

Brightness Scales Above and Below Reference White via Maximum Likelihood Difference Scaling (MLDS)

Soonhyeng An*, Youngshin Kwak*, Junghyun Ham**, Myung Young Lee**

*Dept. of Biomedical Engineering, Ulsan National Institute of Science and Technology, Ulsan, Korea

**TV Picture Quality Team, HE Company, LG Electronics, Pyeongtaek, Gyeonggi-do, Korea

Abstract

Brightness scales were obtained using Maximum Likelihood Difference Scaling method for the colors having higher or lower luminance than that of the reference white. Results showed that CIELAB L^* effectively predicts perceived brightness for colors brighter than the background and the background luminance is the main factor affecting the brightness scale.

Author Keywords

Brightness; reference white; Maximum Likelihood Difference Scaling; MLDS; color brighter than white.

1. Introduction

In conventional displays, the peak luminance generated using a white signal was fixed regardless of the input scene. However, thanks to various technological advancements, the peak luminance can now vary for each frame. For example, in the case of WRGB OLED (WOLED) displays utilizing a white-boost function, the peak luminance changes based on the Average Pixel Level (APL) of the input frame [1]. Dark scenes tend to exhibit higher peak luminance compared to bright scenes. In such cases, viewers may perceive colors that appear brighter than the white in the previous scene. However, the working range of current brightness prediction models is limited to the fixed reference white. Therefore, to fully explain the color appearance of displays with dynamically changing peak luminance, brightness prediction models capable of predicting the brightness of colors exceeding the reference white are needed.

In this study, brightness scales were obtained using the Maximum Likelihood Difference Scaling (MLDS) [2] method with stimuli covering up to 2.4 times the reference white luminance, to evaluate the performance of CIELAB for the

range where L^* exceeds 100.

2. Experiments

The experiment was conducted in a dark room using a SONY BVM-X300 OLED monitor. Figure 1 illustrates the screen presented to the observers. On a uniform gray background with decoration colors in the peripheral area, four test stimuli - two pairs of color patches - were displayed at the center. Above the color pairs, a reference white patch, representing the brightest color patch in the scene without the test stimuli, was shown.

The four test stimuli were selected from a predetermined set of stimuli with uniformly distributed CIELAB L^* values. The L^* difference between colors in a pair was constrained to be less than four L^* difference steps.

The observers' task was to select the pair (left or right) that exhibited a larger perceptual difference. The color pairs were displayed for 2 seconds to prevent adaptation to the stimuli, while the reference white patch remained visible throughout the evaluation.

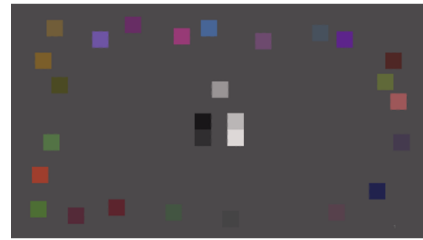


Figure 1. Example of test stimulus

Table 1. Experimental Sessions

Sessions	Lum. Range (cd/m ²)		Ref. white (cd/m ²)	No. of Stimuli	No. of Trials	No. of Observers
	Low	High				
Gray H-1	0.00	49.30	270	11	308 x 3 times	11
	39.34	237.04		11	308 x 3 times	11
	206.43	658.01		11	308 x 3 times	11
Gray H-2	0.00	30.40	270	11	308 x 3 times	11
	14.60	102.90		11	308 x 3 times	11
	64.70	243.20		11	308 x 3 times	11
	174.10	475.20		11	308 x 3 times	11
	363.10	656.20		8	70 x 3 times	11
Gray H-3	0.00	656.20	270	15	965 x 3 times	11
Gray L	0.00	194.58	80	15	965 x 3 times	11
Gray C1-4	36.84	486.44	400	10	202 x 3 times	7
Gray No ref	5.98	398.76	200	12	447 x 3 times	9
Black	5.98	398.76	200	12	447 x 3 times	9
Light Gray	5.98	398.76	200	12	447 x 3 times	9

Table 1 summarizes the experimental conditions. The luminance of the reference white was 270 cd/m², except Gray L session, where it was 80 cd/m². Gray sessions had L* value of 50 as a background. Gray H-1, H-2, H-3 were designed to evaluate the luminance range effect of MLDS method. Gray H and Gray L were to evaluate the effect of reference white luminance difference. Gray C sessions were conducted using the chromatic test stimuli whereas the stimuli in the other sessions were neutral colors. Gray No ref session was conducted without a reference white patch. Black and Light Gray sessions had backgrounds with L* values of 0 and 80, respectively.

