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Impact of Illuminant Metamerism on Colour Fidelity in Graphic Reproduction of Artistic Images

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Abstract: The aim of the research was to to evaluate the quality of illuminant metamerism by using Colour rendering index through similar paintings and half-tone reproduction images within the graphic industry. Employing the methodology of visual perception and testing conducted by standard observers, the study scrutinises how different colour techniques of paintings respond to diverse light sources under standardised conditions. This investigation is pivotal for understanding the chromatic fidelity and consistency of paintings and their reproduction with half-tone colours, by measuring the grey balance field, for all images. To find the most suitable light source and to complete the colour quality, the Osram LED light at 3000 K, 4000 K, and 6500 K is used. The resulting index could be deceptive in cases of significant disparities. The American IES TM-30-18 colour rendering index (CRI) metric, quantifies illumination metamerism's ability to faithfully depict natural colours. At every stage (R1–R15), the average colour reproduction CRI must be more than 90.

Keywords: CCT; colour quality; CRI; illuminant metamerism; visual perception

1 INTRODUCTION

The assessment of colour rendition in various contexts, particularly within the graphic industry, has long been a subject of keen scientific inquiry. Over the decades, researchers have endeavoured to understand the intricacies of illuminant metamerism and its implications for the faithful reproduction of colour [1]. The accurate reproduction of artistic images is a critical concern in the field of graphic reproduction, where color fidelity is paramount.

This research aims to investigate the impact of illuminant metamerism on colour fidelity in the graphic reproduction of artistic images, focusing on works created with acrylic and oil painting techniques. This can significantly affect the perceived colour accuracy of reproduced artwork, leading to discrepancies between the original piece and its printed version. Understanding how different light sources influence colour fidelity is essential for improving reproduction techniques and ensuring that printed images closely resemble the originals. Acrylic paints dry quickly and maintain colour vibrancy, while oil paints dry more slowly, allowing for blending and creating rich textures. These differences influence the way each medium interacts with various illuminants, affecting the colour fidelity of the reproduced image. By understanding these differences, we can improve the accuracy and quality of reproduction industry, lighting engineering, benefiting artists, printers, and the art reproduction. This research will provide valuable insights into the best practices for replicating artworks, ensuring that the printed reproductions remain true to the original pieces.

Efforts to assess the colour rendering abilities of light sources commenced during the 1930s with the emergence of fluorescent lamps, which presented a spectral composition distinct from the prevalent incandescent lamps of that era. Initially, a method known as the spectral bands approach was proposed [CIE 1948], paving the way for standardisation efforts by the International Commission on Illumination (CIE) [1, 2].

Understanding and assessing metamerism requires utilizing colourimetric measurements to evaluate the spectral characteristics of colour methods and inks [3-5].

In the realm of illuminant metamerism and reproduction technology, the accurate portrayal of colour is of paramount importance [2, 3]. As artists strive to convey their intended messages through paintings, and as reproduction technologies advance, understanding the quality of colour reproduction becomes increasingly crucial [6]. Research on metamerism has a long history; however, its application in the context of industry, art, and reproduction on half tone images has been relatively limited [3, 4, 6, 7].

Modern approaches to museum lighting seek to create an optimal balance between two key concerns: limiting the potential negative impact of light on artworks and achieving the best visual appearance through light [4, 8-11].

Modern museum lighting strategies strive to achieve a delicate balance between two key objectives: minimising the potential harm of exposure to artwork and optimising visual perception through strategic lighting [9].

This endeavour enables the representation of predetermined shapes. In the realm of traditional colour painting, the inherent metamerism often leads to colour matches with the original artwork under testing light sources, as reproducing the full spectrum using only three or four inks is inherently challenging [12].

Colour accuracy and consistency are crucial aspects of graphic technology, particularly in fields such as printing and display manufacturing [13]. Hence, the manipulation of light sources, including the adjustment of their chromatic attributes and the precise control of beam orientation, gives the ability to modify the visual characteristics of artworks to align with the specific desired effects [3].

The outcomes of these investigations affirm the viability of light-emitting diodes (LED) as an apt choice for illuminating museum spaces [10, 11]. LED lights are pivotal in various aspects of modern life because of their numerous advantages over traditional lighting technologies. They offer energy efficiency, longer lifespan, durability, and environmental friendliness compared to incandescent and fluorescent bulbs [14]. This selection is supported by their commendable attributes such as efficient energy utilisation, environmental sustainability, protection of artworks from potential harm, and the versatility of the lighting arrangement in terms of rendering accurate colours [15].

Little is known, however, colour rendition, which refers to how a light source affects the colour perception of objects and surfaces, is a crucial aspect of lighting quality. It is influenced by the spectrum of light emitted, how it interacts with surfaces, and how the human visual system processes it [9, 16, 17].

The implementation and adoption of ANSI/IES TM-30-18, an established American National Standard for assessing the colour rendition of light sources, signify substantial progress in lighting technology. Endorsed by the Illuminating Engineering Society, this method has gained increasing traction among lighting manufacturers, different industries, specifiers, and researchers in the past five years.
Its enhanced precision and comprehensive data offerings surpass those of its predecessors, making it the preferred choice for evaluating colour rendition across various industry contexts [16].

