Internal vs. External On-Premise Sign Lighting: Visibility and Safety in the Real World

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FINAL REPORT

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Background and Objectives

Poorly visible on-premise commercial signs have been associated with reduced safety, as drivers trying to locate and make sense of these signs may drive slower than the rest of traffic and perform erratic, last-second maneuvers (IESNA, 2001). One of the main reasons for reduced sign visibility is poor sign lighting (Garvey and Kuhn, 2004). In addressing this issue, past research sponsored by the United States Sign Council Foundation (USSCF) demonstrated that internally illuminated on-premise signs have 40 to 60 percent greater visibility than externally illuminated signs in a controlled test track environment (Garvey, et al., 2004). Even so, an ever-increasing number of jurisdictions are implementing sign ordinances that prohibit the use of internally illuminated on-premise signs, mainly for aesthetic reasons. The objective of this research was to expand on the earlier test track research by evaluating the relative visibility of internally and externally illuminated signs on open roads in the real world.

Methodology

The study was an older-and-younger-driver, gender-balanced, human factors evaluation of the nighttime sign visibility and safety effects of commercial on-premise sign lighting design. The general methodology was an open field, or "real world," study wherein a representative sample of the driving population was asked to find and read internally and externally illuminated signs on actual storefront properties while operating a vehicle on in-use roadways.

Variables

The critical *independent variable* was on-premise sign lighting design (internal versus external illumination). Additional variables included driver age, gender, visual acuity, and driving speed.

The *dependent variable* (or measure of effectiveness) was a real-world combination of detection and legibility distance used effectively in earlier research (Zineddin, et al., 2005).

Location

The six signs were located on sections of US 26 and US 322 Business in State College, PA (Figure 1; A and D are the start and end points, B and C are the two furthest signs). At four of the six sign locations, both US 322 and US 26 are major arterials that are comprised of five-lane (one turn lane), two way cross sections with curbing. At two of the sign locations on Rt. 26 (Summit and Fine Line), the cross section drops to three-lanes (one turn lane), two way. The posted speed limit on the approach to the Animal Medical Hospital and Viet Thai Restaurant signs was 35 mph; the posted speed for the approaches to the remaining four signs was 45 mph.

Figure 1. Test route.

Externally Illuminated Signs

With advice from the USSC, the researchers selected six existing, in use, externally illuminated signs for this study (Figure 2), narrowed down from a field of 25 candidate signs identified by the research team. In the previous research evaluating the relative readability of internally and externally illuminated signs, Garvey and his colleagues (2004) optimized external sign illumination with the use of clean, new, flood lamps aimed with precision at the signs, ensuring a high level of uniform illumination throughout the evaluation. The externally illuminated signs selected for the current study better reflect what drivers are exposed to in the real world in that they varied in lighting quality and brightness level from poor to excellent (Figure 3; Table 1).

Figure 2. Externally illuminated signs, daytime.

Figure 3. Externally illuminated signs, nighttime.

Table 1. Description of external lighting equipment and placement.

Sign	Distance of Lamps to Sign	Number of Lamps	Type of Bulb	Wattage of Bulb
Marrara's	5 ft	2	Halogen	300 W
Summit	4 ft	1	Mercury	100 W
Fine Line	3 ft	1	Metal Halide	50 W
Glantz Johnson	6.5 ft	1	Fluorescent Reflector Lamp	26 W
Animal Medical Hospital	8 ft	1	Halogen	100 W
Viet Thai	6 ft	1	Halogen	Unmarked bulb Between 100 and 200 W

Internally Illuminated Signs

A set of internally illuminated signs identical to the six existing, externally illuminated signs in copy (e.g., message, letter height, font, and spacing), sign shape, color, contrast orientation, and size were designed and fabricated by volunteer USSC members (Figures 4 and 5; See Appendix A for sign specification sheets). The nighttime lighting levels and design were based on sign industry standards that have been found to be optimal for these signs in earlier research (Garvey, et al., 2009).

