

Take deLIGHT in Colours

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Introduction

Many contemporary approaches to museum lighting are oriented towards the fulfilment of qualitative standards, in order to provide visitors with a well-lit space and visual comfort, failing to consider that the surround and the background of the exhibit have a huge impact on visitors' visual perception of artworks. Moreover, lighting design in art exhibitions seldom highlights the uniqueness of each painting or achieve a real enhancement of its colours, in order to provide the museum visitors with the best visual experience, in terms of both visual comfort and enjoyment of the show. This project aims to analyse the factors affecting the visual perception of painted artworks displayed in museum settings and to establish, through a survey, whether there is a preference pattern for the observers. The experiment was conducted at the Light & Lighting Laboratory of KU Leuven Technology Campus Gent, recreating a simple museum scene and conducting a survey. The study investigated the influence of three factors: the Correlated Colour Temperature (CCT) of a LED spotlight, used as accent lighting on the paintings, the lightness of the background and the overall hue content of the paintings. The purpose of the study was to determine a scheme able to provide, depending on the main colours of the paintings and the visual effect required, the most suitable background lightness and colour temperature of the light source.

Experiment Design

A simple museum scene was recreated in the laboratory, building a setup made of a frontal wall, where the paintings were hanged, and two tilted walls, whose function was creating the broadest possible field of view and the feeling of immersion for the observers (Fig. 1). The different background lightness was obtained using curtains of three different colours – white, grey and black – which were set along the perimeter of the setup and manually changed during the tests (Fig. 2). Regarding the light sources, a tunable LED spotlight was used as accent lighting on the paintings, positioned frontally and tilted of 32° in relation to the vertical plane. The spotlight had four channels: the single tunable colours – the R(ed), G(reen) and B(lue) channels - and a fixed warm white channel (phosphor white with a CCT of 3200 K). As ambient lighting, four fluorescent lamps with a CCT of 5900 K were positioned at the top of the setup, above the observers' position, in order

to provide mostly horizontal illuminance and avoid a complete dark surround (uncommon for museum exhibitions), at the same time minimizing the interference with the accent lighting on the paintings. The setup dimensions, the light sources position and the position of the observers were designed following the conventional guidelines for museum lighting [1-2]. The illuminance at the location of the painting resulting from both the ambient lighting and spotlighting was approximately 160 lux (Standard deviation: 10 lux) and satisfied typical light exposure limitations - "Low responsive" category for artworks conservation as stated by the CIE 157:2004 Technical Report [3] - recommended for museum lighting. Regarding the artworks, five paintings were selected among the artworks of the contemporary artist Leonid Afremov [4]: four paintings with different predominant hues - red, blue, green and yellow - and one painting without a predominant hue (Fig 3).