This study explores the quality of illuminant metamerism, focussing specifically on its manifestation in the reproduction of paintings. With advancements in lighting technology and the widespread use of digital reproduction methods and colourimetry, it is imperative to evaluate how well these systems preserve the colour accuracy and fidelity of the original artwork. To this end, we dive into the intricacies of the Colour Rendering Index (CRI) and its role in determining the quality of colour reproduction [17].

By examining the interplay between illuminant metamerism and the CRI, we aim to provide insights that can inform improvements in the reproduction process, thereby enhancing the fidelity and authenticity of reproduced paintings. This involves comparing colour variances across different lighting conditions to discern disparities.

Although our study aims to measure all images in appropriate meaner in the grey balance field. However, these domains endure challenges that stem from inadequate production comprehension and substandard quality.
This method is very limited, since previous studies tend to measure spot parts and many scientists lack understanding of the industry of graphics and the quality of reproduction [6, 10].

Evaluating colour rendition under different lighting conditions is essential to ensure that printed or displayed colours match their intended appearance [9, 10, 16].

1.1 CMYK Reproductive Colours in the Colour of Photorealistic Images

In the field of graphic technology, the convergence of colour management practices and colourimetry is crucial [17]. Digital printing processes has inaugurated a new era characterised by increased precision and fidelity in the reproduction of intricate visual compositions [5].

This symbiotic relationship between colour science and printing technology has paved the way for substantial advancements in the realm of colour accuracy [18, 19]. Moreover, the seamless integration of colour measurement instruments and spectrophotometers within the printing workflow facilitates real-time colour calibration and on-the-fly adjustments. This ensures that the colour output is precisely with specified standards, maintaining unwavering consistency throughout all production cycles [20].

1.2 Illuminant Metamerism

Central to this understanding is the concept of illuminant metamerism, which refers to the phenomenon where colours match under one light source but appear different under another [2, 3].

Metamerism, in which the colours of paintings and different light sources are known as a source of annoyance among painters and museums and among those in the apparel, visual perception and advertising industries [10].

For the average person, it is challenging to obtain paints that create metamerism under a particular light source [10].

In the context of graphic reproduction, metamerism can lead to inconsistencies in colour appearance when viewed under different illuminants. This is particularly crucial for artistic images where colour accuracy is paramount.

2 METHODOLOGIES

This research proposes a technology for realizing the artistic perception of two similar paintings, acrylic and oil, by comparing their reproduction in halftone images under different light sources such as Osram LED lights at 3000 K, 4000 K, and 6500 K, with the assessment by standard observers.

The colour techniques utilized were selected by Royal Talens – Art Creation, a longstanding entity in the art supply industry known for prioritizing quality in its diverse range of colour products. Red, blue, and yellow pigments, examples of subtractive colours, were applied in these paintings to correspond with the CMY colour reproduction, lighting, and viewers' vision, allowing for easy identification between them. The size of the artwork was 250 × 320 mm.

The original works were created under standardized conditions in natural light. The artworks were produced on Italian matte Fabriano I264 paper, compliant with the ISO 9706 long life standard.

This mixed media paper was chosen for its suitability for different colour techniques, comprising 25% cotton and 100% alpha cellulose, with a natural grain and cold press finish. With a weight of 300 g/m², it supports all artistic techniques and facilitates comparison with reproduced samples.

This study presents a detailed workflow for the photographic realization of visual subjects, crucial for high-quality image reproduction in research (Fig. 1).

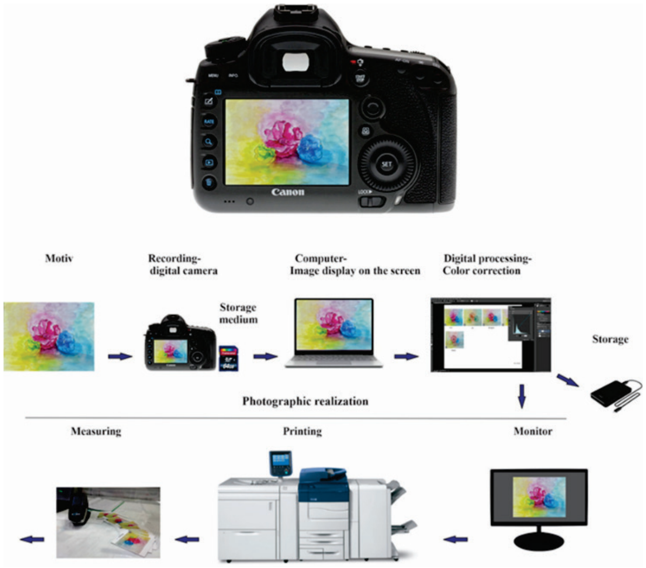


Figure 1 Realization process flow for high-quality image printing

The process begins with capturing the subject using a high-resolution digital camera, the Canon EOS 5DS R, with manual settings to ensure accurate detail and colour.

