RELATIVE VISIBILITY

Internally and Externally Illuminated On-Premise Signs

UNITED STATES SIGN COUNCIL

RESEARCH CONCLUSIONS / PENNSYLVANIA STATE UNIVERSITY

RELATIVE VISIBILITY OF INTERNALLY AND EXTERNALLY ILLUMINATED ON-PREMISE SIGNS

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BACKGROUND

On-Premises Sign Lighting

On-premises signs are exterior signs that are installed on real estate and display information that directly relates to the use or business that is conducted on the specific property (e.g., a doctor's office, retail business, bank, or public institution). On-premises signs are illuminated at night using a variety of lighting techniques; however, there are two predominant lighting configurations: internal illumination and external illumination.

An internally illuminated on-premises sign has its lighting element or lighting source contained inside the sign cabinet, letter module, or sign body. Typical lighting elements used in these signs include high-output fluorescent lighting, neon tubing, and light-emitting diodes (LEDs). An externally illuminated on-premises sign will have the lighting element or source installed outside the sign, directed toward the sign face, letters, or sign message.

National standards exist regarding the fabrication and installation of certain internally illuminated signs, as they are considered "manufactured products" that are complete when they exit the manufacturer's plant. Organizations and testing bureaus such as Underwriters Laboratories and the publishers of the National Electric Code have created guidelines for the fabrication and installation of internally illuminated signs. These guidelines deal mainly with electrical safety. There are, however, few if any rules regarding the installation of lighting for externally illuminated on-premises signs, the appropriate placement of external lighting fixtures, and the type of lighting required. Even though few standards or guidelines exist for the lighting of on-premises signs, some municipalities and governmental entities in the United States have begun to enact bans on certain types of sign illumination. These prohibitions are typically directed at internally illuminated signs.

Traffic Sign Lighting

The *Manual on Uniform Traffic Control Devices* (USDOT, 2003) states that all traffic signs (as distinguished from on-premises signs), must be illuminated at night to have the same appearance as they do during daylight. Traffic sign illumination should be reasonably uniform and bright enough to ensure that the signs are detectable and legible. The MUTCD discusses three modes of illumination:

1. Internal illumination (e.g., fluorescent tubes or neon lamps): illuminates the main message through a translucent material;

2. External illumination (including high-intensity discharge lamps or fluorescent lighting sources): provides uniform illumination over the face of the sign from a source outside the sign; and

3. Some other method such as luminous tubing (e.g., neon), fiber optics, incandescent panels, or the arrangement of incandescent lamps.

Highway research has found no significant difference in legibility distances of traffic signs for as many as ten different sign lighting system designs (McNees and Jones, 1987; Upchurch and Bordin, 1987). However, while highway research indicates that a traffic sign's luminance and luminance contrast have a greater impact on legibility than does sign lighting design, in a study evaluating the effects of sign illumination type on on-premises signs, Kuhn, Garvey, and Pietrucha (1999) found that lighting design did make a difference. These researchers demonstrated that externally illuminated signs perform worse at night than either internally illuminated or neon signs.

The research documented in this report was undertaken to further examine the relative visibility of internally illuminated and externally illuminated on-premises signs. This research will help sign designers make appropriate recommendations to clients, aid sign users in making decisions on their specific sign needs, and assist municipalities in making informed decisions when consideration is given to on-premises sign lighting.

Research Objectives

The purpose of this study was to evaluate the relative performance of internally and externally illuminated on-premises signs. To do this, the performance of six signs that differed in mode of illumination, text and background colors, and contrast orientation (i.e., light letters on a darker background and dark letters on a lighter background) was evaluated. These signs were field tested with older and younger motorists in both daytime and night conditions. The two measures of effectiveness were sign recognition distance and legibility distance:

- **Recognition Distance:** given a target word on a sign, the greatest distance from which a participant can identify its location on that sign. This represents a scenario where a motorist knows the name of the business establishment she/he is looking for and merely has to distinguish that word from words on other on-premises signs.

- **Legibility Distance:** given a target word location on a sign, the greatest distance at which a participant could accurately read the word on that sign. This represents a scenario where a motorist does not know the exact name of the business establishment she/he is looking for and has to read the content of each on-premises sign encountered.

Based on the results, the distance at which drivers can begin to read a sign's message as a function of the type of illumination was calculated. These distances were then converted to time at various approach speeds to determine the amount of time that motorists will have to read the sign content.