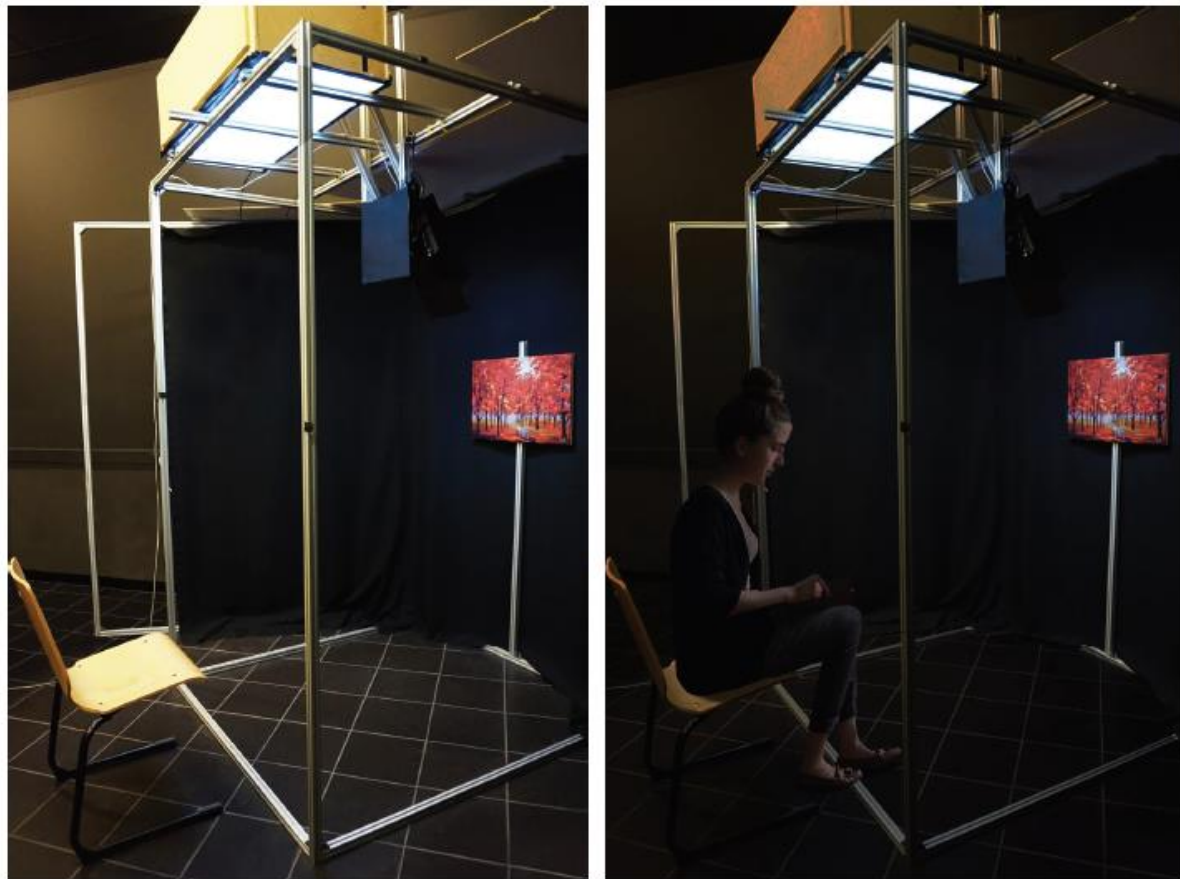


Fig. 1 - Pictures of the experiment setup and of a test subject completing the test.

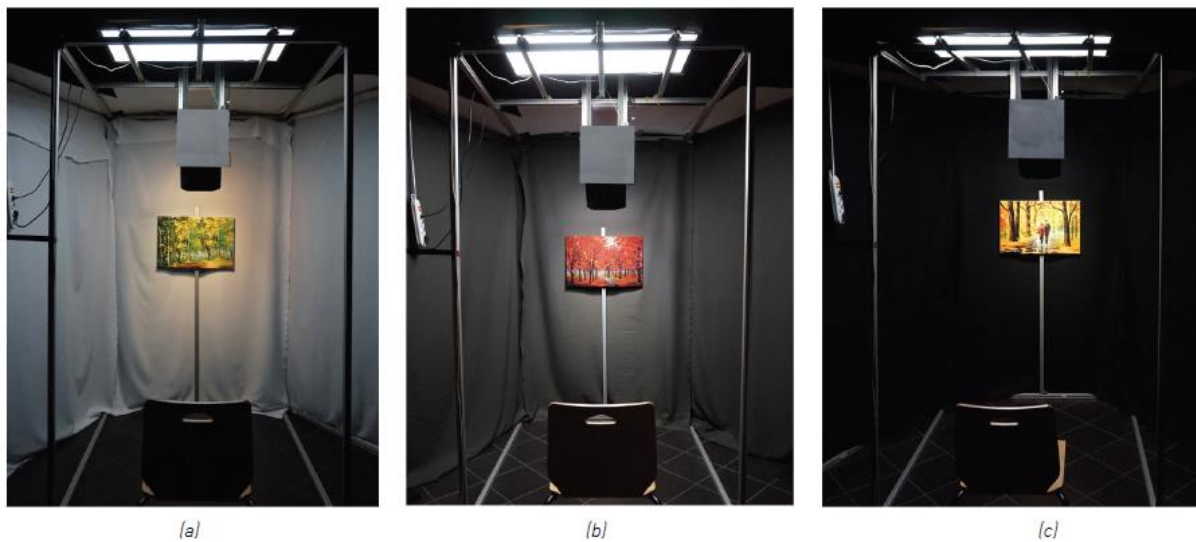


Fig. 2 - Pictures of the experiment setup with the three different backgrounds: (a) white background, (b) grey background and (c) black background.



