The Influence of Natural Light on the Design of Electrical Lighting -Taking Liaohe Art Museum as an Example

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Abstract. In the museum, electrical lighting is a very important part, which will affect the visitors' feelings. This paper mainly studies the impact of natural light on the design of electrical lighting engineering. This experiment was conducted in Liaohe Art Museum. First of all, the lighting situation of each area of the museum was investigated to obtain objective data. Then 30 visitors were invited to conduct subjective survey experiments. The experiment selected two exhibition halls with different lighting methods, one of which only uses artificial lighting (Exhibition Hall 1), and the other uses a combination of natural light and artificial light (Exhibition Hall 3). It was found that people gave a better evaluation score to the exhibition hall combining natural light and artificial light. Therefore, in the museum, the rational use of natural light will bring better psychological feelings to visitors.

1. Introduction
Art museum is an important part of modern urban architectural culture, and it is a type of architecture that cherishes and displays human cultural wealth [1]. The purpose of its lighting design is to choose a reasonable lighting, create a safe and comfortable viewing environment, and transmit the visual effects of the exhibits to the audience. [2] Museums aim for exhibiting, protecting and educating. The first two are usually competing with each other [3]. Of all the interior lighting designs of buildings, museum lighting is the most challenging. The lighting must not only reveal the visual detail and emotional power of the art work to the viewers, but also protect and preserve its content and integrity for the future [4]. The lighting design of the museum aims to strike an appropriate balance between the two main themes: one is to minimize the potential damage of light to the artwork, and the other is to use the lighting to give visitors the best visual impression [5]. The identification of perfect lighting for museum exhibition is complex and is affected by multiple factors including observers’ subjective feelings and emotions.[6] With the development of LED, some experiments have investigated observer preference and visual impressions for museum lighting.[7][8] Most experiments use only artificial light sources to study the effects of colour temperature and illuminance.[9][10]

Through the investigation of Liaohe Art Museum, we found that there was an exhibition hall introducing natural light, so we studied the influence of natural light on people's subjective evaluation. In this study, two exhibition halls (hall 1 and hall 3) of Liaohe Art Museum were selected. Hall 1 uses only artificial light, and hall 3 has both artificial light and natural light. This paper has three components: 1) display of survey results, 2) subjective experiment, 3) analysis of data and conclusion.

2. Introduction to Liaohe Art Museum
Liaohe Art Museum is located in Panjin, Liaoning Province, a famous ecological city in the north. The museum has a construction area of 11,331 square meters, two floors above ground, and a height of
12.8 meters. The exterior design was designed by the Central Academy of Fine Arts. It is the first art museum in China built with clean-water concrete technology and the largest art museum in the Northeast region [11].

The exhibition hall covers an area of about 6,000 m² and is divided into 9 exhibition areas. There is a hall at the main entrance of the museum, which can accommodate more than 500 people, suitable for holding exhibition opening ceremony and other activities. The exhibition halls 1, 2 and 3 on the south side of the first floor are connected to display the fine works of the painters of Liaohé Painting Academy for a long time. Hall 4 on the north side of the first floor has rich lighting effects and is suitable for small-scale art exhibitions. The second floor of the museum has a high lifting frame and a wide field of vision. It can hold various medium and large-scale exhibitions or joint exhibitions. The museum is equipped with comprehensive supporting facilities such as conference rooms, multi-function halls, tea and leisure areas, and insurance warehouses. The multi-function hall has 220 seats, with modern lighting, tuning, simultaneous interpretation and other equipment. There is also a lounge, suitable for holding various large-scale seminars, auctions, lectures and other activities. The leisure area can provide visitors with various beverage services and rest spaces [12].

3. Objective data from the survey

3.1. Hall 1-Use artificial light only
The space plan of Hall 1 is shown in Figure 1. The average illuminance is 84lx and the uniformity is 0.27. The distribution of lighting collection points is shown in Figure 2. The specific lighting conditions are shown in Table 1.

![Figure 1. Space map of Hall 1.](image1)

![Figure 2. Illumination distribution in Hall 1.](image2)

### Table 1. Plane data of Hall 1.

| Space name | Mean illuminance | Mean CCT | Mean SDCM | Mean Ra | Mean R9 |
|------------|------------------|----------|-----------|---------|---------|
| Hall 1     | 84lx             | 4648K    | 7.5       | 92.5    | 78      |
| Illumination uniformity | Ground reflectivity | Wall reflectivity | temperature change |
| 0.27       | 0.36             | 0.69     | 0.3°C     |

3.2. Hall 3-Combination of artificial light and natural light
Hall 3 is located on the north side of the second floor of the museum. The length of the exhibition line is 300 meters. It is suitable for solo exhibitions or small group exhibitions. Its ceiling is made of special material, which introduces natural light and has a lighting coefficient of 0.012. The distribution of lighting collection points is shown in Figure 2. The lighting conditions are shown in Table 2.
4. Subjective evaluation experiment

4.1. Experiment procedure
We conducted subjective evaluation experiments in two exhibition halls. This experiment uses the form of a questionnaire. 30 people were invited to participate. The questionnaire contains 10 word pairs, which are Interesting/Boring, Relaxed/Tense, Modern/Classical, Bright/Dark, Exciting/Calming, Modern/Classical, Beautiful/Ugly, Pleasant/Unpleasant, Distinct/Vague and Active/Respectful. Each visitor rated Hall 1 (only using artificial lighting) and Hall 3 (a combination of artificial lighting and natural light). The highest score of each group of words is 6 points, and the lowest score is 1 point. After that, the feedback of each experimenter was collected for data analysis.

