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Cosmetics Increase Skin Evenness: Evidence from Perceptual and Physical Measures

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Abstract

Background

Cosmetics are commonly attributed with increasing skin evenness, yet little published data characterizes the effect, either perceptually or physically. We therefore investigated whether makeup increases skin evenness using a perceptual measurement and two physical measurements of color and luminance homogeneity.

Materials and Methods

Twenty-two French women (aged 29-45 years) were photographed without cosmetics, with self-applied cosmetics, and with professionally-applied cosmetics. In Study 1, 143 participants rated skin evenness. In Study 2, each face was delineated to create regions of interest (ROI) in the cheek and forehead areas. Both ROIs were then analyzed for luminance homogeneity using an established measure (Haralick homogeneity) and a new measure that incorporates chromaticity (H76).

Results

In Study 1, the faces were rated as having more even-looking skin with either self-applied cosmetics or professionally-applied cosmetics than without cosmetics. In Study 2, the luminance homogeneity measure found that the cheek ROI, but not the forehead ROI, was more homogeneous after both self-applied cosmetics and professionally-applied cosmetics when compared to without cosmetics. The new measure incorporating chromaticity found greater homogeneity in both ROIs in the two cosmetics conditions. The new measure incorporating chromaticity also better predicted the perceived skin evenness ratings from Study 1.

Conclusion

These results provide systematic empirical evidence that makeup increases perceived skin evenness, and that these increases are partly predicted by physical measurements of skin luminance and color. The data also indicate that H76—the new measure of skin evenness that incorporates chromaticity—better predicts perceived skin evenness.

Keywords

cosmetics, evenness, homogeneity, makeup, perception, skin

Disciplines

Cognition and Perception | Psychology

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Running title: Cosmetics and skin evenness

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Results: In Study 1, the faces were rated as having more even-looking skin with either self-applied cosmetics or professionally-applied cosmetics than without cosmetics. In Study 2, the luminance homogeneity measure found that the cheek ROI, but not the forehead ROI, was more homogeneous after both self-applied cosmetics and professionally-applied cosmetics when compared to without cosmetics. The new measure incorporating chromaticity found greater homogeneity in both ROIs in the two cosmetics conditions. The new measure incorporating chromaticity also better predicted the perceived skin evenness ratings from Study 1.

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Introduction

The positive effect of cosmetics on attractiveness is well documented [1-5]. Perceptual measurements predict this effect and physical measurements can provide important mechanistic information about the nature of the visual information that is used to make such perceptual judgments. Cosmetics achieve a positive effect on skin appearance through their influence on several biological factors of attractiveness. One of these factors is skin homogeneity, commonly referred to as skin evenness, which is considered attractive[6]. Skin evenness in female faces is considered attractive because it signals health and fertility [6,7]. For instance, the malfunction of ovaries results in an overproduction of androgens which manifests itself as dermatoses [8,9].

Cosmetics are commonly attributed with influencing skin appearance. It seems an obvious point that makeup can make the skin look more even, yet we are aware of no published quantitative data supporting the claim. We sought to rectify this lack of data by systematically measuring the effect of makeup on skin evenness using both perceptual (Study 1) and physical measurements (Study 2). We did this using carefully-controlled photographs of the same women in three conditions—no makeup, self-applied makeup, and professionally-applied makeup. We predicted that across different measurements, both self- and professionally-applied cosmetics would increase skin homogeneity. We also evaluated the merits of different physical measures of skin homogeneity and tested whether these measurements predict the perceptual evaluations of skin evenness. Finally, we discuss possible mechanisms by which makeup may affect skin evenness.

Study 1

We first collected ratings of perceived skin evenness. Because faces are perceived holistically [10], we had participants rate the appearance of facial skin while viewing entire faces.

