CHARACTERISTICS OF LETTERS AND LEGIBILITY OF INTERNALLY ILLUMINATED SIGNS FOR THE VISUALLY IMPAIRED

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Abstract

Internally illuminated signs have potential to improve legibility of directional signs for the visually impaired. This study investigated the relationship between two characteristics of letters - stroke width and depth - and legibility of positive contrast signs. Letters used for the experiments had two stroke widths: light and bold stroke; and three types of depths: flat, raised, and engraved letters. Participants included thirty-six people with moderate visual impairments and, as a control group, twenty people with normal vision. Their subjective ratings of legibility, perceived brightness and glare were compared and evaluated.

The results indeed emphasize the importance of the nature of visual impairments. In particular, most participants with glare and light scattering problems found the light stroke letters more legible than the bold ones. For those with blur and double-image problems, the flat and engraved letters were rated much more legible than the raised letter.

Keywords: Internally Illuminated Signs, Characteristics of Letters, Legibility, Visually Impaired

1 Introduction

1.1 Background

According to WHO (2010) there are 285 million people with visual impairment worldwide, some 86% of which are people with low vision who have visual acuity of 20/70 to 20/400. There are two-third of the visually impaired aged 50 and over. Some typical conditions of visual impairment include visual field loss, glare, light scattering, blurred and double image vision. Due to these problems, it is difficult for them to see clearly and to go about their daily life independently and confidently. This is especially the case for finding their way through public access buildings, where one of the main navigation aids is directional sign.

In many countries, there are national standards and guidelines on how to design directional sign as well as lighting to improve navigation within public buildings for the visually impaired. These recommendations, however, are based on the design of externally illuminated sign. British Standard (BS8300:2009), for example, recommends approximately 200 lux on directional sign with non-glare materials. Additionally, in real application within a public building, some signs may be illuminated by ambient light of 150-300 lux available in the corridor or circulation space.

On the other hand, lighting the sign externally with much higher light levels in order to increase luminance contrast may not be energy-efficient and can adversely affect the legibility of people with visual impairment by causing discomfort or disability glare. As there are indications from related studies suggesting that internally illuminated signs can help improving legibility for the visually impaired, this study proposes to apply them to directional sign. However, as the current design guidelines are based on externally-lit signs, there is a lack of understanding on how the characteristics of letter on internally illuminated signs can help improving legibility for people with visual impairment.

1.1.1 Lighting conditions for signs

Internally illuminated signs are self-contained, easily controllable in any lighting conditions, and standing out from cluster backgrounds (Garvey, et al. 2010). Suggestion from Institute of Siamese Architect (under the Royal Patronage) (2009) states that luminance level of internally

illuminated signs should be approximately 1,000 cd/m^2, while suggestion from IESNA (2007) states that maximum luminance ratio between task attentions, e.g. signs, and dimmer distance background should be 10:1.

The study by Garvey, et al. (2010) find that internally illuminated signs provided 40% higher visibility and 60% more legibility than those with external illumination on a controlled test task. However, available design guidelines of internally illuminated signs mostly focus on storefronts, billboards, and emergency exit signs.

G. Cook et.al. (2005) research on the legibility and conspicuity of emergency escape signage for people with visual impairments. Twenty-four emergency signs based on UK, EU and ISO standards were tested with the visually impaired and normal-sighted people under both normal and emergency lighting conditions. The results generated on legibility distance, peripheral vision measurement and seven subjective questions analysis. The summary gave high legibility and conspicuity score to the internally illuminated LED outline sign.

P. Freyssinier et.al. (2006) study luminance levels for LED lighted storefront signage to emphasize its attention-getting and legibility. Red channel-letter sign with varied luminance were tested with typical background luminance of nighttime outdoor and daytime inside-mall conditions on three viewing distances. The results showed that in all conditions, the luminance of signs equal to or greater than background luminance were preferred.

Another advantage of LED light source is dimmable. The brightness of the signs can be adjusted when installed and meet the right brightness on on-site installation. In Thailand, the LED lighting technology is gradually replacing the use of traditional light sources.

1.1.2 Designing signs

Characteristics of letters are also important on internally illuminated signs to help controlled glare and make signs more legible. Existing studies reported that for large letters as signs, the positive contrast (lighter text on dark background) is proved to be higher noticeable and legible (H. Cunningham, et al., 2004); (Holick, et al., 2006).