Fig. 3 - Leonid Afremov's paintings: (a) Pink Fog, (b) Summer Forest, (c) Mystery of the Night, (d) Happy Couple and (e) When dreams come true.

Lighting Settings

The tunability of the LED spotlight allowed to obtain five CCT target values, keeping at the same time the colour rendition parameters sufficiently high. The ratio of each channel was optimized using MATLAB and five different CCT values were determined:

- 3000 K and 3500 K (warm CCT);

- 4000 K and 5000 K (neutral CCT);
- 6000 K (cool CCT).

The spectra of each configuration are shown in Fig. 4, measured on the grey background. All configurations had the white point approximately on the Planckian locus, with a Duv factor equal to 10-3. The CIE Colour Rendering Index, Ra, [5] the IES Colour Fidelity Index, Rf [6], and Smet's Memory Colour Rendition Index, Rm [7], all had to have at least a value of 85, whilst the target value for the IES Colour Gamut Index, Rg [6] was 100. As can be seen from Tab. 1, all parameters were sufficiently high and constant across the various configurations.

Experiment Procedure

After measuring each configuration and ensuring a stable replicability of the arrangements, the experiment proceeded with a survey. The multiple configurations were presented to a group of 25 observers, 14 males and 11 females, aged between 22 and 55 years old. Among the participants, 14 were naïve observers, with no prior knowledge of lighting nor art, 9 were employees of the Light and Lighting Laboratory (Researchers and PhD students), one architect and one lighting designer. All observers had normal colour vision, screened with the 24-Plate Ishihara Color Vision Test. During the tests, the observers were asked to evaluate the following factors, on a bipolar scale from 1 to 10:

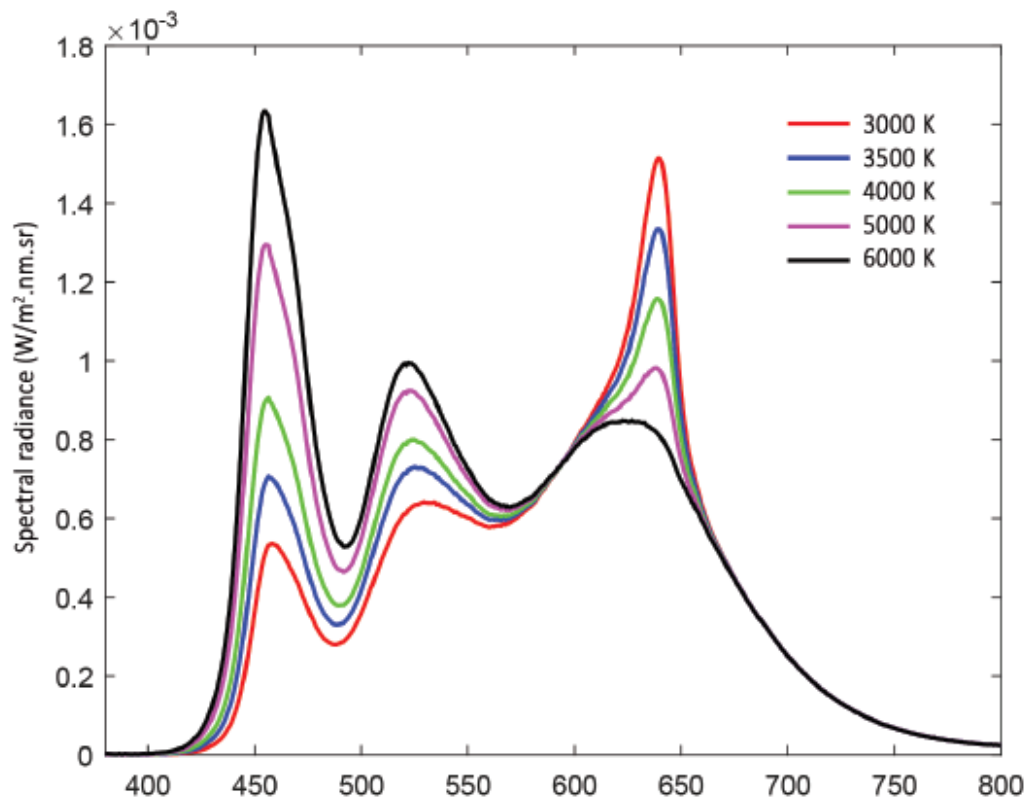


Fig. 4 - Spectra of the LED spotlight for the various CCTs.

