Evaluation of Visual Performance Using LED Signboards under Different Ambient Conditions

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Abstract

This research aimed to study how to make the light emitting diode (LED) signboards be more legible under high illuminative conditions and to avoid the observers feeling dazzling glare under low illuminative conditions. This research firstly studied the literatures to explore the drivers’ visual ergonomic as well as the optical properties of LED, and investigated the relatively existing norms for engineering vehicle LED signboards. Three variables were set in this study: three kinds of ambient condition, four kinds of luminance contrast and two kinds of character form. In the first phase of the experiment, subjects observed LED signboards in both near and distant locations and filled out the SWN scale (Subjective Well-being under Neuroleptics), and in the second phase, subjects were then asked to moved forward and recorded their perceptions of comfort and glare to distance range. The findings demonstrated that, there was no variation in subjective evaluation to display signs with no backgrounds either in the near or distant locations, while to display signs with backgrounds, the subjects perceptions were the farther the distance, the clearer the legibility; higher ambient illumination could effectively reduce observers’ glare perception to LED signboards; signboards with backgrounds at the luminance contrast of 3:1 (L max = 3100, L min = 1033 cd / ㎡) showed the lowest uncomfortable and glare level to observers. The two forms of character showed no significant variation in affecting observers in terms of the comfort and glare perception.

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1. Introduction

Light provide illumination for driving that efficient lane keeping and perception traffic signs. In way, the tasks of the light source can be divided into the categories: automobile headlamps, public light and traffic signs. Light, when traverses the eye in a certain way, interrupts vision temporarily leading to glare. Glare is often experienced by drivers during nighttime driving conditions (i.e. a passing car’s headlights shining into driver’s eyes), and daytime driving conditions (light shining directly into driver’s eyes). In the pioneering works, [1] headlamp was to assess whether alternating different tinted windshields would affect aging drivers’ visual acuity and glare response. Automobile headlamps and public light investigated the effects of discomfort glare on driving behavior [3]. Traffic signs play important roles in traffic safety since they provide regulatory, warning, or guide information about upcoming roadway conditions to approaching road users [5]. Traffic signs installed with good visibility and legibility can give road users enough time to react safely in time.

Traditional traffic lights, which use incandescent lamps as the source of light, are gradually becoming less energy efficient in terms of life span and energy consumption [2]. Advanced countries such as European countries, the United States and Japan are actively using LED to replace incandescent lamp as the LED has a longer life span and lower energy consumption. In addition, progresses in manufacturing technology have resulted in great improvement in LED color and brightness. However, under low illuminative environments, such high brightness might make the observers feel uncomfortable and glare [4]. Currently, High-Brightness LEDs are mainly applied to traffic signboards. Traffic signboards provide the driver various information for safe and efficient navigation. Take the guidance sign traffic light on the rear of national highway engineering vehicle for example, according to the statistics of local National Freeway Bureau, there is about six constructional fatal accidents per year, in which three of them usually occurred during the operation of mobile engineering trucks. Although those accidents were not cause by engineering trucks, all seemed to be relevant to the insufficiency of warning signs on the vehicles and related constructional spots, which also showed a high rate of car accident on the highway constructional operation. Therefore, this research aimed to study how to make the brightness of LED signboards on engineering trucks to reach the most comfortable visual distance which allows drivers to have more time to do proper reactions and judgments, as well as avoid causing glare to drivers when they are driving at close range.

Reduced contrast sensitivity and increased glare has been reported to be one of the primary problems hindering the safety and comfort of drivers [8]. Headlamp glare has been reported to deteriorate visual performance under driving conditions in contrast to conditions without glare, and glare has been reported to have greater impact on visual performance of subjects. Munehiro [6] study pointed out that the legible distance of LED guide light in the daytime is father than road marking, while in the mist the glare level will rise with the increased brightness of LED. As this is the situation, an appropriate change of brightness of LED is necessary. Because of the high brightness, installing LED on road traffic does improve legibility.

On aspect of the application of LED display signs in each country, according to the the Highway Construction Traffic Control Manual of Directorate General of Highways, MOTC (2010.2), there are at least four levels of the brightness of LED display signs in which the darkest level must be the half of the brightest, and the intensity of each LED light must not be less than 2cd. In the manual of the road construction traffic control and safety equipment of Macao Special Administrative Region Transport Bureau (2009.1), it also mentions that the brightness of LED light on the engineering vehicle should be adjusted in accordance with the surrounding illumination. From the various regulations for variable message sign and LED signal on engineering vehicles set by each county, it shows that currently there is no uniform provision to the brightness of LED application on engineering truck. Therefore, this research
focused on the brightness contrast background between LED variable message sign and LED display panel, conducting the study of visibility under different illumination conditions, to investigate how the luminance contrast of LED display sign reached the farthest visible distance under different illumination conditions and without creating glare to drivers in close distance.

