A Quantitative Method of Measuring Color Expression Power in Eye shadow

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Introduction

When consumers buy color cosmetics, they choose one out of many products. Many consumers the primary reason they select a color cosmetic product is for the colorful effect it imparts. This color selection process is often based on the consumer's general complexion, and on what he, or she perceives as enhancing their attractiveness. These choices are made much the same way as those that dictate clothing and fashion purchases. Other beneficial characteristics are appreciated by consumers, but short of total discomfort, these will be sacrificed if the color is "just right"[1]. We verify it with a simple eye shadow survey (see Table 1). Forty-one percent of respondents said, "The color expression power (CEP) is the most important quality in eye shadow as it is with other color cosmetics." In this survey, we did not take colors and brands of eye shadow into consideration.

Defining Color Expression Power

Eye shadow is only one type of color cosmetic products. Because it has various color qualities, we chose eye shadow for this research to measure **color expression power**. A clear definition of color expression power (CEP) has not yet been established. Therefore, we needed to find a general concept of color expression through consumer interviews and other evaluations. Then we converted the consumer's subjective impressions into technical concepts to measure it quantitatively. Consumer interviews demonstrated that CEP means the color difference between the color of products in the package and the color expressed on the skin. But it is a complex idea and not easily expressed as a color difference. We also took into consideration that color is expressed differently by the amount of eye shadow applied. And it also excluded subjective color-preference.

Panel tests show that CEP can be affected by personal affinity for color. Consumers may interpret color expression power as good, in colors they like, and bad in colors they dislike. We believe that accurate CEP must not be affected by personal preferences.

While designing and conducting visual experiments for measuring CEP, we considered the hierarchy of scales. When deriving perceived magnitude scales, one must understand the properties of the resulting scales. Often a psychophysical technique will produce a scale with only limited mathematical use. In such cases, inappropriate mathematical manipulations must not be applied to the scale. Four key types of scales have been defined, presented in order of increasing mathematical power and complexity. These are nominal, ordinal, interval, and ratio scales.[2] Prior panel testing of CEP measurement has resulted in ordinal scale results only.

Like beauty, color is in the eye of the beholder. For as long as human scientific inquiry has been recorded, the nature of color perception has been a topic of great interest. Despite tremendous evolution of technology, fundamental issues of color perception remain unanswered. Many scientific attempts to explain color rely purely on the physical nature of light and objects. However, without the human observer there is no color.

Color Perception

When we studied eye shadow's CEP, we had three critical areas to take into account:

(1) The expressed color on skin is not same as the product's color in the package. That is, customer's skin color affects to CEP.

(2) Measuring the CEP by visual experiment in ordinal scales is not sensitive enough to provide proper measurement. An example is showed at table 2.

(3) Colorant, oil, pigment and light source affect the CEP.

To solve these various problems and improve the CEP in eye shadow, we needed a quantitative method of measuring it. As a result, we developed a quantitative method for evaluating CEP, which is presented in this paper.

Previous Methods of Evaluating CEP

In general, panel tests have been used for measuring CEP into three categories: Good (G), Normal (N), and Bad (B). The criteria of Good (G), Normal (N), and Bad (B) is the degree of how well expressed color is when consumers apply the product on their skin. However, CEP measured by panel test, shows significant individual variation. See Table 2. Because color perception depends on three components - light source, object, observer[3] - we believe that the differences result from the skin color and subjective interpretations of each panelist. This is the weak point in working with ordinal scales. Therefore, we decided to improve the CEP ordinal scale measuring method by developing an interval scale.

Instrumental Experiment to Measure CEP through Interval Scales

Preparation of Standard Skin Sample

To effectively measure CEP in an interval scale, it is important to minimize the background color effect (the panelist's complexion). We produced a standardized background color sample by selecting a popular powder foundation in Korea. We then applied it on Vitroskin(IMS co., USA) and then coated it with protective polymer film to prevent contamination. Vitroskin is an advanced testing substrate that effectively mimics the surface properties of human skin. It contains optimized protein and lipid components and is designed to have topography, pH, critical surface tension and ionic strength similar to human skin. Testing done on Vitroskin generally yields more reproducible results than that performed on human skin because of the consistent topography and color. The color of standard skin color sample we used is L:73.61, a:4.60, b:17.61.

Measurement of Color Difference (Δ E)

To measure CEP in interval scale, we represented the color difference using the Hunter equation while increasing the amount of eye shadow applied. We showed the schematic flow of measuring the color difference between the color of samples in appearance and the color expressed on skin in Figure 1. We measured the color of samples with spectrocolorimeter CR200(Minolta, Japan). The measured color was represented by L, a, b color space. The color difference was calculated by the following Hunter equation.

$$\text{Hunter equation : Color difference}(\Delta E) = \sqrt{\Delta L^2 + \Delta a^2 + \Delta b^2}$$

Results and Discussion

CEP Measuring Method in eye shadow

As shown in Figure 2, when observing a skin surface applied with eye shadow, the light components follow this path:

Reflected light A returns without passing through the eye shadow layer on the skin

Reflected light B returns after single or multiple reflection between the eye shadow layer and skin surface.

So, we may think that the final color is combination of skin color and color of eye shadow layer, but the final color is not a simple addition of color mixture of the eye shadow color and skin color. [3)]

To consider the affect of background skin color, we put Vitroskin on white, and black paper, and then measured each color. They appeared differently when compared against each other and showed deviation with the skin color. So we knew that if we use the Vitroskin to measure the CEP, we need the standard background color similar to skin color. We prepared the standard skin color sample and compared it with skin color, shown in Figure 3. Note that they show the similar color change pattern when increasing the quantity of eye shadow applied.

