PERCEPTUAL HUE CHANGE OF BRIGHTER FACIAL SKIN COLOR INDUCED BY EYE SHADOWS

A pilot study for color theory of makeup

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Abstract: Although it is generally said that the makeup color that best fits facial skin should be of the same type of color, professional makeup artists sometimes use the opponent color to emphasize the beauty of skin color. The present study demonstrated how the colors of eye shadow changed perception of redness or yellowness in the face. Three face colors, neutral, reddish, and yellowish, and 7 typical colors of eye shadow covering all hues were examined. The brightness of the faces was fairly high. Sixteen female students compared the color of faces and ellipses to evaluate their redness and yellowness. Serial and simultaneous presentation of the face and ellipse were implemented. The results showed that only some reddish eye shadows, like red, pink, or purple, enhanced the redness of reddish as well as yellowish faces in the serial presentation of face and ellipses. Examination of the chromaticness index of the colors that had a significant effect of color induction revealed that the colors with high positive values of $a^*$ and medium positive values of $b^*$ showed an assimilation effect in complexion.

Keywords: color induction, complexion, makeup, color assimilation

1. Introduction

The present study was intended as a preliminary investigation of perception of face color induced by makeup, which represents one of the important communication tools. The present study confirmed that some reddish eye shadow colors can produce assimilation effects in the face.

The color of the face conveys a variety of information. Perreira and Telles (2014) found a significant correlation between self-rated health and skin color of Latin Americans; people with darker skin color reported poorer health [1]. Gómez (2008) pointed out the desire for lighter skin in the Latino community [2]. The Japanese have a similar tendency. Ashikari (2005) examined the preference for white skin as a social phenomenon and considered it a symbolic physical characteristic for identifying Japanese people [3]. These studies are about racial identity; skin color inspires us to think about social issues.

Putting aside sociological questions of the preference for whiteness, it must be noted that there are people who want to have a lighter complexion. Inoue (2001) indicated that skin condition could reflect the internal state of the person and affect impression formation [4]. In a society where whiter skin is thought to be a good thing, makeup is an important communication tool to manage the social life. Makeup can change the color of the face. Yogo (2002) concluded that makeup reduced negative emotions like interpersonal anxiety, state anxiety, and excessive tension and increased positive emotions like confidence, satisfaction, and motivation; makeup also activated interpersonal behaviors like self-disclosure, communication, positive attitude of interpersonal relationship, and emotion expression [5]. Makeup can help people to lead a more healthy social life.

Not only the brightness but also hue and chroma are important aspects of complexion. Yoshikawa et al. (2012) hypothesized that the perceived whiteness or brightness of
the face was influenced by hue and chroma as was the lightness in a preliminary paper-based experiment [6]. In their study, 6 experienced cosmetic experts evaluated the brightness of 120 females in an illumination-controlled room. The study revealed that the reddish face appeared brighter or whiter than the yellowish face in areas of high lightness and that low-chroma faces appeared brighter or whiter than high-chroma faces. Thus, the so-called pinkish face seemed to be whiter than the bright yellowish face, and a stronger color made the face appear darker. This research showed the effect of chromatic components of color, such as hue and chroma, on the perception of whiteness in a face. Moreover, Yoshikawa et al. (2010) showed that the facial color of Japanese females had become significantly more yellowish, lighter, and more unsaturated within about 10 years in the 1990s [7]. Deng et al. (2013) showed that the Japanese preferred less yellowish and reddish colors in a complexion than the Chinese [8].

In short, the Japanese tend to appreciate a brighter and more muted face color.

1.1 Makeup method and desirable complexion

The hue of facial color is expressed with a two-color dichotomy in Japan, both in academic research [9] and practice [10]. The hue of foundation is usually expressed in a pink-ocher dimension that ranges from reddish to yellowish colors [11]. Professional makeup artists agree that exaggerated colors, like extreme yellowish or reddish, are generally not preferred. Thus, the desirable change of hue can counteract movements within color circle. Table 1 explains desirable and non-desirable changes of facial colors. It must be noted that the change represents just the direction and that strong hues are not preferred in Japan.

The hue of makeup is usually along a blue-yellow dimension; for instance, near-yellow colors like orange and green are used in yellowish make up, while near-blue colors like purple and pink are adopted for bluish makeup. Which makeup is suitable for a person depends on the facial color.

