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Jean Paul Freyssinier, Nadarajah Narendran, John D. Bullough

Lighting Research Center
Rensselaer Polytechnic Institute, Troy, NY 12180
www.lrc.rpi.edu

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# Luminance Requirements for Lighted Signage

Jean Paul Freyssinier*, Nadarajah Narendran, John D. Bullough
Lighting Research Center, Rensselaer Polytechnic Institute, 21 Union Street, Troy, NY 12180 USA

**ABSTRACT**

Light-emitting diode (LED) technology is presently targeted to displace traditional light sources in backlighted signage. The literature shows that brightness and contrast are perhaps the two most important elements of a sign that determine its attention-getting capabilities and its legibility. Presently, there are no luminance standards for signage, and the practice of developing brighter signs to compete with signs in adjacent businesses is becoming more commonplace. Sign luminances in such cases may far exceed what people usually need for identifying and reading a sign. Furthermore, the practice of higher sign luminance than needed has many negative consequences, including higher energy use and light pollution.

To move toward development of a recommendation for lighted signage, several laboratory human factors evaluations were conducted. A scale model of a storefront was used to present human subjects with a typical red channel-letter sign at luminances ranging from 8 cd/m$^2$ to 1512 cd/m$^2$ under four background luminances typical of nighttime outdoor and daytime inside-mall conditions (1, 100, 300, 1000 cd/m$^2$), from three scaled viewing distances (30, 60, 340 ft), and either in isolation or adjacent to two similar signs. Subjects rated the brightness, acceptability, and ease of reading of the test sign for each combination of sign and background luminances and scaled viewing distances.

**Keywords:** Channel letter, signage, backlighted, red, light-emitting diodes, LEDs, luminance, brightness, retail, background.

## 1. INTRODUCTION

The promise of energy and maintenance cost savings makes light-emitting diodes (LEDs) a viable technology to displace neon and cold-cathode light sources in lighted signage applications, such as backlighted channel-letter signs.

A recent industry survey showed that usage of LEDs for signage doubled between 2003 and 2005 to reach a 14.3 percent share of all electric signage.[1] However, as with any lighting technology, acceptance by the end user is important to its overall success.[2] In order to become a successful replacement to traditional light sources, LEDs need to meet certain subjective criteria. The literature shows that among other attributes, character luminance is an important element of a sign that determines its attention-getting capabilities and its legibility.[3]

Presently, there are no consensus standards for signage in terms of luminance in North America. Because neon and cold-cathode light sources are presently the most widely used sources for backlighted channel-letter signs, LED manufacturers are developing products to meet the luminances typically attained with these two light sources. Further, in many cases the practice of developing brighter signs to compete with signs at adjacent businesses is not rare.[3-5] A field survey of signs in Troy, New York, showed that the luminance of a typical red channel-letter sign can be upwards of 400 cd/m$^2$. This luminance may far exceed what people usually need for identifying and reading a sign. Furthermore, the practice of higher sign luminance has many negative consequences, including higher energy use and light pollution.[3-5]

A better understanding of the luminance requirements of lighted signage will lead to the development of optimal design criteria for creating signs that are more energy-efficient and perhaps more visually effective than current products, with the same or better acceptability by individuals.

### 1.1 Background

On-premise signs are a very common feature of storefronts, as they provide the information people need to identify commercial destinations. Backlighted signs are often preferred because they are more visible after dark, arguably increasing driver and pedestrian safety by reducing the time and distraction a driver faces when scanning the

* e-mail: freysj@rpi.edu, phone: 518-687-7100, fax: 518-687-7120, Web: www.lrc.rpi.edu

surroundings in search of a destination.[6] In order for a sign to be effective in guiding drivers, it must be conspicuous (standing out from the background visual environment), visible (detectable from a reasonable distance), legible (able for its characters to be differentiated), and needless to say, comfortable to look at (i.e., of a brightness that is not too low or too high).[6-8]