ADA (2010) suggested the ratio of stroke width to letter height of about 1:10 to 1:5. Even many research suggested the bold characters will be more legible for positive contrast sign (H. Cunningham, et al., 2004); (Holick, et al., 2006); and (Carroll, 2010). However, there were no suggestions on stroke width for internally illuminated sign. This research assumes bigger stroke meant more light can come out and may cause more glare. Hence, light stroke characters can be more legible due to less glare and light scattering.

Apart from brightness and contrast, edge sharpness and depth perception also affect legibility of the text (May and Georgeson, 2007). Georgeson (2001) studied the degree of blur at edges. He concluded that blur could be measured by the width of the luminance gradient profile, and the smaller the width was the sharper the edge looked. Another research of May and Georgeson (2007) enhanced this finding that the effect of blur increased with the increasing edge scale. Since people recognize objects in three dimensions, letters with raised or engraved edges could have shade and shadow to add in more identification.

1.2 Objectives of the study

This research is to investigate the characteristics of letter on interally illuminated signs that help improving legibility for the visually impaired. The outcome of this research can be a guide on the use of visual elements for internally illuminated signs that provide an inclusive wayfinding system for hospital. Hopefully, this concept can be employed on other Thai public facilities to improve accessibility for everyone.

2 Methods of study

To investigate the relationship between stroke widths and depths of letters and legibility of directional signs for the visually impaired, the experimental study was conducted in a full-scaled test room using LED back-lit signs. The signs displayed common destinations in Thai and English. Standard viewing distance of 4 meters was selected based on visual acuity test for people with visual impairments. There were two groups of participants: the visually

impaired and, as a control group, people with normal vision. They were invited to view and to rate brightness, glare and legibility of each sign. The results from stroke test and depth test were analyzed separately to test the following two hypotheses:

1. Light stroke letters are more legible than bold stroke letters.

2. Three dimensions raised letters are more legible than flat letters.

From the first hypothesis, this research assumes that bigger stroke give more light trespass and may cause more glare. Hence, light stroke characters may be more legible due to less glare and light scattering. From the second hypothesis, since people recognize objects in three dimensions, letters with raised edges could give shades and shadows to aid in identifying letters more clearly.

2.1 Participants

OPD patients from Eye Department of a large public hospital, their relatives, and medical staff were invited as volunteers. A total of 56 participants were separated into treatment and control groups. The treatment group had 36 volunteers with eyesight problems, of 16 males and 20 females, some 64% of which aged 50 and over. Most of them had one normal-sighted eye and one worsen acuity eye between 20/70 – 20/200. Some common symptoms included, for example, seeing glare or flash, blurry eye sight, sore eyes etc. The control group had 20 participants with normal eyesight, of 5 males and 15 females, half of which aged 50 and over.

2.2 Experimental set-up

A pilot study was conducted to select Thai and English fonts, letter configuration, and specifications of signs used for the main experiment. Typeface was CordiaUPC, usually used as directional messages in both Thai and English. This typeface was sans serif style with uniform stroke thickness. Thai letters used were 3 cm in height with 35% letter spacing, and English letters are 1.6 cm in height with 25% letter spacing. The ratio between letter width to height was 1:1, and between stroke width to letter height was 1:5 to 1:10. English text was a mixture of upper and lowercases for easier recognition (Garvey, 2010). The panel arrangement is shown in Figure 1.

Figure 1 – Dimension of sign panel and letters arrangement

Dimension of a light box was 20x60x5 cm and made out of zinc; the front was opened with grooves for changing test panels. Inside of the box was painted white with approximately 80% reflectance. Light sources of each box were 3-piece module of LED HHX-75123w-50, connected 51 modules in parallel and used a dimmable power adapter. Then 9 volts input was selected to provide an average of 1,000 cd/m2 letters luminance and 25-30 cd/m2 background luminance. These were achieved by using 3 mm thick white acrylic sheets with 50% light transmittance as sign panels with blue (8339-02 Highway Blue, MACal 8300 pro) vinyl film applied on top. The blue film had letters and arrows cut-out leaving white spaces for depth treatments.

Measurements of the letter and background luminance were taken and then calculated the luminance contrast using the following formula (as shown in Table 2 and Table 4):

Contrast = [(L1– L2) / L1] x 100

where

L_1 is the luminance of lighter area;

L_2 is the luminance of darker area.

The first hypothesis was Stroke Test configuration. There are two sign panels on the Stroke Test configuration between turning the light off and on, as shown in Table 3. And Table 2 shows contrast between the average luminance of letters and background of Stroke Test.

