International Commission on Illumination
Commission Internationale de l'Eclairage
Internationale Beleuchtungskommission

PO055

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DOI 10.25039/x46.2019.PO055

from

CIE x046:2019

Proceedings
of the
29th CIE SESSION
Washington D.C., USA, June 14 – 22, 2019

(DOI 10.25039/x46.2019)

The paper has been presented at the 29th CIE Session, Washington D.C., USA, June 14-22, 2019. It has not been peer-reviewed by CIE.

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THE IMPACT OF LIGHTING SOURCE AND CALLIGRAPHY FONTS ON THE DEGREE OF PREFERENCE OF CHINESE CALLIGRAPHY WORKS

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DOI 10.25039/x46.2019.PO055

Abstract

Chinese calligraphy is one of traditional arts popular in China as well as many Asia countries. And calligraphy works are usually exhibited in museums and galleries, where lighting conditions play important role. In this paper, a lighting environment display space had been built to simulate the exhibition hall. Then observers were invited to do psychophysical experiments and their subjective evaluations for four fonts of calligraphy works in different lighting environments were obtained. These data were used to analyse the visual impact of the calligraphic fonts and illumination sources on the visitors in the calligraphy exhibition. The results are reference for museums and galleries lighting.

Keywords: Museum lighting; Calligraphy works; Lighting environment; LED light source; Psychophysical experiment

1 Introduction

As one of the national quintessence of Chinese culture, calligraphy has developed in China for more than two thousand years, and has become a national symbol. Gradually museums are becoming one of the popular cultural places for leisure and holiday vacations [1]. Therefore, the museum must not only do exhibitions well, but also provide a comfortable environment for visitors. However, with the increasing applications of LED light sources, museum lighting sare facing various challenges [2]. In addition, through the subjective survey of museum visitors, it was found that visitors' preference for calligraphy exhibits under low illumination and low colour temperature was not too high. Therefore it is highly required to understand the degree of preference of visitors for calligraphy works under the conditions of LED light sources.

In this work, a luminous environment display space was built to simulate the museum calligraphy exhibition hall. Then Observers were invited to do psychophysical experiments to obtain their evaluations for calligraphy works of different calligraphy fonts under 12 groups of colour temperature and illumination combinations. The experimental results were used to research the influence of calligraphy fonts, light source colour temperature, and illumination on visitors' preferences, attractiveness and comfort.

2 Experimental program

The *Kruithof* Comfort Zone published in 1941 is the earliest experimental comfort result of colour temperature and illumination in the field of lighting. Which conclude that low illumination/low colour temperature light source and high illumination/high colour temperature light source are considered as comfortable lighting [3]. At present, in the lighting applications of museums and art galleries in China, the illumination is between 50 lx and 1600 lx, and the colour temperature of the light source is between 2,700 K and 6000 K [4]. However, with the increase of illumination, the degree of preference for the exhibits is not obvious between 200 lx and 800 lx [5].Therefore, this research combines the characteristics of calligraphy works, the selected illumination are 100 lx, 150 lx, 200 lx, the selected light source colour temperature are 2500 K, 3500 K, 4500 K, 5500 K in the experiment.

As is shown in Figure1(a), a luminous environment display space is built to simulate the museum calligraphy exhibition hall, and different lighting conditions have been created to illuminate calligraphy works. In the space, the real calligraphy works were hung on the side of the wall, as shown in Figure 2(b).The calligraphy fonts are seal script, official script, regular script and running script. The selected LED intelligent light source has a colour rendering index Ra=92, and both the colour temperature and luminous flux are adjustable.