In practice, similar color makeup is generally the accepted view [12]; that is, yellowish makeup fits yellowish faces and bluish makeup fits pinkish faces. If the opposite colors are used, the hue of the face is emphasized and does not look as good. In Japan, a face that is too yellowish or too reddish is generally not desired. It was suggested that similar colors fit the face and that opposite colors exaggerate the face color in degrees. For example, a yellowish face should apply brown eye shadow but not pink. This method of makeup is fairly prevailing in daily life.

However, it is also true that some professional makeup artists use the opposite colors to the skin. These professionals know that the opposite colors can induce a desirable face color on an empirical basis. In this paradoxical method, pink eye shadow can be put on the eyelids of a yellowish face. Moreover, not only the desirable change of hue but also a brightening can be expected. This method insists that a similar color makeup especially fits the face and emphasizes its hue.

The effect of color induction by the 2 methods is summarized in Table 2. The gray cells represent the makeup colors that get the desirable complexion for both yellowish and reddish faces.

Incidentally, the professionals consider the seamless blending into the skin as an important aspect of makeup. A good blending of makeup colors not only means that the applied color does not stand out in the face but also that it does not emphasize the undesirable face color. Although this blending effect is talked about among professionals, it is still unclear what it indicates from a standpoint of general color theory.

1.2 Relationship to well-known color illusions

The above-mentioned color induction easily evokes concepts of color illusions like color contrast and color assimilation [13]. Research about these phenomena has been either paper-based or monitor-based, usually using geometrical figures. However, the perceptual color change of complexion cannot be explained by the well-known paper-based color phenomena.

Kitaoka reviewed many perceptual illusions including color illusions [14]. Color contrast is a phenomenon in which the difference between the color of an induced and

| Table 1 Desirable and undesirable color changes within color circle for 2 types of face color |
|-----------------------------------|---------------|----------------|
| Yellowish face                    | Desirable     | Undesirable    |
|                                  | Clockwise     | (to emphasize yellowness) |
|                                  | Counter-clockwise |
| Pinkish face                      | Clockwise     | (to emphasize redness) |
|                                  | Counter-clockwise |

| Table 2 Colors theoretically inducing more reddish and more yellowish faces by 2 makeup methods for 2 face color types |
|---------------|---------------|---------------|---------------|---------------|
| More reddish face | Yellowish colors | Blush colors | Blush colors | Yellowish colors |
| More yellowish face |                  |               |               |               |
| More reddish face | Yellowish colors | Blush colors | Blush colors | Yellowish colors |
| More yellowish face |                  |               |               |               |

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that of an inducing area appears greater. On the other hand, color assimilation is a phenomenon in which the difference between two colors seems to be smaller. Color contrast as well as color assimilation can occur in brightness, hue, and chroma. Although these phenomena are related to the perceptual change of color in complexion, this change cannot be easily explained by the well-known paper-based color phenomena.

First of all, the configuration of the phenomena is different. The induced area of color contrast in previous studies was usually smaller than the inducing area. However, in faces, the induced area is the face itself, while the inducing area is the colored part like the lip or entire eye region. This size relation is opposite to that used in paper-based color contrast. Although the inducing area of color assimilation is usually smaller than the induced area, the former is finely inserted into the latter. This positional relation is different from that of the face [15], which makes it difficult to simply explain the perceptual color change of complexion by paper-based color contrast or color assimilation. At last, the two above-mentioned makeup methods cannot be explained by the well-known color illusions, because the two opposite methods can get the same effect, that is, a desirable complexion.

Although much still remains to be done regarding the relation between classical color illusions and complexion, some research indicated specificity of color perception in the face. Yoshikawa et al. (2012) revealed the above-mentioned perceptual color changes in the face but confirmed that it did not occur in color plate images. Han and Fuchida (2013) reported that perceptual color change appeared in animation face images but was not confirmed in color chips [19]. Kiritani et al. (2004) indicated that the impression induced by makeup color in real faces was different from the impression of illustrations or color paper [20]. Thus, the face could be an important factor to influence color perception.