Figure 4. Internally illuminated signs, daytime.

Figure 5. Internally illuminated signs, nighttime.

Photometric Characteristics

The experimenters documented the luminance (brightness) of the internally and existing externally illuminated signs using a Minolta LS-110 luminance meter (Table 2) and techniques successfully developed in earlier research (Garvey, 2005; Garvey, et al., 2009).

Table 2. Nighttime sign luminance (cd/m^2)

Sign	Color	Internal Illumination	External Illumination
	Red	15	13
	Yellow	150	60
	White	700	15
	Green	60	1.0
	Gold (inlay letters)	80	10
	Green	30	0.5
	White	180	2.9
	Dark Blue	20	0.25
	Light Blue	130	1.25
	Gold (inlay letters)	130	1.5
	Brown	40	0.5
	Red	110	2.5
	Green	187	1.25
	Pink	260	5.0
	Yellow	325	8.0

Five of the signs fell within recommended levels to avoid glare effects for rural, suburban, and urban environmental lighting (i.e., Environmental Zones E2, E3, and E4) under both internal and external illumination, with the sixth (Summit Chiropractic Clinic) accommodating lighting zones E3 and E4 when internally illuminated and Zones E2, E3, and E4 when externally illuminated (Garvey, 2005).

Subjects

A total of 80 subjects participated in the research. Forty viewed the internally illuminated signs and forty viewed the externally illuminated signs. Half of the subjects that viewed each lighting condition were female and half were male. All subjects had valid U.S. driver's licenses. The subjects were selected to represent the U.S. driving population in age (Table 3). The subjects' binocular, static, distance visual acuity was measured using a Sloan letter chart displayed on a Good-Light Company light box. The mean visual acuity for the subjects who viewed the internally illuminated signs was 20/20 and the mean visual acuity for those who saw the externally illuminated signs was 20/19.

Table 3. Subject age group and visual acuity data.

Age Group	Percent of U.S. Driving Population	Number of subjects (half viewed internally illuminated sign and half internally)	Mean Visual Acuity
18-29	20.1%	n=16	20/19
30-44	28.4%	n=24	20/18
45-59	28.4%	n=24	20/20
60+	21.2%	n=16	20/23

Procedure

All eighty subjects drove a 2004 Dodge Stratus sedan along a half-hour route through State College commercial districts at night. The subjects were accompanied by an experimenter in the passenger seat and one in the rear seat. The vehicle was instrumented with a Nu-Metrics distance measuring instrument (DMI) to record sign visibility distances.

The subjects were given simple route directions to follow and were instructed to drive "as they normally would" while emphasizing safety and maintaining the posted speed. To simulate the common experience drivers have when they know what business establishment they are looking for, but do not know its location, the subjects were told the name of the establishment and were asked to read the sign aloud as soon as they could. The moment the subjects read the signs correctly, the experimenter in the passenger seat pressed a button on the DMI. The button was pressed a second time when the vehicle was alongside the signs. The DMI calculated the distance between the two button presses and recorded the result as the visibility distance for that condition.

The internally illuminated signs were placed in front of and blocking the externally illuminated signs while the first half of the subjects participated. The internally illuminated signs were then removed and the second half of the subjects viewed the externally illuminated signs using the same procedures.

Analyses and Results

Gender and Age

Forty males and 40 females participated in the study. On average, the males read the signs at 233 ft and the females at 225 ft. An analysis of variance (ANOVA) was conducted and, not surprisingly, this was not a statistically significant difference ($F=0.28$; $p = .60$). Another ANOVA showed that there was also no statistically significant age group effect ($F=1.58$; $p=.20$), with the youngest age group reading the signs at, on average, 213 ft, the two middle groups at 249 and 236 ft, and the oldest group at 202 ft.

Visual Acuity, Familiarity, Weather

Three separate ANOVAs were conducted on these variables. There were no statistically significant effects as a function of subject static visual acuity ($F=1.72$; $p=.16$). Although visual acuity is often found to be a good predictor of sign legibility, this was not the case for the small range in visual acuity combined with the complex task of finding and reading signs in the real world while driving in live traffic at night.

