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Human (*Homo sapiens*) Facial Attractiveness in Relation to Skin Texture and Color

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The notion that surface texture may provide important information about the geometry of visible surfaces has attracted considerable attention for a long time. The present study shows that skin texture plays a significant role in the judgment of female facial beauty. Following research in clinical dermatology, the authors developed a computer program that implemented an algorithm based on co-occurrence matrices for the analysis of facial skin texture. Homogeneity and contrast features as well as color parameters were extracted out of stimulus faces. Attractiveness ratings of the images made by male participants relate positively to parameters of skin homogeneity. The authors propose that skin texture is a cue to fertility and health. In contrast to some previous studies, the authors found that dark skin, not light skin, was rated as most attractive.

What makes people look twice at a face and sigh in appreciation? Is beauty really in the eye of the beholder, or is the perception of beauty ingrained in the human psyche? It was once widely believed that standards of beauty were arbitrarily variable (Etcoff, 1999). Recent research suggests, however, that people's views of facial attractiveness are remarkably consistent, regardless of race, nationality, or age (Perrett, May, & Yoshikawa, 1994). Three facial characteristics are known to influence human attractiveness judgments: youth (reflects absence of senescence), certain sexually dimorphic sex hormone markers, such as chin size (reflects hormonal health), and symmetry of bilateral traits (reflects developmental health; see Thornhill & Gangestad, 1999, for a review of evidence). These three characteristics all pertain to health, leading to the conclusion that humans have evolved to view certain bodily features as attractive because these features are displayed by healthy individuals (Grammer & Thornhill, 1994; Thornhill & Gangestad, 1999).

Charles Darwin (1871) himself attributed to selection pressures the greater visibility of the human skin associated with relative hairlessness. It has been proposed that skin condition reliably signals aspects of female mate value (Barber, 1995; Symons, 1979, 1995). Although no full explanation has been offered, it is taken for granted that small differences in skin texture and facial hair can have effects on women's sexual attractiveness. Also, human males, universally, are expected to be most sexually attracted by female skin that is free of lesions, eruptions, warts, molds, cysts, tumors, acne, and hirsutism (Symons, 1995). According to Morris (1967), flawless skin is the most universally desired human feature. Skin and hair, so sexy when healthy, seem to be repellent if they are not healthy (Barber, 1995; Etcoff, 1999).

The signaling value of many female body features is linked to age and reproductive condition, both of which correspond to a woman's ratio of estrogen to testosterone (Symons, 1995; Thornhill & Grammer, 1999). Attractive signals correspond to high ratios. Estrogen promotes women's fertility, but it also has costs, especially at very high levels (Dabbs, 2000). Markers of high estrogen may reliably signal a female immune system of such high quality that it can deal with the toxic effects of high estrogen (Thornhill & Grammer, 1999; Thornhill & Møller, 1997). Studies in dermatology have found a relationship between dermatoses (i.e., physiologic and pathologic changes that can occur in the skin, nails, and hair shafts) and elevated levels of sex hormones (testosterone, estrogen). In many types of dermatoses in women, an increase of the level of androgens seems to be responsible for these symptoms. Held et al. (1984) and later Lucky (1995) reported a correlation between an elevated level of testosterone and the formation of acne in women. A malfunction of the ovaries—for example, caused by the polycystic ovary syndrome—always results in an overproduction of androgens, which is clinically manifested as dermatoses in women (Schiavone et al., 1983; Steinberger, Rodriguez-Rigau, Smith, & Held, 1981). These dermatoses affect not only the neck but also the face. Consequently, dermatoses may denote a disturbance of the production of androgen and estrogen and reduced reproductive ability of a woman. Another related trait is the absence or presence of body hair, which is sexual dimorphic (Van den Berghe & Frost, 1986). Females appreciate men's body hair developed under androgens, but males prefer its absence on females (Symons, 1995). Removal of body hair is more prominent in women than in men. Thus, relative hairlessness and smooth skin in women may signal fertility because of its association with low androgen and high estrogen.

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Feather and skin-patch coloration is known to influence sexual attractiveness in a wide variety of nonhuman animals (Andersson, 1994). It has been suggested that skin color has a significant effect on human mate selection because paler skin is a youthful feature (Darwin, 1871; Frost, 1988; Van den Berghe & Frost, 1986). Accordingly, women with paler skin are, in effect, advertising youthfulness, and men prefer lighter skinned women because of associated higher fertility.

