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A Study on the Text Legibility of Large LED Display

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Abstract. This study aims to explore into the legibility of text information on large LED display as the effective segment information, quick search and correct reading performance. This research firstly discussed factors relative to the legibility of LED display, and defined three variables for the experiment, namely color combination of figure/background, tracking and leading. This experiment was carried out respectively at the distance of 44 meters and 28 meters. The best combination of legibility for color combination of figure/background is yellow/blue, amber/amber, and yellow/yellow. Tracking and leading show significant difference at 28 meter, the legibility of leading 150% is better than that of leading 120% and tracking fine-tuned to 100 is better than the tracking standard. Nonetheless, tracking at 44 meters does not show significance. The study concludes the design principles that meet the public visual perception, which results can be referred for the information on LED display design in extensive applications such as the train station, shops, airport, or roads.

Keywords; LED, color combination of figure/background, tracking, leading

1. Introduction

Recently, under the help of government's propaganda and policy guidance, more and more public space and facilities are equipped with LED display, mostly in public

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transportation. Take Taipei Railway Station as an example, the information display system has evolved from the previous traditional flip display, to LED display that offers more information and better operation experience. Although there are some research on small LED display legibility, such as smart watch, pad, electronic paper etc., discussions on large LED display facilities are not as much as we expect. Consequently, this lack of research causes a problem: The legibility efficiency is not high since designers still adopt small LED display design principles when planning LED facilities, without considering the cross-impact in terms of the scale of the facility, environmental illuminance and legibility efficiency. To display huge information monochromatic LED cannot offer, using color combination of figure/background (figure, character/background) to present information is essential.

Legibility is a commonly used ergonomic criterion for display evaluation. It depends on letter size, font type and thickness, letter and line spacing, colour contrast, viewing distance, and ambient illumination. An appropriate display performance will provide as much information in terms of image, text as we need. Legibility measures include reaction time and accuracy associated with find target words in paragraphs visual stimulus recall rate and perceptual ease, and physiological correlates of legibility. There are many factors that affect the legibility of LED information. Above of color, light luminance, tracking and leading are significant factors. Considering leading, Kruk, R. S. & Muter (1984)'s research found that the reading speed in single leading is 10.9% slower than that in double leading. Large LED display facilities with information of different leading can be seen everywhere, but the research on the legibility is quite limited. Consequently, it is necessary to carry out experiments to analyze this territory.

In the field of LED lighting effects on user experience, past research mainly focused on the color rendering evaluation system of light source, as well as the color judgement accuracy under certain conditions, such as color temperature, objects' color and printing material. Nevertheless, the influence of the elements of colors on color deviation of LED lighting has not been studied, which is exactly what this research focuses on.

2. Methods

A. The effect of tracking to legibility

Generally, the legibility of character will be better as it grows larger. Previous researchers mostly focused on reading legibility in article. Some local researchers found that, the cross-impact among different types of fonts, tracking and leading would dramatically affect reading efficiency, and no matter what kind of font it was, leading must be larger than tracking. Concerning about tracking arrangement design, tracking

fine-tuned to 0 was the best, which meant people would spend the least time when reading, in other words, tracking fine-tuned to 0 had the best readability. Besides, there was research pointing that when the tracking and leading were controlled at 3mm, the readability was the best, and if tracking was over 3.75mm or less than 2.75mm, it was terrible. Although most of the participants thought tracking and leading would affect reading in terms of accuracy and efficiency, the research showed that tracking only affect the efficiency, not accuracy.

B. The effect of leading to legibility

Leading refers to the distance between the baselines of successive lines of type. Default leading is 120% of the letter height, for example, letter of 10 point will be using leading of 12 points.

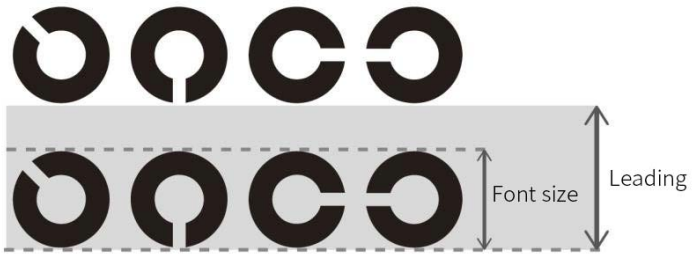

Fig 1. Leading

Existing researches usually discuss the letter size and tracking, but there is no much research can be found in leading, which is also significant for presenting information. When leading becomes larger, the content screen displays will less; conversely, smaller leading help screen contains more information.

