	External	Black vs. White
	Opaque	Yellow vs. White
	Neon	Red vs. White
Clarendon	External	Black vs. White
	Opaque	Yellow vs. White

Black vs. White. Repeated measures ANOVA showed significant group and time-of-viewing main effects for both recognition and legibility distances for fonts. However, no significant color main effect was indicated for the Helvetica font, external illumination comparison, for both recognition and legibility distances, respectively ($F=0.05$, $p=0.827$, and $F=0.38$, $p=0.540$), and no significant interaction between color, subject group, and time of viewing was observed. Two-tailed paired sample t-tests conducted on the same average distances supported this analysis with no significant difference between the averages for the two Helvetica font colors ($t=0.09$, $p=0.926$, and $t=0.67$, $p=0.504$).

Repeated measures ANOVA did, however, indicate significant color main effect for the Clarendon font, external illumination comparison, ($F=19.00$, $p<0.001$, and $F=56.07$, $p<0.001$) for both recognition and legibility distances, respectively. No significant interaction effects between color, subject group, and time of viewing were found. Based on one-tailed paired sample t-tests, white Clarendon text outperformed black Clarendon text with respect to average recognition distance ($t=3.84$, $p<0.001$), but black Clarendon text outperformed white for average legibility distance ($t=8.11$, $p<0.001$). The average recognition and legibility distances for these two color comparisons are presented in Figure 5. The lines indicate those significant differences discussed above.

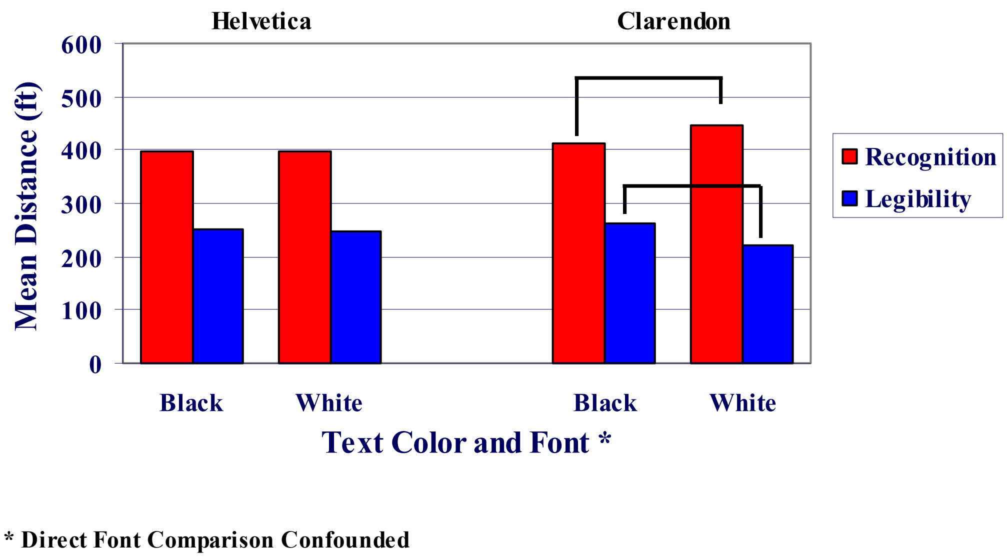


Figure 5. Average distances for black vs. white comparisons, external illumination.

One-tailed paired sample t-tests indicated no significant difference between the Helvetica and Clarendon fonts for the black text for recognition or legibility distance. They also revealed that the white Clarendon font performed better than the white Helvetica font for recognition distance (t=2.30, p=0.06) but worse than the white Helvetica for legibility distance (t=-2.62, p=0.005). However, recall that the Helvetica fonts had a stroke width to height ratio of 1:6.00 while the Clarendon fonts had a ratio of 1:4.80. Thus, it is unknown if the significant differences in the ratios had an impact on font performance.

Black vs. White - Daytime. The black vs. white text comparisons for daytime viewing provided similar findings to the results of the entire study. Repeated measures ANOVA indicated a significant subject group main effect for all comparisons and a significant color main effect for the recognition and legibility distance of the Clarendon font comparison (F=4.51, p=0.40, and F=35.69, p<0.001). It also revealed a group by color interaction effect for the recognition of the Clarendon font (F=3.33, p=0.045). One-tailed paired sample t-tests revealed no significant performance differences between the black and white texts in the Helvetica font. However, these tests did reveal that the white Clarendon text outperformed the black in recognition distance (t=-1.68, p=0.050), but was outperformed by the black Clarendon text in legibility distance (t=6.18, p<0.001). The daytime average recognition and legibility distances for the two black vs. white comparisons are illustrated in Figure 6. The lines note those significant differences discussed above.

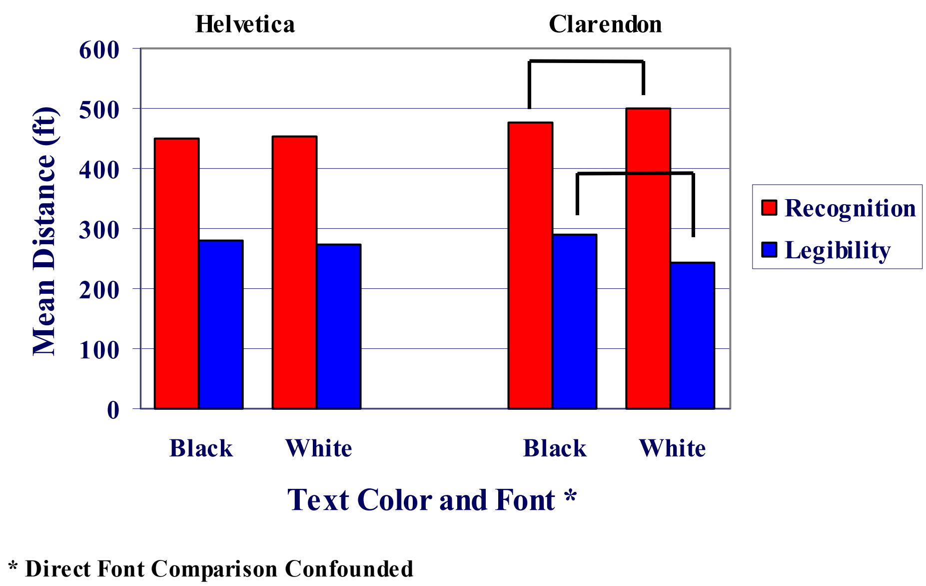


Figure 6. Daytime distances for black vs. white comparisons, external illumination.

For this comparison, one-sided paired-sample t-tests indicated that the only significant difference between the performance of the two different fonts with external illumination was with the legibility of the white text, where the Clarendon outperformed the Helvetica (t=1.98, p=0.025). However, the different stroke width-to-height ratios for the two fonts make it impossible to determine if the stroke width influenced this superior performance of the Clarendon or the other comparisons.

Black vs. White - Nighttime. The black vs. white text comparisons for nighttime viewing, though lower than those of the daytime viewing, provided similar trends evident in the daytime results. Repeated measures ANOVA indicated a significant subject group main effect for all comparisons, but a significant color main effect only for the recognition and legibility distances of the Clarendon font comparison (F=17.66, p<0.001, and F=21.33, p<0.001). A group by color interaction effect was also shown for the legibility of the Clarendon font (F=3.50, p=0.039). As with the daytime subjects, one-tailed paired sample t-tests revealed no significant performance differences between the black and white texts in the Helvetica font, but they did reveal that the white Clarendon text outperformed the black in recognition distance (t=-4.01, p<0.001), but was outperformed by the black Clarendon text in legibility distance (t=5.27, p<0.001). The nighttime average recognition and legibility distances for the two black vs. white comparisons are illustrated in Figure 7. The lines note those significant differences discussed above.

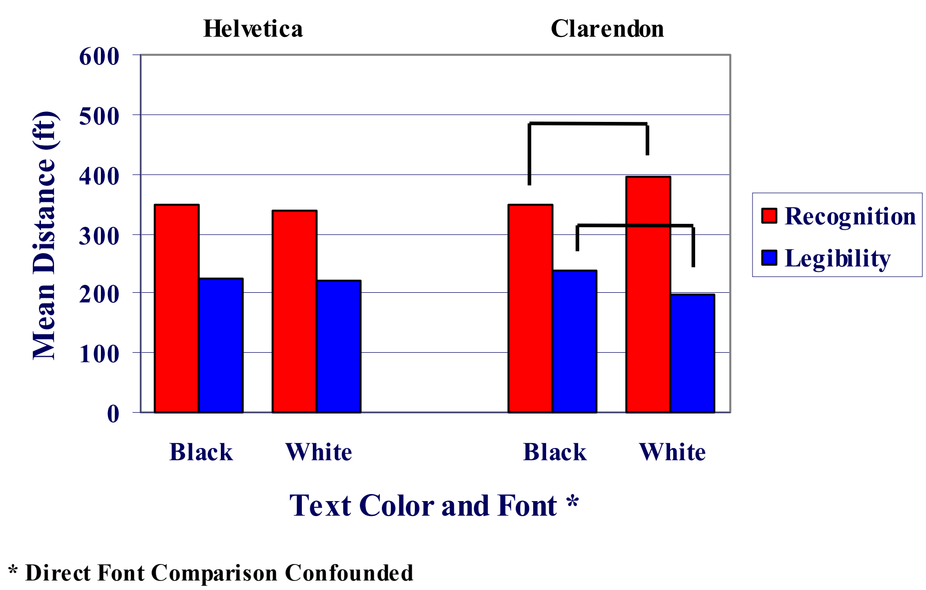


Figure 7. Nighttime distances for black vs. white comparisons, external illumination.

One-sided paired-sample t-tests indicated no significant performance difference in the Helvetica and Clarendon fonts for the black text. However, these tests revealed that for the white text, Clarendon outperformed Helvetica for recognition distance (t=-2.05, p=0.021), but was outperformed by Helvetica for legibility distance (t=1.95, p=0.027). Again, this significant performance difference and the other font comparisons are confounded because of the varying stroke width to height ratios for the two fonts.

Yellow vs. White. Repeated measures ANOVA showed significant group and time-of-viewing main effects for both recognition and legibility distances for Helvetica font. Significant group main effects were shown for recognition distance of Clarendon font, and significant group and time-of-viewing main effects and group by time-of-viewing interaction effect were indicated for the legibility distance of Clarendon font. However, no significant color main effect was indicated for the recognition distance of Helvetica and Clarendon fonts and the legibility distance of Clarendon font, opaque internal illumination, respectively (F=3.77, p=0.56; F=0.00, p=0.974; F=0.18, p=0.675). No significant interaction between color, subject group, and time of viewing was observed for these same distances. Significant color main effect and subject group by color interaction effect was found for the legibility distance of Helvetica font, opaque internal illumination (F=5.83, p=0.018, and F=5.64, p=0.005).

One-tailed paired sample t-tests conducted on the Helvetica font indicated that yellow text outperformed white with respect to average recognition distance (t=2.05, p=0.021) and average legibility distance (t=2.97, p=0.001). Identical tests conducted on the Clarendon font showed no significant differences in color performance for average recognition distance (t=0.22, p=0.412) and average legibility distance (t=0.40, p=0.345). The average recognition and legibility distances for these two color comparisons are presented in Figure 8. The lines indicate those significant differences discussed above.

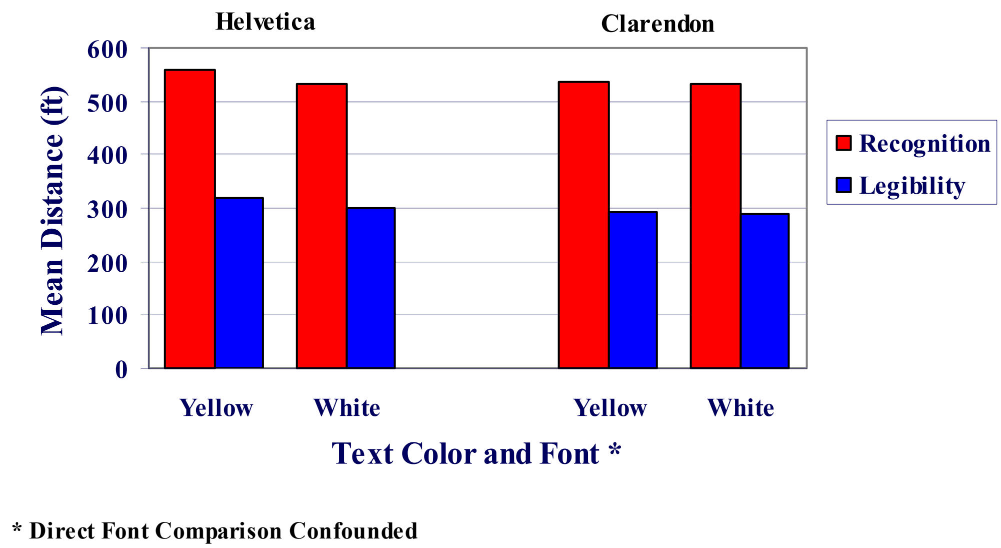


Figure 8. Average distances for yellow vs. white comparisons, opaque illumination.

The Helvetica fonts in this comparison had a stroke width to height ratio of 1:3.69 while the ratio for the Clarendon fonts was 1:4.00, making any comparisons between their performance confounded. One-tailed paired-sample t-tests indicated that the only significant different in font performance was for the legibility distance of the yellow font (t=2.10, p=0.018). As with the black and white text color comparisons, it is impossible to determine if the results of the comparisons are a function of the change in ratio.

Yellow vs. White - Daytime. For the yellow vs. white text comparisons for daytime subjects, repeated measures ANOVA indicated a significant subject group main effect for all comparisons but no significant color main effect for either recognition or legibility distance of either comparison. One-tailed paired sample t-tests also revealed no significant performance differences between the yellow and white texts in either the Helvetica or Clarendon font. The daytime average recognition and legibility distances for the two yellow vs. white comparisons are illustrated in Figure 9.

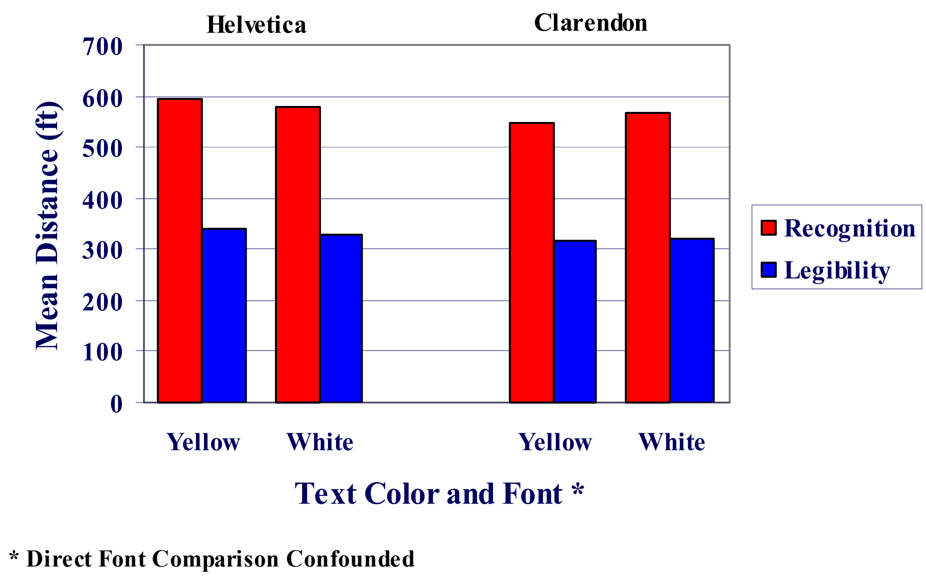


Figure 9. Daytime distances for yellow vs. white comparisons, opaque illumination.

