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Abstract

This study demonstrates the existence of a sex difference in facial contrast. By measuring carefully controlled photographic images, female faces were shown to have greater luminance contrast between the eyes, lips, and the surrounding skin than did male faces. This sex difference in facial contrast was found to influence the perception of facial gender. An androgynous face can be made to appear female by increasing the facial contrast, or to appear male by decreasing the facial contrast. Application of cosmetics was found to consistently increase facial contrast. Female faces wearing cosmetics had greater facial contrast than the same faces not wearing cosmetics. Female facial beauty is known to be closely linked to sex differences, with femininity considered attractive. These results suggest that cosmetics may function in part by exaggerating a sexually dimorphic attribute - facial contrast - to make the face appear more feminine and hence attractive.

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A sex difference in facial contrast and its exaggeration by cosmetics

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Abstract. This study demonstrates the existence of a sex difference in facial contrast. By measuring carefully controlled photographic images, female faces were shown to have greater luminance contrast between the eyes, lips, and the surrounding skin than did male faces. This sex difference in facial contrast was found to influence the perception of facial gender. An androgynous face can be made to appear female by increasing the facial contrast, or to appear male by decreasing the facial contrast. Application of cosmetics was found to consistently increase facial contrast. Female faces wearing cosmetics had greater facial contrast than the same faces not wearing cosmetics. Female facial beauty is known to be closely linked to sex differences, with femininity considered attractive. These results suggest that cosmetics may function in part by exaggerating a sexually dimorphic attribute—facial contrast—to make the face appear more feminine and hence attractive.

1 Introduction

Though a widespread belief in the social sciences holds that standards of beauty are arbitrary cultural conventions (Etcoff 1999), recent work has shown that our preferences are at least partly based in biology, with evidence mounting for several biologically based factors of attractiveness (Fink and Penton-Voak 2002; Rhodes 2006). Yet grooming behaviors such as the application of facial cosmetics have largely not been linked to these factors, and are still considered products of fashion (but see Cárdenas and Harris 2006; Fink and Neave 2005; Law Smith et al 2006 for suggestions of possible biological underpinnings). Use of cosmetics to beautify the face long predates the identification of these factors of attractiveness, which indicates that cosmetics were not developed explicitly to manipulate these factors. However, it is possible that cosmetic usage has evolved over time to exploit one or more of these factors. The study reported here supports this perspective, by showing that cosmetics manipulate one of the biological factors of beauty—sexual dimorphism. Specifically, it is demonstrated that cosmetics exaggerate a previously unknown sex difference in facial contrast.

Female skin has been observed and measured to be lighter than male skin, provided the males and females being compared are from the same ethnic group (Darwin 1871; Edwards and Duntley 1939; Frost 1988, 2005; Jablonski and Chaplin 2000). This sex difference is found in ethnic groups on all continents. That women have lighter skin than men is well known to people living in ethnically homogenous settings, for whom this sex difference is the major source of pigmentation variation. For the most readers this will be a surprise, as the greatest source of pigmentation variation in the modern world is between racial groups. The studies that have established this sex difference have measured body parts not exposed to the sun, to control for the possibility of sex differences in sun exposure and tanning. Because of this, the pigmentation of the face has not been measured in detail, and it is not known whether females are lighter across the entire face, including features such as the eyes and lips.

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In faces of both sexes, the eyes and lips are darker than the surrounding skin, forming an inverted triangle of dark regions surrounded by lighter regions that is characteristic of faces (Sinha 2002; Watt 1994). Curiously, increasing or decreasing the magnitude of this facial contrast has opposite effects on the attractiveness of male and female faces (Russell 2003). In that study, female faces were rated more attractive when the eyes and lips were darkened than when they were lightened, while male faces were rated more attractive with those features lightened than with them darkened. This is interesting considering the relation between sexual dimorphism and attractiveness. It has been shown by a variety of methods that sex differences in facial appearance influence attractiveness judgments. The relation is particularly strong in female faces, with more feminine females considered more attractive (eg Bruce et al 1994; Cunningham 1986; Jones and Hill 1993; O'Toole et al 1998; Perrett et al 1998; reviewed by Rhodes 2006).

