International Journal of Signal Processing, Image Processing and Pattern Recognition
Vol.9, No.6 (2016), pp.437-446
http://dx.doi.org/10.14257/ijsip.2016.9.6.38

Dynamic Visual Performance of LED with Different Color Temperature

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Abstract

In order to research the dynamic visual performance of LED in mesopic vision conditions, based on the visual performance method, the software systems were developed to set different test parameters. And the hardware systems were used to collect the reaction time of testers. Color temperature of LED, ambient luminance, luminance contrast and target speed were selected as the experimental variables, and each variable had three variances. 60 sets of experiments were carried out by 20 testers. The experiment results show that reaction time of high color temperature LED is shorter than the other two. And reaction time decreases with the increasing of the ambient luminance and luminance contrast. And target speed has significant influence on visual performance in the speed range of 60km/h to 80km/h.

Keywords*: Mesopic vision, Color temperature, LED, Visual performance, dynamic target*

1. Introduction

All of the countries are concerned about traffic safety. In 1990, road accidents occupied ninth place in the global table for cause of death [1]. According to 2012 annual report of traffic accident statistics, the traffic accidents caused by lighting conditions are more than 76,000, and account for 37.6% of the total number of traffic accidents [2]. It is obviously that the quality of road lighting at night is an important factor to road traffic safety. Compared with traditional light source, such as high pressure sodium lamp, LED has the advantages of high luminous efficiency, energy conservation and environmental protection [3-4]. And LED has been gradually applied in the field of road lighting. However, Road lighting level is in the mesopic vision conditions [5]. In previous studies, the static visual effect of LED was studied. In order to provide good visual conditions for driving at night, this paper studies the dynamic visual effect of LED, which is significance to the design of actual engineering and the formulation of relevant lighting standard.

Massive achievements have been made on the research of LED visual effect [6-8]. The visual performance method can evaluate the capability of visual operation directly and effectively in different lighting conditions [9-10]. Jiayin Song used static facular as target to study the relationship of road surface luminance and reaction time of the high pressure sodium lamp and three kinds of LED in mesopic vision conditions [11]. When the third type of photoreceptor cells--the ganglion cells were found [12-14], so the optical biological effect of ganglion cells was also needed to be taken into consideration in the study of LED visual performance. Qingwen Zhang carried out a series of studies on the influence of light color temperature on the visual performance, and found that the optical biological effect is closely related to the ratio of blue light in the light source [15-16]. At the same time, the high color temperature sources, which are rich in blue light, are helpful to promote the brain's excitement[17].

ISSN: 2005-4254 IJSIP

Review of the literatures, in the visual performance and color temperature experiments of LED lights, static facular including visual target contrast and eccentric angle generally were used as targets. However, these didn't accurately reflect the dynamic changing process of the target, when drivers close to the target with a certain speed. Therefore, in order to research the dynamic visual performance of LED in mesopic vision conditions, A dynamic visual performance test system has been developed and built in the previous related research [18-19]. When dynamic visual targets were chosen, and three different color temperature LEDs were selected as background light sources, and the testing system was used to collect reaction time of testers.

2. System Structure and Test Principle

As shown in Figure 1, the dynamic target test systems are composed of the upper computer software system, reaction time measuring instrument, projector, lighting sources and screen.