Materials and Methods

Stimuli. Twenty two French women ranging in ages from 29 to 45 (M_{age} = 37 years, SD = 5.3) were photographed facing forward, under constant camera and lighting conditions, with neutral expressions, and closed mouths. Written informed consent was obtained from all the women allowing the use of their photographs for research studies. Each woman was photographed three times: one time without any cosmetics applied, another time with cosmetics she applied herself, and another time with cosmetics applied by a professional makeup artist. This resulted in a total of 66 images, where each of the 22 female faces had a no cosmetics image, a self-applied cosmetics image, and a professionally-applied cosmetics image.

Participants and Procedure. One hundred and forty three participants completed the study (M_{age} = 18.53 years, SD = 0.87). Participants were recruited in-person at Gettysburg College. Ethical approval was received from the Gettysburg College Institutional Review Board and each participant provided written informed consent. Participants were instructed that they would be viewing several faces for which they would have to rate skin evenness. More specifically, participants were asked "How even is the skin on this person's face?", where 1 = very uneven and 7 = very even. The cosmetics conditions were intermixed and participants rated all three versions of each image individually (i.e., all 66 images) and in random order.

Results

Faces wearing cosmetics were rated as having more even skin than faces without makeup. This difference was significant whether the cosmetics were self-applied, $t(21) = 9.00$, $p < 0.001$, Cohen's $d = 1.92$, or professionally-applied, $t(21) = 14.27$, $p < 0.001$, Cohen's $d = 3.04$. We also found a significant difference in perceived evenness between self-applied and professionally-

applied cosmetics, $t(21) = 2.50$, $p = 0.021$, Cohen's $d = 0.53$. The professionally-applied cosmetics faces were rated as having more even skin than the self-applied cosmetics faces (see Figure 1).

Study 2

We next tested the effect of makeup on two physical measurements of skin homogeneity, the first being a measure of homogeneity limited to the luminance channel (Study 2a) used in the dermatology and face perception literatures, and the second being a new measure that considers homogeneity in three color dimensions (Study 2b). We then evaluated the respective contribution of both physical measurements to the global perception of skin evenness.

Materials

All 66 face images used in Study 1 (i.e., the same 22 females with a no cosmetics image, a self-applied cosmetics image, and a professionally-applied cosmetics image) were delineated to create two regions of interest (ROI) for each image: cheek and forehead (see Figure 2).

Study 2a

Methods. We analyzed the two ROIs using a measure called "homogeneity"–a variant of the Inverse Difference Moment proposed by Haralick et al. [11]—that has been used elsewhere to measure skin homogeneity [6,11-13]. Homogeneity is defined from the gray level co-occurrence matrix, a computation that describes the relationship between pixels within a ROI. This matrix defines how often a pair of adjacent pixel values occurs in the ROI. The homogeneity measures the closeness of the matrix to a diagonal matrix (i.e., a matrix with the same pixel values for every adjacent pixel). The higher the parameter is, the closer the matrix is to a diagonal matrix, the less textured the ROI is. The parameter is defined as:

$$\text{Homogeneity} = \sum_i \sum_j \frac{1}{1 + |i - j|} p(i, j)$$

Where *i* and *j* are gray-scale values in adjacent pixels, and *p*(*i*,*j*) is the frequency of their occurrence.

Results. In the cheek ROI, we found that the skin had higher homogeneity after both self-applied cosmetics, $t(21) = 2.84$, $p = 0.010$, Cohen's $d = 0.61$, and professionally-applied cosmetics, $t(21) = 3.61$, $p = 0.002$, Cohen's $d = 0.77$, when compared to no cosmetics. However, in the forehead ROI, there was no difference in homogeneity after both self-applied cosmetics, $t(21) = -0.96$, $p = 0.348$, Cohen's $d = -0.20$, and professionally-applied cosmetics, $t(21) = -0.86$, $p = 0.398$, Cohen's $d = -0.18$, when compared to no cosmetics. There were also no significant differences in homogeneity between self-applied cosmetics and professionally-applied cosmetics for the cheek area, $t(21) = 0.91$, $p = 0.371$, Cohen's $d = 0.19$, or for the forehead area, $t(21) = 0.06$, $p = 0.955$, Cohen's $d = 0.01$ (see Figure 3A).