2. Research Methods

2.1. Subjects

Before experiment proceeding, this research carried out a visual acuity test to all of the subjects in accordance with the standards of obtaining the automobile driving license specified by the Directorate General of Highways M.O.T.C, that is, the naked vision value of both eyes have to be 0.6 or over and each eye has to be over 0.5 or 0.8 after correction, as well as with field of each eye view reach 150 degree, and without night blindness as well as also be able to distinguish among red, yellow and green colors. This study randomly selected 29 subjects (15 males, 14 females, aged between 21 to 30 years).

2.2. Subjects

The purpose of this study was to explore: (1) The farthest and comfortable distance of the luminance contrast of LED display sign under different ambient illuminations; and (2) The effect of the character form of LED display signs to subjects legibility. Three different experimental variables of systems:

(1) The luminance contrast of LED sign

Luminance contrast (Lc) means the luminance ration between the target object and its direct background.

\[ Lc = \frac{L_{\text{max}} - L_{\text{min}}}{L_{\text{min}}} \]

Where \( L_{\text{max}} \): luminance of the target

\( L_{\text{min}} \): luminance of the background

Both \( L_b \) and \( L_t \) where measured in cd/m² using a Luminometer (LP9221 UNM6). The luminance contrast between sign and background was divided into four levels, \( Lc1(L_{\text{max}} = 6200 \text{ cd/m}^2, \ L_{\text{min}} = 0 \text{ cd/m}^2) \), \( Lc2(L_{\text{max}} = 6200 \text{ cd/m}^2, \ L_{\text{min}} = 3100 \text{ cd/m}^2) \), \( Lc3(L_{\text{max}} = 6200 \text{ cd/m}^2, \ L_{\text{min}} = 2066 \text{ cd/m}^2) \), \( Lc4(L_{\text{max}} = 3100 \text{ cd/m}^2, \ L_{\text{min}} = 1033 \text{ cd/m}^2) \).

(2) Ambient conditions

As the outdoor illumination varies, for the control of experimental variables, this experiment was conducted at a built darkroom and simulated the illumination environments around the clock by using three halogen lamps, in which one lamp was connected to dimmer to control the illumination. The variables of environment illumination were set for three classes, including the bright day (30000 Lx), the dark day (5000 Lx) and night (10Lx). LP 9221 S1 Illuminometer was used to measure the illuminance.

(3) Graphical sign

According to the highway construction traffic control manual of Directorate General of Highways, the main directional contents of advance warning arrow sign on engineering warning car are "←" and "<<" two styles. The experimental fetched the front part of the arrow signals of "←" and "<<" (Fig. 1) to proceed the experiment of the interaction between the two characters. And the sign appeared randomly from four different directions of up, down, left and right to avoid the subjects’ learning effect. In this study was reduced to the size of 30cm (L) × 60cm(W), within a total of 16 × 32 LED lights.
Subjective assessment questionnaire: a questionnaire for the subjects to assess their eyes comfort in observing the LED signs at the nearest distance (9.8M) and the most far distant (57M). Questionnaire items were: 1. I feel eye fatigue, 2. I think things look difficult, 3. There is a strange feeling around the eyes, 4. I feel numb, 5. I feel headache 6. I feel dizzy. This experimental signal is easy to identify, and the five-point scale was applied with point 1 to 5 which represented from "strongly disagree, disagree, fair, agree, strongly agree." respectively. Items from1 to 6 were negative visual feelings, item 7 was positive feelings to explore the identification degree to sign. Here, Comfort distance: the distance which subjects feel comfortable while observing the LED display panels – the distance which subject feels the glare while observing the LED display panels; and Glare distance: the distance which subjects feel glare while observing the LED display panel – point of origin.

2.3. Experimental procedure

Subjects firstly filled in the basic personnel information in the classroom and their visual acuity values were confirmed to meet the requirement of this experiment. Next, the researcher presented the experiment details to subjects and explained questions raised by subjects. Then, subjects sat in chairs with the same height as the car seat and, under the condition of 2 level of character x 4 level of luminance contrast x 3 level of ambient illumination of LED display sign luminance and ambient illumination adjusted by the research, observed the LED display panel in both of the nearest distance of 9.8 meters and the farthest distance of 57 meters, and then filled out the subjective assessment questionnaire of their perceptions. In the second phase, the subjects moved forward slowly from the distance of 57 meters until the they felt comfortable with arrow sign of the LED display panel sand recorded the visual distance at that moment. Then the subjects kept on moving forward until they felt glare to the arrow sign of LED display panel, and again recorded the visual distance at that moment. By the end of each test, the subjects took a short rest to avoid the visual fatigue or discomfort. Finally, this research applied Microsoft Excel 2007 to calculate the descriptive statistics for all variables of the experimental results in the first stage. The results of second experimental stage were calculated by SPSS 18.0 software to analyze the interaction between
the three factors, and if there is not interaction, the One Way Anova analysis would be conducted to explore the variation between single-factor variables.