Research on leading effect to legibility showed that, leading had significant effect on reading accuracy, and single leading had higher error rate than double leading. When leading is 1/3- 2/3 of the character height, the legibility is fine, and both 1/2 and 1/3 are the best. When leading is too big, it will cause diffusion feeling to people; while when leading is too small, it will increase the pressure of readability in terms of visibility. From that point of view, leading arrangement design is very important. Research from Kolers, Duchnicky & Ferguson revealed, under the condition of single leading, participants in the experiment spend more time to finish the reading task. However, those differences are quite small and has no significance. On the other hand, Kruk & Muter had found, the reading speed of single leading is 10.9% slower than double leading, which is a huge difference.

C. Legibility of Color

The differences between Color is generated when light stimulate people's eyes' cells. Light refers to the electromagnetic waves that can be seen by human beings, and they are range from 380nm to 780nm. Those visible light waves consist of monochromatic lights of different wavelength, which are visually classified into red, orange, yellow, green, blue, purple etc. Red light has the longest wavelength, and purple has the shortest wavelength. Besides, people's eyes generate different perception when stimulated by those monochromatic lights, according to the length of wave, of which the yellow-green light is the most sensitive one, which has 550nm wavelength.

The legibility of color means defining the meaning of different colors when those colors are used together, to distinguish different things and avoid the confusion. For instance, we usually mark different files with different color; or we set different color as the line color for different public buses in different routes. Some research pointed that, high chromatic aberration in color combination made better legibility. Some scholars combined red, yellow, blue, green, black, and white together and made 30 color combinations in terms of word/background, then they found that white/yellow, yellow/white and green/blue were the worst combinations in legibility error rate test, and red/white, yellow/black were the best combinations. Some research did a house number plate test, and the results showed that the level of legibility was extremely related to the brightness of color, which meant the legibility became lower as the brightness differences was smaller, and the legibility became high as the brightness differences was bigger. Research also found other attributions of color would affect the legibility of color, including saturation and hue. There were some research revealing that different color combination would affect reader's fatigue in legibility, consequently complementary colors would create intense color contrast in layout in terms of word color and background color, which could attract attention for the first sight and subsequently cause visual fatigue, and this would decrease the layout legibility. Previous research found it was suggested to use less color combinations when designing layout, instead increasing the level of color contrast between word and background. It is better to use dark color as background and light color as the object. The legibility of color aims to give different color with different meaning, so as to avoid confusion. Shieh et al. found, color combination significantly affects the viewing legibility of VDT screen, and it is the best to present yellow information on the blue background.

D. Experimental variables

Strong color difference is easy to produce fatigue, decrease readability, although it is better to grasp first attention. Previous researches have proved it is better not to use too much color, but to reinforce the color contrast between letter and background, consequently this research just sets 4 groups of homologous color and two groups of

contrasting color. This experiment contains three independent variables: color combination of figure/background, leading and tracking, as figure 3.1shows, all variable level are as follows:

- Color combination of figure/background: red/red, amber/amber, yellow/yellow, green/green, yellow/blue and red/green.

Fig 2. Color combination of figure/background sample

- Leading: There are two levels of leading, 120% and 150%. Default leading is 120% of the font size. For example, font size 10 will be set 12 pt. font size leading. According to Japanese visual design institution's research, leading which was 1/3 to 2/3 had better legibility, in which 1/2 and 2/3 are the best, consequently 120% and 150% are chose in this experiment.

Fig 3. Leading sample

- Tracking: Tracking standard and tracking fine-tuned to 100. Special kerning and kerning are measured in units of 1/1000 em., which is a measure of relative unit relative to the current font size. Taking 6 pt. font size as an example, 1 em means 6 pt. and for 10 pt. font size, 1 em means 10 em. Special kerning and kerning are proportional to the current font size. Some research found that, it was better to set leading as 0, since it has the best legibility and cost least time when reading. Therefore, tracking standard and tracking fine-tuned to 100 were chose in this experiment.

Fig 4. Tracking sample

Strong color difference is easy to produce fatigue, decrease readability, although it is better to grasp first attention. Previous researches have proved it is better not to use too much color, but to reinforce the color contrast between letter and background, consequently this research just sets 4 groups of homologous color and two groups of contrasting color. This experiment contained three independent variables: color combination of figure/background, leading and tracking, as figure 3.1shows, all variable level are as follows:

