

## How the Colour Fidelity and Gamut of Lightings Affect the Preference of Paintings?

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### ABSTRACT

The goal of this study was to investigate the visual preference of fine art paintings under museum LED lighting sources with various values colour fidelity, colour gamut size and colour gamut shape. An experiment was conducted using a well controlled multichannel LED illumination system. All the above parameters were shown affecting the visual appearance and preference of paintings and the results vary from different types and painting contents and the observers.

**KEYWORDS:** museum lighting, colour fidelity, colour gamut

### INTRODUCTION

LED lightings possess most of the qualities required for Museums and Galleries such as low radiation damage, high energy efficiency, high visibility, and high colour fidelity. Paintings were widely used to study the museum LED lightings and the lighting parameters such as illuminance, CCT (Corrected Colour Temperature) and colour fidelity of the lighting were extensively studied recently<sup>[1-8]</sup>. Large variations on the CCT between 3500K and 5700K was found to be preferred from different labs<sup>[2-7]</sup>. The concept of ‘comfort zone’<sup>[1,4]</sup> in terms of CCT and illuminance were used to evaluate the visibility and preference of the museum lighting. Few study focused on the gamut shape and size of the LED lightings in museums. Some researches<sup>[9-13]</sup> have concluded positive effects of colour gamut on the preference of colourful objects (not including painting). A single colour fidelity index such as CIE-R<sub>a</sub><sup>[14]</sup> is not enough to describe the colour quality of lighting. Recently, CIE TC1-90 proposed IES-TM-30<sup>[15]</sup> metric for test trials. It evaluates not only colour fidelity but also colour gamut size of a lighting. The present experiment has been designed to investigate the impact of these lighting parameters on five colourful fine art paintings.

### EXPERIMENTAL

In a viewing cabinet with tuneable multichannel LED illumination system ‘LEDcube’ produced by ThousLite Inc., China, the experiment was conducted with five paintings painted by Chinese artists shown in Figure 1. Their contents had objects of memory colours, such as fruits, skin, trees and sky.

The lighting parameters are given in Table 1. It can be seen that the experiment was divided into four sections and 15 kinds of lightings vary in CCTs (3500K, 4500K, 5700K), IES-TM-30 R<sub>f</sub> values<sup>[15]</sup> (about 70, 80 and 90 called as low (L), Medium (M) and High (H) respectively), IES-TM-30 R<sub>g</sub> values<sup>[15]</sup> (about 100 and 110 called as low (L) and High (H) respectively), and gamut shape (Yellow-Blue and Red-Green directions). Note that the three CCTs selected are the most preferred CCT found by different research groups<sup>[2-7]</sup> and the IES-TM-30 samples<sup>[15]</sup> were used to define the gamut shape. The experiment was designed to have all lights in each section to have very similar chromaticity coordinates for which observers cannot distinguish the colour differences of the grey background in the cabinet. However, their spectral power distributions are largely different. In other words, these lights are metamers.



Figure 1: Paintings in the experiment. (a) paintings and their pigment types; (b) experimental situation.

Table 1. Lightings used in the study. The gamut shapes of the lightings were calculated in CAM02-UCS with IES-TM-30 samples and averaged into 16 hue bins. (L=low, M=medium, H=high, YB=yellow-blue, RG=Red-green)

