Effects of Ambient Illumination on the Appearance of CRT Colors

Heui-Keun Choh, Du-Sik Park, Chang-Yeong Kim, and Yang-Seock Seo*
Samsung Advanced Institute of Technology, Kyungki-Do, Korea

Abstract

We investigated the effects of ambient illumination on the color appearance of CRT which was positioned in a room illuminated by experimental illuminants, F2, F5, and F8. The luminance of these illuminants were controlled at three levels. The observers adjusted a color patch on the CRT to find achromatic matching on a random color background. The chromaticity of the achromatic color was shifted toward that of the illuminant, which implies the change of the observer's chromatic adaptation state. The shift ratios, calculated in the uniform space u'-v', increased according to the increase of the distance between chromaticities of CRT white and those of illuminants and increased according to the increase of luminance level of the illuminants. These results were implemented in a monitor profile for a color management system to get more consistent color appearance of the CRT which was viewed under various ambient illuminations.

Introduction

Nowadays CRT is one of the most popular device to display color images. In many cases CRT is viewed under ambient illumination. When a CRT is viewed in this condition the color appearance of CRT is influenced by several factors such as chromaticity and luminance of the illuminant, viewing distance, viewing time, and the amount of the flare from the surface of the CRT, etc. In this situation device independent color matching can not accomplish the color appearance matching, because the change of the chromatic adaptation state of the observer is not incorporated. This topic was studied by Fairchild et al.[1] and Brainard et al.[2] using achromatic color matching method and by Katoh[3] and Berns et al.[4] using pictorial images for cross-media color reproduction. In this study we investigated the effect of chromaticities and luminance of ambient illumination on CRT colors using achromatic color matching. The relationship between the shift ratio of the adaptation state and the chromaticities and luminance of the illuminants was obtained, and these results were implemented in a monitor profile for a color management system[5] to get consistent color appearance of the CRT.

Experimental

In order to investigate the effect of ambient illumination on the appearance of CRT color we used achromatic color matching method on a CRT display. This method was used in previous works successfully to study chromatic adaptation.[1,2] However there were slight differences in those methods. In our method, one of the difference was that we used a random color dot background to mimic a pictorial image.

The test stimulus for the measurement of adaptation state subtended 2° and located at the center of the CRT. The initial chromaticity coordinates of the test stimulus was randomly chosen within ± 10.0 in a* and b* coordinate of CIE LAB in order to avoid highly saturated color as an initial test stimulus. The luminance of the test stimulus was set to 12 cd/m^2, which was 20% of CRT white.

The background which served as an adapting stimulus for CRT was square-shaped and extended 12.5°. In order to mimic a complex color image this background was composed by many random color dots. Luminance and CCT(Correlated Color Temperature) of the background was maintained approximately to 12 cd/m^2 and 9300K, respectively.

In this experiment three types of fluorescent lamps, F2, F5 , and F8 were used as experimental illuminants. The chromaticity coordinates of these illuminants are plotted in Figure 3 with those of CRT white(9300K) and D65 as a reference. The luminance of these lamps were controlled at three levels and the luminances of a white paper, placed on the CRT, were measured. The amount of flare was also measured at the center of the CRT. These values are listed in Table 1.

Table 1. The Measured Luminance of a White Paper on the CRT and Flares from the CRT (cd/m^2).

Level	Luminance of a white paper			Flares from the CRT		
	F2	F8	F5	F2	F8	F5
A	33	32	35	1.8	1.8	2.1
B	61	63	59	3.7	3.8	5.2
C	95	98	90	5.5	5.7	5.2

Results and Discussion

Effect of Background Size

In order to investigate the effect of background size on the adaptation states, the achromatic matching experiments were performed under the experimental illuminant F2 using seven different sizes of background from 5.0° to 20.0° in the step of 2.5°. The luminance was fixed to 61 cd/m^2. The effect of ambient illumination was estimated in terms of shift ratio. Shift ratio was defined as the ratio of the distance between CRT white and adaptation point to the distance between CRT white and the illuminant white in u'-v' space as represented in Figure 1.

The shift ratios of the achromatic test stimulus according to the different sizes of backgrounds are plotted in Figure 2. The shift ratio was saturated at the background size of 12.5 degree. This size of background was used for further experiments to avoid the effect of background size.