The visual effectiveness of a sign is determined by several design factors. Features such as corporate color, logos, distinctive shapes, and familiarity are factors that play an important role on customers' identification and recognition of a sign, even at a distance that is too great to read the wording or amidst visual competition.[6] Geometric considerations of a sign affect its visual effectiveness as well. For example, research has shown that the vertical and horizontal offset of a sign with respect to its background influence its visibility.[6, 9, 10] The size and shape of sign characters strongly influence conspicuity;[11] whereas font, the use of uppercase or mixed case, stroke width, and color can influence legibility.[8, 11-14]

Other design factors such as sign luminance and the luminance contrast between the sign and the background are important issues that determine a sign's attention-grabbing ability, visual conspicuity, visibility, and legibility.[3, 4, 8, 15-20] Further, Boyce found that for exit signs (many of which are backlighted), the luminance uniformity of both the sign and the background are important factors in the visibility and readability of the sign.[20] However, over the past few decades, none of these research efforts have studied systematically the luminance requirements of backlighted channel-letter signs.

### 1.2 Goal of present study

To further research in the area of lighted signage using LEDs, a laboratory study was conducted to investigate the luminance requirements of red backlighted channel-letter signs used in commercial signage applications. The goal of this study was to evaluate subjective preference of sign luminance as a function of background luminance, viewing distance, and whether a sign is seen in isolation or adjacent to competing signs.

## 2. METHODOLOGY

Two laboratory human factors evaluations were conducted to identify a suitable range of luminances for red channel-letter signage. A 1:12 scale model of a storefront was used to present human subjects with a typical red channel-letter sign at luminances ranging from 8 cd/m$^2$ to 1512 cd/m$^2$ under four background luminances typical of nighttime outdoor and daytime inside-mall conditions (1, 100, 300, 1000 cd/m$^2$), from three scaled viewing distances (30, 60, 340 ft), and either in isolation or adjacent to two similar signs.

The scale model of the storefront was designed to present the appearance of a local strip mall. The concrete and stone finishes of the wall, floor, and façade were approximated in color, reflectance, and texture by using commercially available paints. White phosphor-converted LEDs (6500 K) were used to illuminate a walkway overhang along the storefront. Figure 1 shows a picture of the scale model used for the experiments.

A set of three scaled 24-in signs was created using translucent red acrylic (Cyro Acrylite SG 211-1), each uniformly backlighted with an array of red LEDs (peak wavelength of 620 nm). Each sign consisted of three similar, uppercase sans serif, characters. Font, character spacing, and size were kept constant in order to maintain the average luminance of the signs approximately the same when needed and to minimize the effects of visual size and sign complexity.

The façade of the storefront (i.e., the immediate background around the signs) was illuminated from above by a linear array of the same type of white LEDs used in the overhang of the storefront. The red and white LEDs were controlled with a computer program that changed their forward current to preset values corresponding to the desired sign and background luminance conditions. The computer program also collected the subjects' responses to each experimental condition.

In Experiment 1, the test sign was presented in isolation. For each distance and for each sign and background luminance combination, twelve subjects responded to the following questions:

Q1. How easy is the sign to read? (responses consisted of a number from -3, very difficult, to +3, very easy)

Q2. How is the brightness of the sign? (responses consisted of a number from -3, too dim, to +3, too bright)

Q3. Is this brightness acceptable? (responses consisted of yes or no)

In Experiment 2, two additional signs were added to the scale model (to the left and right of the test sign) to understand the effect of competing signs on luminance preference and visibility. The tested luminances of the two competing signs were 40, 90, 200, and 450 cd/m$^2$. The distance from the test sign to either adjacent sign was a scaled 22-ft, the typical minimum distance between signs in strip malls. Experiment 2 was conducted for a 30-ft viewing distance only. In Experiment 2, question 1 was substituted with the one below; questions 2 and 3 remained the same. Four subjects participated in Experiment 2.