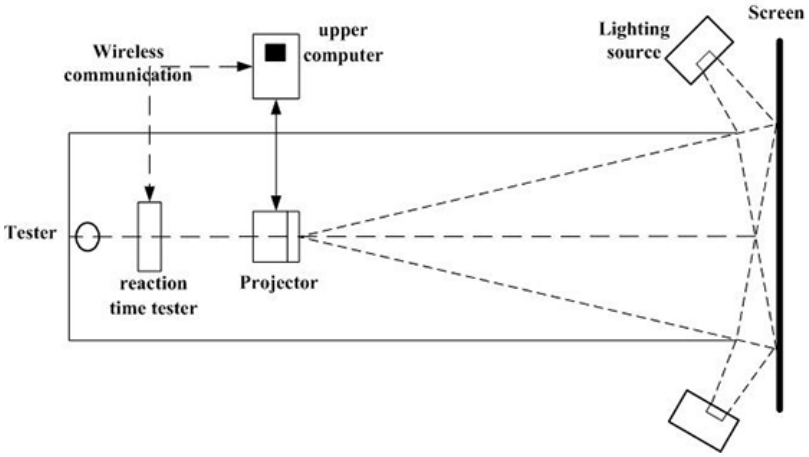


Figure 1. Reaction Time Test System

The reaction time tester was developed based on microcontroller, and the real object was shown in Figure 2.The main computer software system was developed based on three-dimensional graphics software OpenGL. The setting interface of test scheme was shown in Figure 3. The variables of visual target size, brightness, speed, initial position can be set in this software. And then, by the principle of perspective projection, the visual target is projected onto the screen.

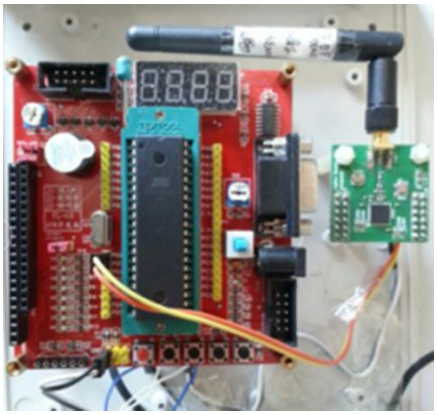


Figure 2. Reaction Time Measuring Instrument

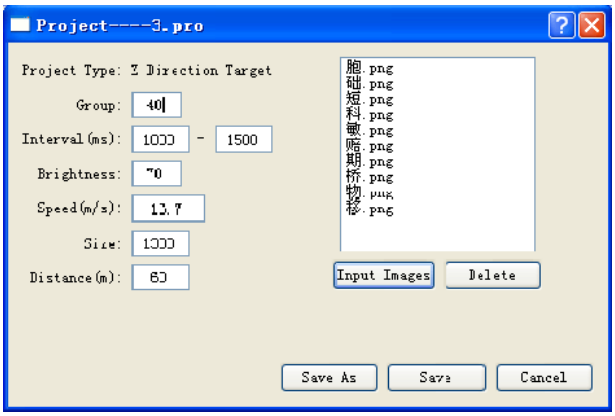


Figure 3. Setting Interface of Test Scheme

The next, as shown in Figure 4, assuming that the initial distance of the target is d=60 m, the target 'C' moves forward along the "Z" axis. The moving time will last 3.6 seconds, so the simulation speed of the visual target is v=60km/h.

As the target begins to move, tester identifies the visual target and presses the button, and this time is defined as the reaction time. In this experiment, the reaction process of the driver with the speed of 60 km/h closing to the object.