This background motivated the hypothesis that there is a sex difference in facial contrast, with female faces having greater contrast than male faces. Further, if this sex difference exists, people may consider faces with greater contrast as more feminine, even though they are not aware of the sex difference. Experiment 1 was designed to determine whether facial contrast is sexually dimorphic, and experiment 2 was designed to see whether facial contrast plays a role in the perception of facial gender. Because typical application of cosmetics involves darkening the eyes and lips, experiment 3 was designed to determine whether female faces have greater facial contrast with cosmetics than without.

2 Experiment 1

2.1 *Method*

To test the hypothesis that there is a sex difference in facial contrast (the luminance difference between the eyes, lips, and the surrounding facial skin), photographs were taken of 118 clean-shaven and cosmetics-free MIT students. This included 51 East Asians (25 female, aged 18 – 22 years, mean age 19.4 years; 26 male, aged 16 – 23 years, mean age 19.8 years) and 67 Caucasians (31 female, aged 18 – 27 years, mean age 20.5 years; 36 male, aged 17 – 28 years, mean age 20.7 years). To avoid systematic differences in illumination, all photographs were taken under standard lighting conditions that have been described in two other studies that used a subset of the images collected for the present study (Russell et al 2006, 2007). The heights of the camera and lamps were fixed, and the chair used by the photographic subjects was adjusted such that their heads were all at the same height. The faces were illuminated by two studio lamps with large diffusing heads, in a small room with white walls (for greater ambient illumination). These two lamps, the camera and tripod, and the chair on which the photographic subjects sat, were kept in locations that were fixed with respect to each other and the room. The lights were centered at 0° elevation (level with the head), to eliminate cast shadows and to minimize variation from shading (Liu et al 1999).

As demonstrated in figure 1, gray-scale versions of each image were individually hand-labeled to define regions corresponding to the eyes (including the skin between the epicanthal fold and the eye, and the skin immediately below the eye), the lips, annuli surrounding the eyes (with the approximate width of the eyes but not including the eyebrow), and an annulus surrounding the lips (with the approximation width of the mouth). Luminance values of all pixels within the eyes were averaged, as were all the pixels in the lips, the annuli surrounding the eyes, and the annulus surrounding the lips, yielding mean luminance values for each of the four regions (eyes, eye annuli, lips, lip annulus). The mean luminance values for the eyes and lips were averaged to produce the mean feature luminance. Similarly, the mean luminance values for the eye annuli and lip annulus were averaged to produce the mean skin luminance. Skin and feature luminance, both being the averages of 8-bit pixel values, could range from 0

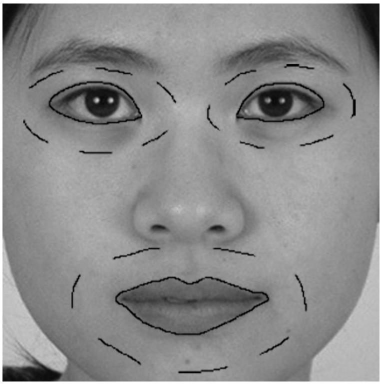

Figure 1. Illustration of feature labelling. Solid lines demonstrate how the boundaries of the eyes and lips were defined. Dashed lines indicate how the boundaries of the annuli surrounding those features were defined.

(black) to 255 (white). Facial contrast was calculated as C_F = (feature luminance − skin luminance)/(feature luminance + skin luminance). This is an adapted version of Michelson contrast, which varies from 0 to 1, with higher values indicating greater contrast, and 0 indicating no contrast.

