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

PO148

**A STUDY ON THE APPROPRIATE CONTRAST OF
LUMINANCE BETWEEN PAINTINGS AND WALL
SURFACES IN MUSEUMS**

Yukino Shimizu et al.

DOI 10.25039/x46.2019.PO148

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 It has not been peer-reviewed by CIE.

© CIE 2019

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from CIE Central Bureau at the address below. Any mention of organizations or products does not imply endorsement by the CIE.

This paper is made available open access for individual use. However, in all other cases all rights are reserved unless explicit permission is sought from and given by the CIE.

CIE Central Bureau
Babenbergerstrasse 9
A-1010 Vienna
Austria
Tel.: +43 1 714 3187
e-mail: ciecb@cie.co.at
www.cie.co.at

A STUDY ON THE APPROPRIATE CONTRAST OF LUMINANCE BETWEEN PAINTINGS AND WALL SURFACES IN MUSEUMS

Shimizu, Y.¹, Muto, S.¹, Yoshizawa, N.¹
¹ Tokyo University of Science, Chiba, JAPAN

7118535@ed.tus.ac.jp

DOI 10.25039/x46.2019.PO148

Abstract

Current guidelines for the museum lighting prescribe the appropriate range of illuminance on the exhibits as shown in the CIE standard to reduce the damage to paintings while balancing the conservation and exhibition. There is a possibility that the brightness of the paintings on the wall is determined by the luminance distribution, thus it is desirable to execute luminance-based design even for the museum lighting. The purpose of this study is to achieve the best light environment with the minimum illuminance on paintings by controlling the contrast of luminance between paintings and wall surfaces. We have conducted painting assessment experiments in an experimental room. Results showed that Quality Evaluation Factor could be ensured even though the illuminance on the paintings were 100lx, provided that the luminance ratio was sufficiently high, whereas Discrimination Factor was always highly evaluated when the painting illuminance was 200lx.

Keywords: Museum lighting, Luminance-based design, Luminance ratio, Paintings,

1 Backgrounds and Purposes

Current guidelines for the museum lighting prescribe the appropriate range of illuminance on the exhibits. The CIE standard (CIE 157:2004) categorizes the responsiveness of the exhibited material to light and sets a limit on the illuminance for each category. This recommended value is important to reduce the damage to paintings while balancing the conservation and exhibition. On the other hand, the brightness of the paintings on the wall is determined by the luminance distribution, thus it is desirable to execute luminance-based design even for the museum lighting. In recent years, with the development of the simulation technologies and low-priced luminance measurement systems, it could be said that it has gradually become possible to introduce a new design method even in museums. By considering the appropriate luminance contrast by which the painting appears brighter, there is a possibility that illuminance on the painting could be reduced and lower the damage to the painting. The purpose of this study is to achieve the best light environment with the minimum illuminance on paintings by controlling the contrast of luminance between paintings and wall surfaces in museums.

2 Luminance ratio

In this study, luminance ratio is calculated by dividing the average luminance of the painting by the luminance on the surrounding wall. Figure1 shows the surrounding area which is said to be the field of stable attention. Luminance is measured using a CCD camera with a fisheye lens.

Figure 1 – The positional relation between a painting and a surrounding wall

3 Experiment Methods

In this research, a subjective experiment was conducted, and the subjects evaluated the appearance and brightness of oil paintings and the appropriateness of the luminance ratio.

The experimental room as shown in Figure 2 was 2900mm in width, 3000mm in depth and 2400mm in height. Buffering space for ambient lighting was made in the location of 1900mm in height behind the subject. Lightness of the ceiling, the walls and the floor were N9.5 (White). Walls on which paintings are displayed with three kind of lightness, N2, N5 and N8, were prepared in this experiment to verify the effect of the lightness of the background.

Figure 2 –Section (left), Plan (right) of the experimental room

Four oil paintings as shown in Figure 3 were used in this experiment. Painting A was “Red Mt.Fuji” drawn by Yasushi Nakao and had a reflectance of the lowest 7.3%, Painting B was a replica of “La Transfiguration” drawn by Peter Paul Rubens and had a reflectance of 15.7%, Painting C was a colourful scenery picture named “Lake Como” drawn by Tadashi Orita and had a reflectance of 26.7%, and Painting D named “The northern Japanese alps” drawn by Kazuo Furuichi was the image of snow mountains in Japan and had a reflectance of the highest 37.2%. The reflectance of the painting was determined as follows; the painting surface was divided into 40 parts, and the reflectance of 40 parts was measured and their arithmetic mean was calculated. The size of all the paintings was 530mm wide × 455mm height.

Figure 3 –Painting A (upper left), Painting B (upper right), Painting C (lower left), Painting D (lower left)

A LED spotlight (blue-phosphor white LEDs, Ra: 97, CCT: 3000K, duv: -0.005) had a trimming function to squarely illuminate the painting. Ambient lightings (purple-phosphor white LEDs, Ra > 93, CCT: 3000K, duv <± 0.005) were installed in the high-sidelight position.