Morikawa (2012, 2014) proposed a new class of illusions, “biological illusions,” which refer to illusions of shape and size related to the human face and body [21, 22]. This new kind of illusion has the feature that a small stimulus change causes a drastic change of impression (5% maximum amount of stimulus change). He also proposed the notion of “echo illusion,” which is a kind of assimilation; the configuration that induces the perceptual contrast in the well-known color phenomena can induce the perceptual assimilation in the human face and body. Morikawa (2014) also extended the research about the brightness assimilation of the face into the décolleté part. These phenomena of perceptual assimilation can be related to the perceptual change of hue in the face.

Since the Color Science Association of Japan launched the new group called Special Interest Group on Cosmetic, Skin and Facial Studies, the study of cosmetic and face has become one of the hot multidisciplinary issues [23]. More evidence-based or quantitative research will be done to establish a comprehensive theory.

### 1.3 Purpose of study

The present study is a pilot study to confirm how makeup perceptually changes facial color. Three face colors, neutral, yellowish, and reddish, were examined to measure their redness or yellowness and to reproduce the empirically observed phenomena of makeup color induction by the 2 methods illustrated in Table 2.

These phenomena have been confirmed in cosmetic practice, but the conditions to obtain them have not been clear. As mentioned above, the opposite method can lead to the same effect, that is, a desirable complexion. To clarify the notion of a desirable complexion, the present study focused on redness and yellowness. The color of eye shadow was adopted as the makeup, because eye shadows cover almost the entire range of hues. Moreover, Kiritani et al. (2004) reported powerful effects of eye shadow on face impression.

### 2. Method

#### 2.1. Participants

Sixteen female undergraduate or graduate students (average age 22.7 years, S.D. 1.1) participated in the experiment. All of them were not professionals but applied makeup on themselves daily.

#### 2.2. Apparatus and materials

A MacBook Pro 15-inch retina display early 2013 and Adobe Flash were used to present the stimuli. The standard stimuli consisted of facial pictures and the comparative stimuli were ellipses.

A picture of averaged faces from Shiseido Co. Ltd. (Figure 1) represented the standard stimulus. There were 2 factors: face color and eye shadow. There were 3 face colors: neutral, yellowish, and reddish. The brightness of these faces was lighter as a Japanese female face. There were 7 colors of eye shadow: red, orange, yellow, green, blue, purple, and pink. All the selected colors reflected the opinion of professional makeup artists to be natural as a cosmetic. Values and chromaticness indexes of the 7 colors on each face are shown in Table 3. A spectroradiometer...
Figure 1 An example of the standard stimuli (neutral face color without any eye shadow)

Table 3 Color indexes of eye shadows in the 3 faces and in the faces without eye shadow