METHOD

Test Site

The evaluation took place at the Pennsylvania Transportation Institute's (PTI's) closed-loop Test Track Facility at Penn State. To maintain uniformity, the signs were all placed at one location at the end of a 1,000-ft straight, flat section of the test track.

Sign Placement and Illumination

The signs were mounted 5 ft above ground level as measured from the pavement to the bottom of the sign. The lights used for the externally illuminated signs were a set of two 150-watt flood lamps ground mounted 7 ft in front of and 7 ft behind the center of those signs. The internally illuminated signs were lit with a bank of four 40-watt fluorescent tube lights mounted in the sign cabinet.

Vehicle and Measurement Instruments

The observational vehicle was a 2001 Dodge Stratus obtained from Penn State's Fleet Operations. Distance marks were placed every 5 ft from the 1,000-ft mark at the end of the tangent section to 70 ft from the sign structure. A 12-ft lane along which the observation vehicle was driven was marked and delineated with traffic cones.

Sign Types and Design

Each sign consisted of a 48-square-inch panel with three six-letter words of a mixed upper- and lowercase font (Figure 1). All of the words on the signs had 6-inch capital letter heights and proportionally sized lowercase letters and used a Roman type font. The lowercase letter height, inter-letter, and inter-line spacings were standardized and were the same on all signs. A total of six signs were tested:

- Internally illuminated signs
  - White background with red lettering
  - Red background with white lettering
- Externally illuminated signs
  - White background with red lettering
  - Red background with white lettering
  - Green background with gold routed lettering
  - Red background with gold routed lettering

Figure 1. Test signs at night.

Subject Recruitment and Screening

A total of 102 older and younger motorists were involved in the experiment. All subjects had current Pennsylvania driver's licenses. To validate the experimental procedures, initial pilot testing was performed with five test participants. The younger and older groups consisted of 52 and 50 subjects, respectively. Fifty-two males and 50 females participated in the study. Fifty-two subjects participated at night and 50 subjects participated in the daytime sessions. The subject selection procedure ensured that there would be adequate statistical power and balance in the study.

PROCEDURE

The subjects were given an informed consent form for review and signature. Visual acuity was then measured, followed by questions regarding the subjects' visual status (e.g., whether or not they wore eyeglasses or contact lenses, or had had eye surgery). The subjects were then taken to the passenger seat of the observation vehicle. During nighttime sessions all overhead lights at the experimental section of the test track were switched off and the car headlights were set on low beam.

Subjects were run individually. The subject was seated in the front passenger seat with an experimenter in the driver seat. The observation vehicle was driven to the 1,000-ft mark upstream of the sign and parked in the center of the 12-ft-wide travel lane. Before each sign was shown, the experimenter read aloud a word for the subject to find (recognition condition). The target word was either the middle or the bottom word. The sign was shown and the subject attempted to find the target word and respond by saying "middle" or "bottom." The subjects were instructed to state the target word location only when they were "certain." This resulted in less than 5 percent errors. The experimenter then drove the vehicle toward the sign at approximately 10 miles per hour until the subject correctly stated the target word position. The experimenter then stopped the vehicle and recorded the distance as the recognition threshold for that condition.

The experimenter then told the subject to read the top word on the sign. The experimenter continued to drive the vehicle toward the sign until the subject correctly read the word, at which point the experimenter stopped the vehicle and recorded the distance as the legibility threshold for that condition. The car was turned around and again parked 1,000 ft upstream of the sign. This procedure was repeated until recognition and legibility thresholds for all six signs were established. To avoid learning or fatigue effects, the order of sign presentation was counterbalanced across subjects.

At the end of the experiment, the participants were driven back to the parking lot and debriefed. They were handed a copy of the informed consent form and compensated for participation. The entire session took approximately 30-40 minutes for each participant.

Analysis

The overall objective of the statistical analyses was to determine if the manipulated variables produced statistically significant effects on sign recognition and legibility distances, and if there were any interactions between those variables. The data were analyzed taking all independent and both dependent variables in a common general linear model (GLM). The GLM was constructed and a multivariate analysis (MANOVA) was employed to evaluate the results. The classification of independent variables is shown in Table 1.

Table 1. Study variables.