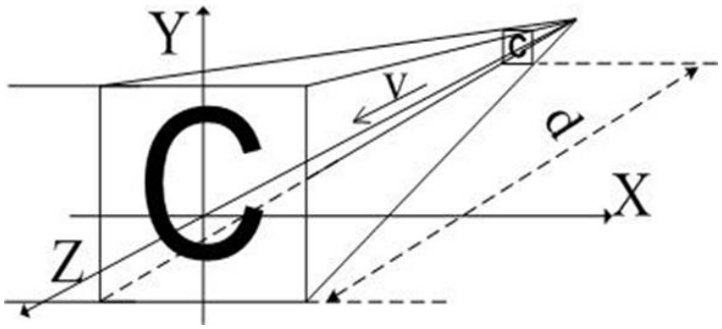


Figure 4. Principle Diagram of Dynamic Target

3. Main Title

Three kinds of color temperature LEDs were selected as light sources, which include low color temperature LED (LLED) (3000K, 50W), middle color temperature (MLED) (4000K, 50W) and high color temperature (HLED) (5000K, 50W). Ten similar recognizable Chinese characters were selected as visual targets. 10 experimenters aged from 20 to 28 who have normal color vision and vision correction were selected in the test. They had 10-15 minutes to adapt to the mesoptic vision environment and to get familiar with the testing procedure in order to ensure the reliability of data. 60 groups of experiments were designed and 3600 reaction time (unit: ms) data were collected in different visual target speed (unit: Km/h) experiments, different ambient luminance (unit: cd/m^2) experiments and different visual target contrast experiments. The data were processed by the method of statistics [20]. The experimental scenes were shown in Figure 5.

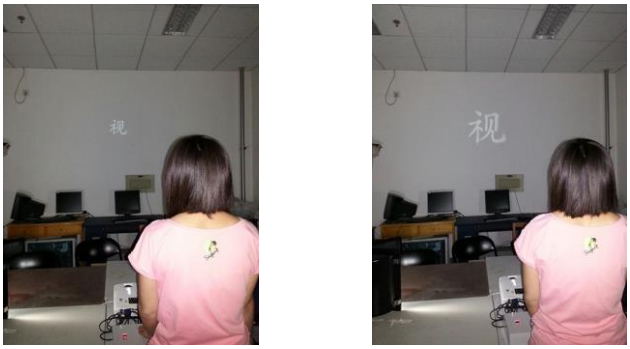


Figure 5. The Experimental Scene

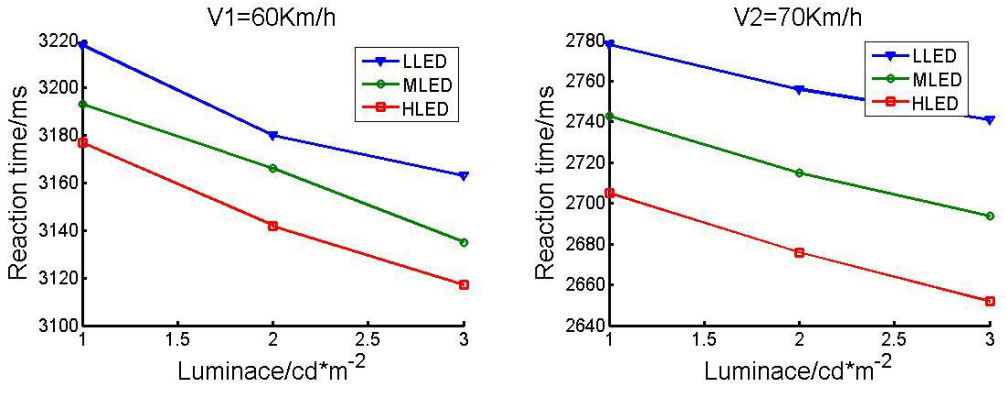
3.1. Relationship Between Reaction Time and Luminance

Reaction time data of three kinds of LED with different ambient luminance and target speed were shown in Table 1. The data reveal that the reaction time of LLED is 1.013 times than that of MLED averagely and 1.022 times than that of HLED.

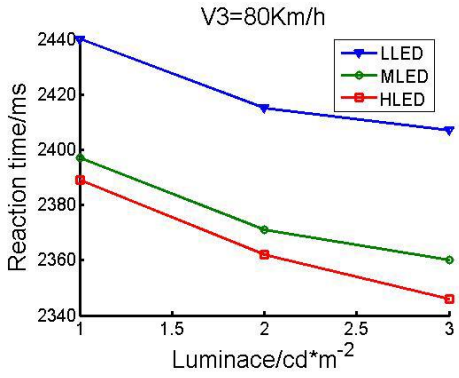
Table 1. ReactionTtime of Three Kinds of LED with Different Ambient Luminance and Target Speed (ms)

Target Speed	Ambient luminance	LLED	MLED	HLED
60	1	3218	3193	3177
	2	3180	3166	3142
	3	3163	3135	3117
70	1	2778	2743	2705
	2	2756	2715	2676
	3	2741	2694	2652
80	1	2440	2396	2388
	2	2412	2372	2362
	3	2407	2359	2345

In order to further study the effect of the luminance, target speed, color temperature on reaction time, three diagrams are obtained as shown in Figure 6.