One-tailed paired sample t-tests conducted on font comparisons indicated no significant differences in performance between Helvetica and Clarendon for daytime viewing of opaque internal illumination. However, the two different stroke width-to-height ratios (1:3.69 for the Helvetica and 1:4.00 for the Clarendon) confound the results of these comparisons.

Yellow vs. White - Nighttime. The yellow vs. white text comparisons for nighttime viewing illustrate similar findings evident in the overall results discussed previously. Repeated measures ANOVA indicated a significant subject group main effect for all comparisons but the legibility distance of the Clarendon font, and significant color main effects only for the recognition and legibility distances of the Helvetica font comparison ($F=3.84$, $p=0.057$, and $F=11.32$, $p=0.002$). A group by color interaction effect was also shown for the legibility of the Helvetica font ($F=4.52$, $p=0.017$). As with the overall results, one-tailed paired sample t-tests revealed no significant performance differences between the black and white texts in the Clarendon font. However, yellow Helvetica text outperformed the white in both recognition distance ($t=-1.92$, $p=0.061$) and legibility distance ($t=-3.71$, p=0.001). The nighttime average recognition and legibility distances for the two yellow vs. white comparisons are illustrated in Figure 10.

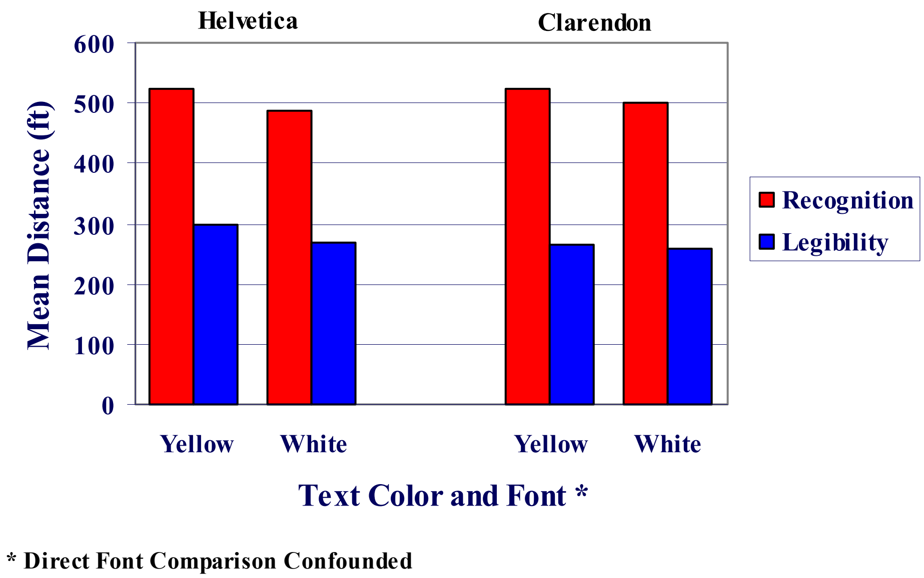


Figure 10. Nighttime distances for yellow vs. white comparisons, opaque illumination.

With respect to font comparisons, only one significant performance difference was found with one-sided paired-sample t-tests, that of Helvetica over Clarendon for the yellow text (t=1.87, p=0.026). The other font comparisons indicated no significant differences in performance. As with other font comparisons, though, the different stroke width to height ratios make these comparisons confounded, providing no insight into a pure performance comparison.

Red vs. White. One-tailed paired sample t-tests conducted on the Helvetica font, neon illumination, revealed that white text outperformed red for both average recognition and legibility distances, respectively (t=2.23, p=0.014, and t=1.99, p=0.025). The average recognition and legibility distances for this color comparison are presented in Figure 11. The lines indicate those significant differences discussed. Since only the Helvetica font was tested in the neon illumination, no font comparisons are available.

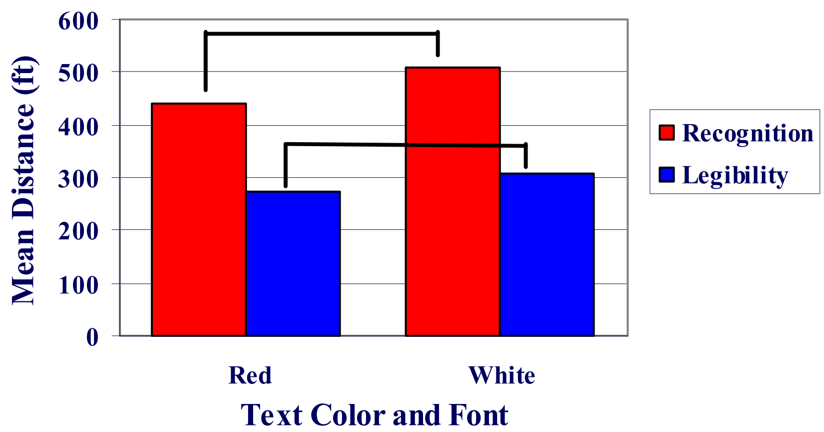


Figure 11. Average distances for red vs. white comparison, neon illumination.

<u>Red vs. White - Daytime</u>. For daytime viewing, one-tailed independent sample t-tests indicated that white neon significantly outperformed red neon for both recognition and legibility distances, respectively (t=-2.46, p=0.009, and t=-1.95, p=0.029). These results mirror those for all viewing conditions. The daytime average recognition and legibility distances for the neon color comparison are given in Figure 12. As with previous figures, the lines illustrate the significant differences in performance.

<u>Red vs. White - Nighttime</u>. One-tailed independent sample t-tests revealed no significant differences in performance of red or white neon for either recognition distance (t=-0.53, p=0.298) or legibility distance (t=-0.81, p=0.241). Nighttime average recognition and legibility distances for the red vs. white neon comparison are provided in Figure 13.

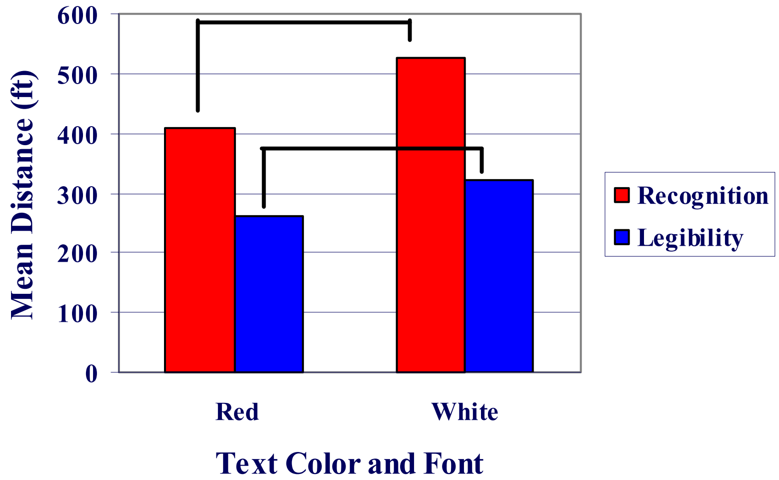


Figure 12. Daytime distances for red vs. white comparison, neon illumination.

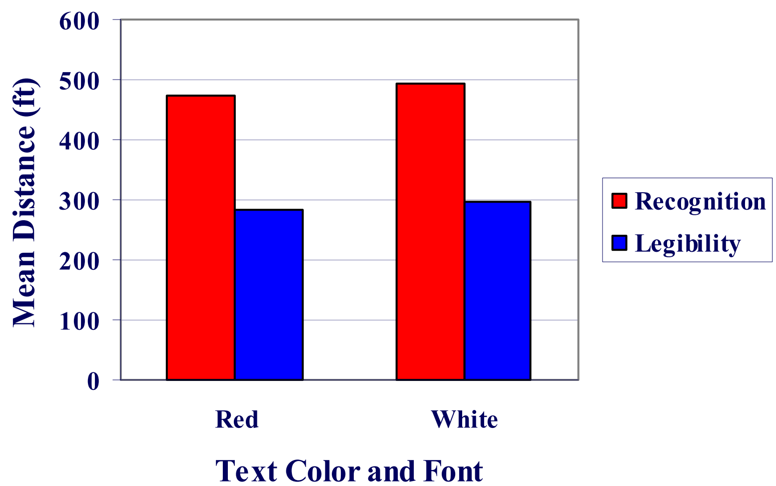


Figure 13. Nighttime distances for red vs. white comparison, neon illumination.

General Findings. All recognition and legibility distances for text color were collapsed across font and lighting technology to determine confounded text color effects. One-tailed paired sample t-tests conducted on the collapsed distances indicated that yellow text outperformed all texts in recognition distance and outperformed black and white text in legibility distance. White text outperformed black text for both recognition and legibility distances, but was not significantly different from red text. Finally, red text was found to outperform black text in legibility but not in recognition distance.

Average recognition and legibility distances for each text color collapsed across font and lighting technology are plotted in Figure 14. It is important to remember that these distances are confounded with respect to font and illumination technology and, therefore, do not represent equal comparisons between these two factors.

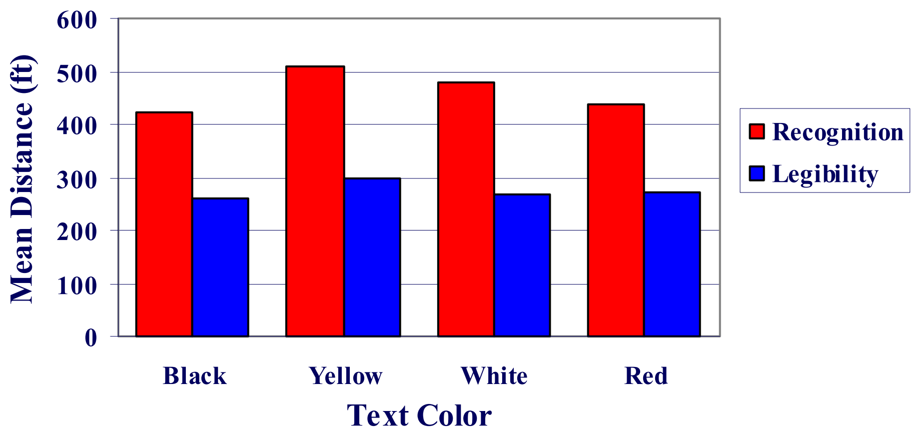


Figure 14. Average recognition and legibility distances by text color with confounding.

To investigate the impact of time of viewing on the performance of color, the recognition and legibility distances were collapsed across signs but separated by time of viewing and text color. One-tailed independent sample t-tests indicated that for recognition and legibility distances, black, yellow, and white text performed significantly poorer during nighttime viewing. However, as stated previously, the stroke width to height ratios were not uniform across all signs. Furthermore, though the red text appears to have performed better at night, the differences in the average recognition and legibility distances for the two viewing times are not significant. The average recognition and legibility distances for each text color by viewing time are given in Figure 15.

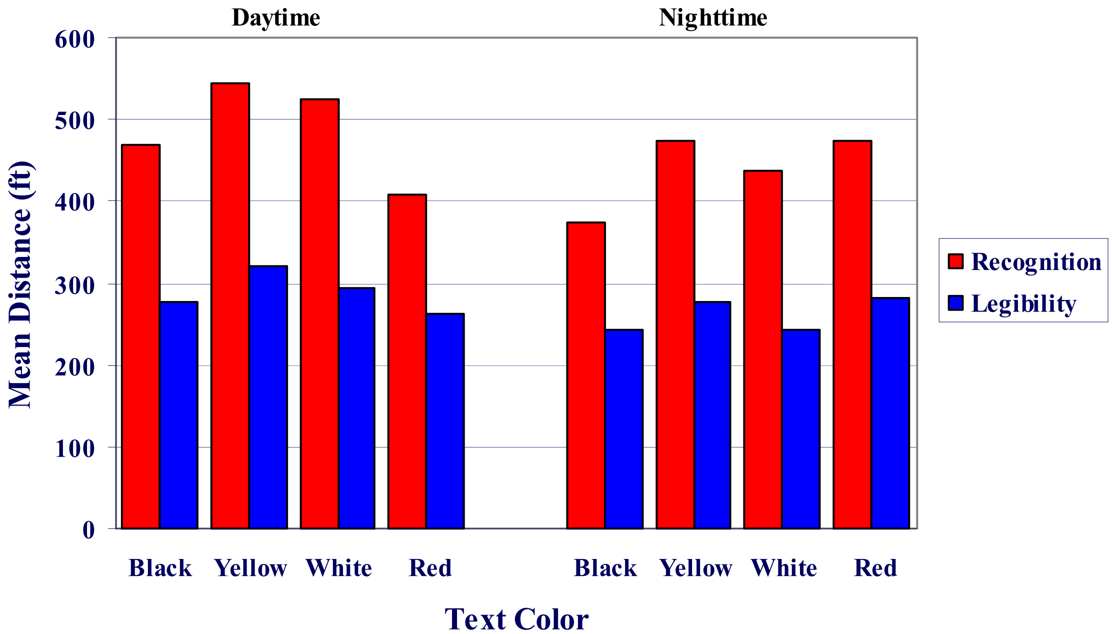


Figure 15. Average recognition and legibility distances by text color, viewing time.

For daytime viewing, one-sided paired sample t-tests indicated that yellow and white text outperformed black in both recognition and legibility distances, with yellow outperforming white for both measures (t=-3034, p=0.001, and t=-6.30, p<0.001) to yield the best performance of the four colors. No significant performance difference was seen between the black and red texts for either recognition (t=1.03, p=0.157) or legibility distance (t=-0.20, p=0.422), or between the white and red texts for legibility distance (t=-1.00, p=0.163). For nighttime viewing, yellow, white, and red text outperformed black for recognition distance, and yellow and red outperformed black for legibility distance. No significant difference was found between the legibility of the white and black texts (t=-.36, p=0.359). Further findings indicate that the yellow and red text outperform white for both recognition and legibility distance, with neither yellow nor red outperforming the other for either measurement. However, as mentioned earlier, the difference in stroke width to height ratios and confound these findings.

Illumination Effects. As with text color, complete within-subject comparisons of illumination technology effects are not possible without confounding the effects of font and color. Those unconfounded illumination technology comparisons possible are provided in Table 10.