Figure 4 – Relative spectral power distribution

Figure 5 – Chromaticity diagram

Illuminance on the painting had three levels (200 lux, 100 lux, 50 lux) and luminance ratio was set to be ten levels (1/3, 1/1.5, 1, 1.5, 3, 4.5, 6, 10, 12.5, 15) by dimming the LED spotlight and the ambient lighting. There were 159 experimental conditions as shown in Table 1 in all.

Table 1 – Experimental Conditions

Wall (Reflectance)	Painting (Reflectance)	Illuminance of Painting	Luminance ratio									
			1/3	1/1.5	1	1.5	3	4.5	6	10	12.5	15
N2 (3.1%)	A (7.3%)	50lx						●	●	●		
		100lx					●	●	●	●		
		200lx					●	●	●	●		
	B (15.7%)	50lx						●	●	●	●	●
		100lx						●	●	●	●	●
		200lx						●	●	●	●	●
	C (26.7%)	50lx								●	●	●
		100lx								●	●	●
		200lx								●	●	●
	D (37.2%)	50lx										
		100lx										
		200lx										
N5 (19.8%)	A (7.3%)	50lx		●	●	●	●	●	●			
		100lx		●	●	●	●	●	●			
		200lx		●	●	●	●	●	●	●		
	B (15.7%)	50lx			●	●	●	●	●	●		
		100lx			●	●	●	●	●	●		
		200lx			●	●	●	●	●	●		
	C (26.7%)	50lx				●	●	●	●	●		
		100lx				●	●	●	●	●		
		200lx				●	●	●	●	●		
	D (37.2%)	50lx					●	●	●	●		
		100lx					●	●	●	●		
		200lx					●	●	●	●		
N8 (59.1%)	A (7.3%)	50lx	●	●	●							
		100lx	●	●	●	●	●					
		200lx	●	●	●	●	●					
	B (15.7%)	50lx			●	●	●	●				
		100lx			●	●	●	●				
		200lx			●	●	●	●	●	●		
	C (26.7%)	50lx			●	●	●	●	●	●		
		100lx			●	●	●	●	●	●		
		200lx			●	●	●	●	●	●		
	D (37.2%)	50lx			●	●	●	●	●	●		
		100lx			●	●	●	●	●	●		
		200lx			●	●	●	●	●	●		

25 university students, aged 21-25 with normal colour vision, participated the experiment. Subjects evaluated the appearance of the painting and the preference for the luminance ratio with 9-point bipolar scales such as “-4: Not preferable” to “4: Preferable”.

Table 2 – Evaluation

Entire evaluation for the appearance of the paintings		
Evaluation scales (-4~+4)		
Dazzling	-	Not dazzling
Dark	-	Bright
Difficult detail discrimination	-	Easy detail discrimination
Invisible brush touch	-	Visible brush touch
Fuzzy outline	-	Clear outline
Not having a sense of space	-	Having a sense of space
Drab	-	Colourful
Unnatural	-	Natural
Difficult to see	-	Easy to see
Not preferable	-	Preferable

The procedure of the experiment was as follows; first, the subject adjusted for 10 minutes to the experimental room whose illuminance and CCT on the painting was 50lx and 3000K, respectively. Next, the experimenter set the lighting condition, then the subject observed the painting for 30 seconds and evaluated it in 2 minutes. After the subject finished evaluating, the experimenter set the next lighting condition. Lighting conditions were presented in random order for each participant.

4 Results

4.1 Factor analysis

We conducted factor analysis to clarify the evaluation scales. As a result, as is the case of previous research (Loe, D. L.1982) , two factors were obtained, and Factor 1 included "Preferable", "Natural", "Colourful" and "Easy to see" and was named "Quality Evaluation Factor", whereas Factor 2 had "Clear outline", "Visible brush touch" and "Easy details discrimination" and was named "Discrimination Factor".

Table 3 – Factor Loading

Evaluation scales	Factor 1 Quality Evaluation	Factor 2 Discrimination
Dazzling /Not dazzling	-0.027	-0.126
Dark/Bright	0.448	0.551
Difficult detail discrimination/Easy detail discrimination	0.535	0.721
Invisible brush touch/Visible brush touch	0.444	0.755
Fuzzy outline/Clear outline	0.487	0.781
Not having a sense of space/Having a sense of space	0.679	0.445
Drab/Colourful	0.658	0.575
Unnatural/Natural	0.825	0.340
Difficult to see/Easy to see	0.826	0.369
Not preferable/Preferable	0.867	0.294

4.2 Multiple regression analysis

We conducted multiple regression analysis to examine the relationship between visual evaluation of paintings and physical values measured in each experimental condition. The objective variables were synthesis variables of Factor 1 and Factor 2. Each factor included evaluation scales whose factor loading was more than 0.6. Resulting from the examination of various explanatory variables, the equations with relatively high coefficients of determination are as shown below.