4.2. Experimental results and analysis
This part will use SPSS software to analyse the subjective experimental data. The main methods used are credibility analysis and single factor analysis of variance. Figure 5 shows the average of each pair of word pairs in two different exhibition halls. The average value of Hall 1 is 3.68, and the average value of Hall 3 is 4.07. Therefore, the way of mixing natural light and artificial light source is better than using only artificial light source. Next, we used SPSS software to perform a single factor analysis of the lighting method.
Figure 5. The average value of ten pairs of words in different exhibition halls.

Cronbach’s Coefficient Alpha is a number between 0 and 1. The larger the value of α, the better the correlation between items and the higher the credibility of internal consistency. When the credibility coefficient is greater than 0.8, it indicates that the experiment has a higher credibility. The result of the credibility analysis of the data shows that the value is 0.908, indicating that the data is highly credible.

ANOVA is a test method used to test whether the mean change of a dependent variable is significant at different levels, and it can analyse the impact contribution of influencing factors. When \( p < 0.010 \), there is a very significant difference. When \( 0.010 < p < 0.050 \), there is a significant difference. When \( p > 0.050 \), there is no difference. The calculation formula is:

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F = \frac{S_A/\sigma^2}{S_E/\sigma^2} \frac{r-1}{n-r}
\]

(1)

\( S_A \) represents the sum of squared effects of factor A, \( S_E \) represents the sum of squared errors, \( \sigma^2 \) is the mathematical expectation, \( r \) is the number of levels of factor A, and \( n \) is the sum of \( n_i \) independent tests.

Table 3. One-way ANOVA.

|                     | F     | P     |
|---------------------|-------|-------|
| Active/Respectful   | 5.003 | 0.029 |
| Beautiful/Ugly     | 0.178 | 0.675 |
| Modern/Classical   | 0.136 | 0.714 |
| Distinct/Vague     | 1.566 | 0.216 |
| Relaxed/Tense      | 3.544 | 0.065 |
| Pleasant/Unpleasant| 18.939| 0.000 |
| Exciting/Calming   | 3.449 | 0.068 |
| Interesting/Boring | 5.674 | 0.021 |
| Bright/Dark        | 1.838 | 0.180 |
| Modern/Classical   | 0.700 | 0.406 |

Table 3 shows the results of the one-way analysis of variance. Whether there is natural light has a very obvious effect on Pleasant/Unpleasant (\( P = 0.000 \)). According to the average data, the average
value of this word pair in Hall 3 is significantly higher than that in Hall 1. Both Active/Respectful and Interesting/Boring have a P value greater than 0.010 and less than 0.050 (P values are 0.029 and 0.021, respectively), so the presence or absence of natural light in the exhibition hall has a significant impact on them, and the score of natural light will be higher. From this we can find that when there is natural light, the psychological feedback of visitors will be better.

5. Conclusion
This paper conducts on-the-spot investigations on the Liaohe Art Museum and conducts related psychophysical experiments. It is concluded that in the art museum, the combination of natural light and artificial light should be used reasonably. Such a light environment can bring better psychological feelings to visitors. Our research on the Liaohe Art Museum found that one of the exhibition halls is special. It not only uses artificial lighting, but also subtly introduces natural light into it. It is precisely because of this that the indicators such as illuminance and uniformity of the exhibition hall are quite different. Therefore, we conducted subjective investigation experiments in Hall 1 using only artificial light and Hall 3 combining artificial light with natural light. 30 people participated in this experiment. The method of single factor analysis of variance was used to analyze the subjective experimental data. The experimental results show that the presence or absence of natural light has a significant influence on the two groups of words Active/Respectful and Interesting/Boring, and it has a very significant influence on the words Pleasant/Unpleasant, and there is natural light Score higher. Therefore, it is concluded that the rational use of natural light can provide visitors with better psychological feedback.

References
[1] Zou Wei 2012 The Forms of Design of Art Galleries in City Planning Forefront of Design pp 71-72.
[2] Wu Jie 2019 Analysis and Improvement Methods of Lighting Survey in Some Museums China Light & Lighting pp 34-37.
[3] Berns, R.S. 2011 Designing white-light LED lighting for the display of art: A feasibility study. Color Res. Appl pp 324–334
[4] Hurlbert and Cuttle 2020 New Museum Lighting for People and Paintings LEUKOS pp 1-5.
[5] Ajmat R, Sandoval J, Arana Sema F, O’Donell B, Gor S, Alonso H. 2011 Lighting design in museums: exhibition vs. preservation WIT Trans Built Environ pp195–206.
[6] Feltrin,Leccese,Hanselaer,Smet 2020 Impact of Illumination Correlated Color Temperature, Background Lightness, and Painting Color Content on Color Appearance and Appreciation of Paintings LEUKOS pp 25-44.
[7] Zhai QY, Luo MR, Liu XY 2015 The impact of illuminance and colour temperature on viewing fine art paintings under LED lighting Light Res Technol pp 795–809.
[8] Chen HS, Chou CJ, Luo HW, Luo MR 2016 Museum lighting environment: designing a perception zone map and emotional response models Light Res Technol pp 589–607.
[9] SzabóF,KériR,CsutiP 2017 The preferred conditions of LED lighting for fine art paintings : the influence of illuminance level and correlated colour temperature In 1st International Museum Lighting Symposium (London) pp 50–52.
[10] Luo H., Chou C., Chen H., Luo M.R. 2013 Using LED technology to build up museum lighting environment In Proceedings of the 12th Conference of AIC Colour, Tyne, UK pp 1757–1760.
[11] Lin Wang 2009 The new position of northeast art, Liaohe Art Museum Arr p 126.
[12] Lifeng Wang and Kai Kang 2007 A Baptism of Liaohe Culture-Design of Liaohe Art Museum in Panjin City, Liaoning Times Architecture pp 68-73.