<table>
<thead>
<tr>
<th>Eye shadow</th>
<th>Face</th>
<th>L&lt;sub&gt;v&lt;/sub&gt;</th>
<th>a&lt;sup&gt;*&lt;/sup&gt;</th>
<th>b&lt;sup&gt;*&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red</td>
<td>Yellowish</td>
<td>42.00</td>
<td>27.60</td>
<td>23.46</td>
</tr>
<tr>
<td></td>
<td>Neutral</td>
<td>40.43</td>
<td>32.04</td>
<td>28.34</td>
</tr>
<tr>
<td></td>
<td>Reddish</td>
<td>68.17</td>
<td>28.37</td>
<td>22.25</td>
</tr>
<tr>
<td>Orange</td>
<td>Yellowish</td>
<td>52.60</td>
<td>17.26</td>
<td>36.01</td>
</tr>
<tr>
<td></td>
<td>Neutral</td>
<td>50.71</td>
<td>21.33</td>
<td>43.18</td>
</tr>
<tr>
<td></td>
<td>Reddish</td>
<td>84.00</td>
<td>18.70</td>
<td>35.29</td>
</tr>
<tr>
<td>Yellow</td>
<td>Yellowish</td>
<td>70.16</td>
<td>-2.75</td>
<td>45.42</td>
</tr>
<tr>
<td></td>
<td>Neutral</td>
<td>70.44</td>
<td>-1.58</td>
<td>54.20</td>
</tr>
<tr>
<td></td>
<td>Reddish</td>
<td>113.17</td>
<td>-2.27</td>
<td>47.42</td>
</tr>
<tr>
<td>Green</td>
<td>Yellowish</td>
<td>51.77</td>
<td>-13.86</td>
<td>25.66</td>
</tr>
<tr>
<td></td>
<td>Neutral</td>
<td>49.45</td>
<td>-13.59</td>
<td>30.71</td>
</tr>
<tr>
<td></td>
<td>Reddish</td>
<td>81.83</td>
<td>-11.53</td>
<td>24.32</td>
</tr>
<tr>
<td>Blue</td>
<td>Yellowish</td>
<td>28.98</td>
<td>7.75</td>
<td>-22.89</td>
</tr>
<tr>
<td></td>
<td>Neutral</td>
<td>28.40</td>
<td>8.61</td>
<td>-21.40</td>
</tr>
<tr>
<td></td>
<td>Reddish</td>
<td>47.80</td>
<td>8.96</td>
<td>-21.76</td>
</tr>
<tr>
<td>Purple</td>
<td>Yellowish</td>
<td>30.64</td>
<td>21.47</td>
<td>-13.30</td>
</tr>
<tr>
<td></td>
<td>Neutral</td>
<td>28.36</td>
<td>26.16</td>
<td>-15.34</td>
</tr>
<tr>
<td></td>
<td>Reddish</td>
<td>47.55</td>
<td>24.03</td>
<td>-16.20</td>
</tr>
<tr>
<td>Pink</td>
<td>Yellowish</td>
<td>70.80</td>
<td>20.36</td>
<td>6.42</td>
</tr>
<tr>
<td></td>
<td>Neutral</td>
<td>67.78</td>
<td>24.26</td>
<td>10.22</td>
</tr>
<tr>
<td></td>
<td>Reddish</td>
<td>110.50</td>
<td>21.06</td>
<td>6.08</td>
</tr>
<tr>
<td>Without eye shadow</td>
<td>Yellowish</td>
<td>213.69</td>
<td>7.32</td>
<td>20.75</td>
</tr>
<tr>
<td></td>
<td>Neutral</td>
<td>210.51</td>
<td>8.93</td>
<td>19.72</td>
</tr>
<tr>
<td></td>
<td>Reddish</td>
<td>207.39</td>
<td>10.55</td>
<td>18.66</td>
</tr>
</tbody>
</table>

Table 3 Color indexes of eye shadows in the 3 faces and in the faces without eye shadow (CS-1000, Konica Minolta, with CS-S10W software) measured the colors: 7 points on the cheek and 2 points on the tail of the eye were measured; thus, the values in Table 3 represent averages.

The distance between the stimulus and the spectroradiometer was about 47 cm. The lip color was not a variable; a natural reddish color was applied to each face. The total number of standard stimuli was 21 (3 faces and 7 eye shadows) for the first half of the experiment. Three faces without eye shadow were used as standard stimuli in the second half of the experiment.

Nine ellipses were prepared as comparative stimuli with respect to each face color. The comparative stimuli were graded according to the reddish-yellowish scale: a smaller number indicates more reddish and a larger number indicates more yellowish color (see appendix). The colors were taken from those of the forehead of each face.

2.3. Procedure

The participants looked at a face of the standard stimulus and adjusted the yellowishness or reddishness of the comparative stimulus to match its color to the face. The experiment was divided into 2 parts. In the first half, the standard stimulus consisted of the faces with eye shadow; in the second half, faces without any eye shadow were presented. In both halves, there were 2 types of stimulus presentation: serial and simultaneous.

In the serial presentation of the first half of the experiment, a trial proceeded in the following way: After presentation of a fixation cross, one of the 22 standard stimuli was randomly presented by pressing the enter key. Another press of the same key showed a comparative stimulus. The standard stimulus re-appeared by pressing the space bar, if needed. Thus, the participants compared the standard and comparative stimuli alternatively and selected the same perceptual color as the standard stimulus.

In the simultaneous presentation, the main procedure was the same as in the serial presentation except for the presentation of the comparative stimuli. They were shown next to the standard stimulus one by one. Thus, the participants simultaneously looked at a face and an ellipse.

For both the serial and simultaneous presentation, there were 2 presentation orders of the comparative stimuli: from the most reddish to the most yellowish ellipse, and vice versa. These 2 orders were repeated 4 times, so that a participant completed 336 trials in total (3 faces, 7 eye shadows, 2 presentation types of the comparative stimuli, 2 orders, and 4 repetitions) in the first half of the experiment.

