Bright Surround Luminance and Perceived Image Contrast

Ari Kim[*1], Hong Suk Kim[1], Seung Ok Park[1], Ye Seul Baek, Youn Jin Kim[2,3]*
[1]Dept. of Physics, University of Daejin, Pocheon, Gyeonggi , Korea
Phone: +82-(0)11-377-9402, E-mail: ari-kim@daejin.ac.kr
[2]Dept. of Colour Science, University of Leeds, Leeds LS2 9JT, United Kingdom
[3]Now with Digital Printing Division, Samsung Electronics, Suwon, Korea

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Abstract

The theory of Bartleson and Breneman[1] that the perceived image contrast changes with surround luminance (the lighter surround provides higher contrast) was tested an over bright condition (8500cd/m²). Contrarily to the Bartleson and Breneman's results, we observed the fact that perceived contrast was decreased when surround luminance increased from dark to over bright through two sets of psychophysical experiments based upon both uniform gray patches and complex color images.

1. Introduction

In 1967, Bartleson and Breneman[1] investigated the changes in perceived contrast with respect to changes in the relative luminance of an image's surround. Their study revealed that the perceived contrast increased with increasing luminance level from dark to dim and to light, i.e. image contrast changes with surround (the lighter surround will provide higher contrast) – the Bartleson-Breneman effect. It was also confirmed by Liu and Fairchild (2006 & 2007).[2-3] In this study, the Bartleson-Breneman effect was tested under over bright surround condition (8500cd/m²). Since portable displays have been widely used under bright outdoor conditions, its effects on the human visual system and display should be studied.

2. Experimental

1) Setup

An LG FLATRON L1732S 19-inch liquid crystal display (LCD) was used in this study and a back light unit (BLU) using an array of CCFLs was placed behind the display. Luminance of the BLU reached up to 8500cd/m². All necessary colors were measured using a spectroradiometer (Minolta CS-1000) under dark viewing condition at a distance of 106cm. which is the 4 times of the display's width (26.5 cm).[5] Optical and colorimetric traits of the LCD and BLU were evaluated as subsequently introduced.

A. Display Evaluation

- Temporal Stability

A white patch was displayed on the LCD used in this study and the CIE XYZ values of the display's mid-point were measured every minute continuously for 180 minutes from the cold start. As shown in Figure 1, the tristimulus values became stable after approximately 120 minutes.

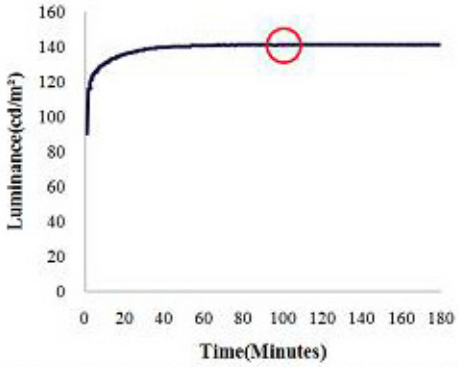


Figure 1 Temporal stability of CIEXYZ for the LCD

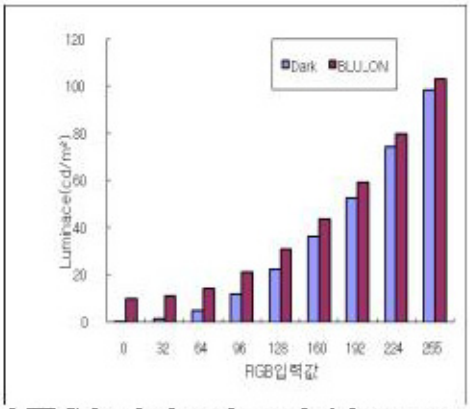


Figure 2 TRC for dark and over-bright surrounds.

- **Tone Reproduction Curve (TRC)**

The tone reproduction curve (TRC) represents the relationship between the digital input count and the resultant luminance. The nine equally spaced neutral patches reproduced on the mobile LCD were measured in terms of CIE XYZ values under both dark and 8500 cd/m² of surround illumination. Figure 2 shows typical power function shaped TRCs for the two surround conditions.

- **Spatial Uniformity**

A white patch was displayed on the mobile LCD screen and 5 unevenly distributed locations were measured. The center of LCD showed the highest luminance level, 98cd/m² and some luminance variations exist across the LCD screen. For the following experiments, location of test stimuli was restricted in the display's center area.

B. Back Light Unit (BLU) Evaluation

- **Temporal Stability**

Luminance of the BLU was measured every minitue from the cold start. It was sharply increased in the beginning and smoothly stabilized to about 8500 cd/m² after 120 minutes.

2) Method

A. Contrast Adjustment

In the first psychophysical experiment, method of adjustment experiment was conducted and observers were asked to manipulate physical contrast of each of given twelve images (See Figure 4.) until they satisfy the level of image contrast using Adobe Photoshop 7.0 under both dark and over-bright surround conditions.

B. Perceived Brightness Estimation

In turn, perceived brightness estimation experiment was performed in order to find factors affecting the change in image contrast revealed in the previous experiment. Nine grey patches were uniformly sampled across 8-bit RGB values (0 to 255). The observers, who participated in the previous experiment, performed perceived brightness magnitude estimations about the nine neutral patches displayed on the LCD The apparent brightness of the LCD's maximum white of which the RGB values are (255, 255, 255), was assigned as an arbitrary brightness magnitude value of 100. Prior to the brightness estimations, observers were required to memorize it in a dark room and judge a ratio of brightness of each test stimulus not only under dark but also under over bright surround conditions.

