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Evaluation of Lightness Preference of Images on OLED and QLED Displays

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Abstract

This research investigated the influence of lightness, lightness contrast, observer characteristics, and display types on image preference and perception. Previous studies have emphasized the importance of color attributes in shaping image quality; in this study, we explored lightness attributes using CIECAM16 color space. Four experiments were conducted on OLED and QLED displays, during which participants adjusted color attributes of images to their preference and rated their preferred images relative to reference images. The results indicated that lightness attributes significantly impact image preference, and that observer characteristics and image content influence lightness preference on each display type.

Introduction

Lightness is defined as the brightness of a color relative to the brightness of a reference white [1]. The perception of lightness involves a non-linear mechanism in human visual processing. This nonlinearity has also been empirically observed in image quality models, particularly in the relationship between image quality and perceptual attributes [2]. Additionally, several color phenomena, such as the Stevens effect and the Bartleson-Breneman effect, are associated with lightness perception and have significant effects on image contrast perception [3]. Image preference refers to the tendency of individuals to favor certain visual images over others based on aesthetic appeal, emotional response, or cognitive associations [4]. This research indicates that lightness perception is quite likely to impact image preference.

Previous studies have highlighted the importance of color attributes such as lightness, chroma, and lightness contrast in shaping image quality and viewer preferences. For example, Pei et al. conducted a subjective video quality assessment on TV displays and observed an increasing trend in preference for higher display brightness levels [5]. Zhu et al. demonstrated that vividness and chroma are critical for determining image naturalness, while clarity and lightness contrast exert a more substantial influence on image preference. Their cross-cultural study also revealed that Chinese observers prefer more colorful images compared to German observers [6]. Safdar et al. examined saturation and vividness in the Jzazbz color space and proposed a perceptual vividness scale to improve naturalness and preference in images [7, 8].

When analyzing complex images, relying on the maximum and minimum luminance pixels does not always align with perceived contrast across the entire image. Research indicates that perceived image contrast, influenced by factors such as lightness, chroma, and sharpness, significantly affects observer preferences and quality judgments. For example, manipulations in image lightness can alter perceived contrast, thereby affecting aesthetic appeal. Studies have shown that images with adjusted lightness levels, even when maintaining identical white and black points, are perceived differently in terms of contrast and preference. This suggests that the human visual system integrates multiple image characteristics to form judgments about image quality and attractiveness [9, 10].

Other factors have also been proven to influence image preferences, such as observer's demographic factors, image content, display technology, and others. The research of Beke et al. identified significant differences in color image preferences between younger and older observers [11]. Park et al. investigated how people perceive image quality differently depending on content type. Their experiments concluded that genre-specific adjustments, such as enhanced saturation for sports scenes, are necessary [12]. Seong et al. conducted experiments on different display types and found that OLED displays generally provide higher image quality than LCD displays due to their greater colorfulness [13].

The goal of this research is to explore the lightness preference in image quality perception, along with its relationship to other influencing factors, such as observer characteristics, image content, and display types. Four psychophysical experiments were designed to investigate the impact of lightness and lightness contrast on image preference and compared the performance of two display technologies: OLED and QLED. In addition, the role of content type and the observer's characteristics, such as age, gender, and cultural background, were analyzed. The insights into the interplay between lightness perception and image preference gained in this research can be applied to improve image quality.

Figure 1: The TV displays setup. Only one TV was used at a time in these experiments. The other was covered with a black cloth.

(a) Reduce lightness 20 units (b) original image (c) boost lightness 20 units

Figure 2: The Example of soccer image in three lightness levels

Experimental Methodology

Stimuli and Lighting Condition

The experiments were conducted in the MCSL Perception Lab under average lighting conditions. The study included 14 4K SDR images of different content (listed in the Appendix), selected to represent various categories such as bright and dark scenes, diverse skin tones, and both animated and real-life scenes. Two 4K TV displays, OLED(S95D) and QLED(QN90D), with a peak luminance of 220 $cd \cdot m^{-2}$ and 600 $cd \cdot m^{-2}$ respectively, were used. The display setup is shown in Figure 1.

Before presenting the stimuli, machine learning-based display models were created to convert the RGB values of the OLED and QLED displays to XYZ (tristimulus values). These XYZ values were then converted to the CIECAM16 color space [14] to apply color enhancements. Two enhancement methods were used to adjust the lightness and lightness contrast attributes:

f_{color}: Lightness

The lightness of each content was adjusted linearly from the original, either increased or decreased, using J values in the CIECAM16 color space while keeping other attributes constant.