Table 1 – Sign panels of Stroke Test configuration

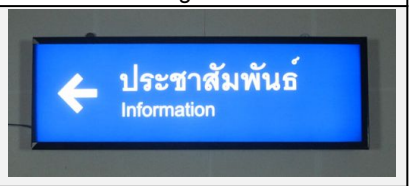
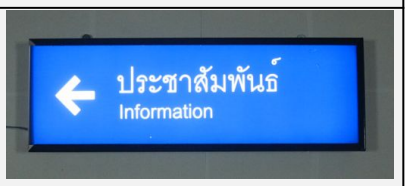
		Light off	Light on
Bold Stroke Letters			
Light Stroke Letters			

Table 2 – Luminance levels of Stroke Test in 300 lux ambient lighting

	Average luminance level (cd/m2)		Contrast* (between letters and background)
	letters	background	
Bold Stroke Letters	1185.84	30.19	97.45
Light Stroke Letters	943.26	30.77	96.74

The Depth Test configuration was set to test depth perception of the letters affecting legibility of the internally illuminated sign. Three sign panels with flat letters, clear raised letters, and engraved letters, as shown in Table 3 were included in this section. Also Table 4 shows contrast between the average luminance of letters and background of Depth Test.

Table 3 – Sign panels of Depth Test configuration

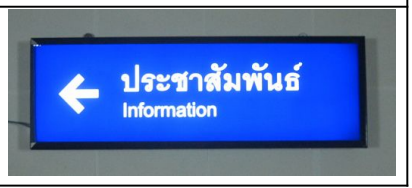
		Light off	Light on
Flat Letters			
Clear Raised Letters			
Engraved Letters			

Table 4 – Luminance levels of Depth Test in 300 lux ambient lighting

	Average luminance level (cd/m2)		Contrast* (between letters and background)
	letters	background	
Flat Letters	1185.84	30.19	97.45
Raised Letters	1026.66	32.66	96.82
Engraved Letters	1048.81	20.26	98.07

The experiments were carried out at the examination room of Eye Department of a public hospital in Bangkok. The test rooms, shown in Figure 2, were set up in the 3.00 m x 4.30 m width and 2.70 m height room. To resemble corridor condition, the room interior and ambient lighting were adjusted, providing an average of 300 lux similar to hospital corridor lighting level suggested by IESNA (2007). Light-levels inside the test room were measured in lux unit using Chroma Meter CL-200, Konica Minolta. The measurement points were in 0.60 x 0.60 m grid on horizontal plane, at 10 cm above the floor. The average illuminance level on vertical plane measured on the test signs were 170 lux.

Figure 2 – Experimental setup

2.3 Test procedure

With courtesy from Eye Department, Ramathibodi Hospital, the study was successfully carried out. Each participant was invited to enter the test room and stood 4 m away from the signs as shown in Figure 3. They were asked to provide demographic information and conditions of their eye-sight. This was also the period their eyes could adjust to the ambient lighting within the test room, which were not much different from that of the waiting area. Then they were asked to randomly observe sets of signs for Stroke and Depth Test, and provided their subjective perception on brightness and glare of each sign. The participant then rated on the Likert scale between 1 to 5 in responded to the following questions, “How is the brightness?” and “How is the glare?” The rating scores were collected and mean scores calculated for the perceived brightness and glare.

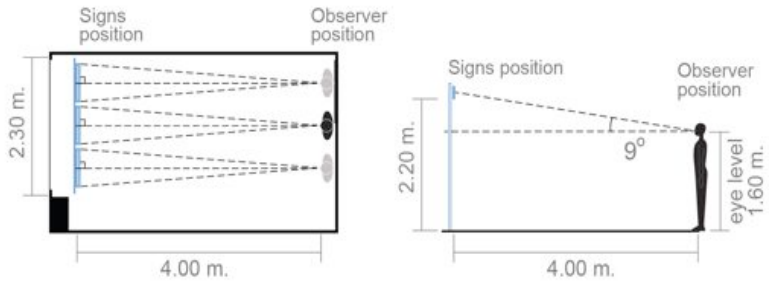


Figure 3 – Participant position in experimental

Finally, the participants were asked to rank the legibility of signs in each test. In the Stroke Test they were to rank between two signs; the sign considered more legible was rated as number 1 and the one less legible as number 2. For the Depth Test, they were asked to rank the most legible sign among the three as number 1, then the ones less legible with number 2 and 3 consecutively. During each test they were allowed to move left or right to view each sign in different angles, but on the same 4 m distance, before giving the rating.