Another possible explanation for preference of lighter skin is infantile mimicry—the imitation of infantile traits by one sex to reduce aggression and to elicit care-taking behavior in the other (Eibl-Eibesfeldt, 1984; Lorenz, 1943). This trend toward infantilization is more advanced in women than in men (Frost, 1988).

Female skin color fluctuates slightly with the menstruation cycle, being lightest near ovulation (Frost, 1988). In contrast, up to 90% of women experience hyperpigmentation during pregnancy (Wong & Ellis, 1984). In addition, melasma (i.e., blotchy, irregular hyperpigmentation) and a variety of dermatoses (e.g., vascular spiders, varicosities, stretch marks, hirsutism, and edema) regularly occur during pregnancy (Winton & Lewis, 1982). Skin darkens during pregnancy, while taking contraceptive pills, and even during infertile phases of the menstrual cycle (Steinberger et al., 1981). Van den Berghe and Frost (1986) have proposed that changes in skin color enable human males to distinguish fertile postpubescent females from infertile prepubescent ones.

In prior research, clinical dermatologists have attempted to describe and classify human skin (Fiedler, Meier, & Hoppe, 1995; Pope, Williams, Wilkinson, & Gordon, 1996; Stoecker, Chiang, & Moss, 1992). The goal of this clinical research was to quantify more precisely parameters that aid in tumor identification. Also, evolutionary psychologists have made suggestions about the importance of the condition of the skin for human facial attractiveness (e.g., Jones, 1996; Symons, 1979, 1995), but, to our knowledge, there has not been an actual test of this hypothesis.

Most of the literature cited is only speculative. Until now, research has lacked an empirical approach to the importance of skin texture for facial attractiveness from an evolutionary point of view. A consequence for the present study was the establishment of a research design that could measure the influence of skin texture on facial beauty.

We provide a tool that measures the influence of skin texture and color on female facial beauty. We predicted that a female face with a homogeneous skin surface would be considered more attractive than a female face that was rich in contrast. We reasoned that skin smoothness would depict healthy levels of reproduction hormones and a relative absence of skin disorders. Furthermore, we reasoned that on an analysis of facial color, high values of blue and green components would have a negative effect on attractiveness ratings. Red-colored cheeks may indicate a normal blood circulation in peripheral vessels. Thus, a reduction of the red component might reveal a physiological imbalance. As an expression of a normal blood circulation, a slightly reddish skin was predicted to be judged as healthy and attractive (Symons, 1995; Zahavi & Zahavi, 1997). Also, in accordance with the theory of Van den Berghe and Frost (1986), we examined the hypothesis that men prefer women with a paler skin because this may be a cure to high fertility associated with young adulthood. Finally, we examined the relationship between facial symmetry and facial attractiveness to see if this relationship was present and, if so, how it might influence other attractiveness relationships of interest.

Method

Stimulus Material

Individual test images. The faces of 20 Caucasian women, ages 18 to 25 years, were used as stimulus faces. These faces were from a database (Americans 1.0 [Digital Photography on CD-ROM]; Digitalogue Co., Tokyo, Japan) of 100 women's faces, photographed with a digital camera under constant light conditions by the Japanese artist Akira Gomi in Los Angeles in 1994. The women responded to Gomi's advertisement in the *Los Angeles Times,* were paid about $50, and signed a consent form allowing their photographs to be used in scientific studies. These faces were judged for their attractiveness in a former study on a 7-point Likert scale (1 = *least attractive,* 7 = *most attractive;* Thornhill & Grammer, 1999). We chose the 20 faces randomly but made sure that faces with ratings of average, below average, and above average attractiveness were included. These images showed the women with neutral facial expressions, and wearing no make-up or adornments (e.g., earrings). No color processing was applied to the original photographs. The digital images had a width of 350 pixels and a height of 480 pixels, were in 24-bit color, and were in a Macintosh PICT file format that did not use any image compression (because this would distort the results of the texture analysis; see below).

Standardization of test images. The digital images were standardized to the same orientation by the following procedure: The shape of facial features was defined by manually marking 51 predefined feature points ("landmarks") in each face (source coordinates; see Figure 1), which could be easily identified in every image (landmark placement reliability was tested with an untrained student and resulted in a mean error of 1.5, $SD = 0.8$, pixels placement error). In a second step, the mean coordinates (destination coordinates) and the respective landmarks were calculated for all of the 100 original faces of the database. After that, the center of gravity (i.e., for x coordinates: $x_{\text{center of gravity}}$ = sum of all x coordinates divided by the number of landmarks; same procedure for y coordinates) of the source coordinates was calculated for each face. Every face was moved on the picture plane so that the center of gravity of a face fell on the center of gravity of the destination coordinates. Using a least squares method, we resized each face to 150% of its original size and then scaled it down in 1-pixel steps until the square sum of the difference between source and destination coordinates reached a minimum. After scaling, we rotated the face 45° around the center of gravity. Resizing and rotating the face is necessary for comparable (equally orientated) images. The same method was then applied for stepwise rotation. Finally, we had pictures that were optimized for size and orientation in relation to the center of gravity of the face (see Bookstein, 1997, and Wolberg, 1990, for additional methodological information).