To ensure that pixel values remained within a perceptually appropriate lightness range and the color gamuts of each display, a “bathtub” distribution was applied to the lightness adjustments. This distribution helped manage extreme values by moderating the changes at the higher and lower ends of the lightness range, creating a smooth transition that prevents unnatural shifts in lightness. The use of the bathtub distribution ensures that changes in lightness are spread consistently across the image, enhancing perceptual balance while allowing for global adjustments.

$$J' = J + J_{change} \tag{1}$$

$$J_{change} = \frac{1}{J+k} + \frac{1}{(100+k)-J} \tag{2}$$

Figure 2 illustrates the effect of lightness adjustments on an example image. Figure 2b shows the original image, which was used as the reference, Figure 2a presents a version with the lightness reduced by 20 units globally. Figure 2c displays the same image with the lightness increased by 20 units. These adjustments provide a clear visual example of how global lightness changes affect overall image lightness, while the bathtub distribution maintains smooth gradations within the modified range.

f_{color}: Lightness Contrast

Lightness contrast is defined as the difference in lightness between the regions of interest in the image. To explore the effects of lightness contrast on observer preferences, a range of lightness contrast adjustments was applied to each content in the experiment. The lightness contrast distribution followed a controlled pattern, encompassing low, medium, and high contrast levels, while the global contrast was held constant.

Lightness contrast was adjusted using an S-curve function applied to the lightness scale in the CIECAM16 color space. Each content's lightness scale was divided into low and high lightness segments based on its mean lightness. Then, Equation 3 was applied to adjust the contrast of the content. This function adjusted the contrasts between the minimum and maximum lightness values while keeping these values consistent between the renderings for a given image content. This nonlinear adjustment enabled contrast modification in the mid-lightness range without affecting global brightness or altering the darkest and brightest regions of the image. The lightness values J of the image were mapped as follows:

$$J' = \begin{cases} \left(\frac{J-J_{min}}{J_{mean}-J_{min}}\right)^{\gamma} \times (J_{mean} - J_{min}) + J_{min} & \text{if } J \leq J_{mean} \\ \left(\frac{J_{max}-J}{J_{max}-J_{mean}}\right)^{\gamma} \times (J_{mean} - J_{max}) + J_{max} & \text{if } J \geq J_{mean} \end{cases} \tag{3}$$

where J_{min}, J_{mean}, and J_{max} represent the minimum, mean, and maximum lightness values in the original image. The J_{mean} was used as the midpoint to divide the image lightness into two segments to achieve the adjustment. The parameter γ controls the degree of non-linearity and determines the strength of the contrast adjustment.

A sequence of contrast levels was applied, ranging from low to high, with values chosen based on perceptual thresholds:

- Low contrast: $\gamma < 1$, yielding low contrast.
- Original contrast: $\gamma = 1$, resulting in no contrast enhancement.
- High contrast: $\gamma > 1$ providing pronounced contrast boosts.

Figure 3 is an example of three levels of lightness contrast for the soccer content. Figure 3b is the original image, Figure 3a has low contrast, and Figure 3c is the high contrast image.

Experimental Procedure

This study was designed to assess observer image preferences. Two types of TVs, OLED and QLED, were utilized to examine the effects of two color attributes, lightness and lightness contrast. Four experiments were conducted, each consisting of two sections: preferred image selection and image preference

(a) Low contrast, $\gamma = 10^{-0.4}$ (b) Original image, $\gamma = 1$ (c) High contrast, $\gamma == 10^{0.4}$

Figure 3: The Example of soccer image in three lightness contrast levels

rating. To ensure consistency, the displays were covered when the other TV was in use, Figure 1. Each TV was given a warm-up period of ten minutes, and each observer was asked for a one-minute adaptation period before each experiment. The four experiments followed the same procedure. The detailed procedure for the experiments is described below.

Section I: Select Preferred Image

In this section, we asked observers to adjust the contents to their preferred rendering. Images were displayed one at a time on either the OLED or QLED display, with each display assessed independently.

A custom-designed Matlab graphical user interface (GUI) facilitated participant interaction. Each observer used specific keys to adjust the image's color attributes in real time:

- The 'up' and 'down' arrow keys were designated for making small incremental adjustments (for Lightness - 2 units of J in CIECAM16, for Lightness Contrast 1 step) to the displayed image's color attributes.
- The 'left' and 'right' arrow keys allowed for larger adjustments (for Lightness - 6 units of J in CIECAM16, for Lightness Contrast 3 steps), enabling more noticeable shifts in color attributes.

A beep sound reminded participants that they had made the adjustment. Participants were instructed to use these controls to navigate through adjustments in lightness and lightness contrast until they identified an image that matched their subjective preference. Fourteen image contents were presented in a random order, and the experiment was repeated twice. Upon finalizing their preferred settings, participants confirmed their choice, and the preference data were recorded and used in Section II.