3. Results

3.1. Comfort distance of the LED signboard system

Fig. 3 shows the comfort distance of the LED signboard system for each independent variable. Fig. 3(a) shows character ambient illumination on comfort distance, Fig. 3(b) shows ambient illumination luminance contrast on comfort distance, Fig. 3(c) shows character luminance contrast on comfort distance, respectively.

Fig. 3 the comfort distance of the LED signboard system for each independent variable

3.2. Glare distance of the LED signboard system

Fig. 4 shows the glare distance of the LED signboard system for each independent variable. Fig. 4(a) shows character ambient illumination on glare distance, Fig. 4(b) shows ambient illumination luminance contrast on glare distance, Fig. 4(c) shows character luminance contrast on glare distance respectively.

Fig. 4 the glare distance of the LED signboard system for each independent variable

4. Conclusions

The distance of LED display sign with background would affect the observer’s viewing comfort. In the visible range, the subjective view comfort of farther distance was superior to short distance. At the condition of without background (Lmax = 6200, Lmin = 0) conditions, there was no variation of the subjective comfort between observing the LED display panel from the farther or short distance. The perceived glare extent of observing the LED display sign in the condition of higher ambient light (30000Lux) was lower than the glare extent in the night; on the contrary, subject’s viewing comfort in the environment with higher light (30000Lux) was superior to the viewing comfort in the night (10Lux),
which indicated that the higher environmental light source around the LED display signs, the lower glare extent the observer perceived. Our data collected while participants were driving under real world conditions, demonstrate that recognition ability under night time conditions is reduced compared with daytime ability, and that these effects are more severe for older drivers. These data are in accordance with previous studies, which have shown that older drivers have poorer sign recognition at night time compared with younger drivers34 and have greater difficulty in recognizing roadside pedestrians.26,35,36.

In the aspect of character form, there was no significant variation between the two character forms in Taiwan engineering vehicle in terms of the extent of comfort and glare. However, in the condition of the interaction with environmental light in 30000Lux, the comfort and glare extent of arrow sign with tail "←" was better than the arrow sign without tail "<"; however, in the night (10Lux) , the above situations were contrary. It was speculated that the ambient light of 30000Lux reduced its value of glare which led the arrow signal with tail to look more comfortable; while in the condition of 10Lux, the perception of less comfort might be because there were more LED lighting points on the arrow sign with tail "←" which resulted the high extent of glare. From the view point of luminance contrast, similar to LED sign with background on Japan engineering vehicles[6], the most comfortable luminance contrast of 3:1 was consistent with the results obtained by ANSI / HFS 100 -1988 (1988) recommending the VDT brightness contrast should be 3 at least, while too high brightness will make the observer feel uncomfortable and glare. When Lc = 0, the perception of uncomfortable and glare will be higher than Lc=3, this finding was also in line with the report of enhancing the night visibility of LED sign device provided by Japan Information Processing Juridical Association which suggested the way of lighting background can prevent the dazzling glare phenomena.

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References

[1] Wen S, Thurmon E L, Mehran A. Tinted windshield and its effects on aging drivers’ visual acuity and glare response. Safety Science 2008; 46:1223–1233.

[2] Ibrahim D, Beasley M. The Benefits of LED Traffic Lights in London and the Pilot Test Sites. IEE Conference Publication 1998; 454:172-176.

[3] Theeuwes J, Alferdinck J W, Perel M. Relation between glare and driving performance. Human Factors 2002; 44: 95-107.

[4] Sammarco J J, Gallagher S, Reyes M. Visual performance for trip hazard detection when using incandescent and led miner cap lamps. Journal of Safety Research 2010; 41: 85-91.

[5] Wood J M, Owens D A. Standard Measures of Visual Acuity Do Not Predict Drivers’ Recognition Performance Under Day or Night Conditions. Optometry and Vision Science 2005;82: 698–705.

[6] Munehiro, Tokunaga, T Asano, Hagiwara. Brightness efficiency of the luminescence type LED gaze guide light which is required under fog occurrence condition, the Hokkaido development engineering works laboratory monthly report, the Hokkaido development engineering works laboratory 2005; 630:23-36.

[7] Anderson S J, Holliday I E. Night driving: effects of glare from vehicle headlights on motion perception. Ophthalmic and Physiological Optics 1995;15:545–551.

[8] Schieber F, Kline D W, Kline T J B, Fozard J L. The relationship between contrast sensitivity and the visual problems of older drivers (SAE Technical Paper No. 920613). Warrendale, PA: Society of Automotive Engineers, Inc. 1992.