A portion of the subjects were from the local State College area and knew the location of some of the business establishments where the six test signs were mounted. The statistical analysis showed slight improvement (254 ft versus 221 ft) in the distance at which the signs were found and read as a function of sign familiarity ($F=4.55$; $p=.04$).

Some of the data were collected during light rain or light snow, or when the roads were wet. An analysis of the data showed that this did not significantly affect sign detection and reading distances ($F=0.59$; $p=.63$).

Speed

Two separate statistical analyses were conducted on the two lighting conditions to determine whether there was a significant correlation between speed and sign reading distance in this study. The hypothesis was that when drivers have difficulty reading a sign, they will slow down, which presents potential traffic safety concerns. While the R^2 values were small (hovering around .10), they were statistically significant ($t=4.93$; $p<.0001$ for externally illuminated signs and $t=4.83$; $p<.0001$ for internally illuminated signs), revealing that the drivers in this study did indeed drive more slowly around less visible signs (Figure 6).

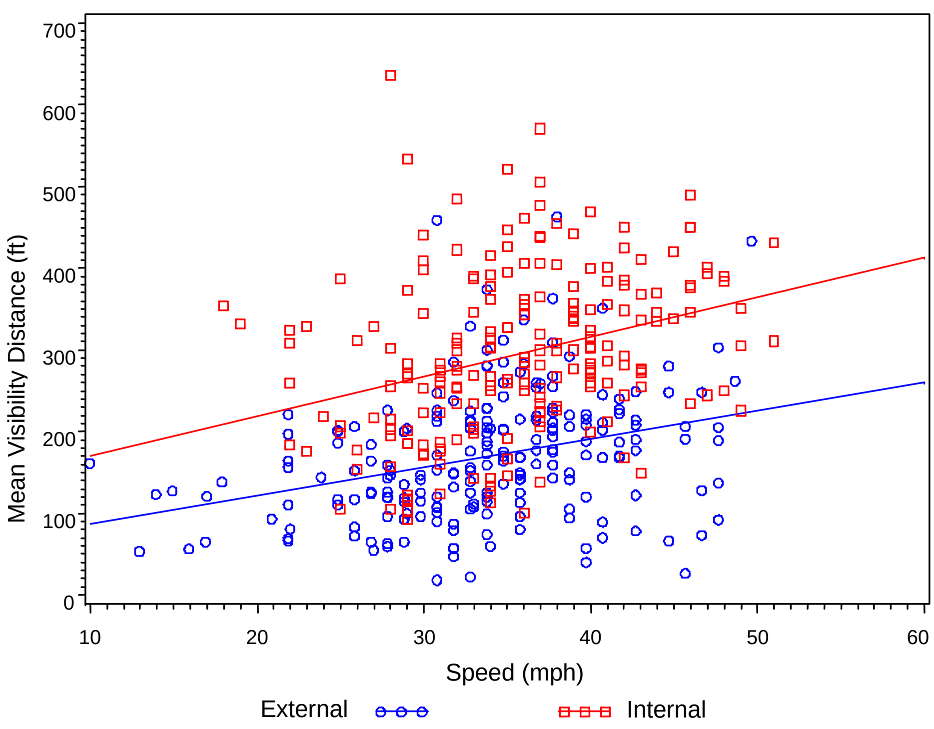

Figure 6. Scatterplot of sign visibility distance in feet by speed in mph.

Sign

Sign visibility differed across the six signs (Figure 7, the numbers in the bars indicate the number of subjects who drove past the sign without ever seeing it). The average reading distances of the six signs varied due to differences in: location, including placement on the left (Summit) or right side of the road (all the others); lateral and vertical sign offset; roadway characteristics (e.g., number of lanes of traffic and curvature); and characteristics of the signs themselves, perhaps most importantly size, color, and shape.

