THE RESEARCH ON THE LEGIBLE FACTORS OF LED DISPLAY ON PUBLIC BUS

[1]CHO, WEI-JEN, [2]LEE, FANG-YI, [3]WU, CHIH-FU, [4]LIN, KAI-CHIEH

[1]The Graduate Institute of Design Science, Tatung University, Taipei, Taiwan
[2,3,4]Department of Industrial Design, Tatung University, Taipei, Taiwan
E-mail：[1]choweijen@gmail.com, [2]angela.fangyilee@gmail.com, [3]wcf@ttu.edu.tw, [4]kclin@ttu.edu.tw

Abstract- In this study, light-emitting diode (LED) designs were improved to enhance the legibility of LED displays on public buses. This study first referenced current visual designs used to develop bus LED displays and subsequently devised the following independent variables, which were Arabic numeral colors (i.e., red, yellow, and green), fonts (i.e., Times New Roman, Arial, and New Johnston Medium), and information display locations (i.e., left and middle). The assessment criteria were longest visual range and glare distance, which were evaluated using descriptive statistics and multivariate analysis of variance. The results showed significant differences in longest visual range between different colors, fonts, and information display locations. By contrast, no significant differences were observed in glare distance between the three variables. New Johnston Medium in yellow and before a black background yielded the optimal information display results. For glare distance, significant differences were observed in glare distance only between different information display locations, in which information displayed at the center produced superior results. The results of this study may serve as a reference when designing LED displays on public buses in the future.

Keywords- LED, visual range, glare distance, information display location

I. INTRODUCTION

1.1. Background and Motivation

In recent years, light-emitting diodes (LEDs) have been widely used in road lighting and transportation facilities. In the future, large-scale LED product use is inevitable. Compared with conventional light bulbs, LEDs save energy, feature a low damage rate, and have a service life 10 times longer than that of conventional light bulbs. Additionally, LED traffic signals and information displays provide the public with clear messages. Accordingly, LEDs have transformed from being ornaments to being general lighting devices. In the field of design, text and numbers are two of the most crucial elements of visual communication. Practical, high-performance, easy-to-recognize text and numbers can be developed by designing, revising, or rearranging their structure.

1.2. Study Objectives

This study investigated the LED displays on public buses to determine the distances required by passengers to identify the various fonts, colors, and Arabic numerals on these buses. The study objectives are as follows:

(1) Explore the factors of influence of LED displays on public buses that create the longest Arabic numeral visual range;

(2) Determine whether different colors, fonts, and information display locations influence the legibility of Arabic numerals;

(3) Examine the degree of glare created by Arabic numerals displayed using LEDs.

II. LITERATURE REVIEW

2.1. LED

An LED is a semiconductor light-emitting device. Initially, LEDs were used as indicator lights and in display panels. In 1996, Nichia Corporation discovered that by coating a layer of light yellow fluorescent powder onto blue LEDs, white LEDs can be fabricated. Since then, white LEDs have been mass produced as lighting devices. LEDs are highly efficient, have a long service life and favorable damage resistance, and have been widely used as vehicle lighting, traffic sign lighting, displays on buses, communications products, and products in biomedical- and biology-related industries (Ma, 2008). Figure 1 shows the internal structure of an LED.

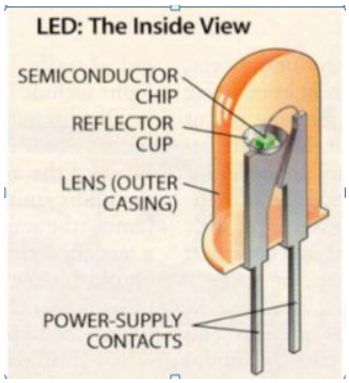

Fig. 1. Internal structure of an LED (Source: Ma, 2008)