In the second half of the experiment, the 3 standard stimuli without any eye shadow were judged regarding their yellowness or redness in comparison with the comparative stimuli. The same serial and simultaneous presentation and order of presentation of the comparative stimuli were also adopted in the second half of the experiment.

3. Results

The perceived redness or yellowness of the faces with 7 eye shadows can be represented as values of chromaticness indexes of the comparative stimuli that were identified as having the same color as the relevant standard stimulus. The redness is represented by a<sup>*</sup> and the yellowness by b<sup>*</sup>.

A 2-way ANOVA (eye shadow and presentation type) was conducted separately for the data of the 3 face colors and for each chromaticness index to obtain the statistical scores, as shown in the subsequent sections. Of interest are the differences of the values of a<sup>*</sup> or of b<sup>*</sup> between the face
without eye shadow and each of the faces with eye shadow. The face without eye shadow was counted as a level within the factor of eye shadow.

3.1 Results of redness

Figure 2 illustrates the perceived redness in the serial presentation. In each graph, the horizontal axis indicates $a^*$ for the 7 eye shadows and the vertical axis represents the difference of $a^*$ between the face without eye shadow and each of the faces with eye shadow. On both axes, the plus area indicates redder hue and the minus area indicates greener hue; a greater index value also represents higher chroma.

In the yellowish face, the presentation method had a significant tendency ($F_{1,15} = 3.706, p = 0.07, \eta^2 = 0.020$); the serial presentation yielded higher scores of $a^*$ than the simultaneous presentation. Eye shadow had a significant main effect, too ($F_{7,105} = 5.147, p < 0.000, \eta^2 = 0.036$). The Ryan method revealed that 3 eye shadows got significantly greater scores than the face without eye shadow: red ($t = 3.542, p < 0.001, r = 0.320$), purple ($t = 3.168, p = 0.002, r = 0.300$), and pink ($t = 3.077, p = 0.003, r = 0.288$).
Figure 4 Difference between the faces with eye shadows and the face without eye shadow as a function of \( a^* \) of the eye shadow (averaged \( a^* \) values with the standard deviations): open triangle for yellow, open square for green, open diamond for blue, cross for orange, filled diamond for red, filled circle for pink and filled square for purple, about the simultaneous presentation.

Figure 5 Difference between the faces with eye shadows and the face without eye shadow as a function of \( b^* \) of the eye shadow (averaged \( b^* \) values with the standard deviations): open triangle for yellow, open square for green, open diamond for blue, cross for orange, filled diamond for red, filled circle for pink and filled square for purple, about the simultaneous presentation.

The interaction between presentation method and eye shadow was also significant \((F_{7,105} = 3.980, p < 0.000, \eta^2 = 0.018)\). Again, for the serial presentation (Figure 2a), the Ryan method revealed that 3 eye shadows got significantly greater scores than the face without eye shadow: red \((t = 4.125, p < 0.000, r = 0.373)\), purple \((t = 3.829, p < 0.000, r = 0.350)\), and pink \((t = 3.126, p = 0.002, r = 0.292)\).

We checked \( \Delta E \) in the serial presentation to confirm if the difference between the face without eye shadow and each of the faces with eye shadow was theoretically perceivable or not (Table 4). Red and pink yielded values close to 1.0, which indicates the just noticeable difference between 2 colors. The value for purple was 0.71, that is, smaller than 1.0 but greater than 0.4, which is above the limit for most people to discriminate 2 colors in a reproducible fashion. The other eye shadows, except green, obtained \( \Delta E \) over 0.4, although only the above-mentioned 3 eye shadows (red, pink, and purple) yielded significant differences compared to the face without eye shadow.