Study 2b

Because this measurement of homogeneity is limited to a single color channel (i.e., to gray levels), it cannot evaluate variations in other color channels, such as redness and yellowness. We therefore propose to analyze both facial regions using a new parameter for global color homogeneity (H_{76}),

Methods. H_{76} color homogeneity is a modification of the 1976 CIELAB ΔE_{ab} color difference metric [14] that is widely used in spectrophotometers for comparing two colors. But rather than comparing two pixels, the H_{76} metric applies the ΔE_{ab} color difference metric to compare the L*, a*, and b* values of each pixel in a region of interest (ROI) to the mean color (μL*, μa*, and μb*) of the ROI.

$$H_{76} = \frac{1}{N}\sum_{i}\sqrt{(L_i^* - \mu L^*)^2 + (a_i^* - \mu a^*)^2 + (b_i^* - \mu b^*)^2}$$

Thus, H_{76} color homogeneity corresponds to the mean value of the color differences between each pixel in the region and the color of the entire region. Because more homogeneously colored regions have smaller differences in color between each pixel and the mean pixel value, lower H_{76} values correspond to more homogeneous regions.

Results. In the cheek ROI, we found that the skin had higher color homogeneity after both self-applied cosmetics, $t(21) = 3.58$, $p = 0.002$, Cohen's $d = 0.76$, and professionally-applied cosmetics, $t(21) = 3.91$, $p = 0.001$, Cohen's $d = 0.83$, when compared to no cosmetics. In the forehead ROI, we also found that the skin had higher color homogeneity after both self-applied cosmetics, $t(21) = 3.97$, $p = 0.001$, Cohen's $d = 0.85$, and professionally-applied cosmetics, $t(21) = 3.37$, $p = 0.003$, Cohen's $d = 0.72$, when compared to no cosmetics. However, there were no significant differences in homogeneity between self-applied cosmetics and professionally-applied cosmetics for either the cheek ROI, $t(21) = 0.33$, $p = 0.747$, Cohen's $d = 0.07$, or the forehead ROI, $t(21) = -1.47$, $p = 0.156$, Cohen's $d = -0.31$ (see Figure 3B).

Comparison of physical measurements with perceived skin evenness

We sought to determine whether the physical measurement of facial skin areas can predict the perceptual judgment of skin evenness and to evaluate the relative ability of the two physical measurements to predict the perceptual judgment from Study 1. Toward this end, we examined the relationships between the perceptual measurement and the two physical measurements using a mixed linear model, with the stimuli being a random effect and H_{76}, Haralick homogeneity, and group (i.e., no cosmetics, self-applied cosmetics, professionally-applied cosmetics) being fixed effects. We did not find a significant association between perceived skin evenness and either physical measurement for the forehead ROI, H_{76} $F(1, 40) = 1.81$, $p = 0.186$, Haralick $F(1, 40) = 0.06$, $p = 0.815$. In contrast, for the cheek ROI there was a significant association between

perceived skin evenness and H_{76}, $F(1, 40) = 18.29$, $p < 0.001$, but not between perceived skin evenness and Haralick homogeneity, $F(1, 40) = 0.10$, $p = 0.749$. Thus, the H_{76} measure was associated with perceptual judgments of skin evenness in one of the two ROIs, while Haralick homogeneity was not associated with perceptual judgments of skin evenness in either ROI.

General Discussion

Evidence from a perceptual measurement supported the hypothesis that cosmetics make facial skin look more even. In Study 1, participants rated the evenness of the skin on facial photographs of women with and without makeup. There was a large effect of makeup, with the skin appearing much more even in the two makeup conditions (i.e., self-applied cosmetics and professionally-applied cosmetics) than in the no makeup condition. There was also a significant difference between the two makeup conditions; the skin appeared more even with professionally-applied makeup than with self-applied makeup.