(a) (b)



(c)

Figure 6. Relationship Between Reaction Time of Three Kinds of LED and Luminance

Combining data and graphs, the following rules are obtained:

(1) The reaction time decreases with the increase of brightness, which indicates that the higher the brightness, the better the visual effect;

(2) The reaction time decreases with the increase of color temperature, which indicates that the higher the color temperature, the better the visual effect;

(3) Ignore the speed factor, the higher the luminance, the bigger effect of color temperature on the reaction time;

(4) Ignore the color temperature factor, the greater the speed, the smaller the effect of luminance on the reaction time;

(5) Ignore the luminance factor, at the speed of 70km/h, the effect of color temperature on the reaction time is the biggest

Based on the software Origin9, Table 2 is obtained. The correlation coefficient R^2 of each function is close to 1, which indicates that the fitting degree is good.

Table 2. Fit Functions of Luminance and Reaction Time in Different Visual Target Speed

Target speed	Light	Fit function	R^2
60	LLED	$Y=3217.2X^{-0.0158}$	0.99
	MLED	$Y=3195.3X^{-0.0162}$	0.93
	HLED	$Y=3177.7X^{-0.0172}$	0.99
70	LLED	$Y=2778.3X^{-0.0121}$	0.99
	MLED	$Y=2743.7X^{-0.0162}$	0.99
	HLED	$Y=2706.1X^{-0.0177}$	0.98
80	LLED	$Y=2438.3X^{-0.01129}$	0.90
	MLED	$Y=2395.9X^{-0.0142}$	0.99
	HLED	$Y=2388.3X^{-0.0165}$	0.99

3.2. Relationship Between Reaction Time and Visual Target Contrast

Reaction time data of three kinds of LED with different luminance contrast and target speed are shown in Table 3. And the average data reveal that at the same target contrast levels, reaction time of LLED is about 28.3ms longer than that of MLED, and about 55.6ms longer than that of HLED.

Table 3. Reaction Time of Three Kinds of LED with Different Luminance Contrast and Target Speed (ms)

Target Speed	Contrast	LLED	MLED	HLED
60	0.3	3229	3201	3181
	0.5	3180	3166	3142
	0.7	3167	3152	3120
70	0.3	2797	2764	2709
	0.5	2756	2715	2676
	0.7	2721	2683	2648
80	0.3	2492	2464	2451
	0.5	2412	2372	2362
	0.7	2353	2335	2318