Independent Variable	**Values**	**Assigned Level Values for Statistical Analyses**
Age	18-35 years - younger participants 65+ years - older participants	Younger participants =1 Older participants =2
Acuity	20/16,20/20, 20/25,20/30, 20/40,20/50	1 to 6 respectively
Time	Day, Night	Daytime =1 Night Time =2
Gender	Male, Female	Male = 1 Female = 2
Sign Type	1. Internally Illuminated and white 2. Internally Illuminated and red 3. Externally Illuminated and white 4. Externally Illuminated and red 5. Externally Illuminated, routed and green 6. Externally Illuminated, routed and red	1 to 6 respectively

The two dependent variables (i.e., recognition distance and legibility distance) were measured and analyzed in feet. All of the factor and response data were modeled in SPSS software. Each data point corresponded to one particular sign type. There were 102 participants in all, each tested with all six sign types for a total of 612 data points for each dependent variable.

The GLM formation was limited to the main factors and 2–way interactions. All higher-order interactions were excluded from the model for two reasons. First, higher-order interactions in complicated models often have little or no logical interpretations. Second, their inclusion in the model only leads to increasing complexity in terms of calculations for the model.

After the initial analysis, post-hoc tests were performed on the significant factors with more than two levels using the Tukey-LSD. Descriptive statistics, various comparison graphs, spread versus level plots, residual plots, and homogeneity tests were also obtained for the model. The level of significance was set at $p < 0.05$ for all analyses.

RESULTS

Gender

The significance of all four parameters of the multivariate test correspond to a p-value of 0.458 (>0.05) and an F-value of 0.781. These analyses indicate that gender did not have a significant effect on either the recognition or the legibility distance of the signs tested.

Age Group

The significance of all four parameters of the multivariate test of the GLM indicate that the p-value for the age factor is 0.001 (<0.05) and an F value of 7.709. This indicates that age group had a significant effect on both legibility and recognition distance. The results are as expected, in that the responses decrease with age, with the younger group having longer recognition and legibility distances than the older group (Figure 2).

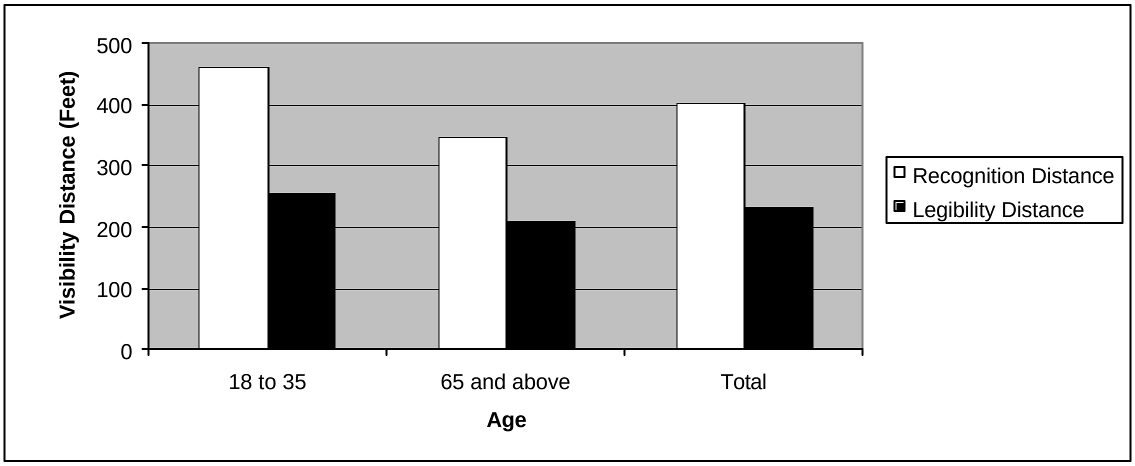

Figure 2. Effect of age group on on-premises sign visibility.

Time-of-Day

The significance of all four parameters of the multivariate test of the GLM indicate that the p-value for the time-of-day factor is <0.001 (<0.05) with an F-value of 55.271. From the test of between-subject effects, the p-value for this factor tested with the recognition distance corresponds to <0.001 (<0.05) and an F value of 52.347, and that for the legibility distance corresponds to <0.001 (<0.05) and an F value of 104.935. This shows that time-of-day had a significant effect on both recognition and legibility distances. As expected, the visibility distances were longer at daytime than at night (Figure 3).