2.2 *Results*

Female faces had greater facial contrast than male faces in both the East Asian (mean facial contrast: females = 0.160; males = 0.150) and the Caucasian (mean facial contrast: females = 0.123; males = 0.113) samples, and the East Asian faces (with dark eyes) had greater facial contrast than the Caucasian faces (with lighter eyes). A 2 (sex) × 2 (race) analysis of variance (ANOVA) of facial contrast found significant main effects of sex ($F_{1,114} = 9.69$, $p = 0.002$, $\eta_p^2 = 0.08$) and race ($F_{1,114} = 134.25$, $p < 0.001$, $\eta_p^2 = 0.54$). The interaction between sex and race was not significant ($F_{1,114} = 0.00$, $p = 0.997$, $\eta_p^2 = 0.00$), indicating that the sex difference in facial contrast did not differ between East Asian and Caucasian faces. Supporting this notion, the effect sizes for the sex difference in facial contrast were very similar for East Asian ($d = 0.55$) and Caucasian ($d = 0.60$) faces.

Figure 2 shows skin luminance plotted against eye and lip (feature) luminance for each face. The sex difference in contrast can be appreciated by noting that the regression line for female faces lies further from the line of equal luminance (along which the skin and features are equally dark) than does the regression line for male faces.

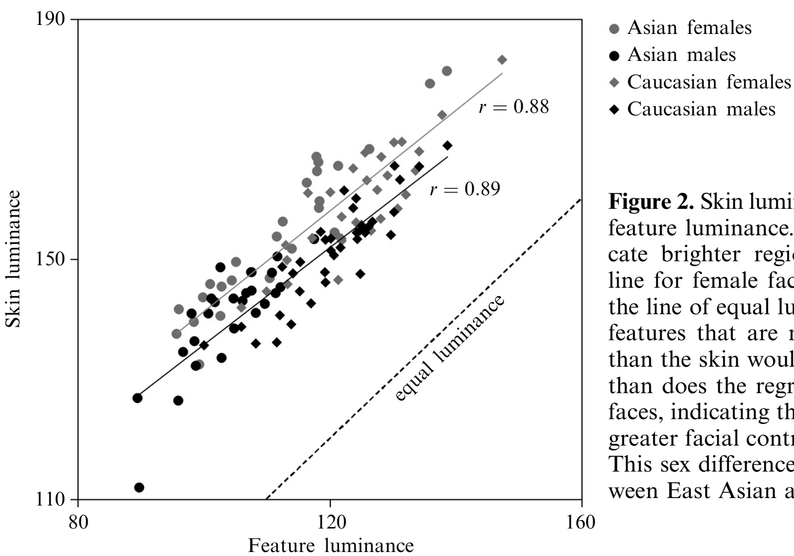

Figure 2. Skin luminance plotted against feature luminance. Larger values indicate brighter regions. The regression line for female faces lies further from the line of equal luminance (faces with features that are no darker or lighter than the skin would lie along this line) than does the regression line for male faces, indicating that female faces have greater facial contrast than male faces. This sex difference does not differ between East Asian and Caucasian faces.

Consistent with previous reports, female skin was lighter than male skin [mean skin luminance: females = 157 (SEM = 1.5); males = 147 (SEM = 1.3)]. Though female eyes and lips were lighter than male eyes and lips [mean feature luminance: females = 119 (SEM = 1.6); males = 114 (SEM = 1.4)], the difference was much smaller than the difference between male skin and female skin. Thus, the sex difference in facial contrast is a result of the sex difference in feature luminance being much smaller than the sex difference in skin luminance.

To rule out the possibility that the sex difference in contrast is simply a function of the sex difference in skin luminance, a 2 (sex) × 2 (race) analysis of covariance (ANCOVA) was carried out with facial contrast as the dependent variable and skin luminance as a control variable. Including skin luminance as a control variable did not affect the pattern of results, with significant main effects of sex ($F_{1,113} = 10.75$, $p = 0.001$, $\eta_p^2 = 0.09$) and race ($F_{1,113} = 106.49$, $p < 0.001$, $\eta_p^2 = 0.49$), but no significant interaction between sex and race ($F_{1,113} = 0.03$, $p = 0.854$, $\eta_p^2 = 0.00$). This indicates that the sex difference in facial contrast exists even when overall skin lightness is controlled.