The captured image data is stored on a secure digital storage medium, typically an SD card, allowing for easy transfer and subsequent processing. The image is then transferred to a computer for digital processing, including inside grey balance, colour correction and enhancements, to faithfully represent the original subject. The processed image is saved and verified on a high-resolution monitor before being printed. The printed image undergoes scientific analysis for accuracy and quality. The Xerox Colour C70 printer was used to reproduce the painting images under conventional operating procedures, with a high quality of 100%, the prints met our predetermined standards for precision and clarity. The colour mode was set to full colour, which provided the best balance between colour accuracy and print consistency.

Laser printers are known for their precision and ability to produce consistent, high-quality prints. The printer was set to its maximum resolution of 1200 × 1200 DPI to capture fine details. Print speed Colour: up to 60/70 ppm, we utilized Xerox Colotech + paper mat, which have a thickness of 300 g/m², for the sample preparation.

To measure the grey balance, we used the spectrophotometric using the X-Rite eXact device, standard observer 2°, which is used to measure the L^* a^* b^* values on grey balance field.

All equipment was calibrated before use according to the manufacturer's guidelines.

This workflow ensures precise reproduction of visual subjects in both digital and physical formats, maintaining the integrity required for experimental research. The techniques of oil- and acrylic-colour, which, although not often used in scientific research comparison, especially in technology of graphic, detecting differences through different light temperature and light sources, turned out to be a good choice.

The purpose of this research is the use of three subtractive colours of paints in different colour techniques to generate illuminant metamerism, thus enabling the representation of premeditated shapes. As an example, painting detection was illuminated by different light sources such as a LED, with matching CCT as 3000 K, 4000 K, 6500 K, luminance and visual perception and measuring the metamerism index to see similarities and differences between them.

2.1 Optical Colour Space Utilizing CMYK for Digital Recording

Using the software program, CMYK reproduction colours were employed for the perceptual analysis of digital records derived from photographic images. To address technical considerations, two distinct photographic images using various techniques were deliberately incorporated into the programme framework.

This arrangement allowed for their simultaneous and consistent operation when alterations were made to the curves. During the subsequent phase, a grey balance field was integrated into all photographic images.

The accurate percentages of this grey balance were established according to the ISO 12647-2 standard (50% Cyan, 40% Magenta, 40% Yellow). This grey balance field configuration facilitates the precise quantification of the half-tone variation across the entire image, obviating the need for part-specific measurements.

Referring to (Fig. 2), for an example of reproduction employing an oil-colour painting within a grey balance field. Similarly, (Fig. 3) illustrates the reproduction of an acrylic-colour painting using the same grey balance field.

Figure 2 Oil-colour painting reproduction with grey balance field

Figure 3 Acryl-colour painting reproduction with grey balance field

Within this spatial framework, tonal adjustments were made within the Generic CMYK profile using the built-in tools available in the property's settings, from the starting point value of 50%.

Halftone images underwent alterations by incrementing and decrementing their values by ±2%, ±4%, and ±6%.

For specific tones, adjustments were consistently applied in increments of three defined percentages: 52%, 54%, and 56%. This modulation procedure was mirrored across the Cyan, Yellow, Magenta, +CMYK - Process, and –CMYK - Process channels. For the –CMYK channel, adjustments are described as relative decrements from the original tone value. Therefore, the values 48%, 46%, and 44% indicate reductions from the original value, respectively.

An enumeration of the initial test samples is provided in (Tab. 1); wherein abbreviated identifiers were used as key markers to signify the tonality and proportion of halftone photographs that were scrutinised within the research.

Table 1 The percentage of halftone image values increment and decrement in the CMYK space.

Variations in the percentage of halftone picture values from the CMYK colour space	The identifiers
Cyan 52%	+2% C
Cyan 54%	+4% C
Cyan 56%	+6% C
Magenta 52%	+2% M
Magenta 54%	+4% M
Magenta 56%	+6% M
Yellow 52%	+2% Y
Yellow 54%	+4% Y
Yellow 56%	+6% Y
CMYK 52% - Process	+2% P
CMYK 54% - Process	+4% P
CMYK 56% - Process	+6% P
CMYK 48% - Process	-2% P
CMYK 46% - Process	-4% P
CMYK 44% - Process	-6% P

This achievement was realised through the application of two distinct methodologies: oil-colour painting and acrylic colour painting. Each methodology was subjected to a comprehensive analysis involving 15 distinct sample variations, all within the context of half-tone colour images.

Additionally, the manipulation of tonality was facilitated through the utilisation of the curve's histogram, affording control over the x-axis.

Due to the relatively minimal tonal disparities and subtle subjective distinctions, a judicious decision was made to exclusively employ the x-axis to effect output adjustments.

The light sources used for the purpose of this research are Osram LED lights with different CCT from 3000 K, 4000 K, and 6500 K as shown in (Tab. 2), the product specification.