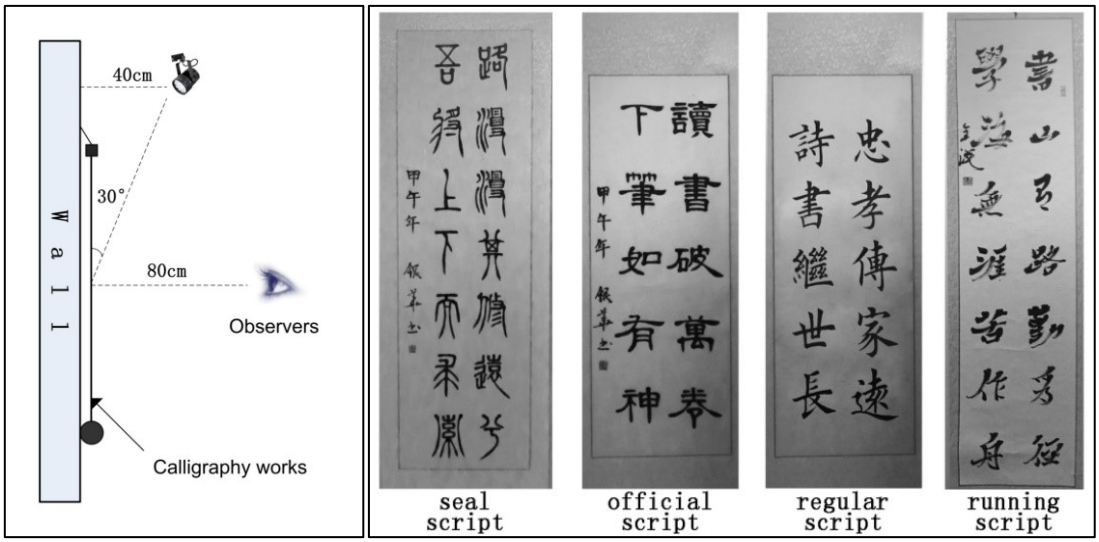

Figure 1(a) – Experiment space scene diagram (b) 4 calligraphy works for experiments

Then 27 observers were selected to simulate museum visitors to do psychophysical experiments. Among them, 14 were male and 13 were female, and the age was 19 to 23 years old. All of them were college students of Dalian Polytechnic University, and all passed the colour blindness and colour weakness test.

During the experiment, the calligraphy works of each calligraphy font was hung on the wall respectively. Different LED light sources were used to illuminate the calligraphy works to achieve a combination of different illumination and colour temperature. Each observer was asked to evaluate the preference, attractiveness, and comfort of each font of calligraphy works in 12 groups of light environments. -3 points means very dislike / attract / comfort, -2 points means dislike / attract / comfort, -1 point means less like / attract / comfort, 1 point means more like / attract / comfort, 2 points means like / attract / comfort, 3 points means very like / attract / comfort [6]. During the experiment, the observer could walk freely in the experimental space to simulate the museum visit behaviour. The time for each observer to participate in the experimental evaluation was approximately 40 min.

At the same time, in order to remove the influence of colour adaptation and other visual phenomena on the final results of the experiment, observers were asked to score in dictation, and the experimenters recorded the data. In order to avoid the influence of the memory color effect, when changing the illumination and the light source colour temperature, the observers were required to close the eye for 20 to 30 s.

3 Observer difference analysis

In the research, 27 observers were invited to participate in the experiment. Each observer evaluated the preference, attractiveness, and comfort for four fonts of calligraphy works in 12 groups of lighting environments. A total of 1296 subjective evaluation data were obtained from the experiment.

The coefficient of variation (CV) was experimentally used as a method to compare data stability between observers [7].,which is given as following:

$$\mathrm{CV} = 100\sqrt{\frac{1}{27}\sum_{i=1}^{N}\frac{(X_i-\bar{X})^2}{\bar{X}}} \tag{1}$$

where

X_i is the mean value of the i-th observer;

$\bar{X}$ is the mean value of all observers;

N is the number of observers; here N=27.

Table 1 shows the CV of evaluation scores under different lighting environment for 4 calligraphy works. Table 2 shows the CV of 27 observers' scores under 12 lighting environments for 4 calligraphy works.

Table 1 – CV of evaluation scores under different lighting environment for 4 calligraphy works