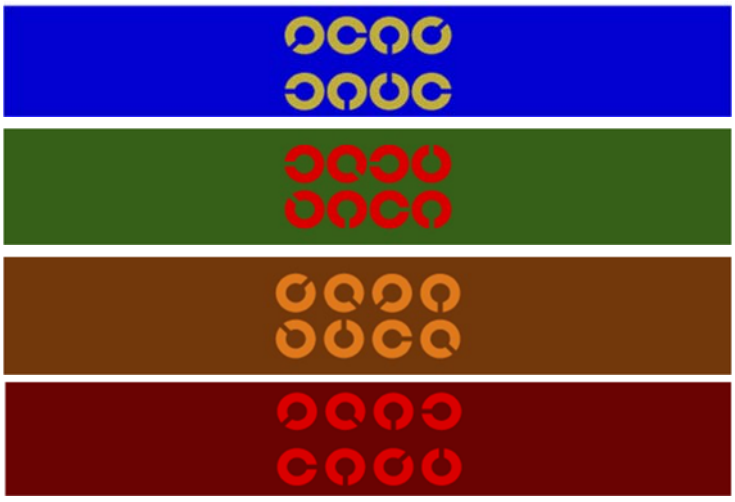

Fig 5. Experimental samples

The experimental equipment was installed two meters high from ground, to simulate the real public space which can also reduce discomfort from neck during the experiment. The distance between participants and LED display was calculated according to the Visual Angle calculation formula which was defined by Human Factors Engineering: Visual Angle= 3438 H/D.VA was set as the minimal parameter, equal the gap height of Landolt's C, then calculating the longest legible distance was 44 meters. According to the suggestion of University (Wisconsin) Facilities Research Center, that 4W (W means the width of screen) equaled the distance from large LED screen, the distance in this experiment was 28 meters based on the experimental screen' width. In this case, the experiment would be carried out respectively at the distance of 28 meters and 44 meters.

E. Experiment Operation

Participants were required to overview all the experiment workflow, then started with the first 44 meters test by viewing all the samples on the LED display board, afterward they had to finish [Long/Short Distance and Degree of Glare Questionnaire].

Later they would move forward till 28 meters away from LED screen and repeated the previous test again, as well as finishing the questionnaire. The experiment would be finished in 30 minutes.

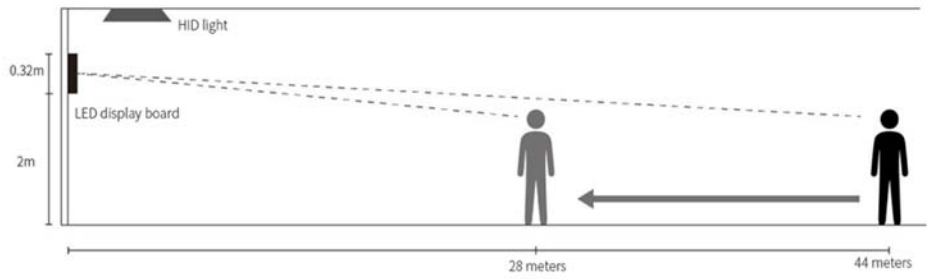

Fig 6. Experiment operation

3. Results

A. Statistical analysis of visual subjective rating at 44 meters

As shown in the table, the SS (sum of squares of deviation) of Color combination of figure/background was 15.059, and it was significant (P<0.05); the SS (sum of squares of deviation) of tracking was 1.502, and it was not significant (P>0.05); the SS (sum of squares of deviation) of leading was 2.377, and it was significant (P<0.05); the SS (sum of squares of deviation) of all these three factors was 4.818, and it was not significant (P>0.05).

TABLE I. VERIFICATION OF WITHIN-SUBJECT EFFECT FOR SUBJECTIVE RATING AT 44 METERS

Resource	Type III SS	df	Average of SS	F	Significance
Color combination of figure/background	15.059	5	3.012	5.262	.000
Tracking	1.502	1	1.502	2.624	.106
Leading	2.377	1	2.377	4.152	.042
Color combination of figure/background * Tracking	2.149	5	.430	.751	.586
Color combination of figure/background* Leading	1.991	5	.398	.696	.627
Tracking * Leading	.109	1	.109	.190	.664
Color combination of figure/background* Tracking * Leading	4.818	5	.964	1.683	.138

It was seen from the results of verification of within-subject effect derived from subjective rating at 44 meters, color combination of figure/background with leading was significant, meaning the two factors have cross-impact; tracking was not significant indicating that it was too far to distinguish little tracking slight adjustment at the distance of 44 meters.

TABLE II. SUBJECTIVE RATING AT 44 METERS COLOR COMBINATION OF FIGURE/BACKGROUND

Color combination of figure/background		**Number**	**Subset**	
			1	*2*
Scheffe test	yellow/blue	60	2.654	
	yellow/yellow	60	2.858	2.858
	amber/amber	60	2.867	2.867
	red/green	60	2.900	2.900
	green/green	60		3.150
	red/red	60		3.275
	significance		.674	.108

TABLE III. SUBJECTIVE RATING AT 44 METERS LEADING

Leading	**Average**	**Standard error**	**95% confidence internal**	
			Lower bound	*Upper bound*
120%	3.031	.060	2.912	3.156
150%	2.769	.055	2.759	2.979

As mentioned before, rating was measured by 5-point scale which stands for “Strongly agree, agree, Neither agree nor disagree, Disagree, Strongly disagree”. Consequently, lower average stands for lower visual fatigue and better legibility. Results showed that yellow/blue (average was 2.654) had the best legibility, followed by yellow/yellow (average was 2.858). It was also known that 150% leading (average was 2.769) had better legibility than 120% leading (average was 3.031).