We can also consider the contrast around the eyes or mouth alone, with eye contrast calculated as C_E = (eye luminance − eye skin luminance)/(eye luminance + eye skin luminance) and mouth contrast calculated as C_M = (mouth luminance − mouth skin luminance)/(mouth luminance + mouth skin luminance). A 2 (sex) × 2 (race) ANOVA of eye contrast showed significant main effects of sex ($F_{1,114} = 6.71$, $p = 0.011$, $\eta_p^2 = 0.06$) and race ($F_{1,114} = 155.51$, $p < 0.001$, $\eta_p^2 = 0.58$). Female faces had greater eye contrast than male faces in both the East Asian (mean eye contrast: females = 0.206; males = 0.189) and the Caucasian (mean eye contrast: females = 0.139; males = 0.131) samples. The East Asian faces (with consistently dark eyes) had much greater eye contrast than the Caucasian faces (with lighter eyes). The interaction between sex and race was not significant ($F_{1,114} = 0.84$, $p = 0.362$, $\eta_p^2 = 0.01$). A 2 (sex) × 2 (race) ANOVA of mouth contrast showed a significant main effect of race ($F_{1,114} = 10.29$, $p = 0.002$, $\eta_p^2 = 0.08$) and a trend toward a main effect of sex ($F_{1,114} = 3.29$, $p = 0.072$, $\eta_p^2 = 0.03$). Female faces had greater mouth contrast than male faces in the Caucasian sample (mean mouth contrast: females = 0.109; males = 0.098) but there was virtually no sex difference in the East Asian sample (mean mouth contrast: females = 0.115; males = 0.114). However, the interaction between sex and race was not significant ($F_{1,114} = 1.58$, $p = 0.211$, $\eta_p^2 = 0.01$). Of the two features, the sex difference in contrast was larger for the eyes than the mouth, particularly for East Asian faces.

It is relevant that there is a sex difference not only in overall luminance of the face, but also in luminance contrast, because contrast is a robust signal for visual perception, and the property to which most neurons in the early visual stream respond. Though luminance contrast is a robust visual cue, the effect size of the sex difference in facial contrast ($d = 0.55$ for East Asians and $d = 0.60$ for Caucasians) is much smaller than effect sizes for well-known sexual dimorphisms such as height ($d = 1.4$; Ogden et al 2004) and waist-to-hip ratio ($d = 1.7$; Dobbelsteyn et al 2001). The smaller effect size is likely the reason why people are not aware of the sex difference in facial contrast, while they are aware of the sex differences in height and waist-to-hip ratio. Though people are not conscious of the sex difference in facial contrast, they may nevertheless use it as a cue in determining the sex of a face or making judgments of facial masculinity or femininity.

3 Experiment 2

A demonstration of the utility of facial contrast for determining the sex of a face can be seen in figure 3. Both images were created by manipulating the same original image of a perceptually androgynous face made by morphing together male and female average faces (see figure A1 in the appendix). To make both images (with Adobe Photoshop),

Figure 3. The Illusion of Sex. The face on the left appears male, while the face on the right appears female. Both images were produced by making slight alterations to the same original image. The eyes and lips were unaltered, and hence equally dark in both images. The remainder of the image was darkened to produce the left image, and lightened to produce the right image. The eyes and lips may appear darker in the right image than in the left image, but are not—it is an example of simultaneous contrast.

the eyes and lips were left unchanged, but the rest of the image was darkened to produce the left image or lightened to produce the right image. Because the eyes and lips were unchanged while the rest of the face was made darker or lighter, facial contrast was decreased or increased. Though a subtle manipulation, it has a powerful effect—making the image on the left with decreased contrast appear male and the image on the right with increased contrast appear female.

In the Illusion of Sex shown in figure 3, the face with lower contrast also has darker skin. Because males have darker skin, it is possible that the difference in skin darkness drives the illusion rather than the difference in facial contrast. To test this possibility, we can create a pair of faces in which facial contrast is manipulated by darkening or lightening the eyes and lips but keeping the rest of the face unchanged. These faces appear in figure 4. Again, the face on the left with decreased contrast appears male and the face on the right with increased contrast appears female. Because the two faces have the same skin tone, this provides evidence that facial contrast alone can be used as a cue for determining the sex of a face. Indeed, facial contrast may in fact be more important than overall lightness—darkening or lightening the entire face has no effect on perceived gender (see figure A2 in the appendix). Collectively, these versions of the

Figure 4. Variant of the Illusion of Sex. The face on the left appears male, while the face on the right appears female. Both images were produced by making slight alterations to the same original image. The eyes and lips were lightened to produce the left image, and darkened to produce the right image. The rest of the face was unaltered, and hence equally dark in both images. That decreasing or increasing facial contrast is sufficient to make a face appear male or female indicates that facial contrast plays a role in the perception of facial gender.