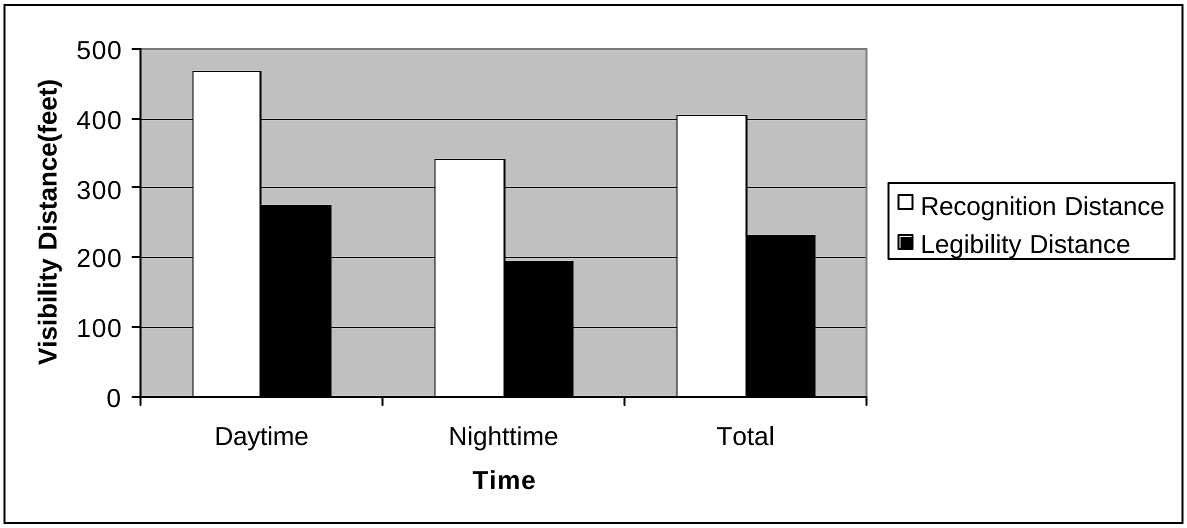

Figure 3. Effect of time-of-day on on-premises sign visibility.

Visual Acuity

The significance of all four parameters of the multivariate test of the GLM indicate that the p-value for the visual acuity factor is <0.001 (<0.05) and an F value of 19.781. This indicates that visual acuity had a significant effect on sign visibility.

From the test of between-subject effects, the p-value for this factor tested with the recognition distance corresponds to <0.001 (<0.05) with an F value of 26.336, and that for the legibility distance corresponds to <0.001 (<0.05) with an F value of 33.417. This shows that visual acuity had a significant effect on both recognition and legibility distance (Figure 4).

It should be noted, however, that this may not be an accurate estimation of the factor effect because of varying frequency of the number of subjects in each level of visual acuity tested. For instance, only two subjects had a visual acuity rating of 20/50. This may indicate that the statistical analysis of this factor is not justified.

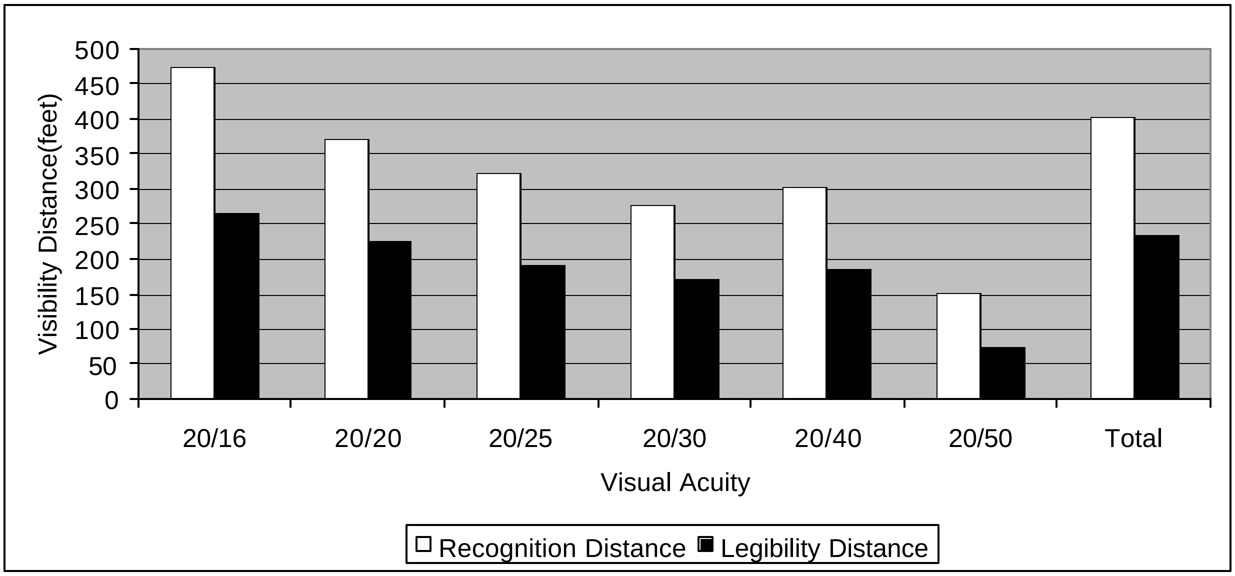

Figure 4. Variation of visual acuity with responses.