Generation of composites. With these prerequisites, two sets of images were produced for the follow-up rating studies. A first set of images (Set A) consisted of 20 pictures that were manipulated in size and orientation, as described above. A second set (Set B) was standardized for shape as well by warping the 20 original images to an averaged image that represented a digital blend (composite, prototype) of the whole sample of 100 original faces taken by Akira Gomi (see Beier & Neely, 1992; Gomes, Darsa, Costa, & Velho, 1999; Wolberg, 1990; for details on digital image warping). Thus, we obtained stimulus faces that were different in shape and texture (Set A), and stimulus faces that were equal in shape (as a result of the image warping) but differed in skin texture (Set B). All faces were cropped digitally with the aid of Adobe Photoshop (Adobe Systems Inc., Seattle, WA) to eliminate hair style cues. This was done by embedding the face into an oval shape that eliminated the external hair shape (see Figure 2).

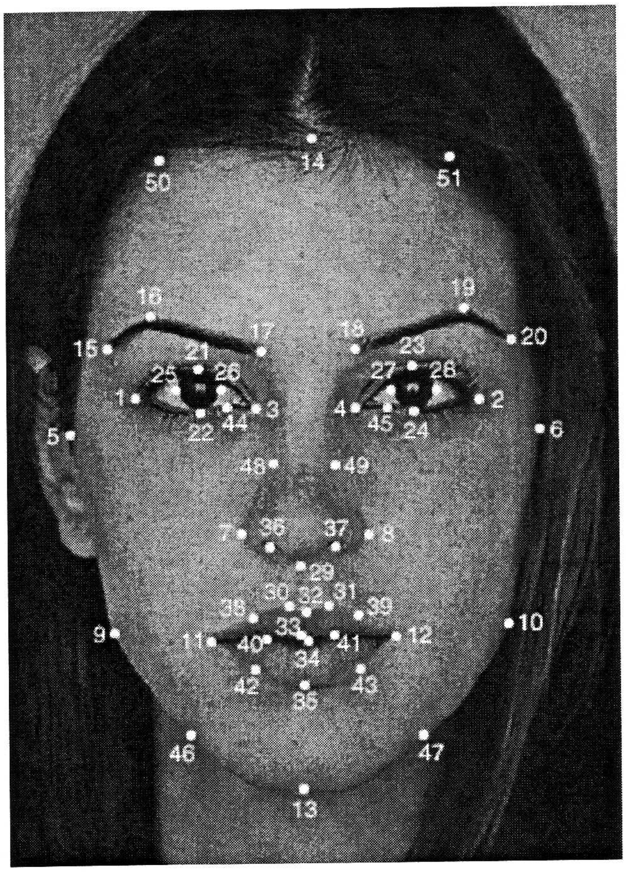

Figure 1. Location of 51 landmarks in each face. These feature points could be easily identified in the images and showed a high placement reliability. Photograph 1994 by Akira Gomi.

Rating Study

Raters. A total of 54 adult male Caucasian volunteers were recruited from the University of Vienna, Vienna Biocenter, Vienna, Austria. Twenty-seven men (mean age = 25 years) rated Set A images and 27 different men (mean age = 23.1 years) rated Set B images. Some of the men were students who were compensated with a research credit in the Human Ethology Program.

Apparatus. The digitized facial pictures were presented to each rater individually in a closed room by an interactive computer program on a 17-in. (43-cm) computer screen at a resolution of 1024 × 768 pixels and 72 dpi. Color profile of the computer screen was calibrated to be standardized for all raters using Adobe Gamma (Adobe Systems Inc., Seattle, WA).