To characterize the color change, we applied small amount of eye shadow on Vitroskin over the standard skin color sample, increased the amount of eye shadow applied, and detected the color difference between the expressed color and the packaged eye shadow color.

As shown in Figure 4, the color difference(Δ E) decreases fast with the increasing amount of eye shadow applied. We tried several curve fittings to explain this tendency, and found that an exponential function, $\Delta E = ae^{-bx}$ describes it best. We repeated this experiment and presented the result in Table 3.

The meaning of 'a' in $\Delta E = ae^{-bx}$ is the color difference between skin and eye shadow product, and 'b' is a factor of decreasing rate of the color difference between the expressed color on the skin and the packaged eye shadow color. If b is large (Fig.4-II), the color difference is small even when small amount of eye shadow is applied on skin. But if b is small (Fig.4-III), the color difference is greater with heavy application.

We think b is the right value representing CEP in eye shadow and define it as 'an index of CEP'. If we simply define the CEP as color difference between the expressed color on skin and the color of packaged eye shadow, the color difference in shades that closely resemble skin tones(Fig.4-I) will always be small and its CEP will be evaluated as large. However, this definition is affected by shade, so we think that this definition is not suitable. On the other hand, the index b, which is defined as a value of CEP, is not affected by eye shadow shades. We can also measure CEP for every shade of eye shadow and compare quantitatively with one another.

Application of the Measuring method

Oil effect on CEP.

To help verify that our method is valid, we considered the effect of oils on the CEP. Eye shadows contain various oils to improve feel of application, adherence to the skin, hardness of the product, and to prevent both breakage and dusting. Oil components also affects the product's color and CEP. Figure 5 shows the change of product color by increasing the oil quantity. By increasing the oil quantity, the value L decrease, and the shade becomes darker. This phenomenon is explained by Frenkel equation where N_p is the pigment refractive index and n_b is the refractive index of medium.

Frenkel equation : R(reflective coefficient) $= \frac{(N_p - n_b)^2}{(N_p + n_b)^2}$

Deviation can be caused by the kind of oil, process and mixing condition. As the amount of oil increases, the medium that the powder contact changes from air to oil. In the Frenkel equation, n_b changes from 1(refractive index for air) to 1.5(for oil), R(reflective coefficient) decreases. It means the color getting darker as the amount of oil increase. Therefore, the amount of colorant needed to show the same color as the package product, varies according to oil amount. Table 4 shows the amount of colorant needed to show the same color and the tendency for decreased colorant with an increased amount of oil. That is, when a formula contains lots of oils, the eye shadow color is dark. When the oil amount is decreased, the formula must contain lots of colorant to achieve the same color of the packaged product – the apparent color od the eye shadow. There is a difference between color of the packaged product and its color on the skin.

To examine the effect of the amount of oils and colorants on the CEP, we compared the empirical law we obtained and the Beer-Lambert law, which relates to light absorption. The Beer-Lambert law is acquired by following derivation:

The reduction of light intensity (symbol : I for the intensity, dI for the change of the intensity) that occurs when light passes through a sample of thickness dx containing absorbing species J at a concentration [J] is proportional to the thickness, the concentration, and the incident intensity, and we can write

$dI = -\alpha[J]Idx$ or $d\ln I = -\alpha[J]dx$ where α is the proportionality coefficient.

This equation applies to each successive layer into which the sample can be regarded as divided, and to obtain the intensity(I_f) that emerges from a sample of thickness l when the incident intensity is I_i we sum all the successive changes :

$$\int^{f} d\ln I = -\int_0^{l} \alpha[J]dx$$

If the concentration is uniform, [J] is independent of x, and the expression integrated to:

$$I_f = I_i e^{-\alpha[J]l}$$

Note that the intensity decreases exponentially with the sample thickness, and that it decreases exponentially with the concentration.

There is a formal resemblance between the Beer-Lambert law and the empirical law we obtained. In the Beer-Lambert law, there is an assumption that medium other than colorant does not absorb the light. So, this law may not apply to the light that passes the eye shadow layer because the powders composing it have properties of reflection, absorption and scattering. But the amount of eye shadow applied is very small(0.62 mg/cm^2) in our experiments, and talc, which compose the main body of eye shadow has a transmittance level over 90%. We believe that it is meaningful that we compare these two laws.

α [J] in Beer-Lambert law and b in $\Delta E = ae^{-bx}$ are values which imply same meaning, so we can expect that with the increasing amount of colorant(high [J] value) the value of b will increase and the CEP will be improved.

We measured the color expression power by the variation of oil contents in eye shadow formula show in Table 4. Figure 6 shows that with decreasing amount of oils (increasing amount of colorants), the color difference decreases fast with the amount of application, and 'b' values increase. These results imply that low contents of oil and high contents of colorants in formula will improve the CEP in eye shadow. This is the result that we expected and means that the method, that we propose, of measuring CEP is useful to formulators.

Summary

We developed a quantitative method for evaluating CEP(color expression power) in eye shadow. This method enables the cosmetic industry to measure CEP on an interval scales, so it is more accurate and reproducible than previous panel tests. Oil, colorants, Pigments and pearls are major factors affecting CEP in eye shadow formulas. We studied the oil effect on CEP using our unique method so CEP could be improved. We believe this method can be applied to other color cosmetics as well. In conclusion, we expected this method to be useful to formulator who want to improve the color expression power in color cosmetics. Additionally, we hope it will contribute toward developing the experiential know-how about color to scientific knowledge.

Reference

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