Section II: Rate Selected Image

Following the image selection phase, each observer participated in a rating session. The images selected during Section I were saved and presented to the observer in a randomized sequence to minimize any sequential bias. Each rating trial consisted of the following sequence:

- Initial Image Display: The first image, serving as the reference, was displayed for 3.5 seconds.
- Noise Background: After the initial display, a noise background image was shown for 1 second to reduce afterimage effects.
- Preferred Image Display: The observer's preferred image was then displayed for 3.5 seconds.

Observers were instructed to rate the adjusted image in comparison to the reference image. Ratings were provided on a scale from 0 to 100, where:

- A score of 50 indicated no preference difference between the original and the selected image.
- A score below 50 indicated a preference for the original (reference) image over the adjusted one.
- A score above 50 indicated a preference for the adjusted image.

These ratings were used for a quantifiable comparison between the observer-selected images and the original images, providing insight into the perceptual impact of different color adjustments on the viewers' preference.

Participants

Individuals with normal color vision were recruited as participants in the experiments. Each participant provided informed consent after being briefed on the study procedures. RIT's Human Subjects Research Office has approved this experiment. A total of 31 observers participated across four experiments, with the number of observers per experiment detailed in Table 1. All participants were paid volunteers.

Table 1: Experiments and the number of observers

Experiments / Display	Lightness	Lightness Contrast
QLED	31	21
OLED	30	20

A demographic survey was conducted to gather information about the participants. The survey collected data on age, gender, region, expertise in color/image science, and feedback on the experiments. Among the participants in the lightness experiments, 65% identified as women, 22% as men, and 13% as non-binary. Geographically, 58% were from North America or Europe, while 42% came from other regions. Additionally, 58% had domain expertise in color or image science. In terms of age, 64% were younger than 25 years old. For the lightness contrast experiments, 71% of participants identified as women, 19% as men, and 10% as non-binary. Geographically, 52% were from North America or Europe. In these experiments, 14% were younger than 25 years old. Most observers, 86%, in the lightness contrast experiment had a background in color or image-related fields. The overall demographic factors are shown in Figure 4.

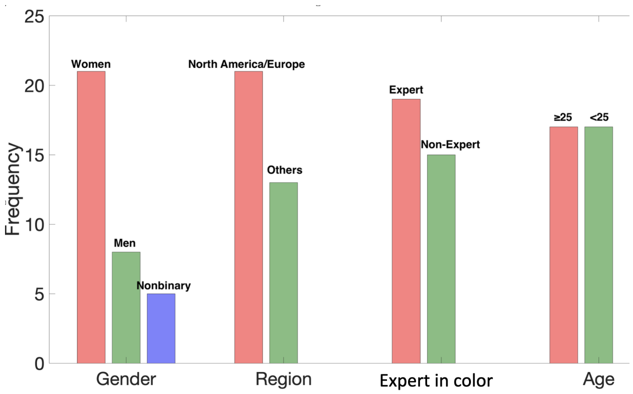

Figure 4: The overall observer demographic factors

Results

Four experiments were conducted to evaluate two displays and two color attributes. In Section I of the experiment, participants adjusted the image to their preference. These preferred images along with their corresponding lightness or lightness contrast levels were recorded. In Section II, the preferred images were compared with reference images. The results were recorded as preference scores.

Results: Lightness

OLED Lightness

The frequency distributions of these lightness changes for each image are shown in Figure 5. Participants exhibited clear trends in their preferences based on specific image content. For images 2, 5, 7, 10, 12, and 13, the preferences increased or slightly increased in lightness. In contrast, for images 1, 4, 6, 9, and 11, observer preferences were distributed across the entire selected lightness range. Images 1, 2, and 3 are all in the animation category. The results showed that observers preferred a wide range of lightness renderings for image 1, a mid-level lightness rendering for image 2, and a lower lightness rendering for image 3.