> Q1. In this scene, how conspicuous is the center sign? (responses consisted of a number from -3, not at all visible, to +3, very conspicuous)

Subjects were presented with each experimental condition three times in random order. The different background luminance and viewing distance conditions were counterbalanced across subjects.


Fig. 1. Pictures of the scale model used for the subjective evaluations of signage brightness. The picture on the left shows the subjects' view during the experiment at a scaled 30-ft distance. The picture on the right shows the test sign amid two competing signs.

## 3. RESULTS

Figure 2 shows the mean subjective ratings to the questions "How easy is the sign to read?" and "How is the brightness of the sign?" for the single test sign conditions at a scaled 30-ft viewing distance. The error bars in the graphs represent the standard errors of the mean. Figure 3 shows the subjective ratings to the question "Is this brightness acceptable?" plotted as a function of the rated brightness for the same conditions.

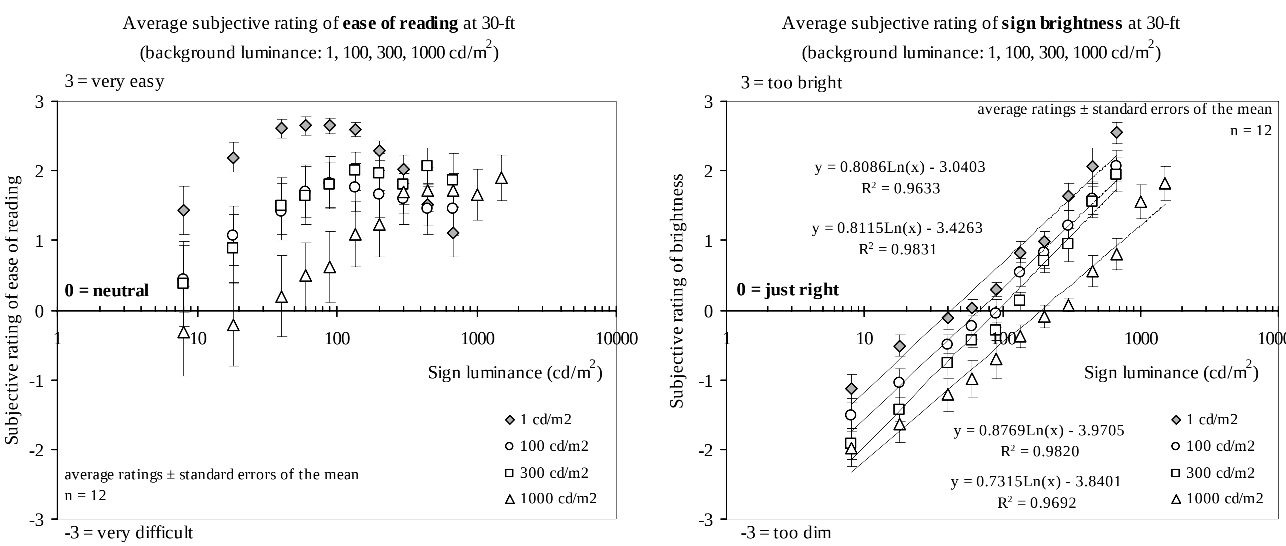


Fig. 2. Mean subjective ratings to the questions "How easy is the sign to read?" (left) and "How is the brightness of the sign?" (right) as a function of sign and background luminance. The error bars show the standard error of the mean.