The statistical Glimmix Procedure was used to determine which of the signs were significantly affected by lighting design. The result was that all of the signs performed statistically significantly better with internal illumination. The biggest improvement was with the Animal Medical Hospital sign, which was read on average 2.36 times further away with internal illumination. This was a 196-ft mean difference, giving drivers almost 4 extra seconds at 35 mph. Furthermore, this sign was completely missed by two drivers when it was externally illuminated. Even the most modest increase (Marrara's Dry Cleaner) resulted in almost 1.35 extra seconds of driver reaction time and this was a sign that was maximally externally illuminated with two 300 watt halogen lamps.

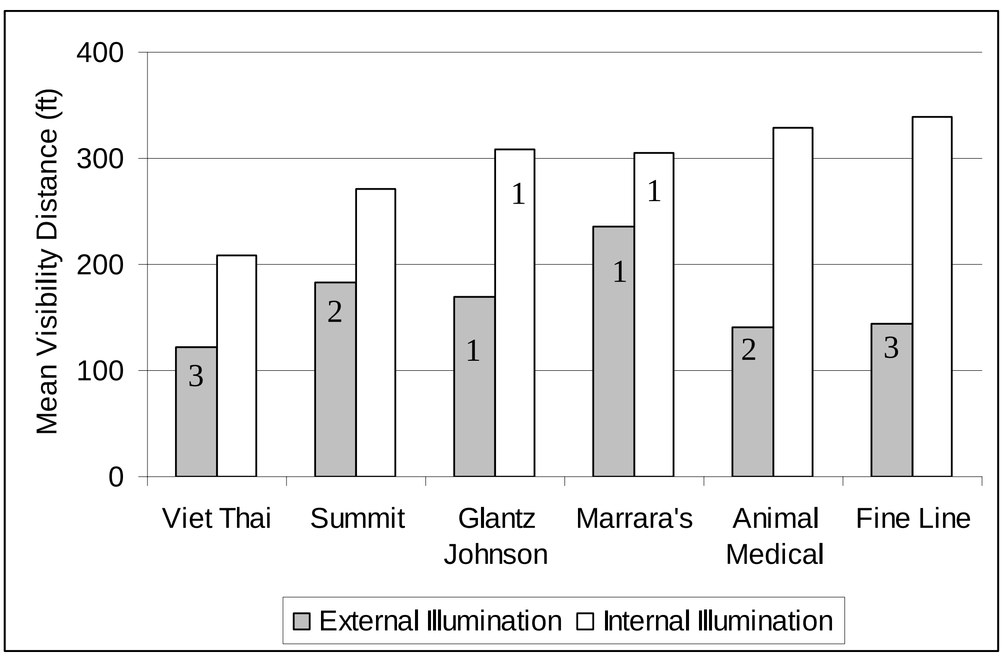

Figure 7. Effect of illumination type on individual sign visibility.

Internal versus External Illumination

The Tukey-Kramer statistical test was used to evaluate the combined visibility of all six signs tested. The test showed a statistically significant improvement in sign visibility when internally illuminated ($t=-10.19$; $p<.0001$). Overall, the internally illuminated signs were visible on average 68 percent further away than the externally illuminated signs (291 versus 173 feet; Figure 8). This is a 118-foot difference, which at 35 mph means that drivers have an additional 2.3 seconds to read and react to the externally illuminated signs (1.8 seconds at 45 mph).