Table 2 Technical specifications of Osram LED lights

Product specification OSRAM LIGHT	LED LIGHT 3000 K	LED LIGHT 4000 K	LED LIGHT 6500 K
Product datasheet	P MR16 35 36° 4.3 W/ GU5.3	PAR16 50 36° GU10	PAR16 50 36° GU10
Nominal wattage	4.3 W/50 W	4.3 W/50 W	2.6 W/35 W
Nominal voltage	220-240	220-240	220-240
Light colour (designation)	Warm white	Neutral white	Cool Daylight
Colour temperature	3000 K	4000 K	6500 K
Luminous flux	350 lm	350 lm	230 lm
Colour rendering index	$Ra \geq 90$	$Ra \geq 90$	$Ra \geq 90$
Beam angle (Ceiling)	30°	30°	30°

In this graphic technology research, a comprehensive visual analysis of the experimental phase was conducted involving nonspecialist surveyors based on the standard ASTM-D1729 [21]. These participants lacked professional knowledge in the field but engaged in the evaluation of photographic images using simultaneous comparisons with originals. Despite their unfamiliarity with metamerism, the 35-observers surveyor group expressed interest in visual perception, colours, communication, and memory compliance.

Participants, 18 women and 17 men, aged 18-60, were classified by age: 18-25 years (10), 25-45 years (15), and 45-65 years (10). Before the experiment, observers underwent binocular and Ishihara tests to ensure normal vision, with only those passing participating. Strict adherence to standardised circumstances was maintained throughout the graphic technology inspection experiment.

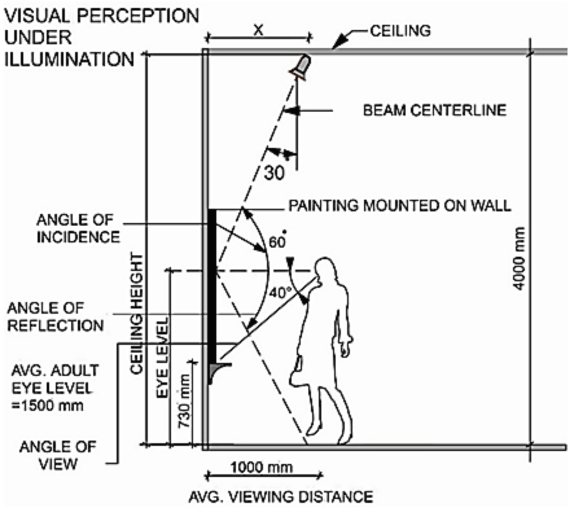


Figure 4 Subjective research

The experiment was conducted in a laboratory atelier with an area of 16 m². The interior walls were painted light grey, and external lighting was eliminated to ensure more accurate results.

This study investigates optimal viewing conditions for wall-mounted paintings under artificial illumination, focusing on geometric relationships between light incidence, reflection angles, and observer position in gallery settings.

The analysis considers a ceiling height of 4000 mm, an average adult eye level of 1500 mm.

The painting is located 730 mm from the floor, and a viewing distance of 1000 mm. The light source, mounted on the ceiling, directs the beam angle at a 30°, minimizing glare and harsh shadows, angle of incidence from the painting 60°. A reflection of 40° angle aligns with the standard observer enhancing visual comfort, finding the best matches of the samples and comparing with original paintings under different light source.

The 60° viewing angle ensures a comprehensive view of the artwork, with the observer positioned 1000 mm from the painting. The standard observers were asked to choose three of the best samples toward original painting under each light sources. These conditions create an ideal viewing environment, enriching the viewer's experience by maximizing detail visibility and minimizing glare. This framework guides optimal light source positioning for the best visual perception, with potential future research exploring variations in painting sizes and room dimensions (Fig. 4).

3 RESULTS AND DISCCUSIONS

Colour evaluations were performed using original painting comparing with acryl and oil-based reproduced samples under three different LED light sources: 3000 K, 4000 K, and 6500 K. Each observer was asked to choose the three best matches to the original painting under each light source. These visual results were ranked, with the best match receiving 5 points, the second-best receiving 4 points, and the third-best receiving 3 points. Each light source represents a different colour temperature, which can significantly influence visual perception, as shown in (Fig. 5).

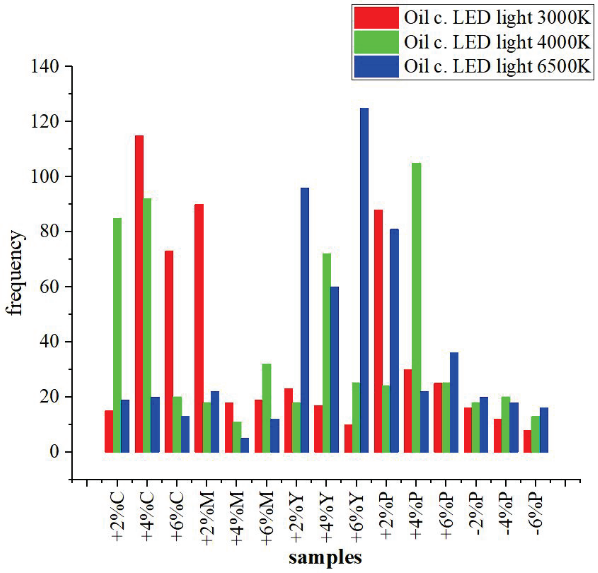


Figure 5 Subjective results of oil colour samples on Osram LED Light 3000 K, 4000K, 6500 K

The *x*-axis lists the samples, which are identified by specific chromaticity, density variations and the percentage of change. The height of each bar indicates how frequently that sample was chosen as one of the best matches during the evaluation. The *y*-axis represents the frequency with which each sample was selected during the visual evaluations under the different LED light conditions. The histogram allows for a comparison of how different light sources influence the visual evaluation of color samples.