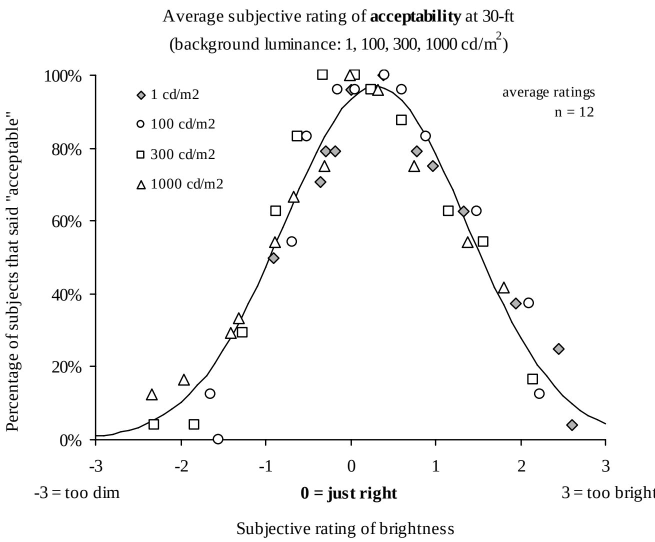


Fig. 3. Percentage of times that each experimental condition at a scaled 30-ft viewing distance was rated as acceptable by subjects.

The subjective ratings of sign brightness show a monotonic relationship with sign luminance. The results also show a significantly different ($p<0.05$) preferred sign luminance (rating of 0, or *just right*) for each background luminance. On the other hand, acceptability ratings for all conditions were similar; in general, higher acceptability ratings were given to the preferred sign luminance and no statistical difference was found among conditions. Under nearly all conditions tested, the sign was rated with a positive readability score, and in fact, the sign remained readable even when turned off. In general, the peak readability ratings corresponded to the preferred sign luminance, as indicated in Figure 3.

Ratings of brightness were similar for the different viewing distances, although a consistently higher sign luminance was preferred for the 60-ft and 340-ft distances. As an example, Figure 4 shows the mean subjective ratings of sign brightness for a 100 cd/m$^2$ background at the three viewing distances. In general, the preferred sign luminance was significantly lower ($p<0.05$) for a scaled 30-ft distance than for 60-ft or 340-ft. Figure 5 summarizes the preferred sign luminances for the four background and three viewing distance conditions.

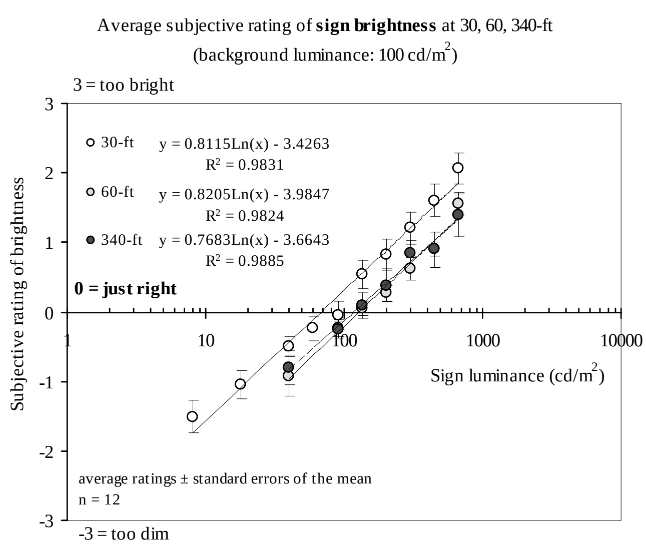


Fig. 4 Mean subjective ratings of sign brightness for a 100 cd/m$^2$ background at the three viewing distances.

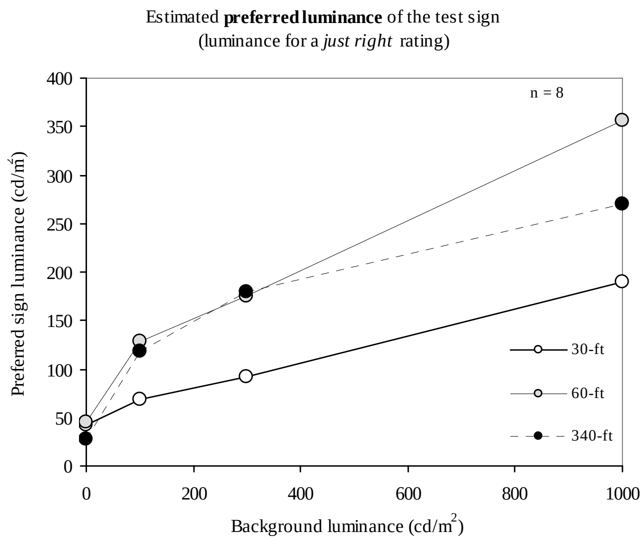


Fig. 5 Preferred sign luminance (for a *just right* rating) for the different background luminance and viewing distance conditions when the test sign was presented alone.