Table 10. Unconfounded illumination effect comparisons.

Font	Text Color	Illumination Comparison
Helvetica	Black	External vs. Translucent
	Yellow	External vs. Opaque vs. Translucent
Clarendon	Black	External vs. Translucent
	Yellow	External vs. Opaque vs. Translucent

External vs. Translucent. Repeated measures ANOVA revealed significant group and time-of-viewing main effects but no group by time-of-viewing interaction effect for both recognition and legibility distances for the Helvetica and Clarendon fonts, black text, external vs. internal translucent illumination comparison. Furthermore, the ANOVA indicated a lighting by time-of-viewing interaction effect for all conditions. One-tailed paired sample t-tests conducted on the black text, Helvetica font, yielded that internal translucent illumination outperformed external for recognition distance ($t=4.22$, $p<0.001$), but was not significantly different for legibility distance ($t=-0.93$, $p=0.177$). Furthermore, identical t-tests conducted on the Clarendon font showed that internal translucent illumination outperformed external for both recognition and legibility distances, respectively ($t=3.18$, $p=0.001$, and $t=3.47$, $p<0.001$). The average recognition and legibility distances for these illumination technology comparisons are presented in Figure 16. The lines note those significant differences discussed above.

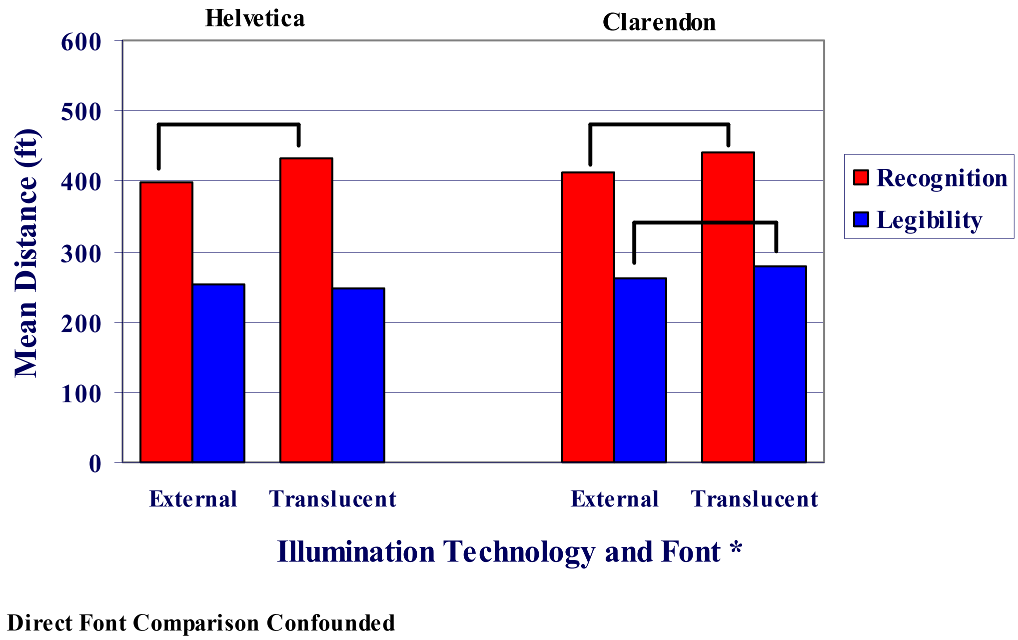


Figure 16. Average distances for external vs. translucent comparisons, black text.

One-tailed paired sample t-tests indicated no significant difference between the Helvetica and Clarendon fonts for the external illumination for recognition or legibility distance. They also revealed that with the translucent internal illumination, the Clarendon font only performed better than the Helvetica font for legibility distance ($t=-2.92$, $p=0.001$). As mentioned earlier, the Helvetica fonts had a stroke width to height ratio of 1:6.00 while the Clarendon fonts had a ratio of 1:4.80. Thus, it cannot be determined if the significant difference in the performance of the legibility of the translucent internal Clarendon or the lack of performance differences in the other comparisons is a result of this change in ratios.

<u>External vs. Translucent - Daytime</u>. For the external vs. translucent illumination comparisons for daytime subjects, repeated measures ANOVA indicated a significant subject group main effect for all comparisons but only a significant lighting main effect for the legibility distance comparison in the Helvetica font. One-tailed paired sample t-tests revealed no significant performance differences between the external and translucent illumination in the Clarendon font and only a significant performance difference in the

legibility of the Helvetica font, where the external illumination outperformed the translucent ($t=-5.11$, $p<0.001$). The daytime average recognition and legibility distances for the two external vs. translucent comparisons are illustrated in Figure 17. The lines illustrate those significant differences discussed above.

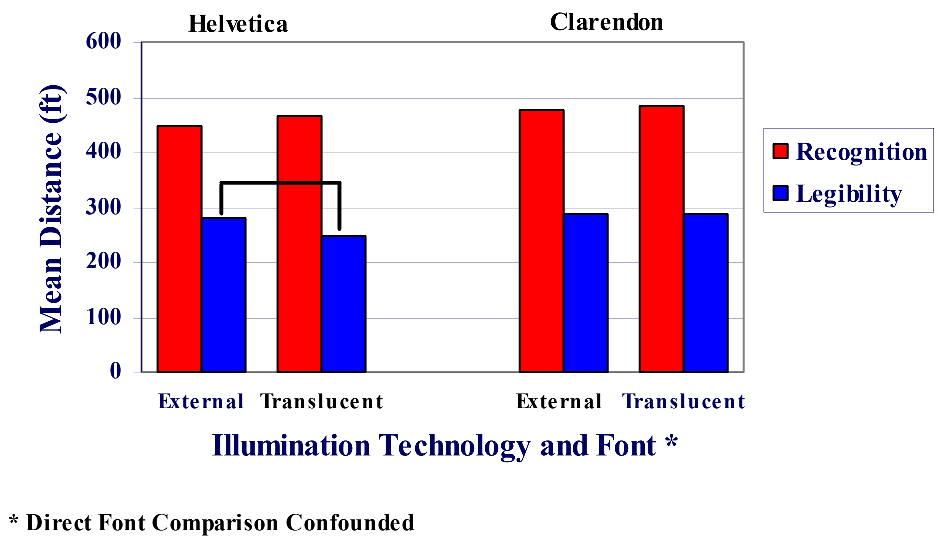
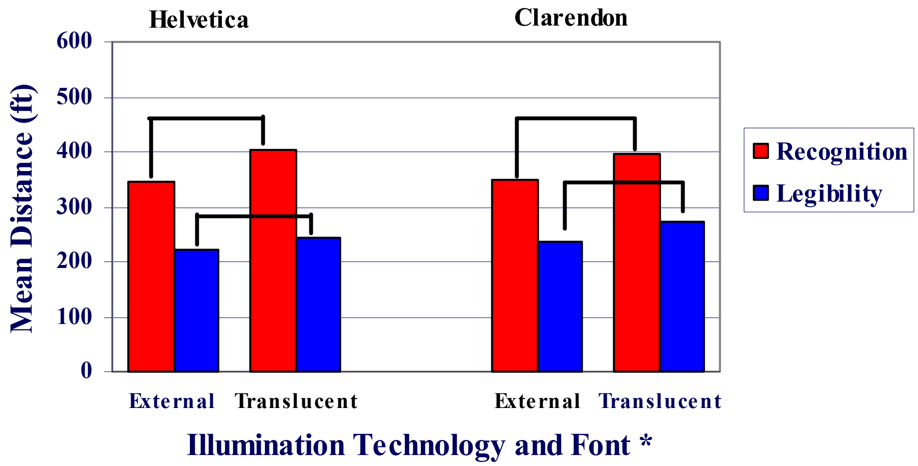


Figure 17. Daytime distances for external vs. translucent comparisons, black text.

One-sided paired-sample t-tests indicated no significant performance difference in the recognition or legibility of the Helvetica and Clarendon fonts for external illumination or for the recognition distance for either font for translucent internal illumination. These tests only revealed that for the translucent illumination, Clarendon outperformed Helvetica for legibility distance ($t=-2.63$, $p=0.005$). Again, the performance comparisons of the fonts for the different illumination technologies are confounded because of the varying stroke width to height ratios for the two fonts.

<u>External vs. Translucent - Nighttime</u>. The repeated measures ANOVA for the external vs. translucent illumination comparisons for nighttime subjects indicated a significant subject group main effect and a significant lighting main effect for all comparisons. Furthermore, one-tailed paired sample t-tests revealed that, in all comparisons

for both recognition and legibility distance, translucent internal illumination significantly outperformed external illumination The nighttime average recognition and legibility distances for the two external vs. translucent comparisons are illustrated in Figure 18. As previously noted, the lines mark those significant differences discussed above.



* Direct Font Comparison Confounded

Figure 18. Nighttime distances for external vs. translucent comparisons, black text.

One-sided paired-sample t-tests indicated no significant performance difference in the recognition or legibility of the Helvetica and Clarendon fonts for either illumination technology. However, the lack of performance differences is is confounded by the varying stroke width to height ratios for the two fonts: 1:6.00 for Helvetica and 1:4.80 for Clarendon.

<u>External vs. Opaque vs. Translucent</u>. Repeated measures ANOVA indicated significant group and time-of-viewing main effects but no group by time-of-viewing effect for all recognition and legibility distances for the Helvetica and Clarendon fonts, yellow text, external vs. opaque vs. translucent illumination comparison. The ANOVA also showed a significant lighting main effect for all conditions in addition to lighting by time-of-viewing interaction effect for the recognition distance for the Clarendon font comparison.

One-tailed paired sample t-tests on the yellow text, Helvetica font, indicated that both the internal opaque and internal translucent illuminations outperformed external illumination for recognition distance ($t=8.56$, $p<0.001$, and $t=9.38$, $p<0.001$) and legibility distance ($t=8.95$, $p<0.001$, and $t=8.64$, $p<0.001$). However, no significant difference in performance between the two internal illuminations was displayed for either recognition or legibility distance, respectively (t=0.-0.14, $p=0.446$, and $t=-0.71$, $p=0.238$).

With the yellow text, Clarendon font, one-tailed paired sample t-tests on the recognition distance revealed that both the internal opaque and internal translucent illuminations outperformed external illumination ($t=8.15$, $p<0.001$, and $t=8.47$, $p<0.001$). With respect to legibility distance, internal translucent illumination outperformed external ($t=2.74$, $p=0.035$), but not so for the internal opaque illumination vs. the external ($t=0.15$, $p=0.442$). Also, no significant difference between internal illumination technology performance was found for recognition distance ($t=0.01$, $p=0.495$), but a significant difference was found between the two technologies for legibility distance ($t=3.28$, $p<0.001$) with the translucent outperforming the opaque. The average recognition and legibility distances for these illumination technology comparisons are presented in Figure 19. The lines indicate those significant differences discussed above.

One-tailed paired-sample t-tests indicated that neither font outperformed the other with respect to recognition distance in any of the three illumination technologies. However, Clarendon outperformed Helvetica in legibility distance for the external illumination ($t=-2.22$, $p=0.014$), while Helvetica outperformed Clarendon in legibility distance for the opaque internal illumination ($t=2.10$, $p=0.018$). However, the different stroke width-to-height ratios for the two fonts confound these results.

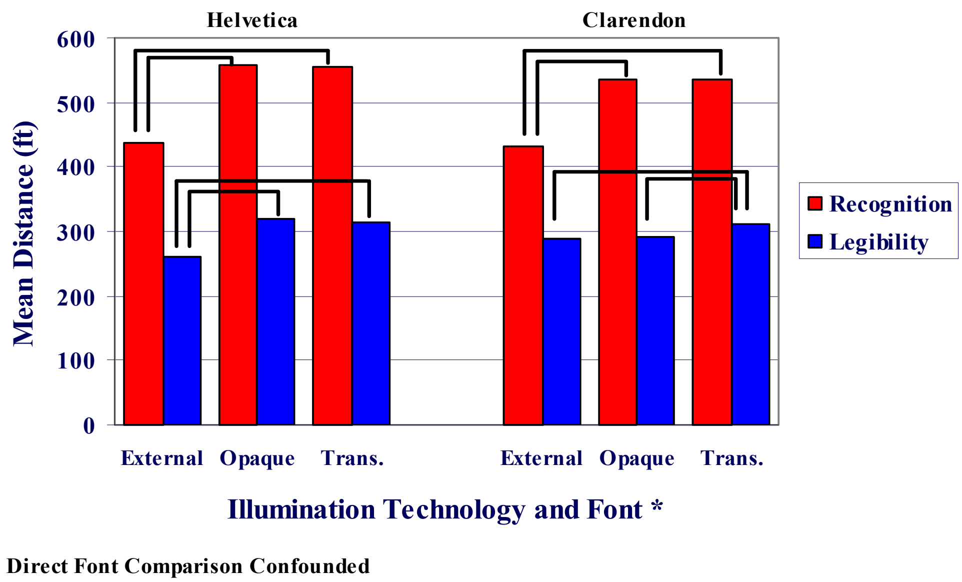


Figure 19. External vs. opaque vs. translucent comparisons, yellow text.

<u>External vs. Opaque vs. Translucent - Daytime</u>. For daytime subjects, repeated measures ANOVA revealed significant group and lighting main effects for all comparisons. Furthermore, one-sided paired sample t-tests on the Helvetica text indicated that both the opaque and translucent internal illumination technologies, respectively, outperformed external for both recognition distance ($t=-5.50$, $p<0.001$, $t=-5.25$, $p<0.001$) and legibility distance ($t=-4.93$, $p<0.001$, $t=-4.53$, $p<0.001$). However, no significant difference was found between the two internal illuminations for either recognition or legibility distance, respectively ($t=-0.20$, $p=0.845$, and $t=-0.41$, $p=0.682$).

Slightly different results were found with the Clarendon font for these illumination comparisons. For example, as with the Helvetica font, both the opaque and translucent illumination technologies outperformed the external for recognition distance, with the translucent outperforming the opaque as well ($t=-3.09$, $p=0.003$). However, the only significant performance difference in legibility distance was found between the translucent and external, with the translucent being the superior illumination ($t=1.75$, $p=0.087$). The daytime average recognition and legibility distances for the external vs. opaque vs.

translucent illumination comparisons are given in Figure 20. The lines note which comparisons are significant.