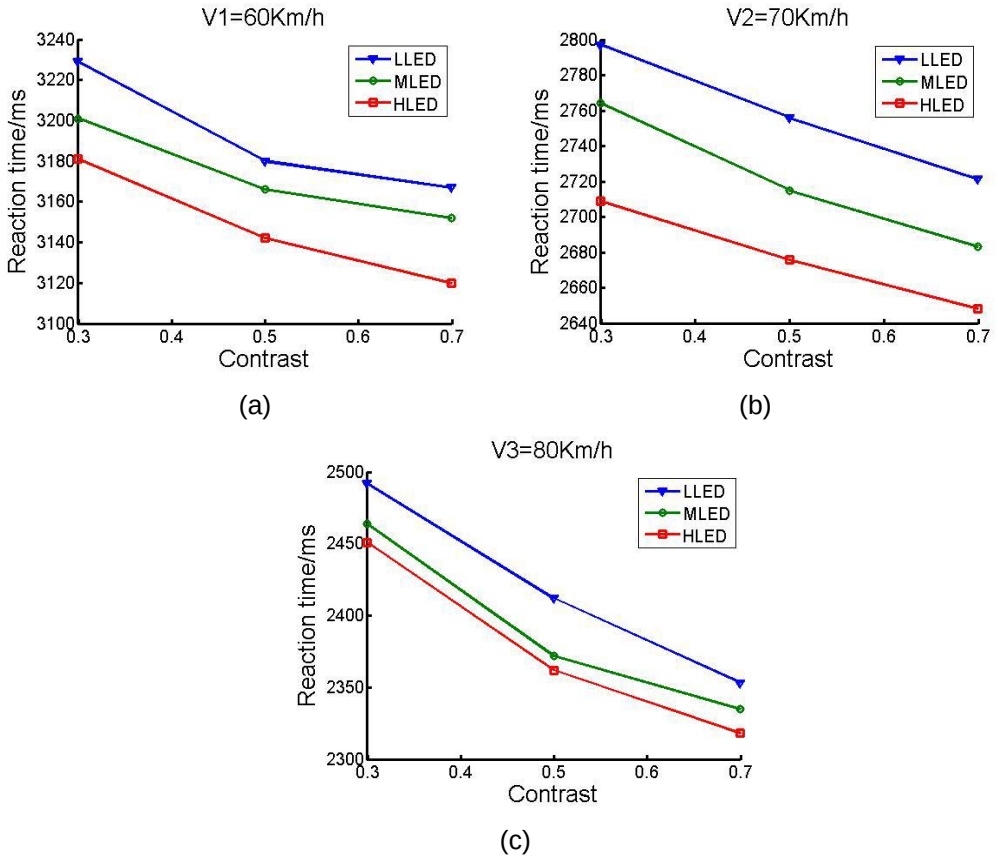


Figure 7. Relationship Between Reaction Time of Three Kinds of LED and Visual Target Contrast

In order to further study the effect of the luminance contrast, target speed, color temperature on reaction time, three diagrams are obtained as shown in Figure 7. Combining data and graphs, the following rules are obtained:

The reaction time decreases with the increase of luminance contrast, which indicates that the higher the luminance contrast, the better the visual effect;

Ignore the speed factor, the higher the luminance contrast, the smaller effect of color temperature on the reaction time;

Ignore the color temperature factor, the greater the speed, the bigger effect of luminance contrast on the reaction time;

Ignore the luminance contrast factor, at the speed of 70 km/h, the effect of color temperature on the reaction time is the biggest

As shown in Table 4, the correlation coefficient R^2 of each function is close to 1, which indicates that the fitting degree is good.

Table 4. Fit Functions of Luminance Contrast and Reaction Time in Different Visual Target Speed

Target speed	Light	Fit function	R^2
60	LLED	$Y=3136.0X^{-0.0235}$	0.92
	MLED	$Y=3129.2X^{-0.0185}$	0.97
	HLED	$Y=3093.7X^{-0.0229}$	0.99
70	LLED	$Y=2691.9X^{-0.0322}$	0.99
	MLED	$Y=2649.7X^{-0.0351}$	0.99
	HLED	$Y=2624.3X^{-0.0266}$	0.99
80	LLED	$Y=2299.0X^{-0.0673}$	0.99
	MLED	$Y=2276.5X^{-0.0646}$	0.97
	HLED	$Y=2260.5X^{-0.0665}$	0.99

3.3. Relationship Between reaction Distance and Visual Target Speed

Due to the difference of speeds, the reaction time cannot be used to evaluate the dynamic visual performance alone. Thus reaction time should be converted into reaction distance. Reaction distance = the reaction time×speed, that means the shorter the reaction distance the better the visual performance. Ignoring the brightness and contrast factors, based on all the experimental data, the average reaction time of each LED at each speed is obtained. According to the average reaction time, the reaction distance can be calculated. The average reaction distance (unit: m) data of three kinds of LED in different visual target speed are shown in Table 5.