Higher bars suggest a higher preference for that sample under the specific lighting condition, indicating how well the sample matches the original painting under that light.

The results reveal significant variations in the colour under different LED light sources and sample conditions. Colour perception appears to be influenced by the light source's colour temperature, with differences observed in both chromaticity and density measurements.

For instance, in the +2% C samples, the LED Light 4000 K source yields notably higher readings than the other sources. Similarly, in the +6% Y samples, the LED Light 6500 K source leads to significantly higher measurements compared to the other sources.

Moreover, the density of the samples also contributes to variations in colour measurements. This is evident from the divergent results between different density levels within the same chromaticity category. For instance, in the +4% Y samples, there is a substantial difference between the Led Light 4000 K measurements for the +4% Y and +6% Y samples, indicating the impact of density on colour appearance. In the context of graphic technology, the presented results show the effects of different lighting conditions LED light at 3000 K, 4000 K, and 6500 K on the visual perception of various acryl samples containing different concentrations of colourants as shown in (Fig. 6).

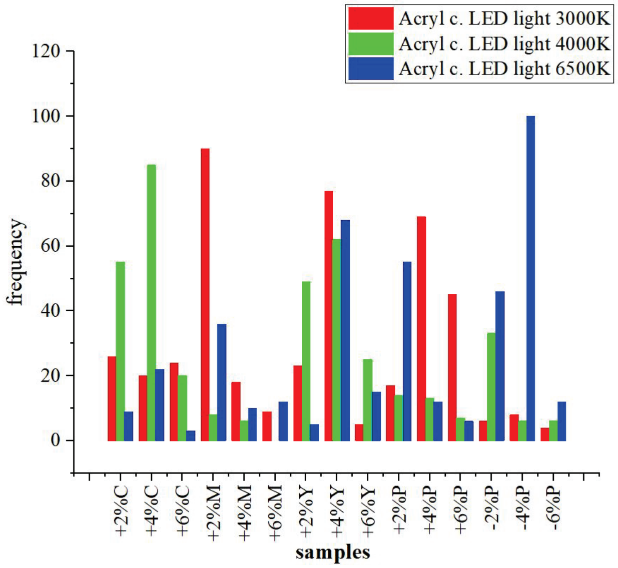


Figure 6 Subjective results of Acryl colour samples on Osram LED Light 3000 K, 4000 K, 6500 K

Varying concentrations of colourants result in significant differences in how the first best samples are perceived under different lighting conditions. This indicates that presence and concentration play a crucial role in the appearance of the colour. The different LED light temperatures (3000 K, 4000 K, and 6500 K) have different effects on the perception of colour.

For instance, higher colour temperatures (e.g., 6500 K) seem to enhance the visibility of certain colourant concentrations, while lower temperatures (e.g., 3000 K) might alter the perception. The interaction between colourants is evident in some cases. For example, at +2% C and +4% C concentrations, the samples appear significantly different at the three light temperatures. This suggests that the interplay between the Cyan colourant and the lighting temperature is intricate.

Negative lightness percentages (–2% P, –4% P, –6% P) demonstrate a pronounced effect of lightness on the perception of the samples. The results indicate a considerable shift in how samples are perceived, especially under LED light with a colour temperature of 4000 K. Looking at specific colourant combinations, such as +2% M and +4% M, the differences in perception under different lighting conditions are notable. This could imply that lighting colourant's interaction with the lighting plays a significant role in colour appearance. The results are not linear in many cases.

For example, the +4% Y samples appear quite differently under the three lighting conditions.

This non-linear response could be attributed to complex colour interactions and human visual perception. The results of the colour analysis of $L^*a^*b^*$ values of first best match samples with metamerism index (*MI*) and *Delta E* (ΔE). Undertaken on both acrylic and oil colour samples, that were illuminated by various light sources with different colour temperatures, provide a comprehensive insight into the nuanced interaction between lighting conditions and colour perception (Tab. 3).

Table 3 The colourimetry measurements between the best sample reproductions of acrylic and oil colour samples.

Sample 1) Acryl s. 2) Oil s.	LED 3000 K +2% M +4% C	LED 4000 K +2% C +4% D	LED 6500 K +2% M +6% Y
1. L*	53.60	58.46	53.61
1. a*	–10.50	–7.12	–10.51
1. b*	–20.45	–12.96	–20.45
2. L*	56.72	43.13	57.79
2. a*	–5.92	–5.31	–3.31
2. b*	–16.85	–10.83	–14.15
ΔL	3.12	15.33	4.18
ΔC	5.99	3.64	9.33
ΔH	3.37	0.50	5.67
ΔE	4.68	15.46	7.40
Δab	5.83	3.15	9.56

Investigation of perceptual differences, as evidenced by the calculated parameters (ΔL), (ΔC), (ΔH), (*MI*), and Δab, provides a foundation for an in-depth understanding of the impacts of illuminant metamerism across the specified colour samples [22].