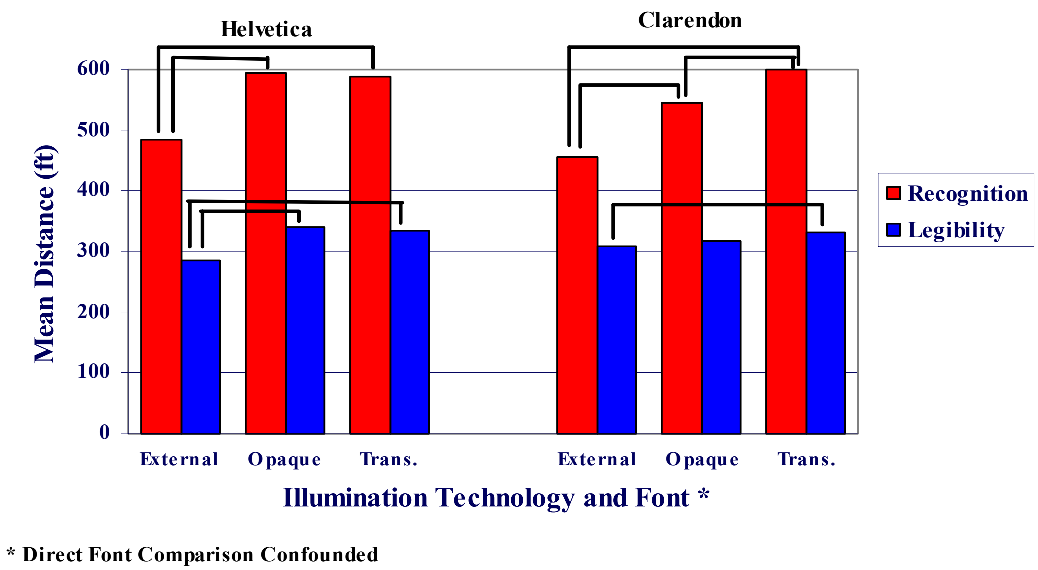


Figure 20. Daytime external vs. opaque vs. translucent comparisons, yellow text.

One-sided paired-sample t-tests conducted on the Helvetica and Clarendon fonts in these comparisons indicated no significant difference in daytime performance between the two. However, because of the different stroke width to height ratios, no true findings can be gleaned from these results.

External vs. Opaque vs. Translucent - Nighttime. For nighttime subjects, repeated measures ANOVA also revealed significant group and lighting main effects for all comparisons. Also, the ANOVA indicated a significant group by lighting interaction effect for the legibility of the Clarendon text. They nighttime results of one-sided paired sample t-tests on the Helvetica text indicated that both the opaque and translucent internal illumination technologies, respectively, outperformed external for both recognition distance ($t=-6.58$, $p<0.001$, $t=-8.46$, $p<0.001$) and legibility distance ($t=-8.40$, $p<0.001$, $t=-8.85$, $p<0.001$). However, no significant difference was found between the two internal illuminations for either recognition or legibility distance, respectively ($t=0.00$, $p=0.999$, and $t=-0.66$, $p=0.511$).

Slightly different results were found with the Clarendon font for these illumination comparisons. For instance, with the Helvetica font, both the opaque and translucent illumination technologies outperformed the external for recognition distance, with the opaque outperforming the translucent as well (t=3.03, p=0.002). However, for legibility distance, the translucent illumination outperformed both the opaque and external illuminations (t=-3.61, p=0.001, t=2.28, 0.013) while no difference in performance was indicated between the external and opaque illumination (t=-0.53, p=0.597). The nighttime average recognition and legibility distances for the external vs. opaque vs. translucent illumination comparisons are given in Figure 21.

One-tailed paired sample t-tests conducted on the fonts indicated that, as with daytime results, Clarendon outperformed Helvetica in legibility with the external illumination (t=-2.23, p.0.014) while Helvetica outperformed Clarendon in legibility with the opaque illumination (t=1.97, p=0.026) and in recognition with the translucent illumination (t=1.72, p=0.045). The remaining font comparisons yielded insignificant performance differences. Once again, as with other comparisons made earlier, the variation in stroke width to height ratios confounds these findings.

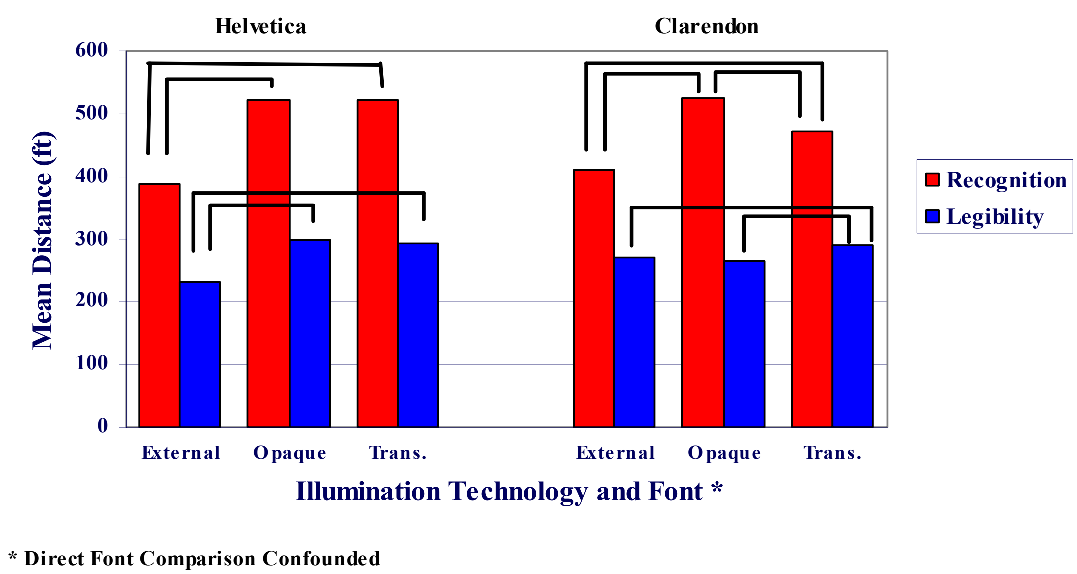


Figure 21. Nighttime external vs. translucent vs. opaque comparisons, yellow text.

General Findings. All recognition and legibility distances for illumination technology were collapsed across text color and font to determine confounded illumination effects. One-tailed paired sample t-tests conducted on the collapsed distances indicated that internal opaque illumination outperformed all other illuminations in recognition distance and outperformed external and internal translucent illumination in legibility distance. No significant difference was found between legibility distance of internal opaque and neon illumination ($t=-1.42$, $p=0.079$). Internal translucent illumination outperformed external for both recognition and legibility distances, but was not significantly different from neon illumination for either distance. Finally, neon illumination outperformed external illumination for both recognition and legibility distances.

Average recognition and legibility distances for each illumination technology collapsed across text color and font are plotted in Figure 22. It is important to remember that these distances are confounded with respect to text color and font and, therefore, do not represent equal comparisons between these two factors.

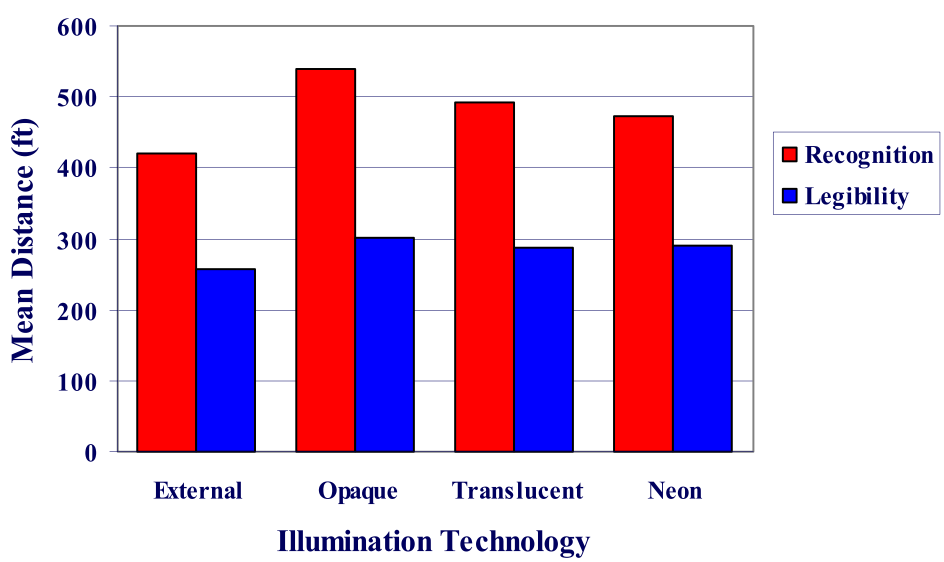


Figure 22. Average recognition and legibility distances by illumination with confounding.

To investigate the impact of time of viewing on the performance of illumination technology, the recognition and legibility distances were collapsed across signs but separated by time of viewing and illumination. One-tailed independent sample t-tests indicated that for recognition and legibility distances, the external and opaque internal illumination technologies performed significantly poorer during nighttime viewing, and the translucent internal illumination performed poorer for recognition distance. However, no significant difference in performance was found for the recognition and legibility distance of the neon technology and for the legibility of the translucent internal illumination. However, as stated previously, the stroke width to height ratios were not uniform across all signs. The average recognition and legibility distances for each illumination technology by viewing time are given in Figure 23.

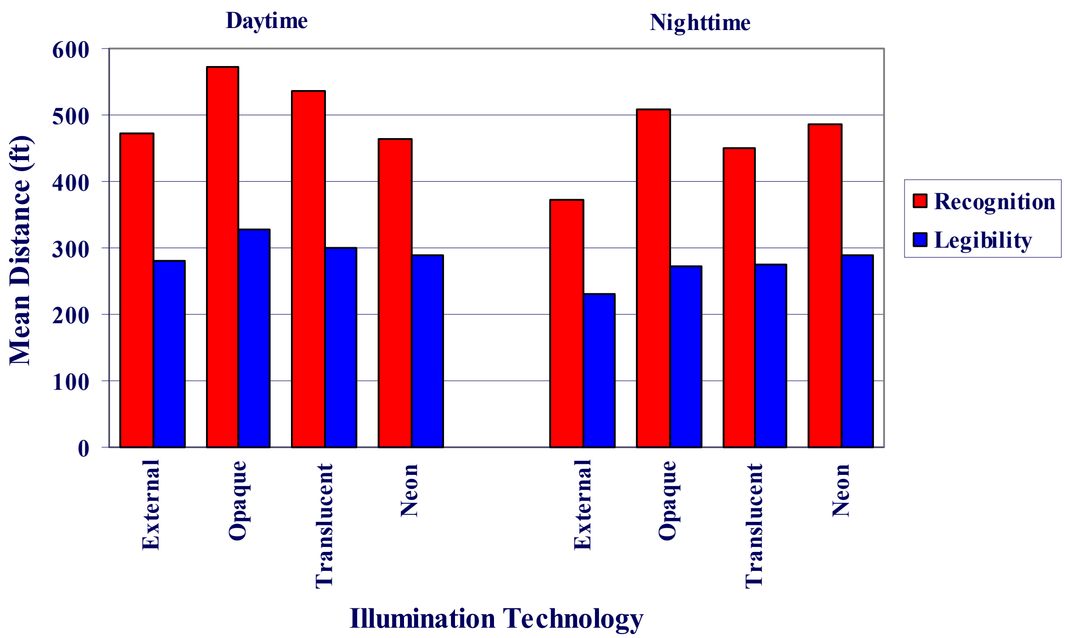


Figure 23. Average recognition and legibility distances by illumination, viewing time.

As with the overall results, for daytime viewing, the opaque internal illumination outperformed all other illumination technologies for both recognition and legibility distance. The internal translucent illumination also outperformed external and neon for recognition distance, and the external for legibility distance. No significant difference in performance was observed between the external and neon illuminations for either measurement. For nighttime viewing, the opaque and translucent internal illuminations and neon all outperformed the external in recognition and legibility distance. However, unlike during the day, neon outperformed the translucent internal illumination in both measurements. Also, no significant difference in performance was seen between the legibility of the two internally illuminated signs (t=-0.40, p=0.345) or between the neon and opaque internal illumination (t=-1.44, p=0.78). However, these results are not conclusive because of confounding by the different stroke width to height ratios for the signs.

Font Effects. All recognition and legibility distances for fonts were collapsed across text color and illumination to determine confounded font effects. One-tailed paired sample t-tests conducted on the collapsed distances indicated no significant difference between Helvetica and Clarendon in recognition distance (t=1.07, p=0.143) and legibility distance (t=-0.41, p=0.340). Average recognition and legibility distances for each test font collapsed across text color and illumination are plotted in Figure 24. It is important to remember that these distances are confounded with respect to text color and illumination and, therefore, do not represent equal comparisons between these two factors.

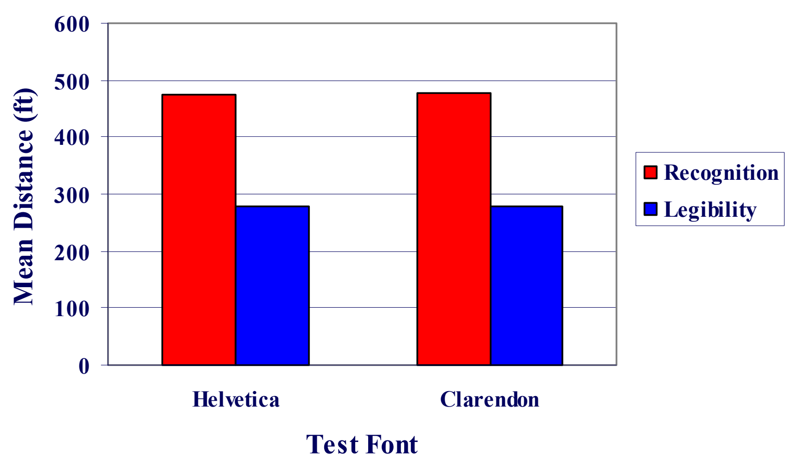


Figure 24. Average recognition and legibility distances by test font with confounding.

To investigate the impact of time of viewing on the performance of the fonts, the recognition and legibility distances were collapsed across signs but separated by time of viewing and font style. One-tailed independent sample t-tests indicated that for recognition and legibility distances, both the Helvetica and Clarendon fonts perform worse during nighttime viewing. These findings support the finding that overall performance for all subjects and all signs drops at night. The average recognition and legibility distances for each test font by viewing time are presented in Figure 25.

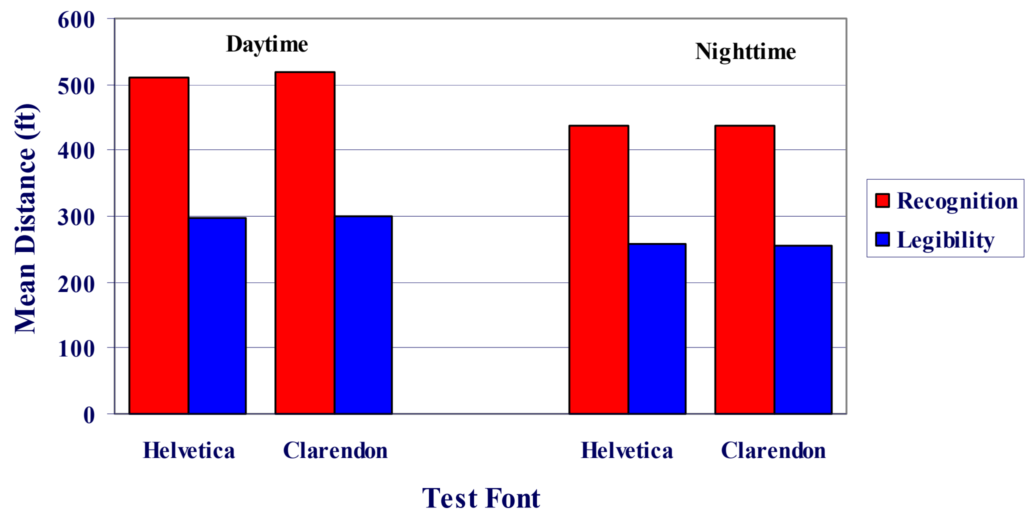


Figure 25. Average recognition and legibility distances by test font, viewing time.