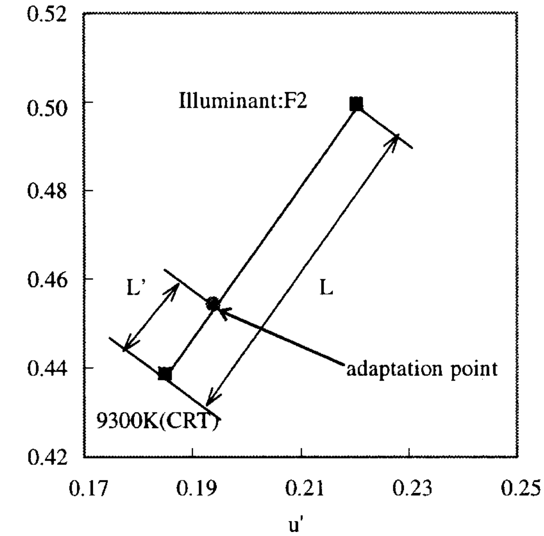

Figure 1. Calculation of shift ratio(L'/L) in u'-v' coordinates.

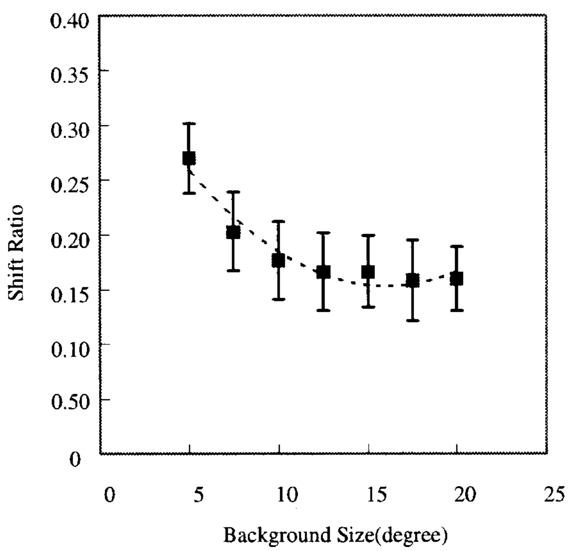

Figure 2. Shift ratios according to the background size.

Effect of Ambient Illumination

Three types of fluorescent lamps(F2, F5, and F8) were used to investigate shift of adaptation states according to the chromaticities of ambient illumination. Because the adaptation point for the CRT (9300K) was measured in a dark room, the deviation of the adaptation points under ambient illumination measures the effects of illumination.

The shift ratios according to the chromaticities of illuminants were dependent on the distance between the chromaticities of the CRT white and those of illuminants in u'-v' coordinates. This tendency could be seen at all three levels of ambient illumination as shown in Figure 4.

Luminance as well as chromaticities of the illuminant is one of the main factors which influences adaptation states on CRT. We performed achromatic color matching experiment at three luminance levels of three types of fluorescent lamps, F2, F5, and F8. The result showed increase of shift ratio according to the increase of luminance of illuminants. While the luminance ratio(luminance of a white paper on the CRT/luminance of CRT white) increased from 0.5 to 1.5, the shift ratio increased approximately 10%.

Formulation of the Shift Ratio

From the above results a formulation of the shift ratio was established using linear regression. The parameters for this formula were distance (D) between the chromaticities of CRT white and those of the illuminant in u'-v' space and luminance ratio (Yr) of illuminant to CRT. This formula can be written as follows;

$$SR = (-0.751\,Y_r + 3.190)\,D + (-0.159\,Y_r + 0.176). \quad (1)$$

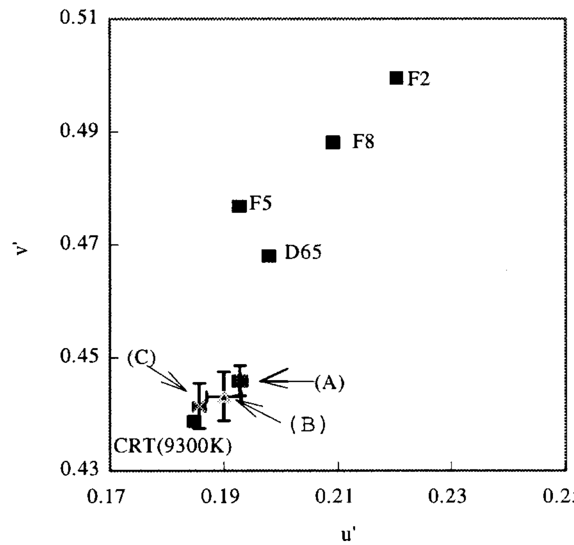

Figure 3. Shifts of adaptation points according to the chromaticities of illuminants. (Luminance level : ~60 cd/m2)(Illuminants : (A) : F2, (B) : F8, (C) : F5)