Thus, in the yellowish face, if the standard and comparative stimuli were presented serially, red, purple, and pink eye shadows made the face...
Table 4  ΔE (difference between the face without eye shadow and each eye shadow) in the serial presentation

<table>
<thead>
<tr>
<th></th>
<th>Red</th>
<th>Orange</th>
<th>Yellow</th>
<th>Green</th>
<th>Blue</th>
<th>Purple</th>
<th>Pink</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yellowish face</td>
<td>0.98</td>
<td>0.51</td>
<td>0.47</td>
<td>0.17</td>
<td>0.54</td>
<td>0.71</td>
<td>0.91</td>
</tr>
<tr>
<td>Neutral face</td>
<td>0.42</td>
<td>0.21</td>
<td>0.63</td>
<td>0.31</td>
<td>0.14</td>
<td>0.53</td>
<td>0.45</td>
</tr>
<tr>
<td>Reddish face</td>
<td>0.67</td>
<td>0.14</td>
<td>0.26</td>
<td>0.10</td>
<td>0.38</td>
<td>0.57</td>
<td>0.42</td>
</tr>
</tbody>
</table>

Table 4 ΔE (difference between the face without eye shadow and each eye shadow) in the serial presentation.

appears more reddish than the face without eye shadow. Furthermore, in the reddish face, the eye shadow had a significant main effect (F7,105 = 4.178, p < 0.000, ηG = 0.028). The Ryan method revealed that 2 eye shadows yielded significantly greater scores than the face without eye shadow: red (t = 3.598, p < 0.008, r = 0.331) and purple (t = 2.376, p = 0.019, r = 0.226). The interaction between presentation method and eye shadow was also significant (F7,105 = 3.321, p = 0.003, ηG = 0.017). Again, in the serial presentation (Figure 2b), the Ryan method revealed that 2 eye shadows got significantly greater scores than the face without eye shadow: red (t = 3.904, p < 0.000, r = 0.356) and purple (t = 3.435, p < 0.000, r = 0.318).

The values of ΔE in the serial presentation (Table 4) revealed that red and purple were over the limit for most people to discriminate 2 colors in a reproducible fashion [24]. However, the pink eye shadow yielded a ΔE over 0.4, although this eye shadow was not significantly different from the face without eye shadow.

Thus, in the reddish face, if the standard and comparative stimuli were presented serially, red and purple eye shadows made the face appear more reddish than the face without eye shadow.

In the neutral face, although the main effect of eye shadow and the interaction between presentation method and eye shadow was significant (F7,105 = 5.276, p = 0.002, ηG = 0.026; F7,105 = 2.515, p = 0.020, ηG = 0.012), there was no significant difference between certain eye shadows and the face without eye shadow. A ΔE over 0.4 was seen for pink, red, purple, and yellow eye shadows. Thus, although Figure 2c suggests that the yellow shadow seemed to make the face less reddish or more greenish and that the red shadow seemed to make the face more reddish, these effects were not significant. In the neutral face, none of the eye shadows had an effect in changing the facial color.

In the simultaneous presentation, there was no significant difference between certain eye shadows and the face without eye shadow (Figure 4).

3.2 Results of yellowness

Figure 3 illustrates the perceived yellowness in the serial presentation. In each graph, the horizontal axis indicates b* of 7 eye shadows and the vertical axis represents the difference of b* between the face without eye shadow and each of the faces with eye shadow. On both axes, the plus area indicates yellower hue and the minus area indicates bluer hue; a greater index value also represents higher chroma.

In the yellowish face, the main effect of eye shadow was significant (F7,105 = 4.359, p < 0.000, ηG = 0.032). The Ryan method revealed that red eye shadow got a significantly greater score than the face without eye shadow (t = 3.306, p < 0.001, r = 0.307). The interaction between presentation method and eye shadow was also significant (F7,105 = 4.394, p < 0.000, ηG = 0.019). Again, in the serial presentation (Figure 3a), the Ryan method revealed that 2 eye shadows got significantly greater scores than the face without eye shadow: red (t = 3.880, p < 0.000, r = 0.354) and pink (t = 3.625, p < 0.000, r = 0.334).

Thus, in the yellowish face, if the standard and comparative stimuli were presented serially, red and pink eye shadows made the face more bluish or less yellowish than the face without eye shadow. The results of ΔE were the same as those described in section 2.2.1.

In the reddish face, eye shadow had a significant main effect (F7,105 = 4.435, p < 0.000, ηG = 0.038). The Ryan method revealed that red eye shadow got a significantly greater score than the face without eye shadow (t = 3.295, p < 0.001, r = 0.306). The interaction between presentation method and eye shadow was also significant (F7,105 = 3.435, p = 0.002, ηG = 0.023). Again, in the serial presentation (Figure 3b), the Ryan method revealed that red eye shadow got a significantly greater score than the face without eye shadow (t = 3.663, p < 0.000, r = 0.337).