Therefore, to provide further evidence the recognition and legibility distances were collapsed across the two most common visual acuity factor levels (20/16 with 51 subjects and 20/20 with 28 subjects) and subjected to independent sample t-tests and an ANOVA analysis for means comparison. The significance value was calculated to be <0.001 (<0.05) for both legibility and recognition, showing that the acuity did indeed have a significant impact on sign visibility.

Sign Illumination

The significance of all four parameters of the multivariate test of the GLM indicate that the p-value for the sign type factor is <0.001 (<0.05) with an F-value of 6.761. This indicates that sign type had a significant effect on on-premises sign visibility. From the test of between-subject effects, the p-value for this factor tested with the recognition distance corresponds to <0.001 (<0.05) with an F-value of 9.772, and that for the legibility distance corresponds to <0.001 (<0.05) with an F-value of 8.763. This indicates that sign type had a significant effect on both recognition and legibility distances. Figure 5 illustrates that overall the internally illuminated signs outperformed the externally illuminated signs and that the routed signs were the poorest performers.

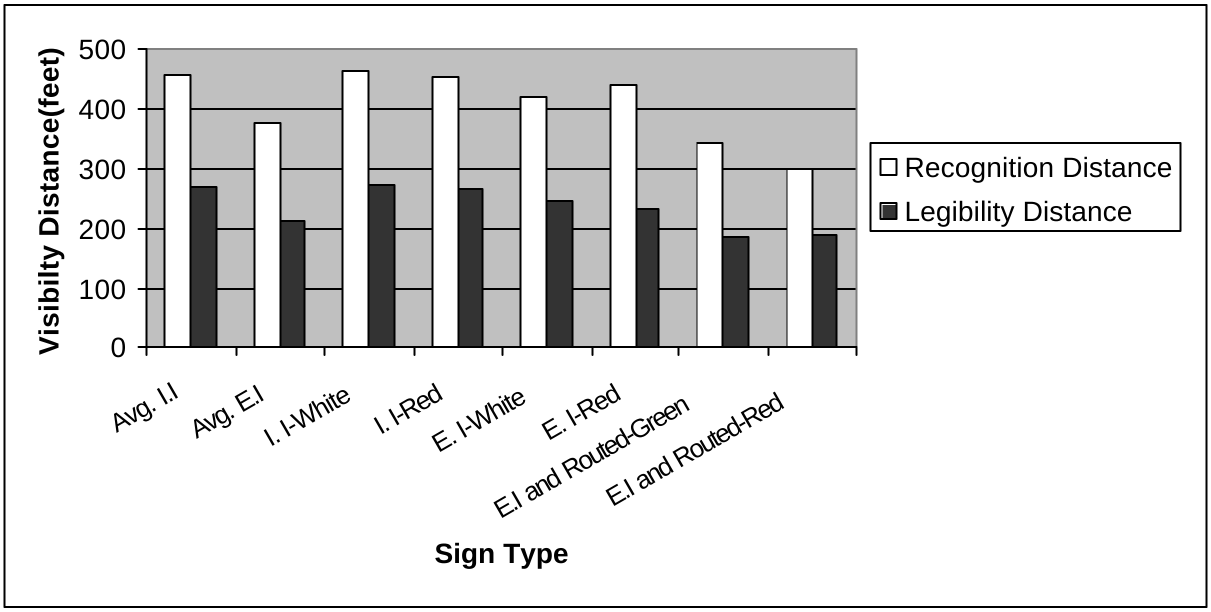

Figure 5. Effect of sign illumination type on on-premises sign visibility (I.I. = internally illuminated; E.I. = externally illuminated).

Time of Day and Sign Illumination Interaction

There was a significant interaction between time-of-day and sign illumination, with p-values <0.001 and F values of 5.186 and 27.429, respectively, for recognition and legibility thresholds (Figures 6 and 7). As illustrated in Figure 6, there was little impact of sign illumination type on either legibility or recognition during daytime viewing. Figure 7 shows the large and statistically significant impact of sign illumination type on nighttime visibility, with internal illumination outperforming external illumination by 40 and 60 percent for the recognition and legibility threshold distances, respectively.