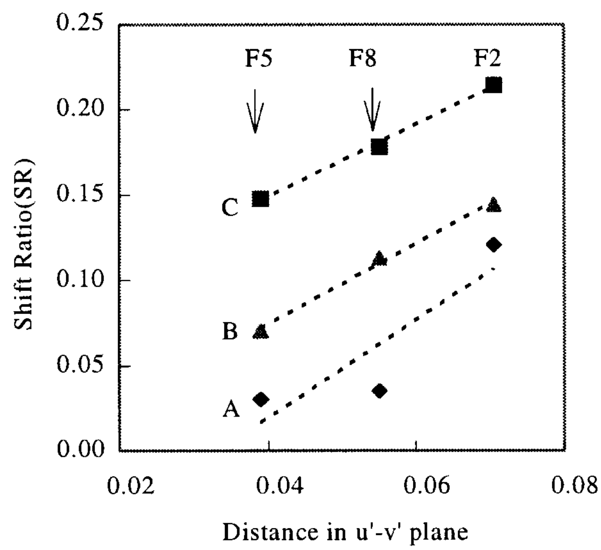

Figure 4. The dependency of shift ratio on luminance levels for three experimental illuminants(F2, F5, and F8). (Luminance levels : A(®) : ~30 cd/m2, B(s) : ~60 cd/m2, C(n) : ~90 cd/m2)

When the luminances of the CRT and illuminant are same, that is Yr = 1.0, this formula can be simplified as

$$SR = 2.439\,D + 0.017. \qquad (2)$$

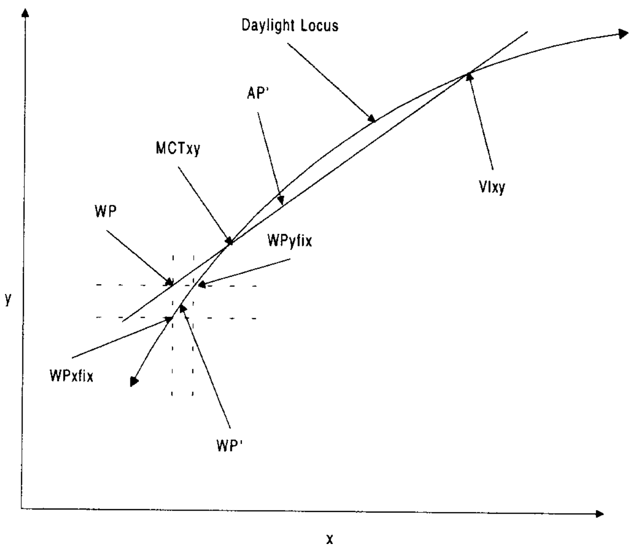

Figure 5. Calculation of new monitor white point(WP') for ICC profile format. (VIxy: chromaticity of the illuminant, MCTxy : chromaticity of the monitor, AP': shifted adaptation point under the illuminant, WP: shifted adaptation point for the monitor profile under the illuminant, WP: shifted adaptation point on the daylight locus for the monitor profile under the illuminant)

Implementation for a Monitor Profile

These results were implemented in a monitor profile(ICC profile format)[5] for a color management system to get consistent color appearance of the CRT under different ambient illuminations. In a monitor profile the mediaWhitePointTag of the monitor is required. Because the adaptation point of the observer shifts toward the illuminant white point, the monitor white point should shift toward opposite direction of illuminant white. The formula was converted from u'-v' coordinates to x-y coordinates, because in the profile format CIE XYZ is used. The approximation of above formula in x-y coordinate is SR = 1.237*D. The new white point of CRT for the mediaWhitePointTag is calculated as follows (Figure 5);

(1) Calculation of shift distance (MCTxy - AP') of adaptation point from the equation using luminance ratio (Yr = 1.0) and chromaticities of illuminant and monitor.

(2) Calculation of WP from the condition that distance (WP-MCTxy) equals distance (MCTxy - AP').

(3) Calculation of the nearest point WP' from WP on the daylight locus. For the simplification, the average value of WPxfix and WPyfix can be used as an approximation of WP'.

Summary

In this study the effects of ambient illumination on the color appearance of CRT was investigated adopting achromatic color matching method. The chromaticity of the achromatic color on the CRT was shifted toward that of the illuminant, which implies the change of the observer's chromatic adaptation state. The shift ratio,SR, calculated in the uniform space u'-v', increased according to the increase of the distance between chromaticities of CRT white and those of illuminants and increased according to increase of luminance level of the illuminant and could be formulated as an equation, $SR = (-0.751\,Y_r + 3.190)\,D + (-0.159\,Y_r + 0.176)$ when D is the distance between the chromaticities of CRT white and illuminant in u'-v' space and Yr is luminance ratio of illuminant to CRT white. These results were implemented in a monitor profile for a color management system (ICC) to get more consistent color appearance of the CRT when it is viewed under various ambient illuminations.

Reference

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