Thus, in the reddish face, if the standard and comparative stimuli were presented serially, red eye shadow made the face more bluish or less yellowish than the face without eye shadow. The results of ΔE were the same as described in section 2.2.1.

In the neutral face, although the main effect of eye shadow and the interaction between presentation method and eye shadow were significant (F7,105 = 3.375, p = 0.003, ηG = 0.027; F7,105 = 2.789, p = 0.011, ηG = 0.013), there were no significant differences between certain eye
Table 5 Eye shadows that changed the perceived color of the face (serial presentation)

<table>
<thead>
<tr>
<th></th>
<th>More reddish</th>
<th>More greenish</th>
<th>More yellowish</th>
<th>More bluish</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yellowish face</td>
<td>Red, Purple</td>
<td>-</td>
<td>Red, Pink</td>
<td>-</td>
</tr>
<tr>
<td>Reddish face</td>
<td>Red, Purple</td>
<td>-</td>
<td>-</td>
<td>Red</td>
</tr>
</tbody>
</table>

shadows and the face without eye shadow. Thus, although Figure 3c suggests that the yellow shadow seemed to make the face appear more yellowish in the serial presentation, there was no statistically significant effect. In the neutral face, none of the eye shadows had an effect in changing the color of the face. The results of ΔE were the same as described in section 2.2.1.

In the simultaneous presentation, there was no significant difference between certain eye shadows and the face without eye shadow (Figure 5).

4. Discussion

The eye shadows that significantly changed the perceived color of the face are summarized in Table 5. In the present study, the reddish and yellowish faces were perceived more reddish or more bluish with the reddish eye shadow colors, which consisted of red, purple, or pink. The red eye shadow was most effective for the modulation of face color and the directions of color change. The neutral face color did not show any significant differences between faces with eye shadow and the face without eye shadow. However, statistically significant results were only obtained in the serial presentation of standard and comparative stimuli. The simultaneous presentation did not induce any significant differences in perceived color between faces with and without eye shadow for all faces.

The results further suggest an effect of colors with relatively greater values of *a* like red, pink, and purple. These 3 colors had the greatest *a* of the 7 used colors (see Table 3). Although the *a* of orange was similar to pink, orange had no effect of color induction. The value of *b* distinguished between orange and pink.

Orange had the second largest *b* of the 7 colors. On the other hand, red, purple, and pink were in the middle rank of *b*. The color with the largest *b* was yellow, which had no color induction effect. Thus, a larger *b* was not effective in the present experiment.

Thus, the chromaticness rather than the hue might be effective for color induction. Colors with larger *a* and middle *b* significantly altered the face color in the direction of the inducing color. The red, purple, and pink made the yellowish face appear more reddish, and the red and purple made the reddish face appear more reddish. These results suggest that the participants judged the redness of the faces rather than the yellowness. In this sense, the cell of “more bluish” in Table 5 might be described as “less yellowish.”

The results of the present study can be understood as an example of color assimilation and demonstrate a biological illusion [21, 22], because they show the possibility of assimilation of hue in the face.

Although the effective colors for induction of color assimilation were revealed, the phenomenon experienced by professional makeup artists was not fully reproduced in the current experiment. The standard method of makeup applies similar colors to the face to suppress the original color. On the other hand, the paradoxical method of makeup uses opponent colors to get the same effect. The experiment showed a successful case of the paradoxical method for the yellow face but a failure of the standard method for the red face. Although the results seem to be favorable of the paradoxical method, other colors, except for red, purple, and pink, had no effect, and in none of the cases did the face look more yellowish. The phenomenon was not stably reproduced. Thus, we are not ready to fully accept the rules of the 2 makeup methods and the relation with general color phenomena.

5. Further research

The present study was a pilot study to obtain initial clues about the phenomenon. It must be noted that the color induction by eye shadow was confirmed under limited conditions of face color and presentation method in the present study.