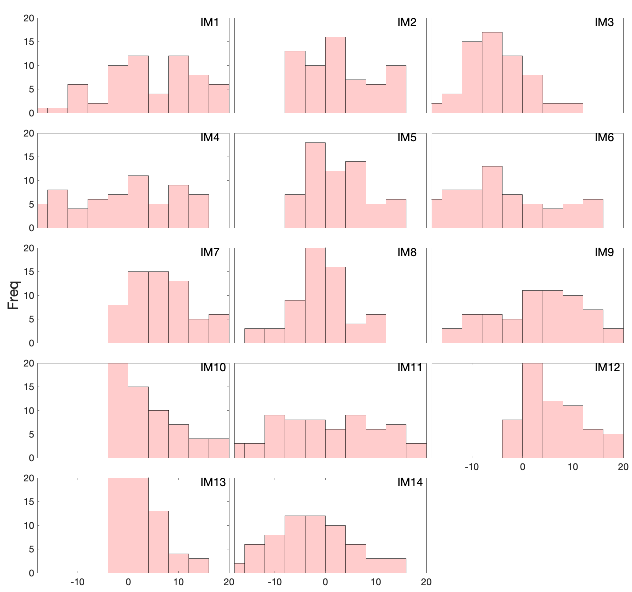

Figure 5: OLED Lightness: frequency distributions of the lightness changes

t-test

A one-sample t-test was conducted to determine whether changing the lightness level improves image preference on the OLED display. The preference score served as the test variable, where scores above 50 indicated that the adjusted image was preferred over the original. The null hypothesis stated that the mean preference score would not significantly exceed 50.

The results showed that the mean preference score was significantly greater than 50 (t(839)=12.21, $p = 5.42 \times 10^{-32}$). The 95% confidence interval for the mean preference score was [55.08, ∞].

These findings suggest that adjusting the lightness level statistically significantly improves image preference on the OLED display.

ANOVA

A five-factor ANOVA was performed to examine the effects of Content, Gender, Country, Expertise, and Age on image lightness preference. The results are summarized in the Appendix. The analysis revealed that all five factors are statistically significant factors in lightness preference. Figure 6 presents the detailed results for each factor. Regarding Gender, there was a significant difference between men and women observers, with men preferring brighter images compared to women. The preferences of non-binary observers fell between those of the other two genders. Significant differences in lightness preferences were observed between the scenes. Participants preferred brighter images for images 7 and 12, while images 3, 4, 6, 8, and 14 were generally preferred to be dimmer than others. A medium-lightness rendering was preferred for the remainder of the images. There were significant differences between the North American/European participants and participants from other countries in that North American/European observers preferred brighter images. Additionally, significant differences were found between older and younger observers in lightness preferences. Older observers preferred brighter scenes. Expertise was also a significant factor, as par-

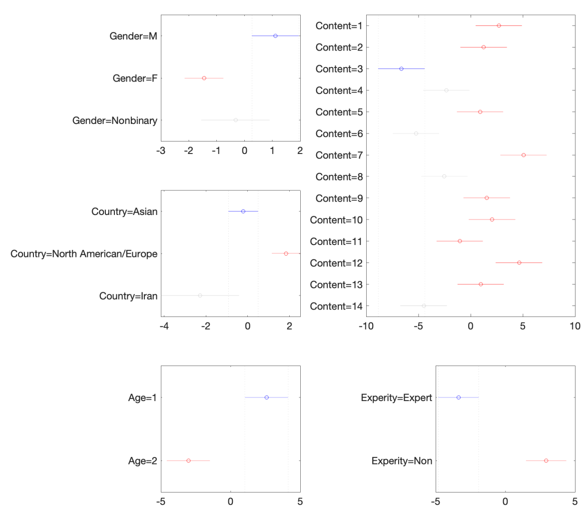

Figure 6: Multiple comparison results of each factor in OLED Lightness experiment. Age 1 indicates older observers and Age 2 younger observers.

ticipants with the background in color/ imaging science preferred dimmer images relative to the non-experts.

QLED Lightness

The frequency distributions of lightness changes on the QLED display are shown in Figure 7. The participants tended to adjust the image dimmer or slightly dimmer to their preferences for many of the images. We suspect that this may be due to the panel of the QLED display being substantially brighter than the OLED display.

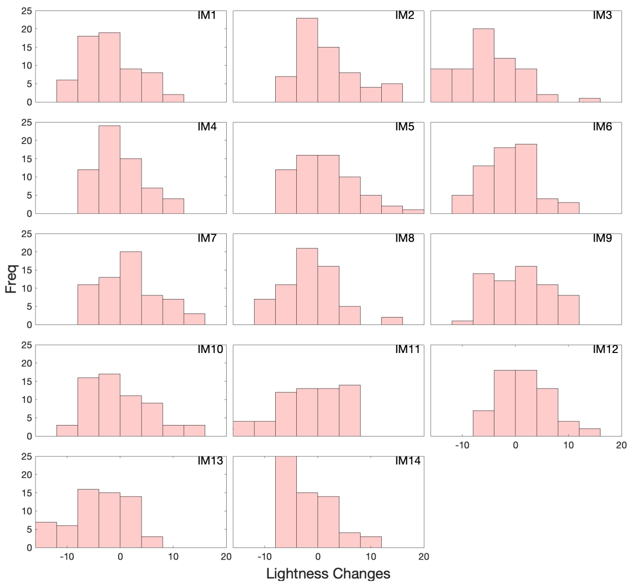

Figure 7: QLED Lightness: frequency distributions of the lightness changes

t-test

A one-sample t-test was conducted to determine whether changing the lightness level improves the image preference on the QLED display. The results showed that the mean preference score was significantly greater than 50 (t(839)=13.33,$p = 5.52 \times 10^{-22}$), the 95% confidence interval for the mean preference score was [53.34, ∞]. which suggests that adjusting the lightness level statistically significantly improves the image preference on the QLED display.