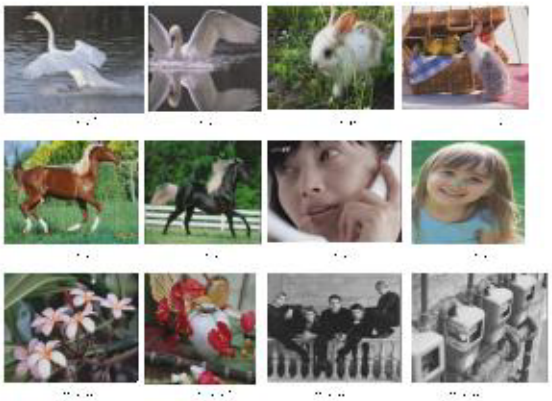


Figure 3 Test images used in the contrast adjustment

3. Results and discussion

Results can be divided into three main issues following experimental structure of Kim[4]: Quantifying the physical contrast, contrast variation and change in perceived brightness.

1) Quantifying Effects of Residual Light from BLU

Although the BLU was placed behind the LCD, a little amount of residual lights from the BLU affects the LCD can be found in reality and this is referred to as residual light. This consequently slightly increases luminance of stimulus on the LCD, e.g. 0.19 to 10 cd/m² for black and 98.50 to 103 cd/m² for white from dark to over-bright as shown in Table 1. In this study, the effects were quantified by means of computing Michelson contrast (See Equation 1) for both dark and over bright surround conditions. Michelson contrast was 0.996 for the former and 0.823 for the latter conditions and there was about 17% of contrast reduction from dark to over bright.

$$C_M = \frac{L_W - L_K}{L_W + L_K} \quad (1)$$

where L_W and L_K denote luminance of white and black, respectively.

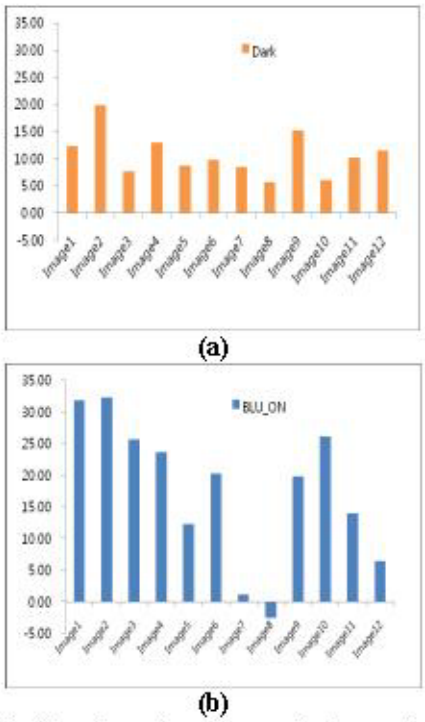
Table 1 Michelson contrast under dark and over-bright surrounds

Surround	Michelson Contrast
Dark (0cd/m²)	0.996
Over-Bright (8500cd/m²)	0.823

2) Contrast Adjustment

For the test images assessed, mean preferred contrast levels defined in Adobe Photoshop 7.0 are plotted in the ordinate of Figure 4. In general, a huge amount of image contrast reduction was found from dark to over bright. Approximately 50% reduction in Photoshop contrast unit was occurred from dark to over-bright.

The measurement results are counter to Bartleson and Breneman effect that the perceived contrast of images increased when the image surround was changed from dark to dim to light. They found that the dark surround of an image causes dark areas to appear lighter while having little effect on light areas. (White areas still appear white despite changes in surround.) The reason why there was little effect on light areas may be the fact that they investigated quite low ambient illumination levels (from dark to light). In addition, the residual light from BLU partially contribute to the contrast loss under over bright but its impact is not large as the surround luminance.



(a)

(b)

Figure 4 Preferred contrast for each image for (a) dark and (b) over-bright: BLU_ON

3) Perceived Brightness Estimation

The perceived brightness estimation data under dark together with over bright are provided in Figure 5. The abscissa represents the perceived brightness magnitudes of the neutral patches measured under dark. The ordinate represents their corresponding perceived brightness magnitudes under over bright. T perceived brightness estimation values are decreased in general, as the surround luminance increases from dark to over bright. However, they showed a nonlinear effect. Bartleson and Breneman (1967) concluded that white areas still appear white despite changes in surround but white appeared a lot darker (60 %) in our experiment.

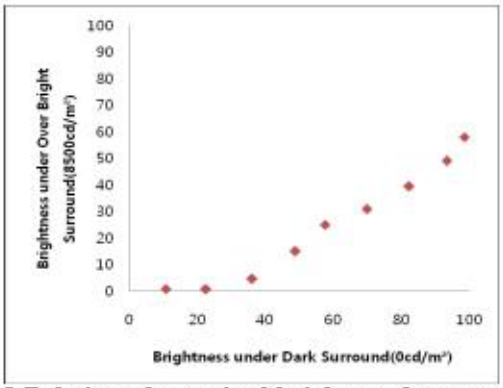


Figure 5 Relation of perceived brightness between dark and over bright

4. Summary

This study visually measured reduction of image contrast when surround luminance is set to 8500 cd/m² (over bright). About 50% reduction of image contrast in Photoshop contrast unit was found from dark to over bright. The measurement results are counter to Bartleson and Breneman effect. In future study, more psychophysical data will be collected under several surround conditions and variation of image contrast will be quantified. Plus, image contrast enhancement algorithm for bright outdoor viewing conditions can be considered.

5. References

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