The present study examined color induction of redness or yellowness in the face to prepare series of comparative stimuli changing their color from more reddish to more yellowish. The desirable complexion was examined from the point of redness and yellowness. The results, however, suggested that the participants judged only the redness. If the participants had focused on the yellowness of the faces, yellowish eye shadow colors might have shown a significant effect of color induction. Other measurements and methods should be investigated to clarify the notion of blending the applied colors seamlessly into the skin.

Moreover, in the present study, the whiteness or brightness of the face was not measured, because the brightness of the comparative stimuli was not constant. The perceptual change of brightness in a face is an important
factor for the ideal complexion. The brightness or whiteness of the face itself can influence the brightness change. The color induction in the face by red, purple, or pink might vary with facial whiteness, and colors other than the 3 might be effective in relation to other face colors.

The present study did not control the lip color, which is another important factor of makeup and effective for changing the complexion. Some professional makeup artists claim that lip color can induce a color contrast in the face. This seems to be a conflicting case of the biological illusion. More systematic control of colors will be needed to reach a definite conclusion about the phenomenon.

6. Acknowledgements

The present study was supported by a grant from the Faculty of Engineering of Chiba University in 2013, partially supported by JSPS KAKENHI Grant Number 15K00678 and is based on an oral presentation at the 61st Spring Meeting of the Japanese Society for the Science of Design (JSSD), which received a good presentation award. We are thankful to Dr. Masaya Koshino of SHISEIDO CO., LTD for his help in color measurement.

7. References

10. http://xbrand.yahoo.co.jp/category/beauty/8767/1.html (the last access date was 23th March 2015)
12. http://www.geocities.jp/net_t3/color/personal03_1.html (the last access date was 23th March 2015)
14. http://www.ritsumei.ac.jp/~akitaoka/ (The last access date was 23th March 2015)
15. There are some paper-based phenomena that could be related to color perception in faces. Miyahara [16] referred to previous research, which had reported that the induced color did not seem to be yellowish but reddish under the blue inducing color. Kitaoka [13] showed new configurations of color contrast and color assimilation as well as classic phenomena. Izawa et al. [17] reported that perception of whiteness in paper was affected by adjacent chromatic colors. The watercolor effect is the perceptual color spreading by 2 adjacent fine wavy lines with opponent colors [18].
20. Kiritani Y, Ushikubo M, Takano R. Impressions of color combination of make-up cosmetics in different


24. A reviewer criticized us for non-disclosure of information about the modulation of apparent facial color and required us to make a comparison with MacAdam ellipses. However, as we have the colorimetric data of complexion and eye shadows, we doubt that we could get the exact MacAdam ellipses corresponding to the face color without eye shadow ($x = 0.347, y = 0.349$, for your information). We are concerned about a read error. Komai & Yamada (1994) [25] indicated that there was about a 5% difference between the experimental values and read values to obtain MacAdam ellipses. A value of 5% is rather large in studies of face illusion (Morikawa, 2012). Moreover, Komai & Yamada (1994) showed the fineness of the colorimetric difference ($\Delta E$). Thus, we adopted the values of $\Delta E$ to represent the information about perceptual limits.


### Appendix: Color indexes of the 9 comparative stimuli (ellipses) related to the 3 faces

<table>
<thead>
<tr>
<th></th>
<th>Yellowish face</th>
<th>Neutral face</th>
<th>reddish face</th>
</tr>
</thead>
<tbody>
<tr>
<td>$L_V$</td>
<td>$a^*$</td>
<td>$b^*$</td>
<td>$L_V$</td>
</tr>
<tr>
<td>1</td>
<td>131.54</td>
<td>3.27</td>
<td>10.71</td>
</tr>
<tr>
<td>2</td>
<td>133.61</td>
<td>1.84</td>
<td>11.66</td>
</tr>
<tr>
<td>3</td>
<td>135.65</td>
<td>0.46</td>
<td>12.56</td>
</tr>
<tr>
<td>4</td>
<td>137.87</td>
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</tr>
<tr>
<td>5</td>
<td>143.08</td>
<td>-2.72</td>
<td>15.06</td>
</tr>
<tr>
<td>6</td>
<td>143.4</td>
<td>-4.64</td>
<td>15.96</td>
</tr>
<tr>
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<td>-7.23</td>
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</tr>
<tr>
<td>9</td>
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<td>-8.01</td>
<td>17.44</td>
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</tbody>
</table>