2.2. Visual Range

In the field of transportation, vision is crucial. A Japanese scholar, Nomura (1996), indicated that of all the external stimuli perceived by the five senses, visual stimuli accounted for 87%. Vision is the general term for visual ability (Xu, Peng, and Wu, 1991). Visual ability refers to a person's ability to identify the details and contours of objects and includes the aspects of visual acuity, contrast

sensitivity, visual rate, color vision, and visual adaptability to brightness. Visual ability affects a person's visual performance. When viewing colors, people experience the subjective characteristics of simultaneous contrasts, where simultaneous contrasts include brightness contrast, color contrast, and hue contrast. Brightness contrast signifies that a color block placed before a darker background appears brighter than when it is placed before a lighter background. Color contrast denotes that a color placed before a colorless background appears more colorful than when it is placed before a more colorful background (Shi, 1996). The LED display screens on buses measure 200 cm and 40 cm in length and height, respectively. In this study, the experiment conditions were set to mirror the distances between pedestrians and buses when they waited for buses. Of the three fonts selected in this study, Arial (which featured the smallest spaces between adjacent numerals) was used and the number "9" was chosen to calculate the distance required to identify the number. Additionally, the trial and error method was adopted onsite to measure the visual range, on the basis of which the longest visual range (120 m) was derived. Furthermore, this study referred to the visual range for liquid crystal displays recommended by the University of Wisconsin Research Center (1963) (i.e., 14 W) and considered the width of buses' LED display screens to obtain a visual range of 28 m. Accordingly, this study required the participants to complete an Assessment Questionnaire on the Degree of Glare Up Close and From Afar when they were 28 m and 120 m away from the buses.

2.3. Glare

The concept of glare includes the degree of glare. Glare occurs when the brightness in the field of vision is more than that the eye can tolerate. Glare can cause visual irritation, discomfort, disturbance, and loss. No acts and regulations currently regulate the glare produced by LED billboards, traffic signs, or vehicle lamps. Whether a person sees glare is determined by the intensity of the ambient light, the person's physiological condition, and factors such as the balance between the light source and the brightness of the surrounding environment, the angle between the direct and indirect light sources, and the distance and angle between the line of sight and the light source (Chung, 2010). The major causes of glare include a high brightness contrast between the light source and background, a light source being overly bright, and a light source occupying a large 3D angle and being close to the field of vision. Figure 2 shows that the degree of glare in the top images is greater than that in the bottom images.

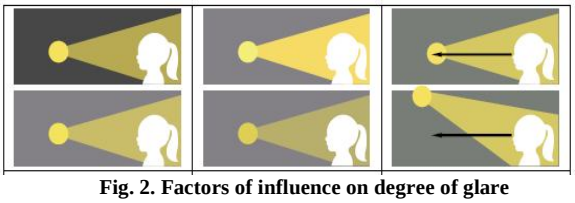

Fig. 2. Factors of influence on degree of glare

2.4. Information Display Locations of Arabic Numerals

A survey conducted in this study showed that two information display locations, which were "number shown on the left" and "number shown in the middle," were used (Figure 3). Accordingly, these two information display locations were used in the experiment design.



Fig. 3. Current information display locations of Arabic numerals in Taipei. Source: compiled by this study

III. STUDY METHOD

For this experiment, studies related to the legibility of LED displays on public buses were reviewed to determine how to select the optimal font, LED color, and Arabic numeral placement, achieve the longest visual range, and eliminate glare when viewed up-close without jeopardizing design aesthetics. Before the start of the experiment, the participants were tested to ensure that they had normal eyesight. The first stage of the experiment involved the participants looking at the LED displays from a distance of 120 m and completing the questionnaire. Afterward, the participants moved to a distance 28 m away from the LED displays before looking at the LED displays and redoing the questionnaire. The test was repeated until 18 test samples were collected. The second stage of the experiment entailed the participants being positioned 120 m away from the LED displays and walking toward the LED displays. They were asked to move 1 m at a time and to record the distance where they began to see the numbers as well as the glare; visual range and glare distance were rounded to the next meter and next 5 meters, respectively. To ensure the reliability of the data, the order of the experiment was switched for all samples and the participants were asked about the visual range and glare distance twice. The visual range and glare distance were recorded only when the participants provided the same answers both times.