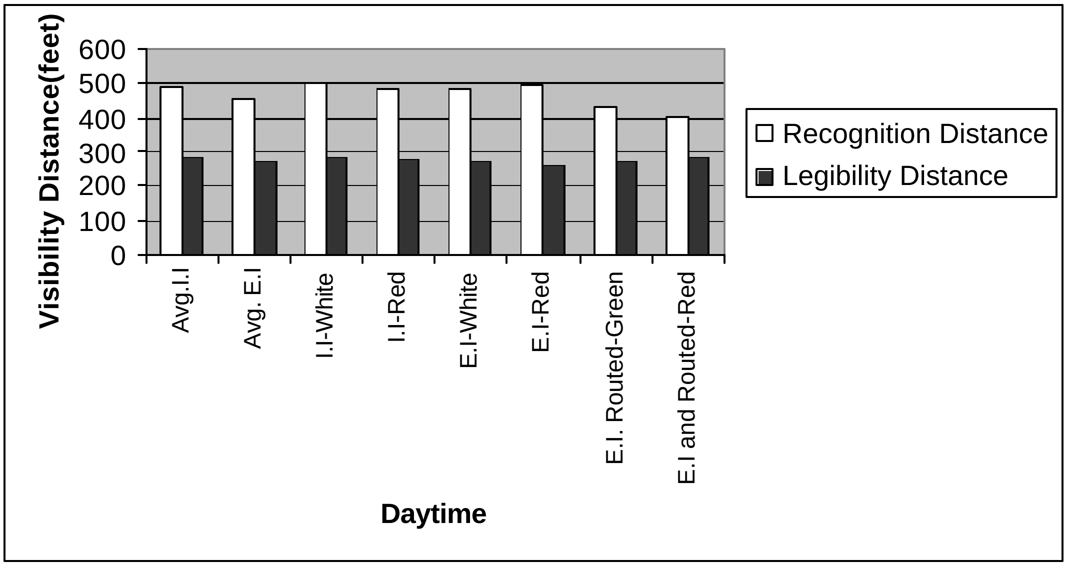

Figure 6. Effect of sign illumination during daylight.

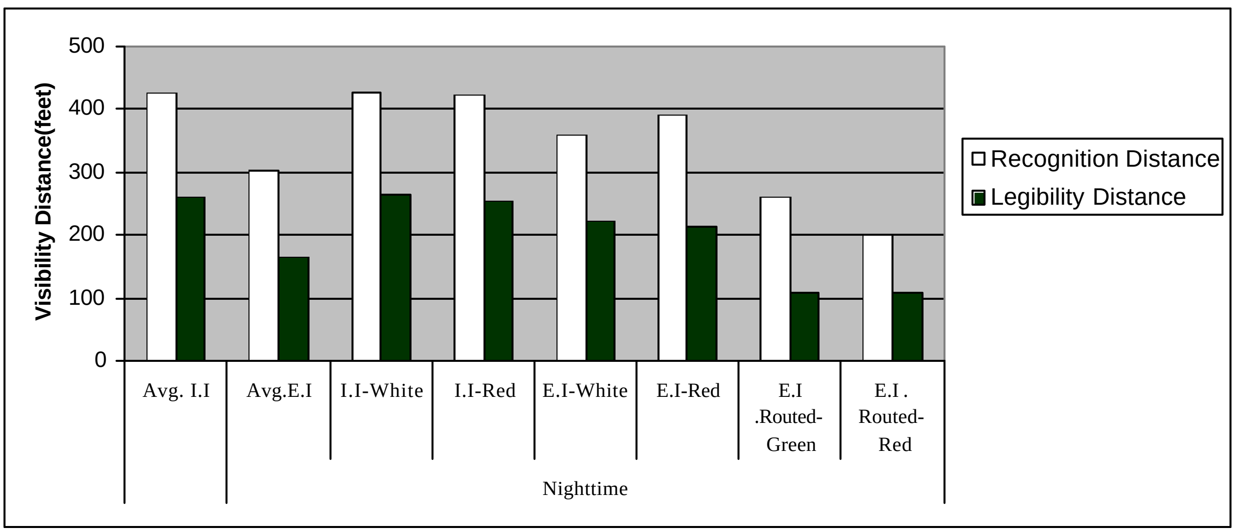

Figure 7: Effect of sign illumination at night.