Tab. 1 - Colour Rendering parameters for the various configurations.

	CCT (K)	Duv	R _a	R _t	R _g	R _m
White Background	3000	0,000	91	89	101	92
	3500	0,000	90	88	101	92
	4000	0,000	90	88	101	93
	5000	0,000	90	88	102	93
	6000	0,000	90	88	102	94
Grey Background	3000	0,000	91	89	101	92
	3500	0,000	91	88	101	92
	4000	0,000	90	88	101	93
	5000	0,000	90	88	101	93
	6000	0,000	90	88	102	94
Black Background	3000	0,000	90	89	101	92
	3500	0,000	90	89	101	92
	4000	0,000	90	88	101	93
	5000	0,000	90	88	102	93
	6000	0,000	90	88	102	94

- the vividness of the colours of the painting (dull/rich);
- the attractiveness of the colours of the painting (low/high);
- the warmth of the colours of the painting (warm/cold);
- the brightness of the colours of the paintings (dark/bright);
- the level of appreciation of the background colour (low/high);
- the overall level of appreciation of the combination light/background/painting (low/high).

The observers completed the experiment seated at a distance of 1,40 m from the paintings and each of them assessed a total of 90 different arrangements: 5 paintings, 3 backgrounds and 5 CCTs, for a total of 75 combinations and 15 additional repeated configurations to assess observers' consistency. The test was divided into three sections, one for each background: once set the background, they had to assess each painting at a time under the five different lighting configurations (Fig. 5). For each painting, before starting to evaluate, all configurations were randomly displayed, in order to let the observers adapt to the average luminance level and

give them an idea of the differences between the configurations.



Fig. 5 - Pictures of the red painting on the white background and the green painting under the black background under the various configurations (from warm to cool CCT).

Results Discussion

The results of the experiment were analysed by computing the geometric mean, its standard error and the median of the 25 evaluations for each quality factor (Overall Appreciation, Background Appreciation, Warmth, Brightness, Vividness and Colours Attractiveness), for every combination Painting-Background-CCT. This analysis allowed to display how the average evaluation of the six factors – Overall Appreciation, Background Appreciation, Warmth, Brightness, Vividness and Colours Attractiveness – varies along with the change of CCT of the paintings' illumination, as illustrated in Fig. 6 for the reddish painting “Pink Fog”.

Firstly, it was observed that the results for the three backgrounds with different lightness— black, grey and white - are not significantly different from each other, showing that the change of background slightly affected the observers' assessments. On the other hand, the observers were able to indicate their favourite background colour at the end of the test: 23 of them preferred the black background and the other two the grey one.

Secondly, it is possible to say that both the warmest and the coolest lighting arrangements were the least appreciated, whilst a CCT of 4000 K was the favourite one for all paintings, although the discrepancies of the assessments between 3500 K, 4000 K and 5000 K are very small.

Lastly, from the collected data it is clear that the predominant hue of the paintings has no impact on the preferred arrangements for the lighting, contrary to what was expected before conducting the experiment.

A second analysis step consisted of comparing the results between the various quality factors. The trends of the Overall Appreciation and the Colours Attractiveness tend to be quite similar to each other for each CCT, effect that could indicate that, when assessing the setting of art exhibitions,

people concentrate more on the artworks than on the surround, and that their satisfaction about the colours' appearance is extremely relevant for their overall enjoyment of the exhibition. Furthermore, it can be observed that the Warmth has a downward trend along with the increase of CCT, whilst the Brightness has an upward trend and the peak of the Overall Appreciation lies in the middle.