Lighting environment		Evaluation project	Calligraphy works			
			Seal script	Official script	Regular script	Running script
2500 K	100 lx	preference	23.68	21.64	18.63	27.61
		attractiveness	20.54	16.28	23.29	23.30
		comfort	16.29	20.97	26.87	30.28
	150 lx	preference	27.34	22.46	25.56	14.69
		attractiveness	29.17	26.25	31.24	20.42
		comfort	26.20	23.31	16.91	26.17
	200 lx	preference	23.25	24.02	22.27	28.08
		attractiveness	22.68	19.58	24.33	24.32
		comfort	20.95	14.93	28.64	25.09
3500 K	100 lx	preference	17.64	31.67	26.51	31.48
		attractiveness	19.38	21.99	22.89	19.83
		comfort	28.72	22.82	32.63	25.29
	150 lx	preference	30.16	25.04	24.29	14.11
		attractiveness	16.58	19.50	26.84	23.02
		comfort	25.21	20.12	30.53	27.57
	200 lx	preference	21.99	26.31	28.17	19.63
		attractiveness	32.03	28.57	24.29	30.21
		comfort	28.50	23.59	12.64	29.48
4500 K	100 lx	preference	12.64	24.86	26.59	27.66
		attractiveness	27.93	28.22	22.24	32.07
		comfort	29.28	21.64	12.94	29.15
	150 lx	preference	21.56	19.59	33.58	27.64
		attractiveness	24.48	24.83	24.29	21.98
		comfort	14.18	26.26	27.37	14.76
	200 lx	preference	23.92	25.50	26.49	21.59
		attractiveness	16.73	28.17	32.27	23.42
		comfort	27.64	18.49	27.50	29.04
5500 K	100 lx	preference	24.35	26.72	21.07	27.29
		attractiveness	26.96	22.05	18.59	26.14
		comfort	19.54	28.30	26.60	25.81
	150 lx	preference	20.83	23.14	22.07	29.30
		attractiveness	22.49	17.29	24.18	23.81
		comfort	28.65	24.24	17.53	24.61
	200 lx	preference	30.39	26.24	26.20	31.07
		attractiveness	24.37	30.49	25.48	27.24
		comfort	19.97	24.64	29.30	20.53

Table 2 – CV of 27 observers' scores under 12 lighting environments for 4 calligraphy works

Observer number	Calligraphy works			
	Seal script	Official script	Regular script	Running script
1	18.21	19.22	23.06	24.34
2	21.06	20.16	21.61	23.96
3	19.58	17.48	26.24	15.18
4	23.93	30.39	31.39	23.24
5	24.14	28.75	17.26	30.66
6	26.66	21.16	24.15	32.51
7	21.30	17.48	19.45	16.17
8	20.21	25.06	20.11	19.23
9	18.07	29.80	21.36	26.06
10	29.49	21.26	26.52	24.54
11	27.86	23.32	28.89	21.37
12	22.92	22.04	20.99	22.26
13	14.27	25.29	22.64	32.24
14	30.43	24.79	21.10	27.16
15	26.17	25.32	24.70	24.27
16	22.06	26.65	30.06	26.49
17	27.33	20.22	17.12	20.56
18	28.94	26.18	14.08	23.03
19	24.38	19.66	19.06	22.25
20	21.77	15.54	26.38	16.12
21	21.54	23.39	28.55	24.30
22	26.16	31.18	21.64	17.69
23	29.28	27.63	20.59	20.44
24	30.01	33.42	19.82	26.32
25	25.34	24.35	23.11	28.24
26	15.07	28.29	27.37	21.01
27	20.94	16.34	26.29	23.20

It is verified that the data in Table1 and Table2 are within the normal range of the psychophysical experiment CV [8].

In order to prove the repeatability of the experiment, the observer were asked to repeatedly evaluate the calligraphy work of seal script without their knowledge. Pearson ***r*** was selected to evaluate the repeatability of the observers' experimental results. Figure 2 shows the correlation coefficient of 27 observers' repeated data on seal script in the same lighting environment.