IV. DATA ANALYSIS

Assessments made in this experiment were divided into two parts. The first part of the assessments involved using the Assessment Questionnaire on the Degree of Glare Up Close and From Afar. The questionnaire contained a five-point Likert scale and was used to record the participants' scores. Subsequently, the mean score for each question was

calculated on the basis of 30 samples. The second part of the assessments entailed using the Distance Record Table, in which the participants were asked to record their visual range and glare distance by referring to the meter marks written on the ground. According to descriptive statistical results, the descriptive statistics of the variables and the means (M) and standard deviations of the participants' line of sight were calculated. A multivariate analysis of variation was employed to obtain differences in the legibility of the LED displays when different factors were placed at different distances. A least significant difference test and a multiple comparison analysis were conducted to identify the key visual range and glare distance.

According to the internal effect tests of participants who experienced a glare at 120 m, of the factors "color," "font," and "information display location," only "color" exhibited a significant effect on glare, revealing that the colors of red, yellow, and green had an interaction effect. The results also showed that the distance of 120 m was generally too far for the participants to clearly see the LED displays. Thus, font and information display location had a nonsignificant effect on glare. In terms of the identifiability of the three aforementioned colors from 120 m, yellow scored the highest (mean = 3.472), followed by green (mean = 3.511) and red (mean = 3.878).

According to the internal effect tests of participants who experienced a glare at 28 m, of the factors "color," "font," and "information display location," only "information display location" failed to demonstrate a significant effect on glare. The test results showed that all participants could clearly see LED display information at 28 m, indicating that color and font affected information identifiability, whereas information display location did not.

The three factors (i.e., color, font, and information display location) had a sum of squared deviation of 3708.352, a degree of freedom of 4, a mean square of 927.088, an F of 53.076, and a p of .000, showing significant interactions ($p < .05$). Two factor interaction-wise, color–font interaction had a p value of 0.000 ($p < .05$; indicating significant interaction) when information display was within visual range. Additionally, when the information display was within visual range and red was the color used, the New Johnston Medium font produced the optimal result (mean = 82.35 m); when yellow was used, New Johnston Medium yielded the optimal result (mean = 93.35 m); and when green was used, Times New Roman generated the optimal result (mean = 89.37 m). These results may be caused by the two typefaces featuring long and thin strokes, making them more identifiable when within visual distance.

CONCLUSIONS

5.1. By comparing the degree of glare and degree of dizziness experienced by the participants at 28 m, green was identified as the color that created the most glare (mean = 3.333), followed by yellow (mean = 3.372); because the difference between the two means was small, the two colors produced glare. Yellow caused the highest degree of dizziness (mean = 2.700), followed by green (mean = 2.644); because the difference between the two means was small, the two colors caused dizziness.

5.2. Significant differences were observed in the visual range between the three colors, whereas no significant difference was observed in the glare distance between the three colors. When within the visual range, yellow could be seen farthest away, signifying that people have higher detectable range to yellow–green lights.

5.3. Significant differences were observed in the visual range between the three fonts, whereas no significant differences were observed in glare distance between the three fonts. When within the visual range, New Johnston Medium was the most identifiable font because it features thicker fonts, straighter lines, and is sans serif.

5.4. Significant differences were observed in the visual range and glare distance between the two information display locations, in which both visual range and glare distance showed that information displayed at the center yielded the optimal results.

5.5. Because illumination differs between day and night, subsequent studies may investigate and compare the legibility of information displays of day and night.

5.6. The participants in this study were aged between 21 and 25 years. Future studies could select bus passengers from different age groups (e.g., office workers and older adults) when exploring the legibility of information displays.

REFERENCES

[1] Ma, X. K. (2008). Current State of Development of LED Lighting Optoelectronic Technologies. Taipei.
[2] Chung, W. C. (2011). "A Study on Vision Ergonomic Assessment of LED Changeable Message Signs on Different Environment Illuminance." Master's Thesis, Graduate School of Industrial Design, Tatung University.
[3] Xu, S. X., Peng Y., and Wu, S. P. (1991). Human Factors and Ergonomics. Yang-Chih Book Co., Ltd. Taipei.
[4] Shi, X.W. (1996). Fundamentals of Interior Lighting Design. Shushin Publishing House, Taipei.
[5] Nomura, J. (1996). The Secrets Adding and Enriching Colors: An Introduction to Chromatics. Taipei.

★★★