These scores on each sign were added up and calculated into percentage for comparison between the treatment group and control group. Further analysis was also carried out, taking into account factors that might have an effect on the perceived brightness, glare and legibility of signs. These included age, gender and symptoms of the visually impaired. It should be noted that although statistical analysis (paired two-sample t-test and one-way ANOVA) was performed, most cases resulted in p-level higher than 0.05 due to small number of subjects in each group. Thus the results presented below were mainly based on a comparison of percentage and sum of scores from subjective ratings and legibility rankings.

3 Results

On average the subjective ratings obtained from the treatment and control group did not show significant differences in their perception and preference of most legible signs. However, the results appeared to indicate a certain relationship between the characteristics of letters and legibility when taken into account the symptoms of visual impairment. Furthermore, there was no significant influence of age and gender on the subjective ratings and legibility.

3.1 Stroke Test

An average of 64% of participants from both groups rated the bold letters as more legible than the light ones and these preferences did not seem to be affected by the eye sight. However, when the results were categorized by the common symptoms as glare problems (including light scattering), blurred sight, double-image problems and other impairments, then compared to the scores from those with normal vision, certain tendencies became clearer as shown in Figure 4.

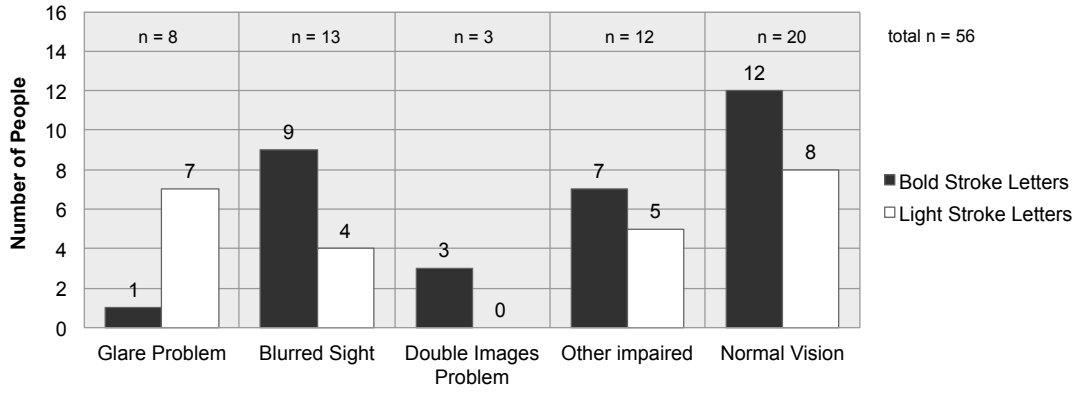


Figure 4 – Legibility rating under Stroke Test, comparison of eye problems

It showed that the bold letters were rated as more legible by 60% (12 out of 20) of the participants with normal vision, and by 68% (19 out of 28) of the visually impaired with blurred sight, double-image problems and other impairments. On the contrary, 87.5% (7 out of 8) of those with glare and light scattering problems found that the light stroke letters were more legible. Therefore, the first hypothesis which assumed that light letters would be more legible seemed to be applicable to those with glare and light scattering problems only.

For perceived brightness and glare, the participants from both groups rated the bold letters as brighter and caused slightly more glare than the light ones (shown in Figures 5a and 5b). This corresponded to the measured luminance of letters, thus the luminance contrast calculated and shown in Table 2. In spite of that, almost two-third of the participants rated the bold

letters as more legible. This result suggested that for short time viewing of directional signs, most people traded off slightly higher than 'just perceptible' glare for better legibility.

Figure 5 – The mean rating of brightness (a) and glare (b) under Stroke Test, compared between treatment group and control group

3.2 Depth Test

The average ranking scores for the most legible sign obtained from both the treatment and the control groups showed almost equal results for each of the three depth configurations. This was particularly the case when considered only the treatment group where the ranking scores for signs with flat, raised and engraved letters were 33%, 36% and 31% respectively. For the control group, while the signs with engraved letters received highest scores around 41%, those with flat and raised letters were given only 31% and 28% respectively. They commented that the raised edges made the letters look like a double image. Their preference had similar patterns as the treatment group who had double-image problems. It appeared that for the participants with normal vision the sign with engraved letters was the easiest to read among the three.