As with the overall font findings, no significant difference in performance was found for daytime or nighttime viewing. However, the aforementioned variation in stroke width to height ratios across test signs confounds this result.

Discussion. Despite the limitations placed upon the data analyses as a result of experimental design and font characteristics, several general trends can be observed in the resulting data. First, between-subject variability influenced data. Primarily, recognition and legibility distances decreased with subject group, most likely as a result of a decrease in visual acuity with age. For instance, recognition distances decreased by 23 percent (127 ft) and legibility distances decreased by 21 percent (68 ft) between Subject Group 1 and Subject Group 2. Differences between Subject Group 1 and Subject Group 3 were even greater at 31 percent (175 ft) for recognition distance and 30 percent (97 ft) for legibility distance. The decreases in performance between Subject Group 2 and Subject Group 3 were smaller at 11 percent (48 ft, 29 ft) for both recognition and legibility distance. Similar trends were found in daytime and nighttime subjects, though the decrease between Subject Group 2 and Subject Group 3 was insignificant for nighttime viewing.

The time of viewing (e.g., daytime or nighttime) influenced sign recognition and legibility. Overall recognition and legibility decreased during nighttime viewing for both recognition distance (15 percent, 78 ft) and legibility distance (14 percent, 41 ft). Similar decreases were illustrated by each sign, with the exception of red neon, which was more visible at night. This finding was a result of poor contrast conditions during daytime viewing. The clear glass of the tubing against a black background made daytime viewing difficult despite illumination. Similar problems arose with daytime viewing as observed throughout the course of the study. These problems included sun angle, glare, and the presence of shadows. For instance, direct sunlight tended to create glare which made sign reading difficult. Similar problems arose when the sun's position was either beside or slightly behind the sign, throwing the sign in shadow and increasing reading difficulty. More uniform, though lower, results came from nighttime viewing because these factors were eliminated. However, sign performance during inclement weather is unknown as these conditions were not tested during the study.

Within-subject analyses yielded several findings regarding sign characteristics. With respect to text color, the data indicated that positive contrast signs perform better than negative contrast signs. This finding concurs with previous highway research on sign performance (Garvey, Thompson-Kuhn, Pietrucha, 1996). During daytime viewing, yellow text on a green background performed the best with white text on a black background performing second best. As stated previously, red neon had poor legibility during the day, but it performed as well as yellow text at night, making these two color combinations superior during nighttime viewing.

Analyses also revealed that internally illuminated and neon signs outperformed externally illuminated ones, with internal opaque illumination performing the best in some comparisons. In other comparisons, both internally illuminated technologies performed equally well. Neon performed better than external illumination but not as well as either internal illumination, most likely influenced by the daytime performance of the red neon. Thus, the performance of the illumination was influenced by an interaction with time of day for reasons discussed above.

Finally, no significant difference in font performance was observed since direct, unconfounded comparisons were impossible. For the most part, the stroke width to height ratio for a Clarendon font was lower than that for a companion Helvetica font in numerous comparisons. Thus, insignificant differences in performance may have been a factor of this lower ratio.

Available Reading Times

The secondary research objective of this study was to determine the time available for message reading for each sign for various traffic approach speeds. This task was undertaken by first calculating the available vehicular travel distances based on the recognition and legibility distances established in the descriptive statistics segment of this report. The averages, standard deviations, 85th percentiles, and 15th percentiles of all signs for overall viewing, daytime, and nighttime viewing are included in Appendix D of this report. The available travel distances were calculated for the averages and 15th percentiles to consider the average and worst case scenarios in viewing conditions. These distances were then converted to available reading times in seconds based on the travel speed of a vehicle in feet per second. The speeds considered ranged from 25 mph to 55 mph in 5 mph increments. These calculations were made for overall viewing, daytime, and nighttime viewing conditions. The results of these calculations are also included in Appendix C and are discussed in the following sections.

These available reading times were then compared to the minimum time necessary to read a sign, process the information, and make a maneuver required by that sign. With on-premise signs, the required maneuver is an exit. In the worst of cases, the full scenario is a lane change, speed reduction, and either a left or right turn out of the traffic flow. A recent synthesis of decision sight distance literature (Garvey, Gates, and Pietrucha, 1995) suggests a conservative value of 5.5 sec to complete this sequence of events with signs that contain five or fewer critical elements. This includes a conservative 1.5-sec interval for an alerted traveler to read the sign and initiate a response (Johannson and Rumar, 1971), combined with a 4.0-sec internal to complete the speed reduction and lane-change maneuver (McGee, Moore, Knapp, and Sanders, 1978). Thus, the available reading times for each test sign were compared to the 5.5 sec minimum to establish whether or not the signs provide significant time to a traveler.

General. As noted in Appendix D, the average recognition distances ranged from 396 ft to 557 ft with the opaque internal illumination with yellow text performing the best and the external illumination with white text performing the worst. Assuming a driver is familiar with the sign they are reading (e.g., recognition task) all signs afford a average reading time sufficient to perform a required maneuver at speeds up to 45 mph. At 50 mph, the externally illuminated signs with white-Helvetica and black-Helvetica text no longer provide the minimum 5.5 sec of reading time. At 55 mph, more signs fail to provide the required time including the remainder of the externally illuminated signs (with the exception of the external-Clarendon sign), the translucent internal illuminated sign with black-Helvetica text and the red neon sign. The 15th percentile distances for recognition ranged from 228 ft to 379 ft, with the translucent internally illuminated sign with yellow-Helvetica text performing the best. Using these distances for recognition distance, various signs begin to fail in time provision at 30 mph. Those that perform the best are the opaque internally illuminated signs with yellow-Helvetica and white-Clarendon text and the translucent internally illuminated sign with yellow-Helvetica text. These three signs provide sufficient recognition reading time up to 45 mph. Beyond this speed, none of the signs provide enough reading time.

The reading times decrease considerably once the assumption is made that the driver is reading an unfamiliar sign (e.g., legibility task). The average legibility distances range from 219 ft to 319 ft (opaque-yellow-Helvetica performing best), and the 15th percentile legibility distances ranging from 139 ft to 225 ft (neon-white-Helvetica performing best). Using the average legibility distances, no sign provides sufficient reading time at 40 mph and higher. All four opaque internal illumination signs provide adequate time at 35 mph along with the translucent internal illuminations signs with yellow text, white neon, and the external illumination sign with yellow-Clarendon text. Using the 15th percentile distances, performance is even poorer. Less than half of the signs provide adequate reading time at 25 mph and none do so at 30 mph and higher. Those that perform the best are all opaque internal illumination signs (except for that with yellow-Clarendon text), the translucent internal illumination signs with yellow text, and the white neon sign.

Daytime. Average recognition distances during daytime viewing ranged from 408 ft to 599 ft with the translucent-yellow-Clarendon text performing the best. Daytime reading time performance for a recognition task is excellent for all signs with each providing adequate time at all speeds with the exception of neon-red-Helvetica text failing to provide 5.5 sec at 55 mph. The 15th percentile distances decrease for recognition, ranging from 178 ft to 429 ft, with opaque-white-Clarendon performing the best and neon-red-Helvetica the worst. Consequently, reading times decrease significantly for the 15th percentile with neon-red-Helvetica failing to provide adequate time at any speed. Others performed better, and the best signs provide sufficient time up to 50 mph, these being the translucent-yellow text signs and the opaque-white-Clarendon signs.

Considering the legibility task, daytime performance decreased as with the overall viewing results. Daytime average legibility distances ranged from 242 ft to 339 ft with the opaque-yellow-Helvetica sign performing the best and the external-white-Clarendon sign performing the worst. With average legibility distances under consideration, signs begin to fail in adequate time performance at 35 mph. Those performing the best are opaque signs with yellow-Helvetica and white-Helvetica text, the translucent signs with yellow texts, and the neon-white sign, all which give adequate reading time up to 40 mph. Beyond that speed no signs give enough reading time to the driver. Using 15th percentile distances, which ranged from 127 ft to 259 ft, all signs fail to provide sufficient reading time at 35 mph and above. At 30 mph, only two signs give a minimum of 5.5 sec: the translucent-yellow-Clarendon and translucent-yellow-Helvetica signs.

Nighttime. Average nighttime recognition distances were lower than those for daytime viewing, ranging from 339 ft to 524 ft. Thus, average available reading times were also somewhat lower. Signs begin to fail at 45 mph, with over half provided enough reading time at 55 mph. Those performing the worst were the external-black-Clarendon and external-white-Clarendon signs, both which failed at 45 mph. The 15th percentile distances ranged from 215 ft to 364 ft. With these distances, signs began to fail at 30 mph, with the best performance coming from the translucent-yellow-Helvetica sign. Those performing the worst were three external signs with black-Clarendon, black-Helvetica, and white-Helvetica text.

Assuming legibility distances, performance during nighttime viewing was even poorer. The average distances ranged from 195 ft to 298 ft and the 15th percentile distances ranged from 130 ft to 224 ft. Considering average distances, only 5 signs provide adequate reading times at speeds over 30 mph, these being both neon signs (white and red), both translucent-yellow signs, and the opaque-yellow-Helvetica sign. Using the 15th percentile distances for legibility, only three signs provide 5.5 sec at any speed. These three were the opaque-yellow-Helvetica, the translucent-yellow-Clarendon, and the neon-white-Helvetica signs, all which only provided sufficient reading time at 25 mph. Beyond this speed, no signs perform adequately.

Discussion. The results from the available reading time analyses concur with the previous findings. In general, external illumination performs poorly and most often fails to provide adequate reading time at speeds of 30 mph and higher. Those signs which perform the best were internally illuminated signs with positive contrast designs. Neon also performed well at night. Also, assuming a 15th percentile distance significantly reduces the number of signs that can provide sufficient reading time at various speeds. All signs tested in this study had a 6" text height. It is unknown to what extent larger text will improve these available reading times.

4. FINDINGS AND RECOMMENDATIONS

This study assessed the performance of four nighttime illumination technologies commonly used by on-premise sign advertisers. These illumination technologies were field tested at night and during the day with different combinations of text and background color. The goal was to determine the impact of the technologies and sign colors on legibility distance. Two commonly used on-premise sign letter styles were used on the test signs. General study findings are provided in the following sections. Design recommendations are also given based on the study assumptions and findings.

SUBJECT AND TIME EFFECTS

The study revealed that for both recognition and legibility distances, younger subjects (ages 30-45) outperformed older subjects (ages 65 and older). These findings were expected based on the fact that the average visual acuity for younger subjects was significantly better than that for older subjects. No significant differences were found in average recognition and legibility distances based on gender.

Research findings also indicated that the test signs performed significantly better during daytime viewing than during nighttime viewing. This finding held for both recognition and legibility distances. Further, the performance difference was not a function of subject visual acuity as the average acuity for daytime subjects was not significantly different from that for nighttime subjects.

COLOR EFFECTS

As discussed previously, certain comparisons of color effects on sign legibility were confounded because of the varying stroke width to height ratios. However, despite these restrictions, some key information was gleaned from the study results. In general, positive contrast signs outperformed negative contrast signs for both recognition and legibility distance, especially during nighttime viewing. Further, when considering neon illumination, white text outperformed red during daytime viewing, but no significant difference in performance was found during nighttime viewing.

ILLUMINATION EFFECTS

As with color effects, complete comparisons of illumination technology effects were not possible because of the presence of different stroke width to height ratios. In general, external illumination performed the poorest. Internal illumination with opaque and translucent backgrounds outperformed external illumination for both daytime and nighttime viewing. Also, neon illumination outperformed external illumination during nighttime viewing, though not during daytime viewing.

FONT EFFECTS

No significant difference in font performance was observed in the study. As discussed earlier, unconfounded comparisons were impossible because of the variety of stroke width to height ratios and kernings. In general, the Clarendon font had a lower stroke width to height ratio than that for a companion Helvetica font in numerous comparisons. This difference in ratio could possibly account for the lack of performance difference.

AVAILABLE READING TIMES

The secondary research objective of this study was to determine the time available for a driver to read a sign message at various approach speeds. These available times were based on the measured recognition and legibility distances and were calculated for the average and 15th percentile distance for each test sign. Speeds considered ranged from 25 mph to 55 mph in 5 mph increments. Calculations were made for overall viewing, daytime, and nighttime viewing conditions, and were then compared to a 5.5 sec minimum required reading time (Garvey, Gates, and Pietrucha, 1995) to determine adequacy.

The results from the available reading time analyses concur with the previous findings from the study. In general, external illumination performs poorly and most often fails to provide adequate reading time at speeds of 30 mph or higher. Those signs which performed the best were internally illuminated signs with positive contrast designs. Neon also performed well at night. Also, assuming a 15th percentile distance significantly reduced the number of signs that provide sufficient reading time at various speeds. All signs tested in this study had a 6" text height. It is unknown to what extent larger text will improve these available reading times.

DESIGN RECOMMENDATIONS

Many factors contribute to sign legibility and detectibility (Thompson-Kuhn, Garvey, and Pietrucha, 1996), most of which interact with each other. As with similar research, this sign legibility study made various basic assumptions regarding on-premise signs. Each assumption is discussed below with design recommendations based on the study results.

Assumption 1: The sign is perpendicular to the observer's line of sign:

Maintain a sign placement within 10 degrees of the driver's central field of vision to ensure that messages displayed are not distorted. If for some reason the observation angle is larger than 20 degrees, adjust letter or symbol width and/or height to account for the distortion. Experimentation will most likely be necessary in such cases.

Assumption 2: The sign has five or fewer critical elements:

Assume that an on-premise sign has five or fewer critical elements. This assumption ensures that an alerted traveler can quickly and easily read the message and initiate a necessary response safely. If a sign has more than five critical elements, the traveler will take longer to read the message. To relate this effect of message sign to the available reading times in Appendix D, see Table 11.

Table 11. Message font size vs. available reading times.