Under illumination of LED light with a colour temperature of 3000 K, the acryl colour sample denoted as +2% M and the oil colour sample typified by +4% C emerge as subjects of enquiry. On examination, the acryl colour sample manifests a distinct alteration in its perceptual attributes. Specifically, an increase in luminance (ΔL) by 3.12 units is accompanied by a concomitant elevation in chroma (ΔC) by 5.99 units and hue (ΔH) by 3.37 units.

This perceptual change corresponds to a metamerism index (*MI*) of 4.68, indicative of a moderate degree of perceptual variation. Similarly to this, the +4% C, at oil colour sample experiences alterations in luminance, chroma, and hue by 15.33, 3.64, and 0.50 units, respectively. This perceptual modulation is further reinforced by an *MI* of 15.46, which substantiates a notable divergence in colour perception under the specified lighting conditions.

Transitioning to the LED light source with a colour temperature of 4000 K, the acrylic colour sample of +2% C and the oil colour sample of +4% D emerge as test subjects.

Upon illumination, the acryl colour sample registers a reduction in luminance of 15.33 units, accompanied by marginal changes in chroma and hue of 3.64 and 0.50 units, respectively.

This perceptual deviation gives rise to an (*MI*) of 15.46, underscoring a discernible shift in colour perception. Parallelly, the oil-colour sample experiences a decrease in luminance, chroma, and hue by 5.31, 5.31, and 10.38 units, respectively. This perceptual transformation is reflected in an (*MI*) of 3.15, which is indicative of a relatively lower degree of colour variation compared to the acryl sample.

Shifting the focus to the LED light source with a colour temperature of 6500 K, the acryl colour sample denoted as +2% M and the oil colour sample of +6% Y assume prominence. The acryl colour sample exhibits incremental shifts in luminance, chroma, and hue by 4.18, 9.93, and 5.67 units, respectively, contributing to an (MI) of 7.40.

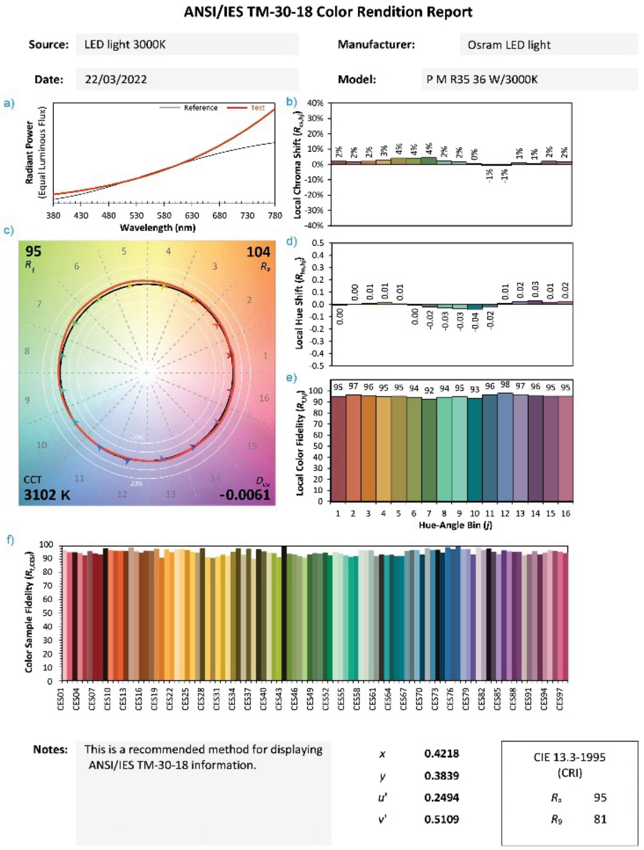
These changes in perceptual attributes signify a moderate level of colour variation attributed to illuminant metamerism. Similarly, the oil-colour sample experiences a transition in luminance, chroma, and hue by 4.18, 9.93, and 5.67 units, respectively, which results in an (*MI*) of 9.56. This value suggests a discernible alteration in colour perception under the stipulated lighting conditions, albeit to a slightly higher degree than in the acryl sample.

In summary, the analysis of the presented results underscores the intricate relationship between illuminant metamerism and the distinct colour samples under varying LED light sources. The calculated parameters, (ΔL), (ΔC), (ΔH), (*MI*), and (Δab), collectively provide an empirical basis for understanding the impact of spectral changes inherent in different lighting conditions on colour perception. These findings illuminate the necessity for judicious lighting selection in the presentation and conservation of artworks, underscoring the significance of accounting for illuminant metamerism to ensure faithful colour representation and perception. Further research and adaptations of these insights in practical settings may facilitate enhanced visual experiences within the realm of art display and appreciation.

The technical memorandum TM-30-18 standard was used developed by Illuminating Engineering Society (IES), employing 99 colour samples and specific evaluation metrics tailored for LED sources. In this investigation, every light source tested demonstrated excellent colour fidelity based on the TM-30 standard. The software BabelColor CT&A utilized the i1Pro / i1Pro 2 (XRGA) device to measure the nanometers (nm) of light sources.