B. Statistical analysis of visual subjective rating at 28 meters

TABLE IV. VERIFICATION OF WITHIN-SUBJECT EFFECT FOR SUBJECTIVE RATING AT 28 METERS

Resource	Type III SS	df	Average of SS	F	Significance
Color combination of figure/background	24.111	5	4.822	10.227	.000
Tracking	4.842	1	4.822	10.268	.001
Leading	4.842	1	4.842	10.268	.001
Color combination of figure/background * Tracking	.486	5	.097	.206	.960
Color combination of figure/background* Leading	6.003	5	1.201	2.546	.028
Tracking * Leading	.004	1	.004	.009	.924
Color combination of figure/background* Tracking * Leading	1.603	5	.321	.680	.639

As shown in the table, the SS (sum of squares of deviation) of color combination of figure/background was 24.111, and it was significant ($P<0.05$); the SS (sum of squares of deviation) of tracking was 4.842, and it was significant ($P<0.05$); the SS (sum of squares of deviation) of leading was 4.842, and it was siginificant ($P<0.05$); the SS (sum of squares of deviation) of all these three factors was 1.603, and it was not siginificant ($P>0.05$). The SS of color combination of figure/ background with leading was 6.003, and it was significant ($P<0.05$).

Results from subjective rating at 28 meters showed, color combination of figure/background, tracking, leading all had significance, by which meant the distance of 28 meters affected fine-tuned tracking.

TABLE V. SUBJECTIVE RATING AT 28 METERS COLOR COMBINATION OF FIGURE/BACKGROUND

Color combination of figure/background		**Number**	**Subset**		
			1	*2*	*3*
Scheffe test	yellow/blue	60	2.463		
	yellow/yellow	60	2.679	2.679	
	amber/amber	60	2.779	2.779	
	red/green	60		2.942	2.942
	green/green	60		3.058	3.058
	red/red	60			3.258
	significance		.274	.107	.274

TABLE VI. SUBJECTIVE RATING AT 28 METERS TRACKING

Tracking	**Average**	**Standard error**	**95% confidence internal**	
			Lower bound	*Upper bound*
Standard	2.979	.055	2.869	3.089
Fine-tuned to 100	2.647	.054	2.640	2.854

TABLE VII. SUBJECTIVE RATING AT 28 METERS LEADING

Leading	**Average**	**Standard error**	**95% confidence internal**	
			Lower bound	*Upper bound*
120%	2.979	.052	2.874	3.083
150%	2.747	.057	2.634	2.860

Results showed that yellow/blue (average was 2.463) had the best legibility, followed by yellow/yellow (average was 2.267). The most significant negative rating was red/red (average was 3.258). Results showed tracking fine-tuned to 100 (average was 2.647) was better than standard tracking (average was 2.979). It was also known that 150% leading (average was 2.747) had better legibility than 120% leading (average was 2.979).

4. Conclusions

This research aims to explore into the information legibility of large LED display in terms of color combination of figure/background, tracking and leading, which is meaningful for design large LED display equipment. Results from the analysis of the questionnaire showed that combination of figure/background significantly affected legibility of large LED display, to be specific, yellow/blue was the best color combination of figure/background, followed by yellow/yellow, but yellow/yellow caused more fatigue than others according to negative rating. Besides, Subjective rating results all showed that 150% leading had better legibility than 120% leading, and tracking fine-tuned to 100 was better than standard tracking. Tracking had no significance at 44 meters, it was deduced that it was too far to distinguish the tracking slight adjustment. Those results including the configuration of color combination, leading and tracking could help the large LED display design in different types of public space as a reference, which is the main purpose in this research.

References

Legibility is a commonly used ergonomic criterion for display evaluation [1] [2] [3]. It depends on letter size, font type and thickness, letter and line spacing, colour contrast, viewing distance, and ambient illumination [4] [5] [6]. An appropriate display performance will provide as much information in terms of image, text as we need. Legibility measures include reaction time and accuracy associated with find target words in paragraphs [7] [8] [9] visual stimulus recall rate and perceptual ease, and physiological correlates of legibility. Considering leading, Kruk, R. S. & Muter (1984) 's research found that the reading speed in single leading is 10.9% slower than that in double leading. [10].

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