READING TIME EVALUATION

The mean legibility and recognition distance thresholds were converted to reading times for various travel speeds to determine the amount of time a motorist would have to read the on-premises signs tested. The reading times were then compared to the minimum time necessary to read an on-premises sign, process the information, and make a maneuver required by the sign. In the worst case, the maneuver for on-premises signs is a lane change, speed reduction, and either a left or right turn out of the traffic flow. A recent synthesis of the minimum required visibility distance literature (USSC, 2003) suggests a conservative value of 8 seconds to complete this sequence of events. The available reading times for each test sign were compared to this 8-second minimum to determine whether the test signs would satisfy this criterion.

The following discussion is divided on the basis of sign content familiarity. If the content matter was familiar to a driver (i.e., common or expected words), the numbers were based on the recognition distance analysis (Table 2). If unfamiliar or unexpected words were used, the numbers were based on the legibility distance analysis (Table 3).

Recognition Distance Analysis

The average reading time for four travel speeds was tabulated (Table 2). The highlighted cells in Table 2 indicate the instances where the sign reading time satisfied the 8-second criterion. From the table, it can be seen that the internally illuminated signs outperformed the externally illuminated signs during both daytime and nighttime viewing. If the externally illuminated signs were to be used at night, speeds would need to be 25 mph or lower. The externally illuminated routed signs would require speed limits below 20 mph to provide sufficient time to read the signs and perform the appropriate maneuver at night.

Table 2. Sign illumination types and available reading times (sec) for sign recognition.

Sign Illumination Type	Time of Day	Mean Threshold Recognition Distance (ft)	Speed (mph)			
			30	35	40	45
Internally Illuminated	Day	494	11.23	9.62	8.41	7.49
Externally Illuminated	Day	455	10.34	8.86	7.75	6.89
Internally Illuminated	Night	422	9.59	8.22	7.19	6.40
Externally Illuminated	Night	299	6.80	5.83	5.09	4.53
Internally Illuminated White	Overall	464	10.55	9.04	7.91	7.04
	Day	504	11.45	9.82	8.59	7.63
	Night	424	9.64	8.26	7.23	6.43
Internally Illuminated Red	Overall	452	10.27	8.8	7.7	6.84
	Day	483	10.97	9.4	8.23	7.31
	Night	420	9.55	8.19	7.16	6.37
Externally Illuminated White	Overall	421	9.56	8.19	7.17	6.37
	Day	486	11.05	9.47	8.28	7.36
	Night	356	8.09	6.93	6.06	5.39
Externally Illuminated Red	Overall	441	10.01	8.59	7.51	6.68
	Day	496	11.26	9.65	8.45	7.51
	Night	386	8.78	7.52	6.58	5.85
Externally Illuminated Routed Green	Overall	343	7.79	6.68	5.84	5.19
	Day	432	9.82	8.41	7.36	6.54
	Night	255	5.79	4.96	4.34	3.86
Externally Illuminated Routed Red	Overall	301	6.85	5.87	5.14	4.57
	Day	406	9.23	7.91	6.93	6.16
	Night	199	4.53	3.88	3.39	3.02

Legibility Distance Analysis

The average reading time for four travel speeds was tabulated (Table 3). The highlighted cells in Table 3 indicate the instances where the average reading time satisfied the 8-second criterion. Compared to the times seen in Table 2, the legibility criteria (unfamiliar words) resulted in the need for lower speeds to satisfy the 8-second criterion. Table 3 illustrates that the internally illuminated signs are more visible than the externally illuminated signs at night and that there is little difference in the daytime. The discrepancy between daytime and nighttime performance is most profound for the externally illuminated routed signs, where at night even at extremely low speeds (15 mph) they provide only slightly more than half the sign reading time criterion of 8 seconds.

Table 3. Sign illumination types and available reading times (sec) for sign legibility.