The observers' responses were converted to psychological scale, where the darkest stimulus psychological value is 0 and lightest stimulus psychological value is 1.

3. Experimental Results

The data analysis results revealed minimal differences in the brightness scale based on the luminance range of the test stimuli or the luminance of the reference white. Additionally, neutral colors and chromatic colors exhibited similar scales. The most notable effect was attributed to the background luminance.

Figure 2 compares the brightness scales (psychological values) of 'Black', 'Gray no ref', and 'Light Gray' sessions. Other sessions have the similar results with 'Gray no ref' session, as they all shared a background with an L* value of.

All three graphs in Figure 2 indicate that when the stimulus luminance is higher than the background luminance, the psychological values show a linear relationship with L*, suggesting that CIELAB effectively predicts the brightness of the colors with luminance greater than the reference white. However, a steep decrease in brightness was observed for stimuli with luminance lower than the background.

It is worth noting that this phenomenon was not observed in previous lightness or brightness scale experiments using magnitude estimation. The key distinction in this experiment is that dark and bright color pairs were compared side by side for

only 2 seconds. We believe this experimental setup closely reflects real video-watching conditions. Such a setup may have amplified the simultaneous contrast effect, making the darker pairs appear even darker compared to the brighter pairs.

4. Conclusions and Discussions

Brightness scales were obtained by comparing the brightness differences between two pairs of color patches using MLDS method under various conditions with stimuli covering up to 2.4 times the reference white luminance. Results showed that the background luminance was the main factor affecting the result.

For colors brighter than the background, CIELAB L* effectively predicts perceived brightness. However, for darker colors, simultaneous contrast effect strongly affects the brightness perception.

This study highlights the complexity of brightness perception in moving images. Further in-depth research is required to understand the dynamic changes in color appearance for moving images. For instance, given that the reference white did not influence the results, future studies should explore how to define the adapted white. Additionally, as this study focused solely on the relative brightness scale, other attributes should also be evaluated.

5. Acknowledgements

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6. References

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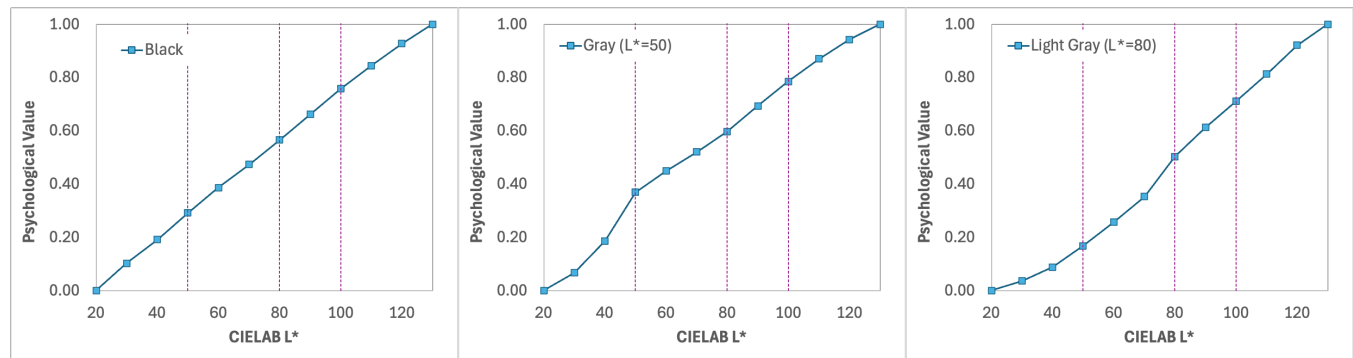


Figure 2. Brightness scale changes by background