For the visually impaired, when their specific symptoms were taken into account, the ranking scores of the engraved letters were relatively moderate compared to the scores of the flat and raised letters, which varied widely depending on the specific symptoms as shown in Figure 6. While the sign with raised letters was voted as the most legible by the participants with glare, light scattering and other visual impairments, the sign with flat letters was voted as the most legible by those with blurred sight. Thus the second assumption that the three-dimensional raised letters would help improving legibility of directional sign for the visually impaired can be applied to those with glare, light scattering and other impairments only.

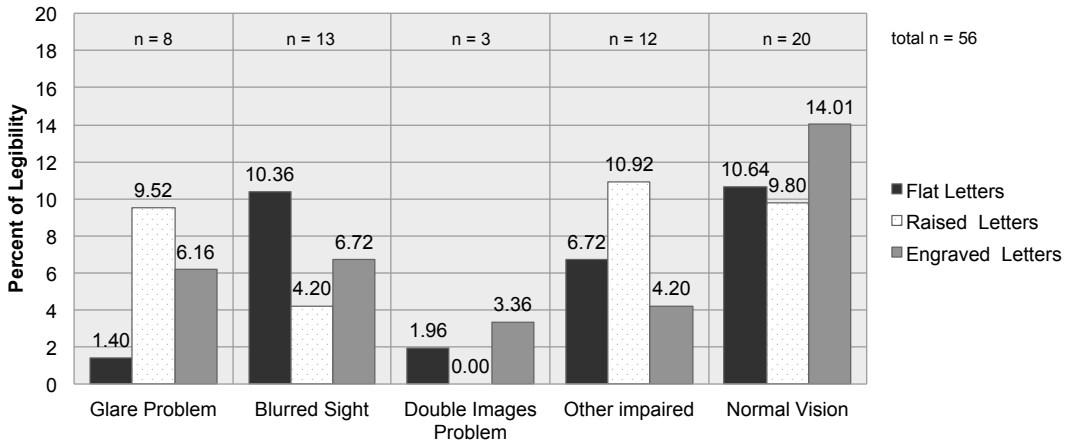


Figure 6 – Legibility rating under Depth Test, comparison of eye problems

For the perceived brightness as shown in Figure 7a, the average ratings for each sign obtained from each group, were more correlated with the measured background luminance of the sign than the contrast luminance as shown in Table 4. In particular, the sign with engraved letters has the lowest background luminance (20.26 cd/m^2) compared to that of the signs with flat and raised letters (30.19 and 32.66 cd/m^2 respectively). This due to the manufacturer of the sign with engraved letters that used 4 mm thick acrylic sheet instead of the 3 mm used for the other two types of depth.

The extra thickness of the acrylic sheet was needed for the engraving process and resulted in the lowest background luminance of this particular sign. Since the luminance of engraved letters was in the same range as that of the other two signs (1048-1185 cd/m^2), the luminance contrast of this sign was the highest among the three. This may explain the highest votes for the most legible sign by the participants with normal vision. In addition to the highest luminance contrast, some 38% of the control group who voted for this sign also commented that the dimmest sign background made the overall sign looked comfortable, and made the letters appeared brighter and easier to read, despite of slightly higher glare.

While the perceived brightness appeared to be related to the measured luminance background of the signs, the perception of glare obtained from both groups were more corresponded to the contrast luminance as shown in Figure 7b. Apart from those with glare, light scattering and other impaired problems, the perception of glare seemed to have little influence on the ranking of the most legible sign.