Sign Illumination Type	**Time of Day**	**Mean Threshold Legibility Distance (ft)**	**Speed (mph)**			
			15	**20**	**25**	**30**
Internally Illuminated	*Day*	282	12.82	9.61	7.69	6.41
Externally Illuminated	*Day*	270	12.27	9.20	7.36	6.14
Internally Illuminated	*Night*	258	11.73	8.80	7.04	5.86
Externally Illuminated	*Night*	161	7.32	5.49	4.39	3.66
Internally Illuminated White	*Overall*	275	12.50	9.38	7.50	6.25
	Day Time	285	12.95	9.72	7.77	6.48
	Night Time	264	12.00	9.00	7.20	6.00
Internally Illuminated Red	*Overall*	265	12.05	9.03	7.23	6.02
	Day Time	279	12.68	9.51	7.61	6.34
	Night Time	251	11.41	8.56	6.85	5.70
Externally Illuminated White	*Overall*	246	11.18	8.39	6.71	5.59
	Day Time	271	12.32	9.24	7.39	6.16
	Night Time	221	10.05	7.53	6.03	5.02
Externally Illuminated Red	*Overall*	234	10.64	7.98	6.38	5.32
	Day Time	257	11.68	8.76	7.01	5.84
	Night Time	211	9.59	7.19	5.75	4.80
Externally Illuminated Routed Green	*Overall*	185	8.41	6.31	5.05	4.20
	Day Time	270	12.27	9.20	7.36	6.14
	Night Time	106	4.82	3.61	2.89	2.41
Externally Illuminated Routed Red	*Overall*	192	8.73	6.55	5.24	4.36
	Day Time	280	12.73	9.55	7.64	6.36
	Night Time	105	4.77	3.58	2.86	2.39

DISCUSSION

The study assessed the performance of two types of signs illumination techniques used on on-premise signs. These signs were field tested during the day and night with human subjects. The goal was to determine the effect of illumination type, age group, time of day, and gender on on-premises sign recognition and legibility distance.

Subject Age Group Effects

The study revealed that for recognition and legibility distances, the younger subjects (ages 18-35 years) outperformed the older subjects (ages 65 and above years). This was expected, as the average visual acuities for the younger subjects were better than those of the older participants.

Gender Effects

The study showed no significant differences in the average visibility distances due to the gender of the participants.

Time of Day Effects

The results indicated that the test signs had significantly better recognition and legibility distances when viewed during the daytime then at night. This difference in performance was not a function of subject age or visual acuity.

Sign Illumination Effects

The design of all six signs was comparable to on-premises signs used in practice by the signing industry. The two internally illuminated signs were lighted as per the state of practice in on-premises signing. The four externally illuminated signs were illuminated using standard external lighting sources, mounting distances, and heights. The illumination of the externally illuminated signs was, however, set to maximize sign brightness and light uniformity. The lighting of these signs was checked before each experimental session to ensure that there was no shifting of the lights or buildup of dirt on the lamps. In other words, the lighting of the externally illuminated signs was optimal for testing sign visibility.

Unfortunately, while the rigor used in this study to optimize the illumination of the externally illuminated signs produced the greatest visibility distances these signs could attain, it is not representative of the way externally illuminated sign lighting is maintained in the "real world." Research (Garvey, 2003) shows that many externally illuminated signs in the built environment are under-lit, poorly aimed, dirty, and/or non-uniform. The result of this is that the visibility distances obtained in this research for the internally illuminated signs will be comparable to what would be found in practice, while the visibility distances found with the externally illuminated signs in practice could be substantially shorter than those found in this research.

Even with the ideal controlled test track conditions used in this research, the results show that the internally illuminated signs provided significantly longer visibility distances and longer available reading times than externally illuminated signs. This conclusion is based on the higher mean average recognition and legibility distances and average available reading times that the signs were projected to provide motorists at various speeds. The internally illuminated signs had 40 and 60 percent longer average nighttime recognition and legibility distances and could be comfortably read while traveling 10 mph faster than the externally illuminated signs.

The difference between the nighttime visibility of the internally and externally illuminated signs was exacerbated when the externally illuminated signs were of the routed variety. In these cases, nighttime recognition and legibility of the internally illuminated signs were 86 and 145 percent longer than the externally illuminated signs. With regard to the time allotted to read the signs, the internally illuminated signs provided sufficient reading time at speeds up to 35 mph compared to only 20 mph for the routed signs (recognition task). The superiority of internal illumination found in this research concurs with a previous study of on-premises sign illumination, which found that internally illuminated signs provide longer visibility distances when compared to externally illuminated signs (Kuhn et al., 1999).

Not surprisingly, the interaction between sign illumination type and time of day shows that the type of illumination has little effect on sign reading distance during the daytime.

However, even during daylight there was a substantial reduction in performance with the routed signs. The internally illuminated and the externally illuminated non-routed signs appear identical during daylight operations. The results show that in daylight hours this appearance was legible and recognizable 35 and 38 percent further away, respectively, than the routed signs.

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