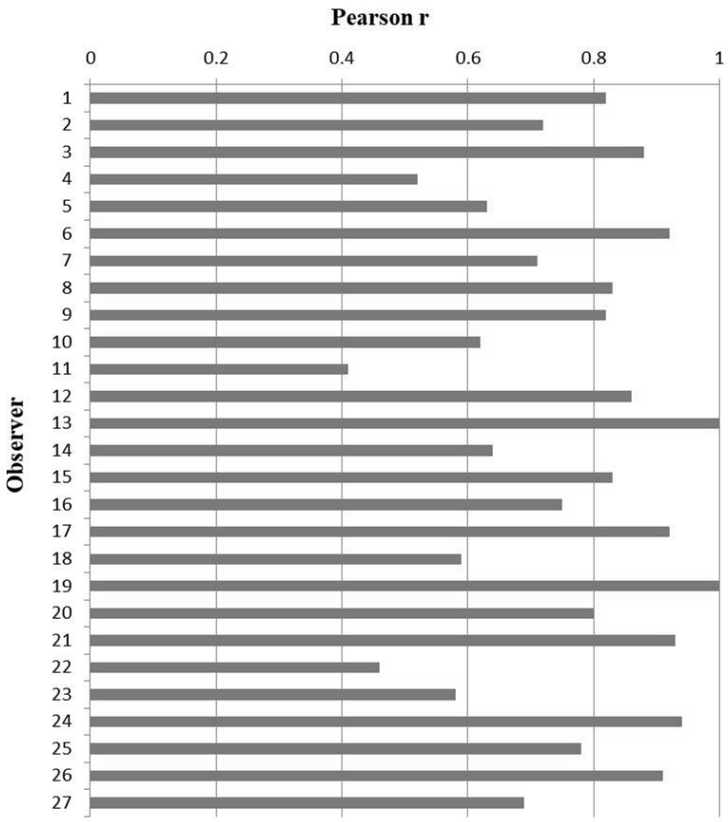

Figure 2 – Correlation coefficient for repeat experimental repeatability

The minimum value of ***r*** is 0.41 and the maximum value is 1. The ***r*** value of most observers is above 0.6, and the average value of ***r*** is 0.76. Therefore, the repeated data has a strong linear relationship, and the repeatability of the observer evaluation is relatively high.

4 Results and discussion

4.1 Influencing factors of observer evaluation

One-way Analysis of Variance was used to analyse the observer's evaluation. The factors are colour temperature, illumination, and calligraphy fonts. And the results are shown in Table 3. Significance ***p*** was used to determine whether the observer's evaluation has significant differences under different conditions. When the significance ***p*** is less than 0.010, there is significant difference in the evaluation. When the significance ***p*** is greater than 0.050, there is no significant difference in the evaluation.

Table 3 – Results of factor analysis of variance for different colour temperature, illumination and calligraphy fonts

Factor	significance ***p***		
	preference	attractiveness	comfort
colour temperature	0.000	0.009	0.002
Illumination	0.003	0.001	0.008
Calligraphy fonts	0.006	0.394	0.642

The results in Table 3 indicate that the significance ***p*** for preference of the colour temperature, illumination, and calligraphy fonts are 0.000, 0.003, and 0.006, both less than 0.010. It shows that the observers have significant differences on the evaluation of preference under different colour temperatures, different illuminations and different fonts. That is to say, the colour temperature, illumination and calligraphy font have a great influence on the evaluation of the observer's preference.

The significance ***p*** for attractiveness of the colour temperature, illumination, and calligraphy fonts are 0.009, 0.001, and 0.394. The significance ***p*** of colour temperature and illumination is less than 0.010, which indicates the observers have significant differences on the evaluation of attractiveness under different colour temperatures and different illumination. The significance ***p*** of calligraphy font is above 0.050, which indicates that the observers have no significant difference on the evaluation of attractiveness. That means the calligraphy fonts have no influence on the observer's attractiveness evaluation.

In the comfort evaluation, the significance ***p*** of colour temperature, illumination, and calligraphy fonts are 0.002, 0.008, and 0.642. The significance ***p*** of lighting environment is less than 0.010, which indicates the observers have significant differences on the evaluation of comfort. The significance ***p*** of calligraphy font is above 0.050, which show observers have no significant difference on the evaluation of comfort, or the fonts have no influence on the observer's comfort evaluation.

4.2 The impact of lighting environment on observer evaluation

In order to facilitate the analysis of the data, all the scores between -3 and 3 were converted to between 1 and 6 [6]. The One-way Analysis of Variance shows that the colour temperature and illumination are important factors affecting the observer's evaluation. Therefore, the influence of the colour temperature and illumination on the observer's evaluation is first discussed.

Figure 3 is the mean value of 27 observers for four calligraphy works in different colour temperature. It was found observers have higher preferences for calligraphy works at 3500 K and 4500 K colour temperatures. And observer's preference evaluation is more consistent at 3500 K colour temperature. The observer's attractiveness slowly decreases as the colour temperature increases. When the mean value is between 3.14 and 3.47; the downward trend is not obvious. The observers have the highest comfort at 3500 K colour temperature, and observer's comfort evaluation is more consistent at 4500 K colour temperature. The comfort at 2500 K colour temperature is significantly lower than the other 3 groups of colour temperature.