Lighting	Text Color	Font	Average Legibility Distance (ft)	Available Reading Time (sec) Approach Speed (mph) 25	30	35
Opaque	Yellow	Helvetica	319	8.7	7.3	6.2
Translucent	Yellow	Clarendon	310	8.5	7.0	6.0
Neon	White	Helvetica	307	8.4	7.0	6.0
External	White	Clarendon	219	6.0	5.0	4.3

This table is a sample of the legibility reading time table from Appendix D, which assumes that each sign has five or fewer elements. A minimum required reading time of 5.5 sec (Garvey, Gates, and Pietrucha, 1995) is used to compare to the available reading times to determine the adequacy of the sign at various approach speeds. Thus, in the sample table, two reading times, those for the external-white-Clarendon sign at 30 and 35 mph, do not provide at least 5.5 sec of reading time. If a sign has more than five elements, subtract 1 sec from the available reading time listed in the tables in appendix D for each three additional critical elements that are added to the sign. Then, check the new reading time against a minimum of 5.5 sec to determine if the new reading time is adequate for a particular traffic approach speed. For example, if the external-white-Clarendon sign in table 11 had seven critical elements, then the time afforded at 25 mph would be 5.0 sec rather than 6.0 sec (i.e., 1 sec is subtracted for the additional two words in the message). Thus, the new time of 5.0 sec does not satisfy the minimum 5.5-sec reading time.

Assumption 3: The observer is alert and looking for the sign:

Assume that observers are alert and looking for a particular on-premise sign. If it is assumed that an observer is not looking for a sign, its conspicuity should be increased to attract the observer's attention. Conspicuity can be addressed via surround complexity, brightness contrast, border, color, size, shape, or display (Thompson-Kuhn, Garvey, and Pietrucha, 1996).

Assumption 4: The observer is not familiar with the sign:

Assume that the driver is unfamiliar with the on-premise sign and use the *legibility* distances and related available reading times provided in this study. If it is assumes that the driver is familiar with the sign, the *recognition* distances and related available reading times should be used. In other words, text height can be reduced by 30 percent and still provide adequate reading time if the driver is familiar with the sign.

Assumption 5: The observer has 20/40 or better visual acuity:

Assume that the average visual acuity of the driver population is 20/40 or better. This assumption is conservative and should be maintained, as this minimum visual acuity is required for holding a driver's license in most states.

Assumption 6: Copy is alphanumeric:

Assume that all text used is alphanumeric. If symbols are icons are used to convey a sign's meaning, legibility distance can improve. However, if the use of symbols reduces the size of the sign, conspicuity can be reduced. Furthermore, the observer should be able to easily recognize or understand the symbol for its use to be effective. The specific degree to which icons can increase legibility distance of on-premise signs is not known.

Assumption 7: Copy is displayed in lower case:

If possible, always use mixed- or lower-case letters in a sign display. If a sign will has uppercase-only letters, the text height should be increased by 15 percent to account for increased reading time.

Assumption 8: Copy is not abbreviated:

The words illustrated on a sign should be full text and not abbreviated in any manner. If abbreviations are used, longer cognitive processing time may be required, increasing the time necessary for a driver to read the sign. If the abbreviation is well-known and easily recognizable by an observer, this problem may not arise. It is unknown to what extent abbreviations reduce legibility distance of on-premise signs.

Assumption 9: Copy display uses positive contrast:

Positive-contrast signs (light text on darker background) perform better both at night and during the day and should be used whenever possible. If a negative-contrast sign is used, text height should be increased by 20 percent to account for decreased visibility performance.

Assumption 10: Fonts are simple, not ornate:

The two fonts tested in this study were Helvetica and Clarendon, neither of which is highly ornate. The impact of more ornate text styles frequently used in the on-premise sign industry on recognition and legibility distances is unknown.

Assumption 11: Internal or neon illuminated technology is used:

Internal illumination (with either opaque or translucent background) and neon illumination perform equally well and outperform external illumination under all viewing conditions. If external illumination is used, text height should be increased by 25 percent to account for the decreased visibility performance. Furthermore, neon illumination performs best at night, but any design with clear glass tubing presents visibility problems during daytime viewing when subjected to direct sunlight.

DISCUSSION

The design recommendations contained in this report are based on previous research (Thompson-Kuhn, Garvey, and Pietrucha, 1996) and the results obtained in this study. There is still, however, research that is needed to improve our understanding of sign visibility. Answers to the following questions would greatly improve the design guidelines for on-premise signs:

- How does letter height affect legibility and detection?
- How do the various methods of external illumination affect performance?
- What is the optimal amount of negative space and how should it be arrayed?
- How do extremely ornate fonts affect legibility and detection?
- What are the impacts of changes in internal contrast and luminance?
- How do sign size and brightness interact with setback and mounting height?

- What are the detection and legibility distances of signs that are in themselves symbols, such as the McDonald's arch and the Texaco star?

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APPENDIX A:
SUBJECT CHARACTERISTICS

Table A - 1. Subject Gender and Visual Correction.

Group	Testing Time	Gender		Visual Correction		
		Female	Male	Contacts	Glasses	None
1	Day	11	9	5	9	6
	Night	15	5	3	12	5
	Total	**26**	**14**	**8**	**21**	**11**
2	Day	11	5	0	13	3
	Night	9	7	1	14	1
	Total	**20**	**12**	**1**	**27**	**4**
3	Day	2	8	0	8	2
	Night	5	5	0	9	1
	Total	**7**	**13**	**0**	**17**	**3**
Total		**53**	**39**	**9**	**65**	**18**

Table A - 2. Average Subject Visual Acuity and Contrast Sensitivity.

Visual Statistic	Subject Group	Gender		Visual Correction			Viewing Order			
		Female	Male	Contacts	Glasses	None	A	B	C	D
Acuity	**30-45**	19.5	19.4	21.9	19.9	16.9	20.8	18.0	18.8	20.3
	65-74	26.5	28.3	30.0	26.9	28.8	27.0	28.1	27.1	26.4
	75+	30.0	30.0		30.0	30.0	29.2	30.7	32.0	25.0
	Total	23.5	25.7	22.8	25.4	21.7	25.1	24.8	24.5	23.1
CS 1.5	**30-45**	59.0	58.6	69.4	59.0	50.9	69.5	49.0	56.0	61.0
	65-74	45.0	55.4	70.0	48.9	43.8	42.5	52.5	50.0	52.9
	75+	32.9	46.2		40.6	46.7	58.3	30.7	39.0	35.0
	Total	50.3	53.5	69.4	50.0	48.6	56.6	45.0	50.2	55.3
CS 3	**30-45**	118.0	115.4	144.4	111.4	108.2	111.4	110.5	110.5	136.0
	65-74	76.1	78.2	85.0	76.9	74.8	68.6	74.8	85.4	82.6
	75+	55.7	74.2		59.7	113.3	85.5	67.4	56.4	44.0
	Total	93.9	90.2	137.8	83.5	101.6	89.0	87.0	90.2	106.6
CS 6	**30-45**	111.7	128.6	118.8	110.0	131.4	124.0	112.0	108.5	126.0
	65-74	59.8	58.0	45.0	61.2	49.0	57.0	64.4	60.1	55.1
	75+	43.7	42.5		41.1	53.3	49.3	40.1	38.4	45.0
	Total	83.2	78.2	110.6	71.7	100.1	81.0	76.6	77.2	91.4
CS 12	**30-45**	66.6	65.3	69.4	58.2	79.0	59.9	63.5	67.8	73.4
	65-74	26.3	25.8	15.0	27.3	20.8	28.1	20.0	28.1	28.1
	75+	20.3	13.5		12.1	37.0	29.0	9.9	10.2	11.5
	Total	45.3	35.8	63.3	33.3	59.1	40.5	34.6	42.1	50.2
CS 18	**30-45**	20.2	19.0	21.6	17.0	23.8	19.8	19.0	19.5	20.8
	65-74	8.0	6.2	4.0	7.6	6.5	9.3	5.4	7.3	7.0
	75+	9.0	6.0		5.8	14.3	9.8	9.1	3.6	0.0
	Total	14.1	10.7	19.7	10.2	18.4	13.5	11.9	12.0	13.5

APPENDIX B:
SIGN DESIGN PROCEDURE

Table B - 1. Distractor words.

Word Footprint									
Middle Ascender (MA)		Middle Descender (MD)		Ending Ascender (EA)		Ending Descender (ED)		No Ascenders or Descenders (NAD)	
Word	Sign	Word	Sign	Word	Sign	Word	Sign	Word	Sign
fulton	1	lompoc	1	dorset	2	luning	3	lamson	5
delano	5	hosper	2	dunnel	3	linsey	17	lisman	18
helena	9	harper	7	lanark	8	lowery	7	lavaca	12
dundee	11	dupree	12	durant	6, 13	dorsey	9	frazee	15
hobson	6, 13	forgan	14	larned	15	harney	14	lorman	16
hamlin	16	borger	17	dassel	18	forney	11	donora	8

Table B - 2. Word Combinations with Target Word on Top

Sign Number	1	2	3	5	17
Top Word	TARGET	TARGET	TARGET	TARGET	TARGET
Middle Word	MA	MD	EA	NAD	MD
Bottom Word	MD	EA	ED	MA	ED

Table B - 3. Word Combinations with Target Word in Middle

Sign Number	6. 13	7	8	9	16
Top Word	MA	MD	EA	ED	MA
Middle Word	TARGET	TARGET	TARGET	TARGET	TARGET
Bottom Word	EA	ED	NAD	MA	NAD

Table B - 4. Word Combinations with Target Word on Bottom

Sign Number	11	12	14	15	18
Top Word	MA	MD	ED	NAD	EA
Middle Word	ED	NAD	MD	EA	NAD
Bottom Word	TARGET	TARGET	TARGET	TARGET	TARGET

Table B - 5. Sign distribution by lighting technology and color scheme.

Lighting Technology	External			Internal Opaque			Internal Translucent			Neon		
Target Location	T	M	B	T	M	B	T	M	B	T	M	B
Helvetica Color Scheme A		#9					#3					
Helvetica Color Scheme B			#15	#2				#16				
Helvetica Color Scheme C	#17					#11					#13	
Helvetica Color Scheme D											#6	
Clarendon Color Scheme A	#1								#14			
Clarendon Color Scheme B		#7				#12	#5					
Clarendon Color Scheme C			#18		#8							
Clarendon Color Scheme D												

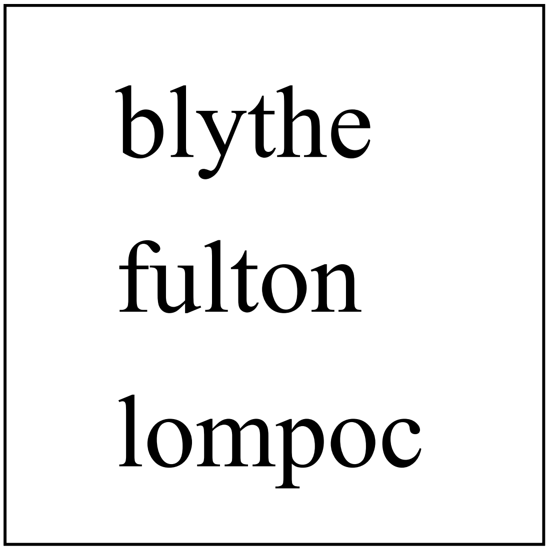

Figure B – 1. Sign 1
(External – Clarendon – Color Scheme A)

Figure B – 2. Sign 2
(Internal Opaque – Helvetica – Color Scheme B)

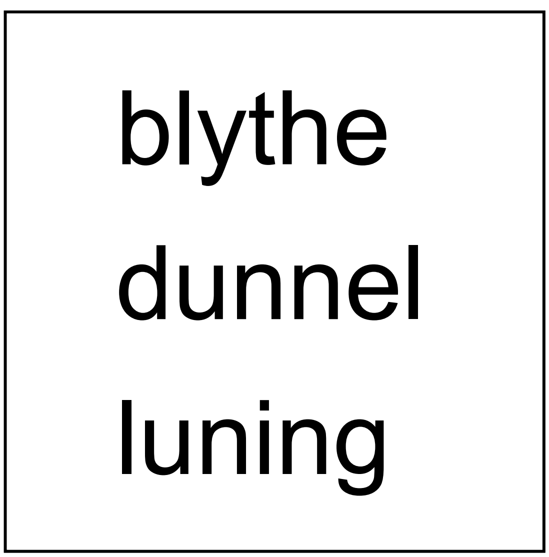

Figure B – 3. Sign 3
(Internal Translucent – Helvetica – Color Scheme A)

Figure B – 4. Sign 5
(Internal Translucent – Clarendon – Color Scheme B)

Figure B – 5. Sign 6
(Neon – Helvetica – Color Scheme D)

Figure B – 6. Sign 7
(External – Clarendon – Color Scheme B)

Figure B – 7. Sign 8
(Internal Opaque – Clarendon – Color Scheme C)

Figure B – 8. Sign 9
(External – Helvetica – Color Scheme A)

Figure B – 9. Sign 11
(Internal Opaque – Helvetica – Color Scheme C)

Figure B – 10. Sign 12
(Internal Opaque – Clarendon – Color Scheme B)

Figure B – 11. Sign 13
(Neon – Helvetica – Color Scheme C)

Figure B – 12. Sign 14
(Internal Translucent – Clarendon – Color Scheme A)

Figure B – 13. Sign 15
(External – Helvetica – Color Scheme B)

Figure B – 14. Sign 16
(Internal Translucent – Helvetica – Color Scheme B)

Figure B – 15. Sign 17
(External – Helvetica – Color Scheme C)

Figure B – 16. Sign 18
(External – Clarendon – Color Scheme C)

APPENDIX C:

SIGN VIEWING ORDERS

Table C - 1. Sign viewing order A.

Lighting Technology and Sign Location				
External **Location 1**	**Internal Translucent** **Location 5**	**Internal Opaque** **Location 4**	**External** **Location 2**	**Neon** **Location 3**
blythe borger linsey	harney forgan blythe	dundee forney blythe	frazee larned blythe	
dorsey blythe helena	blythe dunnel luning	dupree lavaca blythe	dassel lisman blythe	
harper blythe lowery	hamlin blythe lorman	lanark blythe donora		hobson blythe durant
blythe fulton lompoc	blythe lamson delano	blythe hosper dorset		

Table C - 2. Sign viewing order B.

Lighting Technology and Sign Location				
Neon **Location 3**	**External** **Location 2**	**Internal Opaque** **Location 4**	**Internal Translucent** **Location 5**	**External** **Location 1**
hobson blythe durant		dupree lavaca blythe	blythe dunnel luning	harper blythe lowery
	dorsey blythe helena	blythe hosper dorset	blythe lamson delano	blythe borger linsey
	blythe fulton lompoc	dundee forney blythe	harney forgan blythe	dassel lisman blythe
		lanark blythe donora	hamlin blythe lorman	frazee larned blythe

Table C - 3. Sign viewing order C.

Lighting Technology and Sign Location				
Internal Opaque **Location 4**	**External** **Location 2**	**Neon** **Location 3**	**External** **Location 1**	**Internal Translucent** **Location 5**
lanark blythe donora	frazee larned blythe		dassel lisman blythe	blythe lamson delano
dundee forney blythe		hobson blythe durant	blythe fulton lompoc	hamlin blythe lorman
blythe hosper dorset	blythe borger linsey		dorsey blythe helena	blythe dunnel luning
dupree lavaca blythe			harper blythe lowery	harney forgan blythe

Table C - 4. Sign viewing order D.

