A Study of a^*b^* Acceptable Ellipsoid in the Blue Region

Hwa Lyung Woo, Jeong Ryeol Kim, A Rum Son, Seung Jun Lee, Sam Soo Kim
School of Textiles, Yeungnam University, Gyongsan 712-749, Korea

1.Introduction

In instrumental color control processes, the results of color-difference calculations between standards and their matches often determine whether these matches are pass or fail. There is no doubt that the pass/fail decisions significantly affect the color quality of products and the production lead-times as well as the production costs. For accurate quantification of color difference, a reliable color-difference formula is required. Currently, there are many color-difference formulae, including the so-called advanced formulae, such as CMC, BFD, CIE94, and the CIELAB and CIELUV recommended by the CIE in 1976. While CIE94 was recommended by CIE, CMC has become ISO and British standard. The American Association of Textile Chemists and Colorists (AATCC) also recommended the use of CMC. Apart from the structural differences between BFD and the rest of the formulae, the results from those formulae are not the same and in some color regions the differences are quite significant. Users would have difficulties in deciding which formula to use and how the results from different formulae are compared to each other.

Judgments of color-differences can be made along vectors that vary from different color centers in different directions. This is the type of method used in the RIT-DuPont data set and subsequent color-difference work from the Munsell Color Science Laboratory. In these experiments, the method of constant stimuli is used to compare color-difference pairs to an anchor pair. The color differences of the test pairs are chosen to vary along specific vectors in color space around the various color centers. The anchor pair is considered the aim tolerance limit. Subjects make a binary pass-fail (equivalently, less than-greater than) decision on each trial. Test pairs with a color difference perceived as greater than the anchor pair difference are failed, and test pairs with a perceived color difference smaller than the anchor pair difference are passed (This method has been referred to as "pair comparison," which may be confused with paired-comparison methods of psychometric scaling; we prefer the term "method of constant stimuli," or MCS.). Using probit analysis, for example, a tolerance threshold along each vector can be determined at the point where the color difference corresponds to a 50% likelihood of passing and failing. This threshold corresponds to the tolerance in the anchor pair. By testing various color centers and vectors, the data can be used to specify color-difference equations.

This study attempts to evaluate and quantify color-difference perception and acceptability. The goal of this experiment is to investigate a^*b^* acceptability in the blue region, to help to develop more accurate color-difference formulae.

2.Experimental

From the various center was determinated in the blue region, about h_0 = 235~305°. Polyester fabrics were used and the dyed sample pairs in each color center including those mainly varing along each direction of L^*, a^*, b^*, C^*, and h_0 were prepared to give total 100 pairs for all centers. The size of color-differences sampled was relatively small: mean ΔE^*=1.

Each color-difference pair was prepared from 6.5 X 5cm^2 cut rectangular samples attached to stiff cardboard side-to-side with a hairline separation between them. The sample pairs were measured with a Macbeth Color Eye 3100 spectrophotometer in specular component excluded(SPEX) and UV included modes. In each pair CIELAB coordinates of samples and the color-difference were calculated for the Illuminant D65 and the 10° Observer. Instrumental measurements were repeated 3 times throughout the visual tests period.

Observations were performed in Light Booth(The Judge II, Macbeth) and the simulated fluorescent daylight had a correlated color temperature of 6500°K. Forty color normal observers assessed each test color-difference pair against a 9-step gray scale of the same size and substrate as the test pair. The observational task was first to pick the gray-scale pair thought to be closest in magnitude to the test pair, then to answer a gray-scale grade(GS) up to 1 decimal point.

3.Results and Discussion

As claimed by Luo and implied by the BFD formula, the chromaticity-discrimination ellipses are not always toward to the origin in a^*b^* plane. The degree of ellipse rotation is also known to be prominent in the blue region($h^\circ \cong 270$). Like most of earlier worker's data, it is again confirmed by the data from this study. Thus, in effect, either a $\Delta a^* \Delta b^*$ or a $\Delta C^* \Delta H^*$ term is needed for the more exact calculation of a color- difference. The ellipse in the a^*b^* chromaticity plane and corresponding ellipse parameters can be easily converted to $\Delta C^* \Delta H^*$ microplane. The a^*b^* ellipse is defined as below Eq. (1) and a chromaticity discrimination ellipse is the cross section through the center of a color discrimination ellipsoid.

$$(\Delta E)^2 = b_{11}(\Delta a)^2 + 2b_{12}(\Delta a)(\Delta b) + b_{22}(\Delta b)^2 = 1 \quad (1)$$

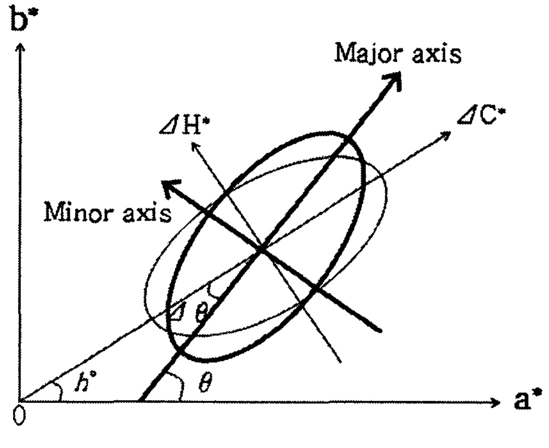

Fig. 1 Chromaticity-discrimination ellipse in a^*b^* diagram.

Among three principal axes of an ellipsoid, the axis close to the L^* axis is designated as L, and two axes close to the a^*b^* plane designated as C(long axis) and H(short axis). In most cases, these are roughly equivalent to the tolerance sized along the lightness, chroma, and hue directions in the CIELAB space. When it is difficult to assign the proper axis directions due to the significant tilting of an ellipsoid, the highest point of an ellipsoid(ΔL) is denoted as L, and the major and minor axes of an ellipse(cross section of an ellipsoid projected onto the a^*b^* plane) are denoted as C and H, respectively.

Let us set the general form of the color-difference formula as below(BFD unit ellipse).

$$\Delta E=\left[\left(\frac{\Delta L^*}{S_L}\right)^2+\left(\frac{\Delta C^*}{S_C}\right)^2+\left(\frac{\Delta H^*}{S_H}\right)^2+S_R(\Delta C^*)(\Delta H^*)\right]^{1/2}$$

The ellipse rotation occurs only in the blue region near $235 < h_0 < 305$ and the maximum rotation angle is 35° at $h_0 = 270$, then Δθ could be the following form.

$$\Delta\theta = 0 \quad \text{if } h_0 \leq 235 \text{ or } h_0 \geq 305\text{, otherwise}$$

$$\Delta\theta = -[0.169(h_0-270)]^2 + 35$$

Reference

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