Estimation equation of "Quality Evaluation Factor":

$$Y = -2.58 + 0.66\log X_1 + 0.58\log X_2 - 0.14X_3 + 0.15X_4 \quad (1)$$

Estimation equation of "Discrimination Factor":

$$Y' = -2.71 + 0.63\log X_1 + 0.67\log X_2 - 0.13X_3 + 0.15X_4 \quad (2)$$

where

- Y is the value of synthesis variables of Factor 1;
- Y' is the value of synthesis variables of Factor 2;
- X_1 is luminance ratio (painting luminance/surrounding luminance)
- X_2 is Illuminance on the painting
- X_3 is lightness of the painting
- X_4 is lightness of the wall surface

Figure 6 – Plots of predicted and measured values of Factor 1 (left), Factor 2 (right)

Factors 1 and 2 were both predicted by luminance ratio, illuminance on the painting, lightness of the painting and lightness of the wall surface. It showed that the higher the luminance ratio and the higher the illuminance on the painting becomes, the higher the evaluation is, while the lower the lightness of the painting and the higher the lightness of the wall surface becomes, the higher the evaluation is.

4.3 Preference of the paintings

Figure 7, 8, and 9 show average evaluation values and fitted curves of the preference of paintings which had the highest factor load in Factor 1. The higher the luminance ratio is, the smaller the difference in the evaluation of each illuminance on the painting becomes.

When the background lightness was N8, 100 lx was enough illuminance on the painting for the painting A (reflectance: 7.3%) because the appearance of the painting under 100 lx was always

preferable to 200lx. For painting B (reflectance: 15.7%) the preference of the appearance under the painting illuminance of 100lx reached to the preference under 200lx when the luminance ratio was about 3. For painting C (reflectance: 26.7%), the preference under 100lx got close to 200lx at the luminance ratio 6, and for painting D (reflectance: 37.2%), the luminance ratio 7 was necessary to have the same preference between 100lx and 200lx.

Figure 7 – Preference of the paintings on N8 background

When the background lightness was N5, the appearance of the painting A under 100lx was again always preferable. For painting B, the preference of the appearance under the painting illuminance of 100lx reached to the preference under 200lx when the luminance ratio was about 5. For painting C, the preference under 100lx got close to 200lx at the luminance ratio below 5, and for painting D, the luminance ratio over 7 was necessary to have the same preference between 100lx and 200lx.

Figure 8 – Preference of the paintings on N5 background

When the background lightness was N2, as to painting A, 100lx condition was evaluated higher than 200lx when the luminance ratio became about 3.5 or higher, and 50lx condition was evaluated higher than 200lx when the luminance ratio became about 6.5 or higher. As to painting B, 100lx condition was evaluated higher than 200lx when the luminance ratio became about 11 or higher. As to painting C, the evaluation of 200lx condition was always higher than other illuminance conditions, however, the difference from the evaluation of 100lx was small.

These results indicated that in the most settings the appearance of the paintings was preferred even though the painting illuminance was only 100lx, provided that the luminance ratio was sufficiently high.

Figure 9 – Preference of the paintings on N2 background

4.4 Clear appearance of paintings

Figure 10, 11 and 12 shows average evaluation values and fitted curves of the clear appearance of paintings which was the highest factor load in Factor 2.

Figure 10 – Clear outline of paintings on N8 background

When the background lightness was N8 and N5, there was a tendency that the higher the luminance ratio was, the smaller the difference in the evaluation of the paintings became among various conditions of illuminance on the paintings, however, the paintings under the illuminance of 200lx looked always clear despite of the luminance ratio.

When the background lightness was N2, paintings with illuminance 200lx were always highly evaluated in clear appearances.

Figure 11 – Clear outline of paintings on N5 background

Figure 12 – Clear outline of paintings on N2 background

5 Conclusions

The results of the subjective experiment showed that Quality Evaluation Factor could be ensured even though the illuminance on the paintings were 100lx, provided that the luminance ratio was sufficiently high, whereas Discrimination Factor was always highly evaluated when the painting illuminance was 200lx. In this paper, we did not clarify the quantitative values for required luminance ratio to acquire the preferable appearance for the paintings, however, by continuing to accumulate data on various paintings and settings, we could get some useful luminance-based guidelines for museums.

Acknowledgments

We are grateful to CCS.inc for providing the lighting equipment used in this research.

References

- Loe, D. L. and Rowlands, E. 1982. Preferred lighting conditions for the display of oil and watercolour paintings. *Lighting Res. Technol.*, 14, 173-192.
- CHRISTOPHER, C. 2007. *Light for Art's Sake*: Butterworth-Heinemann.
- CHRISTOPHER, C. 2007. *LIGHTING BY DESIGN*: Architectural Press.
- CIE 2004. CIE 157:2004. *Control of damage to museum objects by optical radiation*. Vienna