Figure 4 is the mean value of 27 observers for four calligraphy works in different illumination, where it can be seen that the observer's preference at 150 lx and 200 lx illumination are significantly higher than 100 lx. The observers have the highest preference at 150 lx. The observer's attractiveness is significantly improved as the illumination increases. The observers have the lowest comfort at 100 lx illumination, and the comfort is higher at 150 lx and 200 lx illumination. And observer's comfort evaluation is more consistent at 150 lx illumination.

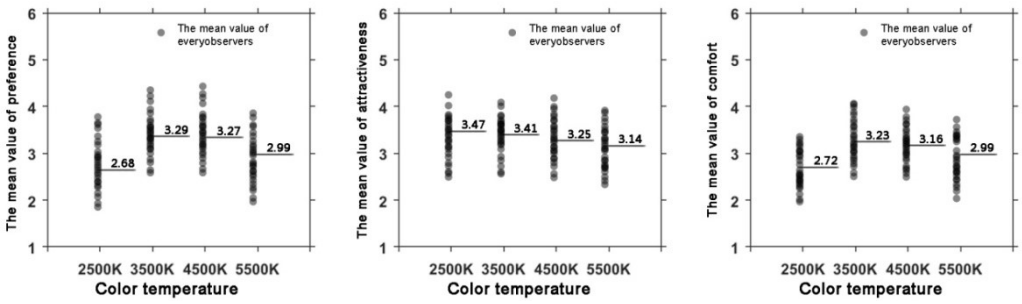

Figure 3 – The mean value of 27 observers in different colour temperature

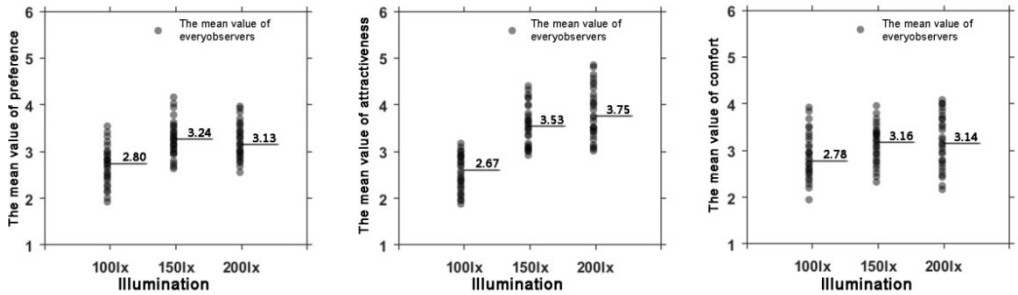

Figure 4 – The mean value of 27 observers in different illumination

4.3 The impact of calligraphy fonts on observer evaluation

The One-way Analysis of Variance shows that the observers have no significant difference on the evaluation of attractiveness and comfort. That is to say, the calligraphy fonts have no influence on the observer's attractiveness and comfort evaluation. And the calligraphy fonts have a great influence on the evaluation of the observer's preference.

Figure 5 is the mean value of observers' preference for the 4 fonts of calligraphy works in different colour temperature. It can be seen that 2500K colour temperature is the highest preference degree for seal script, and the colour temperature gradually decreases as the preference increases. The official script, regular script and running script have higher preferences at 3500 K and 4500 K colour temperatures. Observers have low preference at 5500K colour temperature, but slightly higher than the preference at 2500K.

When the light source colour temperature is 2500 K, the observer's preference for official script, regular script and running script are extremely low. The observer's preference for the seal script is much higher than the above three fonts. And 2500 K is the highest colour temperature for seal script. When the light source colour temperature is 3500 K, observers have higher preferences for 4 calligraphy fonts. Among them, 3500 K is the highest colour temperature for official script. At the same time, observer's preference is more consistent at 3500 K colour temperature. When the light source colour temperature is 4500 K, the observer's preference is slightly lower than 3500 K. Among them, 4500 K is the highest colour temperature for regular script and running script. When the light source colour temperature is 5500 K, the observer's preference is significantly reduced. However, the observer's preference for seal script is only reduced by 0.05.