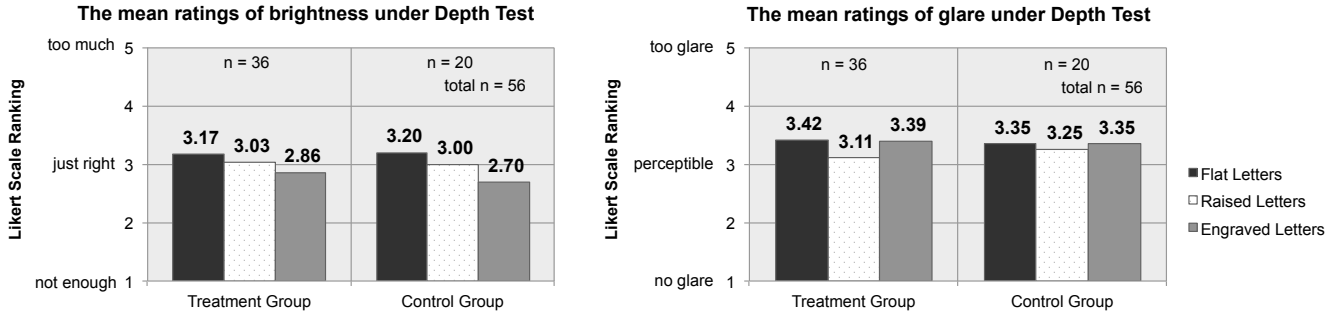


Figure 7 – The mean rating of brightness (a) and glare (b) under Depth Test, compared between treatment group and control group

4 Conclusions

This paper reviewed factors affecting the legibility and existing design guidelines of directional sign in public access buildings for the visually impaired, and identified limitations of using external lighting to illuminate the signs. Based on evidence drawn from related studies, this study suggested that internally illuminated signs could help improving legibility of directional signs for the visually impaired. However, as the current design guidelines are based on externally illuminated signs, there is a lack of understanding on the relationship between the characteristics of letter on internally-lit signs and legibility of people with visual impairment.

This paper reports on the experimental study carried out in a full-scaled test room to investigate the relationship between stroke widths and depths of letters and legibility of directional signs for the visually impaired. To simulate a typical corridor setting, the test room and ambient lighting was adjusted to provide an average of 300 lux on horizontal plane. Fifty-six volunteers participated in the study: the visually impaired and people with normal vision, as a control group. Two sets of LED back-illuminated positive contrast signs with white texts in both Thai and English on blue background were used. Background luminance of all signs, except the one with engraved letters, were around 30 cd/m^2 and the luminance contrast between letters and background were slightly below 100. Each participant was invited to view the sign randomly at 4 meters distance and to rate brightness, glare and legibility of each sign. The results obtained from Stroke Test and Depth Test were analyzed separately.

4.1 Main Findings

While there seemed to be no relationship between age, gender and legibility, the main findings indeed underlines the importance of specific symptoms of visual impairment.

1 The internally-lit sign with old stroke letters seemed to be easier to read for most of the visually impaired and those with normal vision. According to their comments, in spite of slightly higher perceived glare, the bold letters appeared brighter and easier to identify.

2 For people with glare and light scattering problems, however, light stroke letters were more legible than the bold ones. This may be explained by smaller illuminated areas of the light stroke letters, which resulted in lower letter luminance and luminance contrast.

3 The assumption that the three-dimension raised letters could help improving legibility for the visually impaired can only be applied to those with glare, light scattering and other impairments. For most people with normal vision and those with double-image problems, the raised letters appeared like double-images and thus harder to read.

4 The sign with engraved letters were found to be the most legible by most people with normal vision and those with double-image vision. However, this finding may also be influenced by the fact that this particular sign had the lowest background luminance compared to the other two signs, thus providing highest luminance contrast.

5 The visually impaired with blurred vision, in particular, found the sign with flat letters most legible.

6 For short-term viewing, most people appeared to trade off the slightly higher than ‘perceptible glare’ for more legible sign.

4.2 Further Study

It should be noted that due to the limited number of participants from both groups, the statistical analysis was performed but most analysis did not show significant differences in their perceptions. So a future study is needed to verify these findings with larger number of participants. In addition to the number of participants, the viewing distance used in this study was 4 m and this was due to the size of the test room used. Longer viewing distance, which could occur in real situation when they navigate within a public building, should be further investigated. Also the study did not test the legibility distance due to limited experimental space, but it is an important factor for signage.

For energy efficiency, more efficient specifications and layout of LEDs light source should be improved in order to reduce the electricity used for internally illuminated signs, while improving the legibility and level of comfort. Additionally, a future study should explore the application of edge-lit LED, since the edge lit technology will be more economic and flexible to implement in a manufacturing scale. The edge-lit technique might also help reducing strong contrast between letters and background that caused the differences among the three characteristics of letter difficult to be identified at first glance.

Despite of some constraints due to the number of participants in each group and manufacturing process of the sign, the main findings provide a better understanding of the relationship between main design parameters of the internally illuminated sign, the perceived brightness and glare, and particularly the legibility for people with visual impairment. These results suggest certain trends toward the characteristics of letter that can be applied to improve the legibility and navigation for the visually impaired in public access buildings, where people with normal vision are still the main users.

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