Table 5. The Average Reaction Distance of Three Kinds of LED in Different Visual Target Speed

Lighting source	Target speed	Average reaction time(ms)	Average reaction distance(m)
LED	60	3187	53.224
	70	2758	53.787
	80	2402	53.332
MLED	60	3165	52.849
	70	2717	52.988
	80	2376	52.739
HLED	60	3145	52.528
	70	2678	52.214
	80	2365	52.503

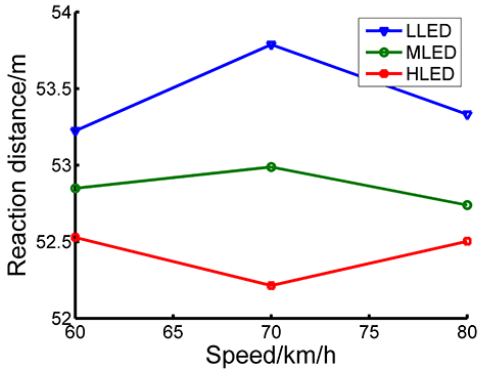


Figure 8. Relationship Between Reaction Distance of Three Kinds of LED and Target Speed

The relationship between the reaction distance and speed is shown in Figure 8.From Figure 8, it can be seen that the reaction distance shows a fluctuant trend with the increase of the speed. So it can indicate that the visual performance of LED isn't more appropriate at everyone speed. To make further researches on the effect of speed on the visual performance, HLED was chosen as the background light source, the background brightness was set to 1cd/m^2, and the contrast was set to 0.5, and the speed was set to 20, 40, 60, 80, 100, 120km/h separately. After experiments in these conditions, reaction time was obtained. Corresponding reaction distance was calculated as shown in Table 6. The relationship between the reaction distance and speed is shown in Figure 9.

Table 6. The Average Reaction Distance of HLED in Different Visual Target Speed (m)

Target speed	20	40	60	80	100	120
Reaction time	9115.3	4733.4	3171.0	2388.0	1968.8	1664.4
Reaction distance	51.046	52.067	52.955	53.013	54.142	54.925

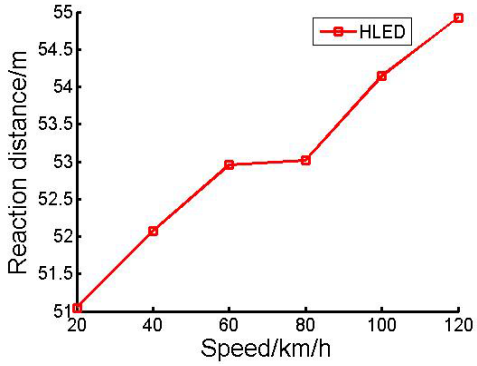


Figure 9. Relationship Between Reaction Distance of HLED and Target Speed

The figure reveals that the reaction distance increases greatly with the increase of the speed except for the speed arrange at 60-80km/h. This figure shows that visual performance is relatively better at low speed. But low speed does not apply to actual operating speed on the road, and high speed is dangerous. Therefore the speed ranging from 60km/h to 80km/h can not only ensure a relatively good visual performance but also meet the actual application.

4. Conclusion

Based on the method of visual performance, LLED, MLED, HLED were chosen as background light sources. The self-developed testing system was used to collect reaction time data. And dynamic experiments had been carried out in different conditions. The results of dynamic experiments show that the reaction time decreases with the increasing of the background brightness and the contrast, which is the same as the results of static experiments [19]. Under the same experiment conditions, the reaction time of HLED is the shortest, while that of LLED is the longest, which verifies the theory of optical biological effect. High color temperature light source inhibits secretion of melatonin and helps to increase the response speed, while low color temperature light source is the opposite. And target speed has significant influence on visual performance, in addition to the target speed in the range of 60km/h to 80km/h.

Acknowledgments

This research is supported by the Science and Technology Project of Henan Province Department of Transportation (No. 2013-2-10).

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