Section	Lighting	R <sub>f</sub>	R <sub>g</sub>	Gamut Shape	CCT /K	duv	Illuminance /lx	Plotting R <sub>f</sub> / R <sub>g</sub> values and the gamut shapes
1) 3500K -R <sub>f</sub> /R <sub>g</sub>	1-1	L	L	YB	3524	-0.0049	752.8	
	1-2	L	H	YB	3549	-0.0055	753.8	
	1-3	M	L	YB	3533	-0.0053	749.9	
	1-4	M	H	YB	3506	-0.0045	751.9	
2) 4500K -R <sub>f</sub> /R <sub>g</sub>	2-1	L	L	YB	4522	-0.0048	752.8	
	2-2	L	H	YB	4546	-0.0051	750.9	
	2-3	M	L	YB	4468	-0.0050	751.6	
	2-4	M	H	YB	4526	-0.0045	750.6	
	2-5	H	L	YB	4436	-0.0054	750.0	
	2-6	H	H	YB	4454	-0.0047	745.4	
3) 5700K -R <sub>f</sub> /R <sub>g</sub>	3-1	L	L	YB	5716	+0.0049	747.1	
	3-2	L	H	YB	5725	+0.0045	744.3	
	3-3	M	L	YB	5702	+0.0049	745.5	
	3-4	M	H	YB	5769	+0.0042	752.1	
2) 4500K -Shape	4-YB	M	H	YB	(Using the same lighting as 2-4)			
	4-RG	M	H	RG	4500	-0.0050	749.1	

In each of the four sections studied, all the lightings were assessed using the pair comparison method. The observer was first asked to adapt to the high or medium R<sub>f</sub> but low R<sub>g</sub> lighting (such as lighting 1-3 in Section 1) for one minute. Then the first lighting of a random pair will illuminate the painting for 3 seconds followed by the second lighting of this pair for another 3 seconds; Observers need to choose a more preferred one from these two lightings, and then go into another random pair until all the lighting pairs were compared. The same experiment was repeated twice in a section. A single observer finished all lightings in each section for every individual painting. In total, 14 observers (6 males and 8 females) participated in the experiment and 3920 assessments were accumulated.

**RESULTS AND DISCUSSION**

The percentage of the preference choice of each lighting was transferred to z score in each section. From the mean result of all the 14 observers shown in Figure 2, we can conclude as following:

- i) For oil paintings (#1-3), observers prefer lightings with larger colour gamut (yellow bars > blue bars);
- ii) Observers prefer lightings with higher colour fidelity (yellow / blue bars increase around the horizontal axes) for all the paintings except Painting #4;
- iii) When the observers assessing colour gamut size and colour fidelity (yellow / blue bars) of the lighting, the results of oil paintings (#1-3) are more significant (z-scores away from zero) than water colour paintings (#4-5);
- iv) Colour gamut shape (pink bars in subfigure (d)) of the lightings had more significant effects on the water colour paintings (#4-5) than the that of oil paintings (#1-3).

For painting #4, the impact of the colour fidelity of lightings was totally different form other paintings while it was influenced by gamut shape of the lightings most significantly. One of the reasons is that the high colourfulness content with water colour pigment are more sensitive to the colour gamut and fidelity of the lightings. Lightings with different parameters change the pigment colour appearance so largely that this painting has different art styles under different lightings.