ANOVA

A five-factor ANOVA was conducted to examine the effects of Content, Gender, Country, Expertise, and Age on image lightness preference on the QLED display. The results are summarized in the Appendix.

The analysis revealed that Content, Country, Age, and Expertise are significant factors in lightness preference, while Gender ($p = 0.1432$) does not appear to have an impact on lightness preference on the QLED display.

Figure 8 presents the detailed results for each factor. The significant factors identified were image content and country, whereas gender was not significant. Regarding gender, no statistically significant differences were observed among the groups. All genders preferred a relatively low lightness rendering.

For content, many images were adjusted to lower lightness rendering, with images content 3 and 13 being dimmed more significantly than others. Differences were also observed among country groups. Participants from North America and Europe preferred brighter images compared to other country groups.

Significant differences were found in age groups. The result was similar to the lightness preference in the OLED display. The lightness preference of the older group (Age = 1) differed from that of the younger group (Age = 2), indicating a relatively brighter preference among older participants. Similar results were found for the Expertise factor. Experts preferred dimmer images than the non-experts.

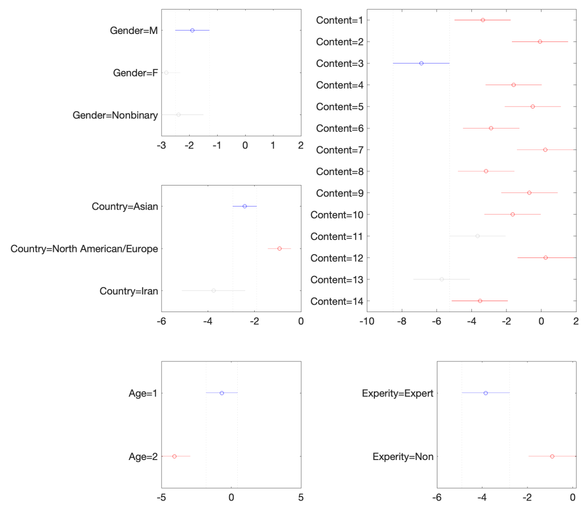

Figure 8: Multiple comparison of each factor in QLED Lightness experiment. Age 1 indicates older observers and Age 2 younger observers.

Results: Lightness Contrast

OLED Lightness contrast

The frequency distributions of OLED lightness contrast responses are presented in Figure 9. For contents 1 and 5, observers preferred decreased contrast. For contents 13 and 14, a contrast level that was slightly lower than that of the original images was preferred. The preferences were distributed differently, with no clear trend observed for the images.

t-test

A one-sample t-test was conducted to determine whether changing the lightness contrast level improves image preference on an OLED display. The results showed that the mean preference score was statistically significantly greater than 50 (t(559)=8.02,$p = 3.06 \times 10^{-15}$). The 95% confidence interval for the mean preference score was [53.34, ∞]. The results suggested that adjusting the lightness contrast level significantly improves image preference.

ANOVA

Four factors - Content, Gender, Country, and Age - were used in the ANOVA to examine their effects on image lightness contrast preference. Fewer non-expert observers participated in the lightness contrast experiment, so expertise was not included as a factor. The results are summarized in the Appendix.

Figure 10 presents the detailed results for each factor. The analysis indicates that Content and Country were significant fac-

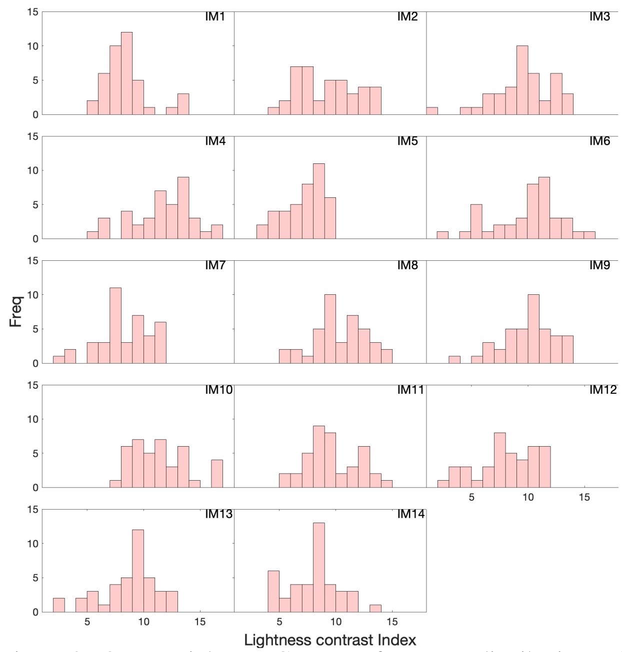

Figure 9: OLED Lightness Contrast: frequency distributions of the lightness contrast changes