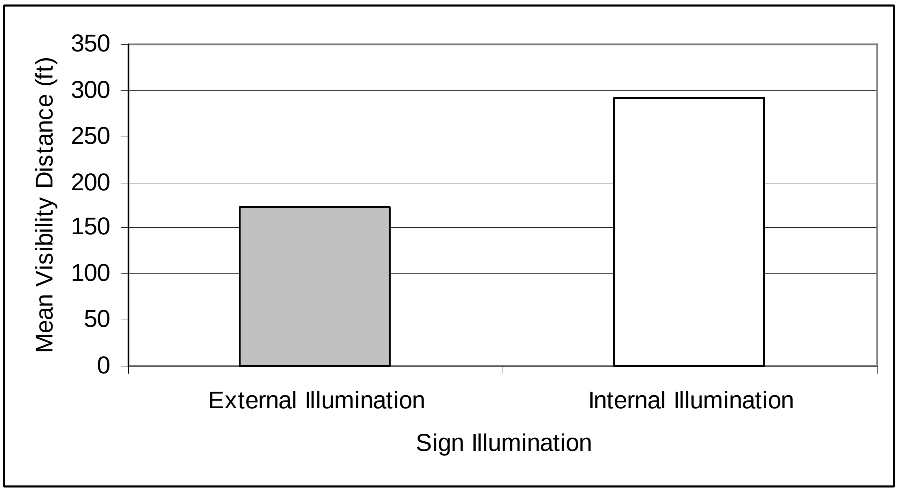

Figure 8. Effect of illumination type on overall sign visibility.

Conclusions

The primary objective of this research project was to conduct a one-to-one comparison between internally and externally illuminated, on-premise signs on open roadways, using real drivers, and actual in-use signs. To fairly evaluate the differences in nighttime visibility between signs that are internally illuminated and signs that are externally illuminated, the signs must be identical in all aspects other than lighting design. This was accomplished by fabricating exact internally illuminated replicas of the existing externally illuminated signs and placing them in front of the existing signs, so that not just the signs, but the locations and offsets (and therefore the visual surround and roadway characteristics) were identical.

The results of this research clearly demonstrate the superiority of internally illuminated signs across a wide variety of driving conditions, sign offsets, sign sizes, shapes, colors, and external lighting designs and quality levels. The overwhelmingly positive response from the participating establishments and their patrons, as well as the visual evidence from Figures 2-5, also demonstrate the fallacy that internally illuminated signs are inherently less esthetically pleasing than externally illuminated signs.

Furthermore, internal sign illumination avoids some of the intractable problems with external illumination, illustrated in Figure 3, such as: difficulty in maintaining the directionality of the light source over time, which often results in non-uniform light distribution (e.g., Viet Thai); "hot spots," especially on metallic inlay signs (e.g., Fine Line Homes, where the luminance on the house reached over 3,000 cd/m^2); and light trespass, both onto other properties and into the eyes of oncoming drivers (e.g., Marrara's and Glantz, Johnson).

Although on-premise signs are a critical wayfinding device for drivers, poorly visible on-premise signs negatively impact road user safety by causing drivers to slow down in traffic (demonstrated in this research) or make erratic maneuvers. Internally illuminated on-premise signs have been shown to significantly increase the distance at which these signs can be read over externally illuminated signs. This was first demonstrated in a test track study where 40 to 60 percent improvements were found. The present study showed that even greater improvements (almost 70 percent on average and 240 percent in the best case) can be made when actual in-use, externally illuminated signs are upgraded to ones that use internal illumination.

In this study, internally illuminated signs gave drivers on average about 2 seconds (and in extreme cases almost 4 seconds) more time than externally illuminated signs to read the signs and maneuver their vehicles (known as Viewer Reaction Time or VRT), which could transfer to a tremendous safety benefit.

Another way to look at it is that to get the same VRT for an externally illuminated sign that you get with an internally illuminated sign of exactly the same size, design, color, placement, etc., the driving speed would need to be reduced by approximately 40 percent. For example, to equal the VRT of an internally illuminated sign at 25 mph, a driver would need to approach an externally illuminated sign at about 15 mph (see Table 4 for more examples).

Table 4. The reduction in speed of a driver approaching externally illuminated signs needed to achieve the VRT of an internally illuminated sign.

Internally Illuminated	Externally Illuminated
15 mph	10 mph
25 mph	15 mph
35 mph	20 mph
45 mph	25 mph
55 mph	30 mph
65 mph	40 mph

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APPENDIX A

Internally Illuminated Sign Specification Sheets