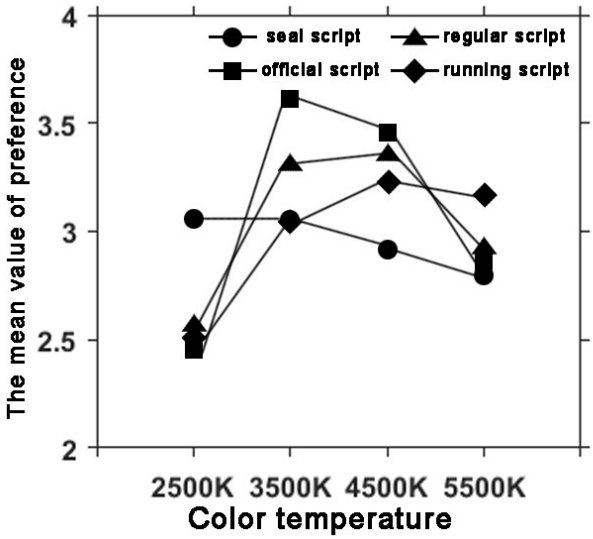

Figure 5 – The mean value of observers' preference for the 4 fonts of calligraphy works in different colour temperature

Figure 6 is the mean value of observers' preference for the 4 fonts of calligraphy works in different illumination, where different fonts have roughly the same preference under each group of illumination. 150lx is the highest illumination for observers, and 100lx is the lowest illumination for observers. Observers have the least difference in the preference for seal script under different illumination. The difference in the preference of regular script is greater. That is to say, the preference of regular script is affected by illumination. The preference of official script and running script under 200lx are lower than the preference under 150lx.

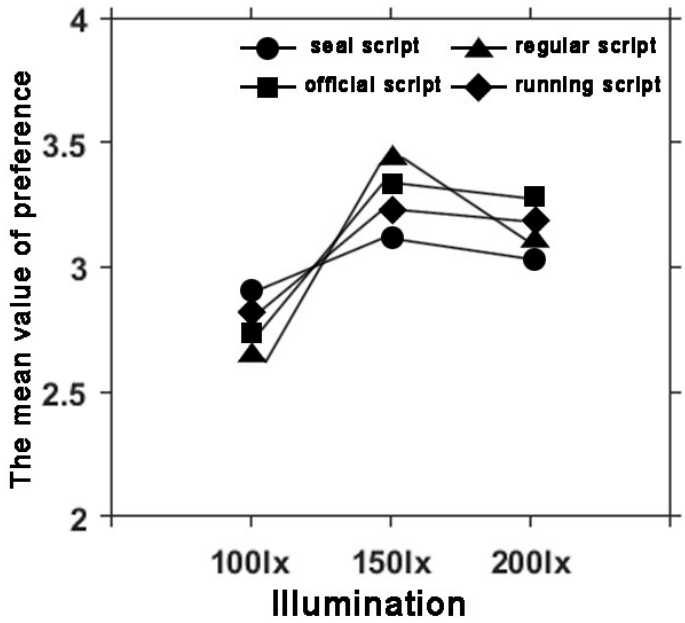

Figure 6 – The mean value of observers' preference for the 4 fonts of calligraphy works in different illumination

In summary, the influence of calligraphy fonts on observer's preference is less than the influence of lighting environment. The colour temperature has a great influence on the preference of official script, and the illumination has a great influence on the preference of regular script.

5 Conclusions

In this paper, a lighting environment display space had been built to simulate the museum calligraphy exhibition hall, and different lighting conditions have been created to illuminate calligraphy works. 27 observers were invited to do psychophysical experiments. Their preferences, attractiveness, and comfort for four fonts of calligraphy works in different lighting environments were obtained. These data were used to analyse the visual impact of the calligraphic fonts and illumination sources on the visitors in the calligraphy exhibition. The results show the calligraphy fonts have no obvious effects on observers' attractiveness and comfort. It was found that the observers' comfort was greatly affected by the colour temperature of light source. When the light source colour temperatures are 3500K and 4500K, the observer's comfort is higher. The degree of attractiveness increased as the illumination increased. The degree of preference is affected by calligraphy font, colour temperature and illumination, but the effect of light source colour temperature and illumination is greater than calligraphy font. The colour temperature and illumination under which the observers had the highest preference for seal script, official script, regular script and running script were 2500K 100lx, 3500K 150lx, 4500K 150lx, 4500K 200lx respectively. The results are reference for museum and gallery lighting design.

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