Ratings of brightness were similar whether the sign appeared alone or adjacent to other signs, although a consistently higher sign luminance was preferred when adjacent signs were present. As an example, Figure 6 shows the mean subjective rating of sign brightness for a background luminance of 100 cd/m$^2$ and a scaled 30-ft viewing distance when the sign was presented alone and amid adjacent signs. The results show a statistically significant difference ($p<0.05$) between these two conditions. Similarly, a significantly higher ($p<0.05$) preferred sign luminance (*just right* rating) was found for each background luminance. Figure 7 summarizes the preferred sign luminances for the four background and one viewing distance conditions tested.

Finally, when the test sign was presented with adjacent signs, conspicuity ratings were positive for all conditions where the sign luminance was equal to or greater than the *just right* luminance.

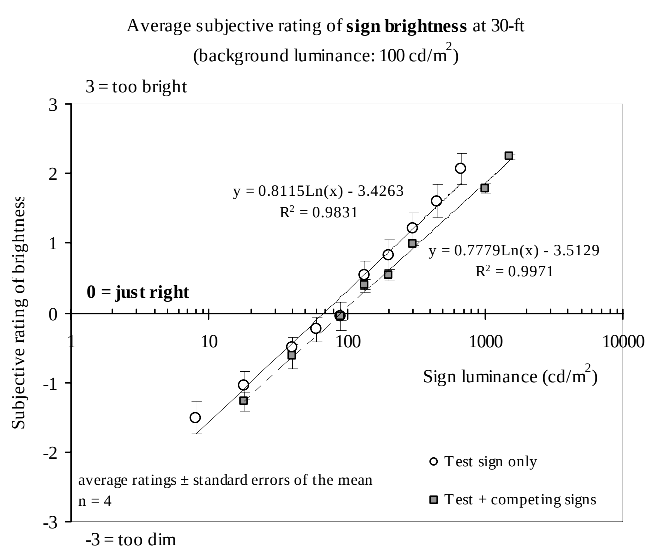


Fig. 6 Mean subjective ratings of sign brightness for a 100 cd/m$^2$ background at a scaled 30-ft viewing distance for a test sign presented alone and amid two adjacent signs.

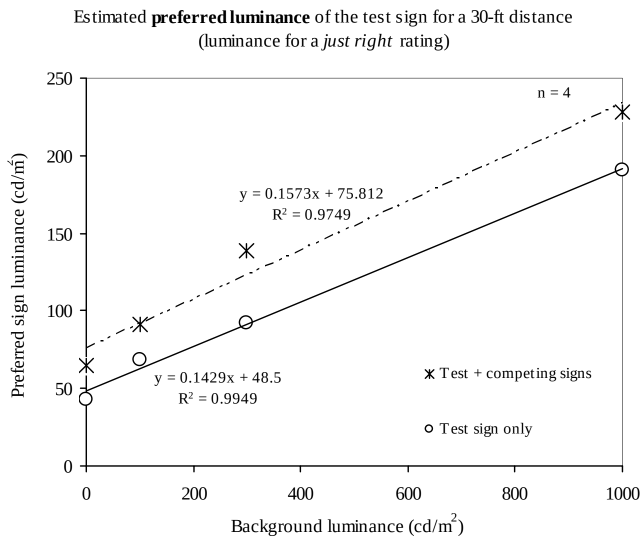


Fig. 7 Preferred sign luminance (for a *just right* rating) for the different background luminances at a scaled 30-ft viewing distance for the conditions when the test sign was presented alone and amid two adjacent signs.