tors in lightness contrast preferences. The image content, as shown in Figure 10b, is particularly impactful. Participants preferred a reduction in contrast for contents 1, 5, 7, 12, 13 and 14. In contrast, for image contents 4 and 10, they preferred an increase in contrast. For other contents, participants favored the middle lightness contrast rendering. Country was also found to be a significant factor, with Asian observers preferring less contrast compared to observers from North America and Europe.

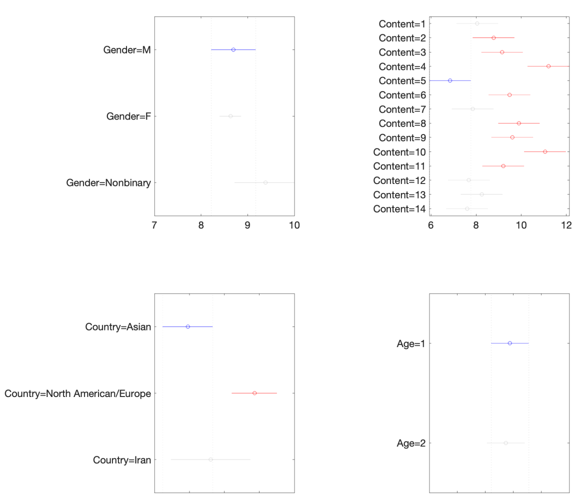

Figure 10: Multiple comparisons of each factor in OLED Lightness contrast experiment

QLED Lightness contrast

The frequency distributions of QLED lightness contrast responses are presented in Figure 11. For most of the image contents, observers generally preferred low or medium-low lightness contrast renderings. In image content 3 and 6, larger variations in preference were shown. The lightness of the higher-lightness region was reduced when applying lower contrast rendering. we suspect that the preference for lower contrast may be due to the brightness of the QLED panel.

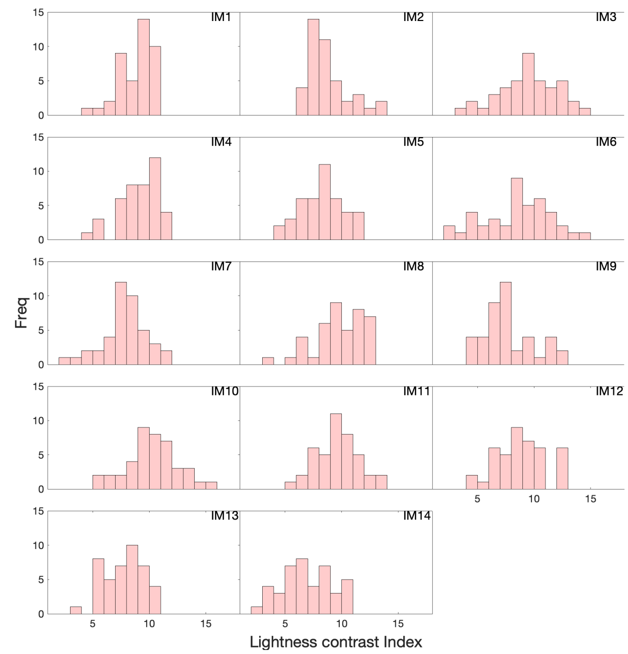

Figure 11: QLED Lightness Contrast: frequency distributions of the lightness contrast changes

t-test

A one-sample t-test was conducted to determine whether changing the lightness contrast level improves image preference on the QLED display. The results showed that the mean preference score was significantly greater than 50 (t(587)=4.86,$p = 7.72 \times 10^{-7}$). The 95% confidence interval for the mean preference score was [51.3, ∞]. Adjusting the lightness contrast level statistically significantly improves image preference on the QLED display.

ANOVA

A four-factor ANOVA was conducted to evaluate the effect of Content, Gender, Country, and Age on lightness contrast preference. Only 14% of non-expert observers participated in the QLED display, so the Expertise factor from our analysis was removed. The results, presented in the appendix, show that significant differences were observed for Content, Gender, and Country. However, the effect of Age was not significant.