For example, LED Light 3000 K showed exemplary lighting quality with notable characteristics such as uniformity of radiant power throughout the spectrum (630 - 780 nm), minimal local chroma and hue changes, rendering fidelity (Rf-95), and preservation of the gamut (Rg-104) as it shown (Fig. 7).

However, slight deviations were observed, such as a marginal increase in CCT to 3102 K and a (Duv) value indicating a minimal change in CCT from the black body (-0.0061). Additionally, while overall colour rendering fidelity was high (Rf 95), specific hue bins (R6, R7, R8, R10) fell slightly below this threshold.


ANSI/IES TM-30-18 Color Rendition Report

Source: LED light 3000K **Manufacturer:** Osram LED light

Date: 22/03/2022 **Model:** P M R35 36 W/3000K

Notes: This is a recommended method for displaying ANSI/IES TM-30-18 information.

x	0.4218
y	0.3839
u'	0.2494
v'	0.5109

CIE 13.3-1995 (CRI)	
R_a	95
R_9	81

Figure 7 LED light measurement at 3000K using TM-30-18 color rendition.

High quality lighting may be observed using LED Light 4000 K in (Fig. 8). Specifically, (a) the radiant power increases considerably between 630 nm and 680 nm. In (b) and (d), there are minor fluctuations in the local hue and chroma shifts.

The colour vector graphics (CVGs) in (c) show a rendering gamut (Rg-100) and rendering fidelity (Rf-96), with a higher CCT of 4100 K than what is required technically.

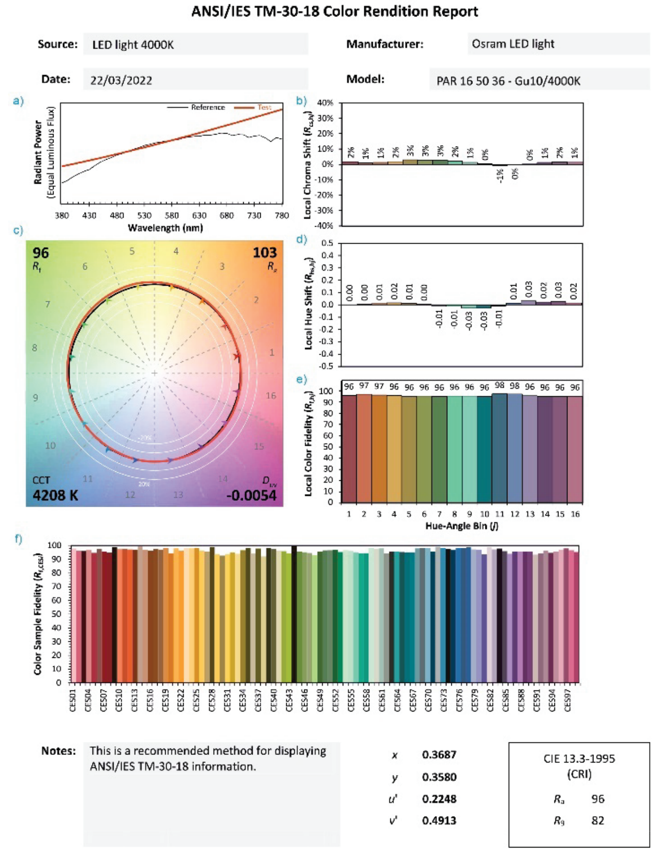
Is visible in the Duv measure a small CCT variation from the black body (–0.0015).

Despite a high CRI (Rf 96) in (e), some hue bins (R10, R11, R12) remain slightly less than 95.

The characteristics of artificial light vary among different sources, exhibiting nuanced differences despite advances aimed at daylight emulation. In (Fig. 8), under LED light, 6500 K demonstrates fluctuations in radiant power (a) between 430 nm and 580 nm, accompanied by varying percentages of local hue and chroma shifts in (b, d).

In line with technical criteria, is shown by the colour vector graphics (CVG) in (c). High-quality illumination with rendering fidelity (Rf-93) and rendering gamut (Rg-100).

A change in the CCT value of 0.0050 from the black body is reflected in the Duv measurement.