Illusion of Sex indicate that, while people are not consciously aware of the sex difference in facial contrast, they nevertheless use it as a cue in perceiving the sex of a face.

Though facial contrast is known to have different effects on male and female attractiveness (Russell 2003), its relation to perceived masculinity and femininity has not been explained. Because facial contrast is used as a cue for perceiving the sex of a face, it would not be surprising if it were also used as a cue for making judgments of masculinity and femininity. To test the hypothesis that facial contrast is related to judgments of masculinity and femininity, twenty-nine subjects (fifteen female) gave Likert-scale ratings of masculinity (for male faces) or femininity (for female faces) to full-color (RGB) versions of 117 of the 118 images described above. The image excluded from the set was an Asian female personally known by several subjects. Cronbach's α indicated high reliability of the judgments of masculinity ($\alpha = 0.88$) and femininity ($\alpha = 0.95$). Facial contrast was positively correlated with rated femininity of female faces ($r = 0.31$, $p = 0.022$), but negatively correlated with rated masculinity of male faces ($r = -0.46$, $p < 0.001$).

These correlations between rated femininity and masculinity and facial contrast could be a byproduct of skin luminance (which is also sexually dimorphic). With skin luminance as a control variable, facial contrast was still positively correlated with rated femininity of female faces ($r = 0.36$, $p = 0.008$) and negatively correlated with rated masculinity of male faces ($r = -0.39$, $p = 0.002$). Even with skin luminance controlled, greater facial contrast was rated more feminine in female faces but less masculine in male faces. Another possible confound could come from analyzing the Caucasian and Asian faces together. To take both skin luminance and ethnicity into account, the results were analyzed as a partial correlation with skin luminance and ethnicity as control variables. With skin luminance and ethnicity controlled, facial contrast was correlated positively with rated femininity of female faces ($r = 0.24$, $p = 0.078$), but negatively with rated masculinity of male faces ($r = -0.05$, $p = 0.700$). Controlling for ethnicity and skin luminance yields the same pattern of results (a positive correlation between contrast and femininity but a negative correlation between contrast and masculinity), but the correlations were weaker and not statistically significant (particularly for male faces). To summarize, in a set of real faces, a significant relationship was found between facial contrast and rated masculinity and femininity, but it was modulated by ethnicity. Overall, the ratings were weakly consistent with greater facial contrast being considered more feminine and less masculine.

4 Experiment 3

Typical cosmetics usage, by darkening the eyes and lips while little changing the luminance of the rest of the face, should increase facial contrast. To confirm that this is the case, 12 Caucasian females (18 – 21 years, mean 19.6 years) were photographed. These individuals were photographed twice, once with and once without cosmetics. For the photographs with cosmetics, the women were instructed to "apply cosmetics as you would when going out at night", and applied the cosmetics themselves at home.