Lighting Technology and Sign Location				
Internal Translucent **Location 5**	**External** **Location 1**	**External** **Location 2**	**Neon** **Location 3**	**Internal Opaque** **Location 4**
hamlin blythe lorman	blythe fulton lompoc	harper blythe lowery		blythe hosper dorset
harney forgan blythe	dassel lisman blythe	dorsey blythe helena		lanark blythe donora
blythe lamson delano	frazee larned blythe		hobson blythe durant	dupree lavaca blythe
blythe dunnel luning	blythe borger linsey			dundee forney blythe

APPENDIX D:

AVAILABLE READING TIMES

Table D – 1. General Distances.*

Sign	Lighting	Scheme	Font	Recognition Distance				Legibility Distance				Legibility Index	
				Mean	Std Dev	85th	15th	Mean	Std Dev	85th	15th	Mean	15th
2	Opaque	Yellow	Helvetica	558	170	748	363	320	97	420	221	53	37
16	Translucent	Yellow	Helvetica	556	159	727	380	314	90	406	221	52	37
5	Translucent	Yellow	Clarendon	536	166	728	351	311	87	399	219	52	37
12	Opaque	Yellow	Clarendon	536	176	715	321	291	85	391	196	49	33
8	Opaque	White	Clarendon	533	156	679	373	289	85	386	213	48	36
11	Opaque	White	Helvetica	533	169	706	329	300	85	379	204	50	34
13	Neon	White	Helvetica	510	123	644	359	308	68	379	226	51	38
18	External	White	Clarendon	448	139	607	285	220	68	294	141	37	24
14	Translucent	Black	Clarendon	441	139	608	286	280	80	370	186	47	31
6	Neon	Red	Helvetica	439	176	606	283	272	102	356	172	45	29
15	External	Yellow	Helvetica	437	144	612	282	260	85	361	158	43	26
3	Translucent	Black	Helvetica	433	139	599	278	247	78	329	172	41	29
7	External	Yellow	Clarendon	433	145	587	286	290	101	386	184	48	31
1	External	Black	Clarendon	413	150	590	229	263	84	366	169	44	28
9	External	Black	Helvetica	398	134	543	233	252	79	351	173	42	29
17	External	White	Helvetica	397	162	612	230	248	79	335	158	41	26

* Ranked in descending order according to Recognition Distance

Table D – 1. General Distances.*

Sign	Lighting	Scheme	Font	Recognition Distance				Legibility Distance				Legibility Index	
				Mean	Std Dev	85th	15th	Mean	Std Dev	85th	15th	Mean	15th
2	Opaque	Yellow	Helvetica	558	170	748	363	320	97	420	221	53	37
16	Translucent	Yellow	Helvetica	556	159	727	380	314	90	406	221	52	37
5	Translucent	Yellow	Clarendon	536	166	728	351	311	87	399	219	52	37
13	Neon	White	Helvetica	510	123	644	359	308	68	379	226	51	38
11	Opaque	White	Helvetica	533	169	706	329	300	85	379	204	50	34
12	Opaque	Yellow	Clarendon	536	176	715	321	291	85	391	196	49	33
7	External	Yellow	Clarendon	433	145	587	286	290	101	386	184	48	31
8	Opaque	White	Clarendon	533	156	679	373	289	85	386	213	48	36
14	Translucent	Black	Clarendon	441	139	608	286	280	80	370	186	47	31
6	Neon	Red	Helvetica	439	176	606	283	272	102	356	172	45	29
1	External	Black	Clarendon	413	150	590	229	263	84	366	169	44	28
15	External	Yellow	Helvetica	437	144	612	282	260	85	361	158	43	26
9	External	Black	Helvetica	398	134	543	233	252	79	351	173	42	29
17	External	White	Helvetica	397	162	612	230	248	79	335	158	41	26
3	Translucent	Black	Helvetica	433	139	599	278	247	78	329	172	41	29
18	External	White	Clarendon	448	139	607	285	220	68	294	141	37	24

* Ranked in descending order according to Legibility Distance

Table D – 2. Daytime Distances.*

Sign	Lighting	Scheme	Font	Recognition Distance				Legibility Distance				Legibility Index	
				Mean	Std Dev	85th	15th	Mean	Std Dev	85th	15th	Mean	15th
5	Translucent	Yellow	Clarendon	600	169	778	406	331	90	421	260	55	43
2	Opaque	Yellow	Helvetica	593	180	769	369	340	103	449	221	57	37
16	Translucent	Yellow	Helvetica	589	160	726	427	335	95	438	257	56	43
11	Opaque	White	Helvetica	578	173	753	358	330	91	428	226	55	38
8	Opaque	White	Clarendon	566	154	701	430	320	85	411	238	53	40
12	Opaque	Yellow	Clarendon	546	177	745	332	316	91	420	205	53	34
13	Neon	White	Helvetica	527	120	659	400	321	80	416	230	54	38
18	External	White	Clarendon	501	127	630	361	243	65	313	178	41	30
15	External	Yellow	Helvetica	486	150	632	311	287	90	383	178	48	30
14	Translucent	Black	Clarendon	485	142	632	342	289	78	369	205	48	34
1	External	Black	Clarendon	478	146	639	335	289	72	378	217	48	36
3	Translucent	Black	Helvetica	465	144	632	329	248	70	328	177	41	30
7	External	Yellow	Clarendon	456	157	642	288	309	104	428	201	52	34
17	External	White	Helvetica	454	173	662	266	274	84	354	164	46	27
9	External	Black	Helvetica	449	135	602	324	280	77	367	205	47	34
6	Neon	Red	Helvetica	409	201	568	180	263	120	357	129	44	22

* Ranked in descending order according to Recognition Distance

Table D – 2. Daytime Distances.*

Sign	Lighting	Scheme	Font	Recognition Distance				Legibility Distance				Legibility Index	
				Mean	Std Dev	85th	15th	Mean	Std Dev	85th	15th	Mean	15th
2	Opaque	Yellow	Helvetica	593	180	769	369	340	103	449	221	57	37
16	Translucent	Yellow	Helvetica	589	160	726	427	335	95	438	257	56	43
5	Translucent	Yellow	Clarendon	600	169	778	406	331	90	421	260	55	43
11	Opaque	White	Helvetica	578	173	753	358	330	91	428	226	55	38
13	Neon	White	Helvetica	527	120	659	400	321	80	416	230	54	38
8	Opaque	White	Clarendon	566	154	701	430	320	85	411	238	53	40
12	Opaque	Yellow	Clarendon	546	177	745	332	316	91	420	205	53	34
7	External	Yellow	Clarendon	456	157	642	288	309	104	428	201	52	34
1	External	Black	Clarendon	478	146	639	335	289	72	378	217	48	36
14	Translucent	Black	Clarendon	485	142	632	342	289	78	369	205	48	34
15	External	Yellow	Helvetica	486	150	632	311	287	90	383	178	48	30
9	External	Black	Helvetica	449	135	602	324	280	77	367	205	47	34
17	External	White	Helvetica	454	173	662	266	274	84	354	164	46	27
6	Neon	Red	Helvetica	409	201	568	180	263	120	357	129	44	22
3	Translucent	Black	Helvetica	465	144	632	329	248	70	328	177	41	30
18	External	White	Clarendon	501	127	630	361	243	65	313	178	41	30

* Ranked in descending order according to Legibility Distance

Table D – 3. Nighttime Distances.*

Sign	Lighting	Scheme	Font	Recognition Distance				Legibility Distance				Legibility Index	
				Mean	Std Dev	85th	15th	Mean	Std Dev	85th	15th	Mean	15th
12	Opaque	Yellow	Clarendon	525	176	702	310	266	71	342	193	44	32
2	Opaque	Yellow	Helvetica	523	155	701	356	299	88	379	206	50	34
16	Translucent	Yellow	Helvetica	523	153	723	365	294	82	394	198	49	33
8	Opaque	White	Clarendon	500	153	646	333	258	73	352	200	43	33
13	Neon	White	Helvetica	495	126	653	354	296	55	368	225	49	38
11	Opaque	White	Helvetica	487	153	651	296	269	66	329	194	45	32
6	Neon	Red	Helvetica	474	140	609	337	282	78	359	198	47	33
5	Translucent	Yellow	Clarendon	471	138	628	321	291	81	389	208	49	35
7	External	Yellow	Clarendon	411	130	542	281	272	95	382	182	45	30
3	Translucent	Black	Helvetica	402	128	546	266	245	85	332	166	41	28
14	Translucent	Black	Clarendon	398	121	517	258	271	81	373	169	45	28
18	External	White	Clarendon	396	131	563	274	197	62	265	132	33	22
15	External	Yellow	Helvetica	389	121	522	253	233	71	314	156	39	26
1	External	Black	Clarendon	349	125	500	222	237	88	353	152	40	25
9	External	Black	Helvetica	347	112	477	216	223	71	298	142	37	24
17	External	White	Helvetica	340	127	453	216	222	65	276	157	37	26

* Ranked in descending order according to Recognition Distance

Table D – 3. Nighttime Distances.*

Sign	Lighting	Scheme	Font	Recognition Distance				Legibility Distance				Legibility Index	
				Mean	Std Dev	85th	15th	Mean	Std Dev	85th	15th	Mean	15th
2	Opaque	Yellow	Helvetica	523	155	701	356	299	88	379	206	50	34
13	Neon	White	Helvetica	495	126	653	354	296	55	368	225	49	38
16	Translucent	Yellow	Helvetica	523	153	723	365	294	82	394	198	49	33
5	Translucent	Yellow	Clarendon	471	138	628	321	291	81	389	208	49	35
6	Neon	Red	Helvetica	474	140	609	337	282	78	359	198	47	33
7	External	Yellow	Clarendon	411	130	542	281	272	95	382	182	45	30
14	Translucent	Black	Clarendon	398	121	517	258	271	81	373	169	45	28
11	Opaque	White	Helvetica	487	153	651	296	269	66	329	194	45	32
12	Opaque	Yellow	Clarendon	525	176	702	310	266	71	342	193	44	32
8	Opaque	White	Clarendon	500	153	646	333	258	73	352	200	43	33
3	Translucent	Black	Helvetica	402	128	546	266	245	85	332	166	41	28
1	External	Black	Clarendon	349	125	500	222	237	88	353	152	40	25
15	External	Yellow	Helvetica	389	121	522	253	233	71	314	156	39	26
9	External	Black	Helvetica	347	112	477	216	223	71	298	142	37	24
17	External	White	Helvetica	340	127	453	216	222	65	276	157	37	26
18	External	White	Clarendon	396	131	563	274	197	62	265	132	33	22

* Ranked in descending order according to Legibility Distance

Table D – 4. General Reading Times.

Sign	Lighting	Scheme	Font	Available Recognition Reading Time (sec) #															
				Mean Distance *	Approach Speed (mph)							15th % Distance *	Approach Speed (mph)						
				(ft)	25	30	35	40	45	50	55	(ft)	25	30	35	40	45	50	55
1	External	Black	Clarendon	412	11.2	9.4	8.0	7.0	6.2	5.6	5.1	228	6.2	5.2	4.4	3.9	3.4	3.1	2.8
2	Opaque	Yellow	Helvetica	557	15.2	12.7	10.9	9.5	8.4	7.6	6.9	362	9.9	8.2	7.1	6.2	5.5	4.9	4.5
3	Translucent	Black	Helvetica	432	11.8	9.8	8.4	7.4	6.5	5.9	5.4	277	7.6	6.3	5.4	4.7	4.2	3.8	3.4
5	Translucent	Yellow	Clarendon	535	14.6	12.2	10.4	9.1	8.1	7.3	6.6	350	9.5	8.0	6.8	6.0	5.3	4.8	4.3
6	Neon	Red	Helvetica	438	12.0	10.0	8.5	7.5	6.6	6.0	5.4	282	7.7	6.4	5.5	4.8	4.3	3.8	3.5
7	External	Yellow	Clarendon	432	11.8	9.8	8.4	7.4	6.5	5.9	5.4	285	7.8	6.5	5.6	4.9	4.3	3.9	3.5
8	Opaque	White	Clarendon	532	14.5	12.1	10.4	9.1	8.1	7.3	6.6	372	10.1	8.5	7.2	6.3	5.6	5.1	4.6
9	External	Black	Helvetica	397	10.8	9.0	7.7	6.8	6.0	5.4	4.9	232	6.3	5.3	4.5	3.9	3.5	3.2	2.9
11	Opaque	White	Helvetica	532	14.5	12.1	10.4	9.1	8.1	7.3	6.6	328	8.9	7.5	6.4	5.6	5.0	4.5	4.1
12	Opaque	Yellow	Clarendon	535	14.6	12.2	10.4	9.1	8.1	7.3	6.6	320	8.7	7.3	6.2	5.5	4.8	4.4	4.0
13	Neon	White	Helvetica	509	13.9	11.6	9.9	8.7	7.7	6.9	6.3	358	9.8	8.1	7.0	6.1	5.4	4.9	4.4
14	Translucent	Black	Clarendon	440	12.0	10.0	8.6	7.5	6.7	6.0	5.5	285	7.8	6.5	5.6	4.9	4.3	3.9	3.5
15	External	Yellow	Helvetica	436	11.9	9.9	8.5	7.4	6.6	5.9	5.4	281	7.7	6.4	5.5	4.8	4.3	3.8	3.5
16	Translucent	Yellow	Helvetica	555	15.1	12.6	10.8	9.5	8.4	7.6	6.9	379	10.3	8.6	7.4	6.5	5.7	5.2	4.7
17	External	White	Helvetica	396	10.8	9.0	7.7	6.8	6.0	5.4	4.9	229	6.2	5.2	4.5	3.9	3.5	3.1	2.8
18	External	White	Clarendon	447	12.2	10.2	8.7	7.6	6.8	6.1	5.5	284	7.7	6.5	5.5	4.8	4.3	3.9	3.5
			Maximum:	557							Maximum:	379							
			Minimum:	396							Minimum:	228							
			Range:	161							Range:	152							

Sign	Available Legibility Reading Time (sec) #															
	Mean Distance *	Approach Speed (mph)							15th % Distance *	Approach Speed (mph)						
	(ft)	25	30	35	40	45	50	55	(ft)	25	30	35	40	45	50	55
1	262	7.1	6.0	5.1	4.5	4.0	3.6	3.2	167	4.6	3.8	3.3	2.8	2.5	2.3	2.1
2	319	8.7	7.3	6.2	5.4	4.8	4.4	4.0	220	6.0	5.0	4.3	3.7	3.3	3.0	2.7
3	246	6.7	5.6	4.8	4.2	3.7	3.4	3.0	170	4.6	3.9	3.3	2.9	2.6	2.3	2.1
5	310	8.5	7.0	6.0	5.3	4.7	4.2	3.8	218	5.9	4.9	4.2	3.7	3.3	3.0	2.7
6	271	7.4	6.2	5.3	4.6	4.1	3.7	3.4	170	4.6	3.9	3.3	2.9	2.6	2.3	2.1
7	289	7.9	6.6	5.6	4.9	4.4	3.9	3.6	182	5.0	4.1	3.6	3.1	2.8	2.5	2.3
8	288	7.9	6.5	5.6	4.9	4.4	3.9	3.6	212	5.8	4.8	4.1	3.6	3.2	2.9	2.6
9	251	6.8	5.7	4.9	4.3	3.8	3.4	3.1	171	4.7	3.9	3.3	2.9	2.6	2.3	2.1
11	299	8.2	6.8	5.8	5.1	4.5	4.1	3.7	202	5.5	4.6	3.9	3.5	3.1	2.8	2.5
12	290	7.9	6.6	5.6	4.9	4.4	4.0	3.6	194	5.3	4.4	3.8	3.3	2.9	2.7	2.4
13	307	8.4	7.0	6.0	5.2	4.7	4.2	3.8	225	6.1	5.1	4.4	3.8	3.4	3.1	2.8
14	279	7.6	6.3	5.4	4.8	4.2	3.8	3.5	184	5.0	4.2	3.6	3.1	2.8	2.5	2.3
15	259	7.1	5.9	5.0	4.4	3.9	3.5	3.2	156	4.3	3.5	3.0	2.7	2.4	2.1	1.9
16	313	8.5	7.1	6.1	5.3	4.7	4.3	3.9	220	6.0	5.0	4.3	3.7	3.3	3.0	2.7
17	247	6.7	5.6	4.8	4.2	3.7	3.4	3.1	156	4.3	3.5	3.0	2.7	2.4	2.1	1.9
18	219	6.0	5.0	4.3	3.7	3.3	3.0	2.7	139	3.8	3.2	2.7	2.4	2.1	1.9	1.7
	319							Maximum:	225							
	219							Minimum:	139							
	100							Range:	86							

Shaded areas represent inadequate available reading time for the approach speed.
* Converted to Road Distance

Table D – 5. Daytime Reading Times.