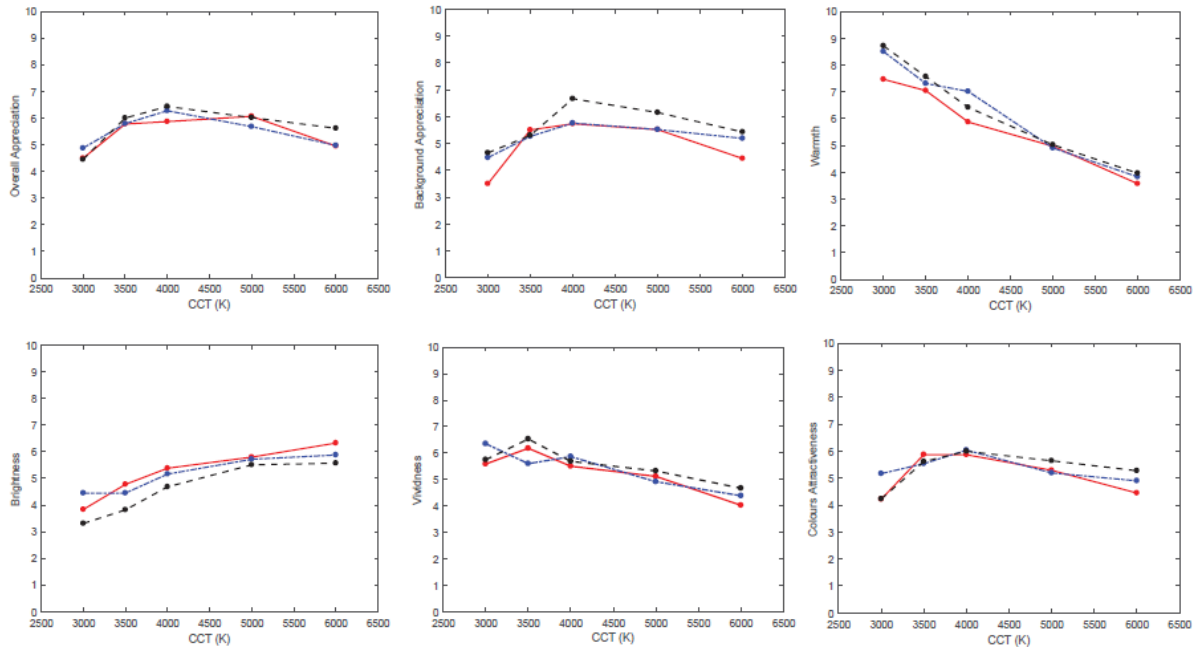


Fig. 6 - Plotted results for the Reddish painting "Pink Fog" for each quality factor.

Conclusions

In conclusion, neither the predominant colours of the artworks nor the background lightness were found to have a relevant impact on people's assessments of art exhibitions' settings. In this study, CCT was the main factor affecting people's appreciation of art exhibitions and proper lighting configuration neither too warm nor too cold was found to enhance the artworks as effectively as possible. Furthermore, it was observed that the Overall Appreciation of the scene could be interpreted as a trade-off between the perceived Warmth and the perceived Brightness and it is mostly correlated with the perceived Colours Attractiveness.

References

- [1] C. Cuttle, *Light for Art's Sake. Lighting for Artworks and Museum Displays*, Butterworth-Heinemann, 2007, pp. 288. ISBN: 978-0750664301.
- [2] M. Bonomo., C. Bertolaja, *L'illuminazione delle opere d'arte negli interni. Guida alla progettazione*, Ediplan, 2013, pp. 120, ISBN:978-8896726099.

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- [3] Commission International de l'Eclairage, CIE 157- *Control of Damage to Museum Objects by Optical Radiation*, Vienna (A), 2004.
- [4] *The official online gallery of Leonid Afremov*, <https://afremov.com/>, accessed on 10th April 2017.
- [5] K. Houser, M. Mossman, K. Smet, L. Whitehead, *Tutorial: Color Rendering and its Applications in Lighting*, LEUKOS, Vol. 12, pp.
- [6] A. David, P.T. Fini, K.W. Houser, Y. Ohno, M.P. Royer, K. Smet, M. Wei, L. Whitehead, *Development of the IES method for evaluating the color rendition of light sources*, Optics Express, Vol.23, pp. 15888–15906, 2015. DOI: 10.1364/OE.23.015888.
- [7] K. Smet, W.R. Ryckaert, M.R. Pointer, G. Deconinck, P. Hanselaer, *A memory colour quality metric for white light sources*, Energy and Buildings, Vol. 49, pp. 216-225, 2012, DOI: 10.1016/j.enbuild.2012.02.008.