Evidence from two physical measurements supported the hypothesis that cosmetics make the pattern of light reflected by the facial skin more homogeneous. In Study 2, we made physical measurements of the facial photographs. In Study 2a, we used the Haralick-inspired "homogeneity" measurement that has been used in the dermatology and face perception literatures to quantify skin homogeneity. Using this measurement, we found that cheek skin was more homogeneous (even) with makeup than without, but that the forehead skin was no different with and without makeup. Because this "homogeneity" measure only considers a single color channel (i.e., a grayscale image) we proposed a new measure of skin homogeneity, H_{76}, that is based on ΔE_{ab} color difference. In Study 2b, we used the H_{76} measurement and found that forehead skin as well as cheek skin was more homogeneous with makeup than without. Given that foundation and other products are applied to the forehead as well as the cheeks, the results with the H_{76} color

homogeneity measure are more consistent with the claim that makeup makes the skin more even across different regions of the face. Further, when we compared the two physical measures to the perceptual ratings from Study 1, the Haralick-inspired homogeneity measurement did not relate to perceived skin evenness ratings for either ROI, while the H_{76} measurement related to the perceived skin evenness ratings for the cheek ROI. These data offer preliminary evidence that H_{76} more closely reflects perceptual judgments, perhaps because it includes chromatic as well as luminance information.

Though the finding that makeup makes skin appear more even is unsurprising, this intuitively obvious point is now supported by quantitative empirical evidence. The data presented here can be used as a reference to compare other uses of cosmetics, other cosmetic products, other target faces (e.g., of different ages or ethnic backgrounds), and other measurements.

Our findings provide evidence that both self-applied and professionally-applied cosmetics increase skin evenness. Interestingly, professionally-applied makeup resulted in more even-looking skin in Study 1, though no such difference was registered by the physical measurements in Study 2. We also found larger effects of cosmetics on skin homogeneity with a perceptual judgment than with physical measurements. These findings suggest that there are factors affecting the perception of skin evenness that are not captured by the physical measurements of isolated skin patches. This notion is consistent with findings from the perception of visual texture indicating that the perception of the texture of an image region is affected by adjacent regions of the visual field[15]. In other words, the apparent evenness of a patch of facial skin should be affected by adjacent visual areas, such as the facial features, and therefore the perceptual judgment of skin appearance should be affected by its visual context. Both of the physical measures we tested here are independent of their surrounding contexts, and we believe that this is likely part of why they

do not more closely match human perceptual judgments. An alternative explanation is that other facial skin areas not included in the physical measurements—such as the nose and the skin under the eyes—may be critical for the judgment of skin evenness. Further research will be needed to better characterize the mechanisms through which cosmetics have a larger effect on perceived skin homogeneity than physical measurements of skin homogeneity.

Conclusion

In conclusion, we found that cosmetics increase apparent skin evenness. The increase in perceived evenness can be partially explained by a physical measurement of luminance homogeneity, and even better explained by a measurement of luminance and chromatic homogeneity. This new measurement of skin homogeneity, H_{76}, will be helpful when rating the coverage effect of foundation or other cosmetic products. The perceptual and physical measurements are complementary, the first to predict the effect of makeup on facial skin evenness, the second to highlight the mechanisms supporting this effect.

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Figure Captions

Figure 1. Ratings of perceived skin evenness depending on cosmetics condition.

Comparison of evenness ratings for faces with no cosmetics, self-applied cosmetics, and professionally-applied cosmetics. Asterisks indicate significant differences (***$p < 0.001$, *$p < 0.05$). Error bars represent the standard error of the mean.

Figure 2. Delineated facial areas.

The delineated cheek and forehead areas used for the physical measurements of homogeneity.

Figure 3. Skin homogeneity measurements depending on cosmetics condition.

Comparison of (A) Haralick operator skin homogeneity and (B) H_{76} color homogeneity for faces with no cosmetics, self-applied cosmetics, and professionally-applied cosmetics. Lower values represent greater homogeneity and asterisks indicate significant differences (**$p < 0.01$, *$p < 0.05$). Error bars represent the standard error of the mean.