ANSI/IES TM-30-18 Color Rendition Report

Source: LED light 4000K **Manufacturer:** Osram LED light

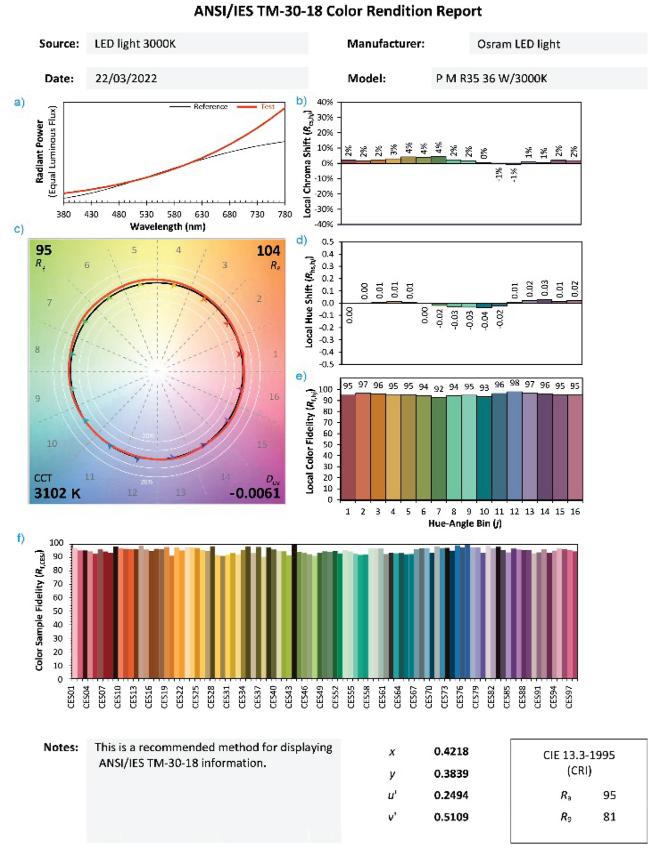
Date: 22/03/2022 **Model:** PAR 16 50 36 - Gu10/4000K

Notes: This is a recommended method for displaying ANSI/IES TM-30-18 information.

x	0.3687
y	0.3580
u'	0.2248
v'	0.4913

CIE 13.3-1995 (CRI)	
R_a	96
R_9	82

Figure 8 LED light measurement at 4000K using TM-30-18 color rendition.


ANSI/IES TM-30-18 Color Rendition Report

Source: LED light 3000K **Manufacturer:** Osram LED light

Date: 22/03/2022 **Model:** P M R35 36 W/3000K

Notes: This is a recommended method for displaying ANSI/IES TM-30-18 information.

x	0.4218
y	0.3839
u'	0.2494
v'	0.5109

CIE 13.3-1995 (CRI)	
R_a	95
R_9	81

Figure 9 LED light measurement at 6500K using TM-30-18 color rendition.

While some hue bins (R5, R10, R11) fall below Rf 95 in (e), others surpass this threshold, notably R2, R7, and R16.

The data appears to be comprehensive and cover various aspects of colour rendition and illuminant properties. It seems to facilitate analysis of how different hues, chromatic shifts, and illuminant conditions impact colour rendition performance.

Across all colour temperatures, certain wavelengths exhibit notable differences in intensity.

At shorter wavelengths (e.g., 380 nm to 500 nm), the LED lights tend to have higher intensities, with variations depending on the colour temperature.

Longer wavelengths (above 500 nm) show decreasing intensities across the spectrum, again with differences between colour temperatures.

4 CONCLUSIONS

The utilisation of standardised LED lighting has been found to reduce the occurrence of illuminant metamerism, especially when accompanied by a clearly defined spectral power distribution. This finding emphasizes how well standardized LED light works to decrease the impacts of illuminant metamerism.

These results highlight the intricate relationship between colourants, lighting conditions, and human perception. The variations observed underscore the need to carefully consider lighting conditions and colourant concentrations in graphic technology applications to ensure accurate and consistent colour reproduction.

Based on the comparison of TM-30-18 results for LED lights at different colour temperatures (3000 K, 4000 K, and 6500 K), the preferable option depends on the specific requirements of the application and the pigments. Further exploration could delve into the underlying mechanisms of colour perception, aiding in the refinement of colour management strategies in practical applications.

In summary, the comprehensive analysis conducted in this study sheds light on various critical aspects of colour rendition and its response to differing illuminant properties. The findings offer valuable insights into the intricate relationship between illuminant characteristics and colour performance metrics. By identifying and visualising trends in colour fidelity, chroma, and hue shifts across different entries, this research provides a comprehensive understanding of the overall colour rendition performance. Furthermore, examination of how alterations in illuminant properties correspond to shifts in colour performance metrics uncovers the nuanced connections between these factors. Grouping entries based on illuminant properties serves as a robust approach to comparing colour rendition variations under distinct lighting conditions. Delving deeper, the investigation of outliers or extreme shifts in colour fidelity and other metrics offers a deeper comprehension of their connection to specific illuminant properties.

It is concluded that the absorbance of light by oil and acrylic colours depends on various factors such as the composition of the pigment, the thickness of the paint layer, and the specific properties of the paint medium.

In summary, oil paints generally absorb more light than acrylic paints due to their higher pigment concentration and thicker consistency. Acrylic paints, on the other hand, are generally less absorbent than oil paints. Acrylic paints have a more translucent quality, allowing more amount of light to pass through the paint layer.

Natural daylight or full-spectrum lighting is often preferred for viewing both oil and acrylic paintings and their samples, although LED lights with lower colour temperatures, such as 3000 K and 4000 K with high CRI up to ≥90 can it be the most preferable for illuminating acrylic artworks.

These lights generally exhibit higher colour fidelity and a wider colour gamut compared to higher colour temperatures like 6500 K. The balanced spectrum of lower colour temperatures enhances the rendition of various hues, contributing to accurate colour representation and visual clarity.

This study, by untangling the complexities of colour rendition under varying illuminations, contributes to enhancing our knowledge of colour management and reproduction strategies, ultimately benefiting applications in graphic technology and related fields.

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