The significant main effect of Content suggests that preferences for lightness contrast varied significantly across different Content. Gender also exhibited a significant effect. A significant difference was observed between the female and non-binary groups, while no significant difference was found between male and female groups. Country emerged as a significant factor, indicating that regional differences may play a role in lightness contrast preference. In contrast, Age did not have a significant effect on lightness preference, suggesting that preferences were consistent across different age groups.

Figure 12 presents results for each factor. For the Gender factor, the non-binary participants preferred higher contrast rendering than the other two genders. North American/European participants preferred higher contrast images compared to other participants. Overall, observers preferred less contrast in images 7, 9, 13, and 14 compared to the rest of the contents.

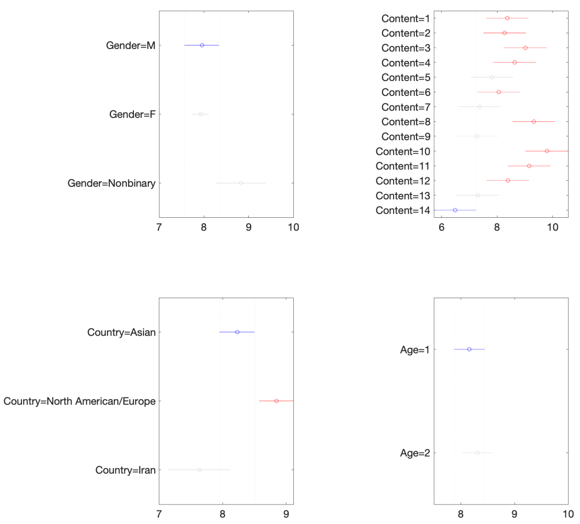

Figure 12: Multiple comparisons of each factor in QLED Lightness contrast experiment

Discussion and Conclusion

This study investigates lightness and lightness contrast preferences across different display types, along with the impact of observers' characteristic factors. We conducted four experiments focusing on lightness and lightness contrast on OLED and QLED displays under identical ambient environment settings. For each experiment, the preferred images were selected, and then they were compared with the original images. The experimental results contain the preferred image and the preference scores.

First, we confirmed whether adjustments made by subjects to the lightness (contrast) of images affect their preferences for those images. The preference scores from four experiments were used in the one-sample t-test, and the results showed that adjusting these attributes improved perception of image quality. We

TV	Color attributes	Content	Gender	Country	Age	Expertise
OLED						
	Lightness	✓	✓	✓	✓	✓
	Lightness contrast	✓	✗	✓	✗	
QLED						
	Lightness	✓	✗	✓	✓	✓
	Lightness contrast	✓	✓	✓	✗	

Figure 13: ANOVA Results for Image Lightness Preference Factors (✓: Significant, ✗: Non-Significant)

then conducted ANOVA analyses on our datasets to identify factors, such as Content, Gender, Age, and Country, that influence image preferences. The results indicated similarities between the two different types of displays across certain factors, such as Content, Country, and Age. Content emerged as a significant factor. Traditional content categories were insufficient to capture the observed differences. For example, content labeled 1-3, all animated images, showed significant differences among the lightness experiments. Country was another influential factor. Participants from North America and Europe preferred brighter and higher-contrast images compared to participants from other regions. The results demonstrated a significant impact on image preference, indicating that regional differences affect preferences.

Expertise was another factor that was tested in the lightness experiment, and it showed that it was a significant factor in image lightness preference.

Age was divided into two groups. The results indicated that it is significant in lightness perception. However, for lightness contrast, the age factor was not significant. This change may have been affected by the shift in the percentage of observers under 25 years of age from 50% in the lightness experiment to 14% in the lightness contrast experiment. Future work is needed to further explore this question. The results of the Lightness experiment suggest that age influences image preference. The older group preferred brighter images compared to the younger group, possibly aligning with age-related changes in the visual system. To gain more insight, additional older observers are needed for a more detailed analysis. Regarding the gender factor, different results were observed between the OLED and QLED displays. For the lightness experiment, gender was significant on the OLED display, whereas in the lightness contrast experiment, gender was significant on the QLED display.

While there are distinct characteristics between the two displays, the frequency distribution plots of the selected contents indicate specific trends for each display in the Lightness experiments. For the QLED display, there was an overall trend where observers tended to tune down the lightness for all content. In contrast, the OLED display showed no significant trend. Regarding the lightness contrast experimental results, low to medium-low contrast was preferred on the QLED display. To achieve this rendering, the high-lightness regions in the image were dimmed. The underlying reason might be that the QLED display was brighter than the OLED display.