Available Recognition Reading Time (sec) #

Sign	Lighting	Scheme	Font	Mean Distance * (ft)	Approach Speed (mph) 25	30	35	40	45	50	55	15th % Distance * (ft)	Approach Speed (mph) 25	30	35	40	45	50	55
1	External	Black	Clarendon	477	13.0	10.8	9.3	8.1	7.2	6.5	5.9	334	9.1	7.6	6.5	5.7	5.1	4.6	4.1
2	Opaque	Yellow	Helvetica	592	16.2	13.5	11.5	10.1	9.0	8.1	7.3	368	10.0	8.4	7.2	6.3	5.6	5.0	4.6
3	Translucent	Black	Helvetica	464	12.7	10.6	9.0	7.9	7.0	6.3	5.8	328	8.9	7.5	6.4	5.6	5.0	4.5	4.1
5	Translucent	Yellow	Clarendon	599	16.3	13.6	11.7	10.2	9.1	8.2	7.4	405	11.1	9.2	7.9	6.9	6.1	5.5	5.0
6	Neon	Red	Helvetica	408	11.1	9.3	8.0	7.0	6.2	5.6	5.1	178	4.9	4.1	3.5	3.0	2.7	2.4	2.2
7	External	Yellow	Clarendon	455	12.4	10.3	8.9	7.8	6.9	6.2	5.6	287	7.8	6.5	5.6	4.9	4.3	3.9	3.6
8	Opaque	White	Clarendon	565	15.4	12.9	11.0	9.6	8.6	7.7	7.0	429	11.7	9.8	8.4	7.3	6.5	5.9	5.3
9	External	Black	Helvetica	448	12.2	10.2	8.7	7.6	6.8	6.1	5.6	323	8.8	7.3	6.3	5.5	4.9	4.4	4.0
11	Opaque	White	Helvetica	577	15.7	13.1	11.2	9.8	8.7	7.9	7.2	357	9.7	8.1	7.0	6.1	5.4	4.9	4.4
12	Opaque	Yellow	Clarendon	545	14.9	12.4	10.6	9.3	8.3	7.4	6.8	331	9.0	7.5	6.4	5.6	5.0	4.5	4.1
13	Neon	White	Helvetica	526	14.4	12.0	10.3	9.0	8.0	7.2	6.5	399	10.9	9.1	7.8	6.8	6.0	5.4	4.9
14	Translucent	Black	Clarendon	484	13.2	11.0	9.4	8.3	7.3	6.6	6.0	341	9.3	7.8	6.6	5.8	5.2	4.7	4.2
15	External	Yellow	Helvetica	485	13.2	11.0	9.5	8.3	7.4	6.6	6.0	310	8.5	7.0	6.0	5.3	4.7	4.2	3.8
16	Translucent	Yellow	Helvetica	588	16.0	13.4	11.5	10.0	8.9	8.0	7.3	426	11.6	9.7	8.3	7.3	6.5	5.8	5.3
17	External	White	Helvetica	453	12.4	10.3	8.8	7.7	6.9	6.2	5.6	265	7.2	6.0	5.2	4.5	4.0	3.6	3.3
18	External	White	Clarendon	500	13.6	11.4	9.7	8.5	7.6	6.8	6.2	360	9.8	8.2	7.0	6.1	5.5	4.9	4.5
			Maximum:	599							Maximum:	429							
			Minimum:	408							Minimum:	178							
			Range:	191							Range:	251							

Available Legibility Reading Time (sec) #

Sign	Mean Distance * (ft)	Approach Speed (mph) 25	30	35	40	45	50	55	15th % Distance * (ft)	Approach Speed (mph) 25	30	35	40	45	50	55
1	288	7.9	6.5	5.6	4.9	4.4	3.9	3.6	216	5.9	4.9	4.2	3.7	3.3	2.9	2.7
2	339	9.2	7.7	6.6	5.8	5.1	4.6	4.2	220	6.0	5.0	4.3	3.7	3.3	3.0	2.7
3	247	6.7	5.6	4.8	4.2	3.7	3.4	3.1	175	4.8	4.0	3.4	3.0	2.7	2.4	2.2
5	330	9.0	7.5	6.4	5.6	5.0	4.5	4.1	259	7.1	5.9	5.0	4.4	3.9	3.5	3.2
6	262	7.1	6.0	5.1	4.5	4.0	3.6	3.2	127	3.5	2.9	2.5	2.2	1.9	1.7	1.6
7	308	8.4	7.0	6.0	5.2	4.7	4.2	3.8	199	5.4	4.5	3.9	3.4	3.0	2.7	2.5
8	319	8.7	7.3	6.2	5.4	4.8	4.4	4.0	237	6.5	5.4	4.6	4.0	3.6	3.2	2.9
9	279	7.6	6.3	5.4	4.8	4.2	3.8	3.5	203	5.5	4.6	4.0	3.5	3.1	2.8	2.5
11	329	9.0	7.5	6.4	5.6	5.0	4.5	4.1	225	6.1	5.1	4.4	3.8	3.4	3.1	2.8
12	315	8.6	7.2	6.1	5.4	4.8	4.3	3.9	203	5.5	4.6	4.0	3.5	3.1	2.8	2.5
13	320	8.7	7.3	6.2	5.5	4.8	4.4	4.0	229	6.2	5.2	4.5	3.9	3.5	3.1	2.8
14	288	7.9	6.5	5.6	4.9	4.4	3.9	3.6	203	5.5	4.6	4.0	3.5	3.1	2.8	2.5
15	286	7.8	6.5	5.6	4.9	4.3	3.9	3.5	176	4.8	4.0	3.4	3.0	2.7	2.4	2.2
16	334	9.1	7.6	6.5	5.7	5.1	4.6	4.1	256	7.0	5.8	5.0	4.4	3.9	3.5	3.2
17	273	7.4	6.2	5.3	4.7	4.1	3.7	3.4	162	4.4	3.7	3.2	2.8	2.5	2.2	2.0
18	242	6.6	5.5	4.7	4.1	3.7	3.3	3.0	176	4.8	4.0	3.4	3.0	2.7	2.4	2.2
	339							Maximum:	259							
	242							Minimum:	127							
	97							Range:	132							

\# Shaded areas represent inadequate available reading time for the approach speed.
* Converted to Road Distance

Table D – 6. Nighttime Reading Times.

Sign	Lighting	Scheme	Font	Available Recognition Reading Time (sec) # Mean Distance * (ft)	Approach Speed (mph) 25	30	35	40	45	50	55	15th % Distance * (ft)	Approach Speed (mph) 25	30	35	40	45	50	55
1	External	Black	Clarendon	348	9.5	7.9	6.8	5.9	5.3	4.7	4.3	221	6.0	5.0	4.3	3.8	3.3	3.0	2.7
2	Opaque	Yellow	Helvetica	522	14.2	11.9	10.2	8.9	7.9	7.1	6.5	355	9.7	8.1	6.9	6.1	5.4	4.8	4.4
3	Translucent	Black	Helvetica	401	10.9	9.1	7.8	6.8	6.1	5.5	5.0	265	7.2	6.0	5.2	4.5	4.0	3.6	3.3
5	Translucent	Yellow	Clarendon	470	12.8	10.7	9.2	8.0	7.1	6.4	5.8	320	8.7	7.3	6.2	5.5	4.8	4.4	4.0
6	Neon	Red	Helvetica	473	12.9	10.8	9.2	8.1	7.2	6.5	5.9	336	9.2	7.6	6.5	5.7	5.1	4.6	4.2
7	External	Yellow	Clarendon	410	11.2	9.3	8.0	7.0	6.2	5.6	5.1	280	7.6	6.4	5.5	4.8	4.2	3.8	3.5
8	Opaque	White	Clarendon	499	13.6	11.3	9.7	8.5	7.6	6.8	6.2	332	9.1	7.5	6.5	5.7	5.0	4.5	4.1
9	External	Black	Helvetica	346	9.4	7.9	6.7	5.9	5.2	4.7	4.3	215	5.9	4.9	4.2	3.7	3.3	2.9	2.7
11	Opaque	White	Helvetica	486	13.3	11.1	9.5	8.3	7.4	6.6	6.0	295	8.0	6.7	5.7	5.0	4.5	4.0	3.7
12	Opaque	Yellow	Clarendon	524	14.3	11.9	10.2	8.9	7.9	7.2	6.5	309	8.4	7.0	6.0	5.3	4.7	4.2	3.8
13	Neon	White	Helvetica	494	13.5	11.2	9.6	8.4	7.5	6.7	6.1	353	9.6	8.0	6.9	6.0	5.4	4.8	4.4
14	Translucent	Black	Clarendon	397	10.8	9.0	7.7	6.8	6.0	5.4	4.9	257	7.0	5.8	5.0	4.4	3.9	3.5	3.2
15	External	Yellow	Helvetica	388	10.6	8.8	7.6	6.6	5.9	5.3	4.8	252	6.9	5.7	4.9	4.3	3.8	3.4	3.1
16	Translucent	Yellow	Helvetica	522	14.2	11.9	10.2	8.9	7.9	7.1	6.5	364	9.9	8.3	7.1	6.2	5.5	5.0	4.5
17	External	White	Helvetica	339	9.2	7.7	6.6	5.8	5.1	4.6	4.2	215	5.9	4.9	4.2	3.7	3.3	2.9	2.7
18	External	White	Clarendon	395	10.8	9.0	7.7	6.7	6.0	5.4	4.9	273	7.4	6.2	5.3	4.7	4.1	3.7	3.4
			Maximum:	524							Maximum:	364							
			Minimum:	339							Minimum:	215							
			Range:	185							Range:	150							

Sign	Lighting	Scheme	Font	Available Legibility Reading Time (sec) # Mean Distance * (ft)	Approach Speed (mph) 25	30	35	40	45	50	55	15th % Distance * (ft)	Approach Speed (mph) 25	30	35	40	45	50	55
1	External	Black	Clarendon	236	6.4	5.4	4.6	4.0	3.6	3.2	2.9	150	4.1	3.4	2.9	2.6	2.3	2.0	1.9
2	Opaque	Yellow	Helvetica	298	8.1	6.8	5.8	5.1	4.5	4.1	3.7	204	5.6	4.6	4.0	3.5	3.1	2.8	2.5
3	Translucent	Black	Helvetica	244	6.6	5.5	4.7	4.2	3.7	3.3	3.0	164	4.5	3.7	3.2	2.8	2.5	2.2	2.0
5	Translucent	Yellow	Clarendon	290	7.9	6.6	5.6	4.9	4.4	4.0	3.6	206	5.6	4.7	4.0	3.5	3.1	2.8	2.6
6	Neon	Red	Helvetica	281	7.7	6.4	5.5	4.8	4.3	3.8	3.5	196	5.4	4.5	3.8	3.3	3.0	2.7	2.4
7	External	Yellow	Clarendon	271	7.4	6.2	5.3	4.6	4.1	3.7	3.4	180	4.9	4.1	3.5	3.1	2.7	2.5	2.2
8	Opaque	White	Clarendon	257	7.0	5.8	5.0	4.4	3.9	3.5	3.2	198	5.4	4.5	3.9	3.4	3.0	2.7	2.5
9	External	Black	Helvetica	222	6.0	5.0	4.3	3.8	3.4	3.0	2.7	140	3.8	3.2	2.7	2.4	2.1	1.9	1.7
11	Opaque	White	Helvetica	268	7.3	6.1	5.2	4.6	4.1	3.7	3.3	192	5.2	4.4	3.7	3.3	2.9	2.6	2.4
12	Opaque	Yellow	Clarendon	265	7.2	6.0	5.2	4.5	4.0	3.6	3.3	191	5.2	4.3	3.7	3.3	2.9	2.6	2.4
13	Neon	White	Helvetica	295	8.0	6.7	5.7	5.0	4.5	4.0	3.7	224	6.1	5.1	4.4	3.8	3.4	3.0	2.8
14	Translucent	Black	Clarendon	270	7.4	6.1	5.3	4.6	4.1	3.7	3.3	167	4.6	3.8	3.3	2.8	2.5	2.3	2.1
15	External	Yellow	Helvetica	232	6.3	5.3	4.5	3.9	3.5	3.2	2.9	154	4.2	3.5	3.0	2.6	2.3	2.1	1.9
16	Translucent	Yellow	Helvetica	293	8.0	6.7	5.7	5.0	4.4	4.0	3.6	196	5.4	4.5	3.8	3.3	3.0	2.7	2.4
17	External	White	Helvetica	221	6.0	5.0	4.3	3.8	3.3	3.0	2.7	155	4.2	3.5	3.0	2.6	2.3	2.1	1.9
18	External	White	Clarendon	195	5.3	4.4	3.8	3.3	3.0	2.7	2.4	130	3.5	2.9	2.5	2.2	2.0	1.8	1.6
				298							Maximum:	224							
				195							Minimum:	130							
				103							Range:	94							

\# Shaded areas represent inadequate available reading time for the approach speed.
* Converted to Road Distance