Facial contrast was measured with gray-scale images of the faces by the same methods as in experiment 1. Mean facial contrast was 0.16 (SD = 0.04) in the faces wearing cosmetics, and 0.12 (SD = 0.01) in the faces without cosmetics, a significant difference as assessed by a paired-samples, two-tailed t-test ($t_{12} = 5.6$, $p < 0.001$, $d = 1.70$). The increase of facial contrast was also consistent—all 12 faces had greater contrast with cosmetics than without. This large increase in facial contrast achieved with cosmetics more clearly differentiates male and female faces. The effect size of the sex difference in facial contrast comparing the 36 male Caucasian faces and the 12 female Caucasian faces wearing cosmetics ($d = 1.85$) compares favorably to the effect sizes of the sex differences in height or waist-to-hip ratio. Application of cosmetics increased both eye contrast [with cosmetics, mean eye contrast = 0.17 (SD = 0.03); without cosmetics, mean eye contrast = 0.13 (SD = 0.03); paired-samples, two-tailed $t_{12} = 3.2$, $p = 0.009$, $d = 1.15$] and mouth contrast [with cosmetics, mean mouth contrast = 0.16 (SD = 0.04); without cosmetics, mean mouth contrast = 0.10 (SD = 0.02); paired-samples, two-tailed $t_{12} = 5.1$, $p < 0.001$, $d = 1.70$]. These results confirm that cosmetics are used in a way that accentuates a sexually dimorphic feature (facial contrast).

5 Discussion

Investigation of a large set of faces showed that females have greater facial contrast than do males. This sex difference in facial contrast was found in both East Asian and Caucasian faces. Female or male faces with greater facial contrast were rated as more feminine or less masculine than faces with less contrast, though the relation was very weak for male faces. Decreasing or increasing the facial contrast in an androgynous face (figures 3 and 4) is sufficient to make it appear male or female. These findings indicate that, while people are not consciously aware of this sex difference, their perceptual systems nevertheless make use of it. Because femininity and attractiveness are strongly related (Bruce et al 1994; Cunningham 1986; Jones and Hill 1993; O'Toole et al 1998; Perrett et al 1998; Rhodes 2006), these results help explain the previous finding that female faces are more attractive with increased facial contrast than with decreased facial contrast (Russell 2003).

In the current study, typical application of cosmetics was found to increase the contrast between the eyes, lips, and the rest of the face—precisely the manipulation capable of making the face appear more feminine. It is extremely unlikely that this would happen by chance. Parts of the face could be lightened or darkened in many different spatial patterns, but only this particular pattern is related to how male and female faces differ. Further, there is a direction to the spatial pattern—increasing the contrast makes the face appear more feminine, but decreasing it makes the face appear more masculine. Yet cosmetics consistently increase facial contrast. Faces are rated more feminine (Cox and Glick 1986) and more attractive (Cash et al 1989; Cox and Glick 1986; Graham and Jouhar 1981; Huguet et al 2004; Mulhern et al 2003) when wearing cosmetics than when not wearing cosmetics, whether the cosmetics are self-applied [as in the Cash et al (1989) study] or professionally applied (as in the other studies). Together with the current findings, this suggests that an important function of cosmetics may be to increase the apparent femininity, and hence attractiveness, of the female face by increasing facial contrast.

Accentuating sex differences to make the female face appear more feminine and thereby more attractive is not limited to changing facial contrast. Another common manipulation of a sexually dimorphic facial feature is eyebrow plucking. Brow thickness and brow-to-eye distance are both sexually dimorphic (Burton et al 1993; Farkas and Munro 1987), with females having thinner brows that are higher above the eye. Standard advice (Aucoin 1997; Brown and Iverson 1997) instructs women to pluck the eyebrows from the bottom side, resulting in a thinner brow that is also further from the eye, making the face appear more feminine. It is likely that accentuation of sexual dimorphism as a way to enhance facial attractiveness is a general strategy of cosmetics and other grooming behaviors.

In addition to sexual dimorphism, there are other biologically based standards of facial beauty, including averageness (Langlois and Roggman 1990), symmetry (Thornhill and Gangestad 1993), and youth (Zebrowitz 1997). It is likely that cosmetics are—or could be—used to manipulate all of these factors. While it is widely believed that cosmetics are an arbitrary cultural phenomenon largely dictated by fashion, the present findings suggest an alternative scientific explanation for the use of cosmetics, premised upon their manipulation of biologically based factors of facial beauty.

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Appendix

Figure A1. This androgynous face was produced by morphing together Caucasian male and female averaged faces. It was manipulated to produce the faces in figures 3, 4, and A2.

Figure A2. No illusion. Both the right and left images appear androgynous. The entire original image (figure A1) was lightened to produce the left image, and darkened to produce the right image.

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