## 4. DISCUSSION

The experiments of this study yielded very interesting results regarding the visibility and subjective appearance of the test signs.

Figure 2 is a representative example of the readability and brightness ratings of the test sign for all viewing conditions. Under nearly all conditions tested, the test sign was rated with a positive readability score. In fact, most of the subjects commented that the sign was easy to read even when it was turned off. The likely reason for this is the high contrast between the red acrylic and the light gray façade. Additionally, Figures 2 and 3 show that the maximum ease of reading and acceptability ratings generally corresponded to the sign luminances rated as *just right* (i.e., preferred luminance ≅ rating of approximately zero). Further, the test sign was rated with a positive conspicuity score in all the conditions where the test sign was presented at a luminance equal to or greater than the preferred luminance. These results seem to agree with previous research on visibility and conspicuity of signage.[3, 4, 6-20.]

Perhaps even more interesting are the effects of viewing distance and the presence of competing signs on the preferred sign luminance. Figure 4 shows, as a representative example of all background luminances, a higher preferred luminance for viewing distances of 60-ft and 340-ft compared to 30-ft. These differences may be explained by the fact that as the viewing distance increased in the present experiments, so did the visual size of the background (which itself had a dark surround), effectively increasing the overall average luminance to which the viewer was adapted. This resulted in a higher preferred sign luminance. As would be expected, this effect is stronger for background luminances equal to or higher than 100 cd/m$^2$. For the four tested background luminances, statistical significance was found between the 30-ft and either the 60-ft or 340-ft distances, but there was no difference between the 60-ft and 340-ft conditions.

Adding competing signs resulted in higher preferred sign luminances, arguably because of the same reason mentioned above. By virtue of being in the field of view, the competing signs perhaps increased the effective background luminance, resulting in a brighter test sign for the same *just right* rating (Figure 7).

Eventually, by understanding the magnitude of each of these effects on preferred luminance and visibility of a sign, recommendations can be made for different conditions, or even for a range of conditions. Data such as those presented in this paper can be used to assess the impact of sign characteristics on visibility and appearance. For example, if a sign had a luminance of 135 cd/m$^2$, it would receive positive readability scores for all of the distance and background luminance conditions tested in this study. Similarly, such a sign would be rated as acceptable by at least 80 percent of viewers even if competing signs were present.

# 5. SUMMARY

Presently, there are no consensus-based luminance standards for lighted signs based on visibility. In this study, two human factors laboratory experiments were conducted to determine a suitable range of luminances for red channel-letter signs under typical background light levels and viewing distances, and whether the sign was seen in isolation or amid similar competing signs.

The results of these experiments show that:

- The preferred sign brightness is a function of background luminance, with brighter backgrounds calling for brighter signs. For the conditions tested, the most preferred sign luminance ranged from ~40 $cd/m^2$ to ~190 $cd/m^2$ for background luminances of 1 $cd/m^2$ and 1000 $cd/m^2$, respectively (Figure 5).
- If adjacent signs are present, a higher sign brightness is preferred. However, in the range tested, the incremental sign luminance or its acceptability rating was not a function of the adjacent signs' luminance. For these conditions, the most preferred sign luminance ranged from ~65 $cd/m^2$ to ~230 $cd/m^2$ for background luminances of 1 $cd/m^2$ and 1000 $cd/m^2$, respectively (Figure 7). *Acceptability* ratings were similar to those conditions without competing signs.
- The effect of viewing distance on preferences for sign brightness was similar to the effect of having competing signs in the field of view (Figures 4 and 6). In both cases, the resulting differences in ratings were reliably found.

This study is a start to furthering our understanding of appropriate sign luminance and ways to reduce energy use and light pollution for backlighted signs. Studying the effects of different sign colors and a field study are the next logical steps in validating these findings.

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