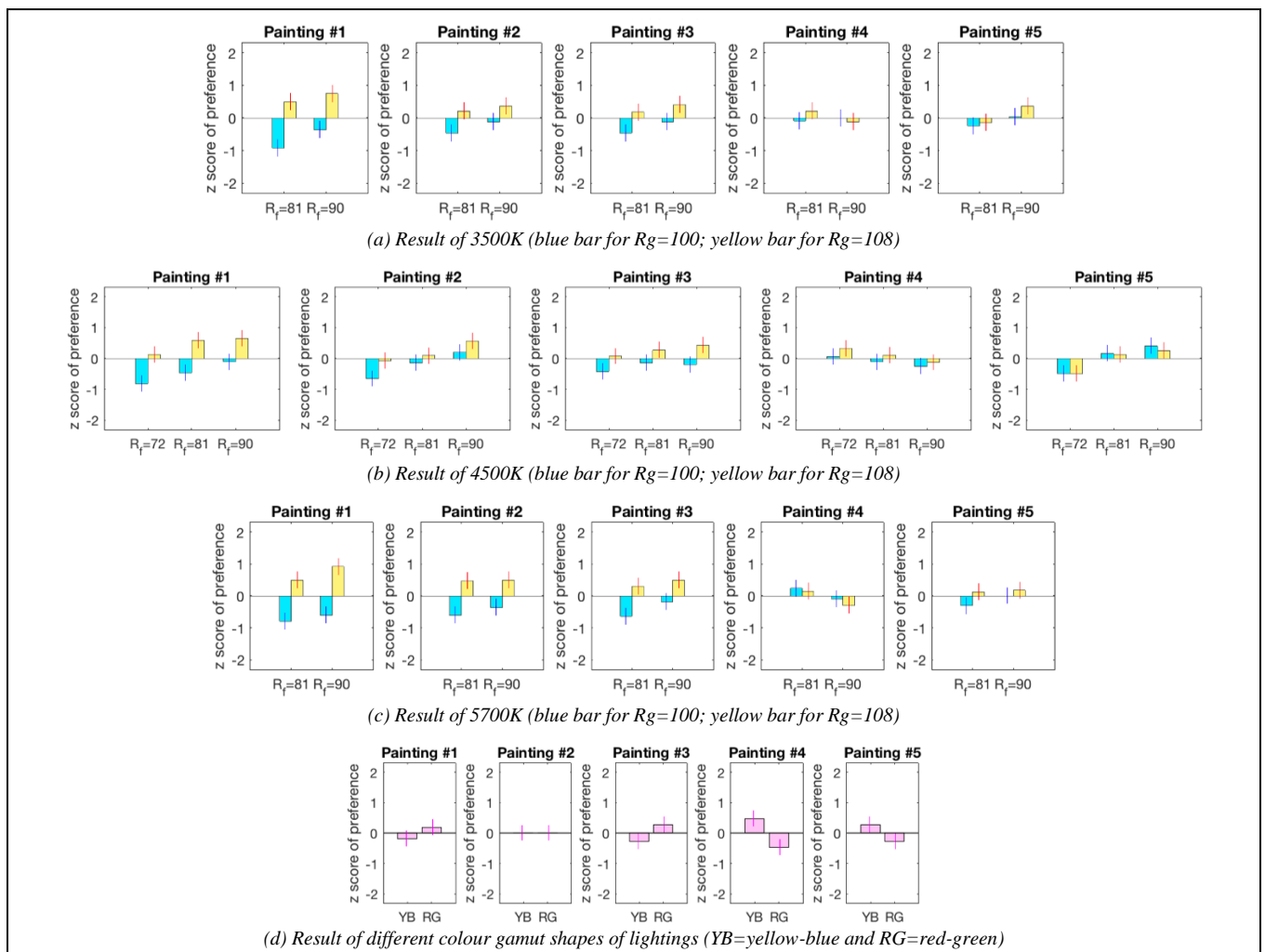


Figure 2: The z scores of preference by all the observers in the section 1~4, where blue bars for low  $R_g$  and yellow bars for high  $R_g$

To illuminate the colour changes of the paintings under different experimental lightings, five to ten colours of each painting was measured by a JETI-1211uv tele-spectral-radiometer. Colour shifts of them are compared in CAM02-UCS space. The result indicates that the colours of Painting #4 produced a largest colour shift under lightings with different gamut, and the gamut shape had more impact than gamut size ( $R_g$ ) on this painting which agree with the above speculation. The reason why the preference score showing insignificant

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results of gamut size for Painting #4 is that people had different opinions on preferences of these kinds of colour shifts. To prove this, the observers are grouped into 4 groups (A, B, C and D). In the grouped preference scores, some of the trends are much clearer and, in some cases, become opposite comparing to the average result. The results indicated that larger colour shift dose not always affect the performance in a same direction. The observer preference of colour fidelity and colour gamut of museum lighting will vary according to the types and contents of the paintings, and the individual observer's aesthetic view.

## CONCLUSION

The present experimental results showed that colour fidelity, colour gamut size and colour gamut shape of a museum LED lighting source will affect the visual appearance and preference of paintings and the results vary from different types and painting contents and observers.

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