This study highlights the significant impact of lightness and lightness contrast on image preferences across OLED and QLED displays. Through these experiments, it was demonstrated that both image content and individual observer characteristics, such as gender, cultural background, and expertise, play significant roles in shaping preferences. Our findings revealed that lightness adjustments consistently enhance image appeal, with preferences varying based on the interplay of content type and observer demographics. Similarly, lightness contrast, when optimized, significantly influences visual preference, emphasizing the importance of tailored image processing.

We believe our findings will provide a strong foundation for the development of display technologies and image quality enhancement algorithms, particularly in applications requiring personalized adaptive, content-based adjustment and user-specific visual optimization. Future work includes identifying key factors influencing the impact of image content.

Acknowledgements

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Susan Farnand is an Associate Professor and the Graduate Program Director of the Program of Color Science at the Rochester Institute of Technology (RIT). Her research interests center around human color vision and perception and include color imaging, individual differences in color vision, visual attention, image quality metrics, color 3D printing, and color reproduction in archival applications. Prior to joining RIT, Dr. Farnand was a senior research scientist at Eastman Kodak Company working primarily on projects in perceptual image quality measurement and modeling. She holds a BS in Engineering from Cornell University and an MS in Imaging Science and a PhD in Color Science from RIT. Dr. Farnand recently completed her term as President of the Society for Imaging Science and Technology.

Appendix

The lightness contrast is indexed from 1 to 17, where 1 represents the lowest contrast and 17 represents the highest contrast. The γ values range from $10^{-0.4}$to $10^{0.4}$, with each step increasing the exponent by 0.05. A smaller γ value corresponds to a lower contrast index.

Table 2: Anova results of lightness preference experiment on the OLED display

ID	Mean Difference	df	Mean Sq	F	p
Content	10406.2	13	800.48	14.72	0
Gender	837.7	2	418.84	7.7	0.0005
Country	1136.5	2	568.25	10.45	0
Age	680.1	1	680.12	12.5	0.0004
Expert	981.8	1	981.82	18.05	0
Error	46120.8	848	54.39		
Total	60055.7	867			

Table 3: Anova results of lightness preference experiment on the QLED display

ID	Mean Difference	df	Mean Sq	F	p
Content	3889.2	13	299.17	10.39	0
Gender	112.2	2	56.08	1.95	0.1432
Country	567.6	2	283.81	9.86	0.0001
Age	248.4	1	248.36	8.63	0.0034
Expert	215.6	1	215.59	7.49	0.0063
Error	24416.7 848	28.79			
Total	29138.8 867				

Table 4: Anova results of lightness contrast preference experiment on the OLED display

ID	Mean Difference	df	Mean Sq	F	p
Content	861.67	13	66.28	10.92	0
Gender	23.9	2	11.95	1.97	0.1406
Country	68	2	34.00	5.6	0.0039
Age	0.29	1	0.29	0.05	0.8276
Error	3284.08 541	6.07			
Total	4310.5	559			

Table 5: Anova results of lightness contrast preference experiment on the QLED display

ID	Mean Difference	Df	Mean Sq	F	P
Content	465.31	13	35.79	8.19	0
Gender	33.99	2	16.99	3.89	0.0211
Country	70.38	2	35.19	8.05	0.0004
Age	1.18	1	1.18	0.27	0.6041
Error	2487.65	569	4.37		
Total	3131.26	587			

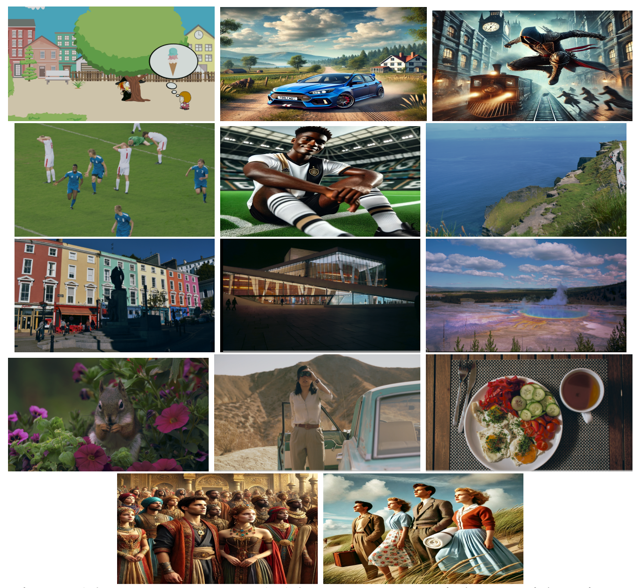

Figure 14: Image content 1-14. Due to copyright considerations, images 2, 3, 5, 13, and 14 are represented by images generated using ChatGPT.