Procedure. The two sets of stimulus faces (Set A and Set B) were rated in separate studies for 10 adjectives.[1] Set A was rated in the first study, and Set B was rated in the second study. In both studies, observers were asked simply to make their judgments of the 10 adjectives of the faces on a 7-point Likert scale (1 = *least,* 7 = *most*) using a mouse and clicking on buttons at the bottom of the computer screen. Faces were presented one at a time and remained visible until the observer made his decision. Participants were allowed to view pictures as long as they wished. They were not informed of the purpose of the study (that we were looking for a possible correlation between skin texture and facial attractiveness). Only the attractiveness ratings, and not the ratings based on the other 9 adjectives, were used in the present study. Order effects of presentation were controlled by presenting faces as well as adjectives to raters in randomized order (i.e., the order of the faces and adjectives was changed for every rater). Demographic data of the participants were ascertained, and participants signed a statement of informed consent and agreement for the data to be used for scientific purposes.

Analysis of Facial Texture

Image enhancement. Before we analyzed the images using a co-occurrence matrix, we thought that the application of an image-sharpening filter ("Mexican hat kernel"; see Sonka, Hlavac, & Boyle, 1993, for details) appeared useful. Image sharpening makes edges steeper (Rosenfeld & Kak, 1982). Here, the central pixel is replaced by the average of itself and its neighborhood. These neighboring pixels are multiplied by a set of integer weights. By convention, these weights are to be multiplied by pixels surrounding the central pixel. Dividing it by the sum of the positive weights normalizes the sum. This scheme was applied to every pixel of the input image in the region of interest (i.e., a rectangle that reached from the edge of the lower lip to the lower edge of the eyes and was limited by a line through the promontory of the cheekbones at the sides; see Figure 2). Thus, contrast enhancement made it easier to segment pixels with differing gray values. After that, we subjected the sharpened faces to texture analysis and computed the texture parameters described in the Appendix for every picture.

The co-occurrence matrix. For the analysis of texture, classification, and image segmentation, we used a method based on co-occurrence matrices (Davis, Johns, & Aggarwal, 1979; Dhawan & Sicsu, 1992; Haralick, 1979). Co-occurrence matrices are based on second-order statistics, which are the spatial relationships of pairs of gray values of pixels in digital texture images. They count how often pairs of gray levels of pixels, which are separated by a certain distance and lie along a certain direction, occur in a digital image of texture. Co-occurrence matrices are not used directly, but features based on them are computed. The purpose of these features is that they capture some characteristics of textures, such as homogeneity, coarseness, and periodicity. In a classic article on this subject, Haralick, Shanmugam, and Dinstein (1973) suggested 14 texture operators. Out of Haralick's original 14 features, we chose 7 operators that performed best in past studies and were therefore used most frequently (Davis et al., 1979; Dhawan & Sicsu, 1992; Ohanian & Dubes, 1992). The Appendix provides a more detailed description and formal definition of co-occurrence matrices and texture parameters.

Analysis of Facial Color

We determined skin color in a red, green, and blue (RGB) color space and separately in a hue, saturation, and value (HSV) color space. Color was measured by calculating the mean hue, value, and saturation of the same picture region we used for texture analysis. Colors in the RGB color space are represented as values between 0 and 65,535 for red, green, and blue. The hue of the HSV color space component is an angular measurement (on the HSV hexacone), analogous to a position in a color wheel. A hue value of 0° indicates the color red, a value of 120° indicates the color green, and a value of 240° indicates the color blue. Saturation describes color intensity and distinguishes a strong color from a weak color. A saturation score of 0 means that the color is colorless, whereas a saturation at maximum value means that the color is at maximum colorfulness for that hue. The value component describes brightness or luminance. A value of 0 represents black; a maximum value means that the color appears brightest. Color spaces are closely related to each other, but most of them do not correspond

[1] Adjectives used in the rating studies were as follows (translation from German to English in parentheses): *gesellig* (sociable), *intelligent* (intelligent), *attraktiv* (attractive), *dominant* (dominant), *lebhaft* (lively), *ängstlich* (anxious), *sorgsam* (careful), *selbstsicher* (self-confident), *gesund* (healthy), and *ausgeglichen* (balanced).

Figure 2. Face blends. Original face (left), the averaged face ("composite") that resulted by combining 100 individual faces (middle), and the warp of the original face to the mean composite face (right). In the right image, the rectangle marks the region for which the co-occurrence matrix was performed and shows the contrast enhancement filter. Photograph 1994 by Akira Gomi.

directly to human vision. The HSV system does, which has many advantages for image processing because the color information is separated in ways that correspond to the human visual system's response. For more information on the use of HSV color spaces, see *Advanced Color Imaging on the MacOS* (Apple Computer Inc., 1995).

Analysis of Facial Symmetry

We used a digital image analysis algorithm for the detection of symmetry in a face. The program, developed by Karl Grammer, created a window on the picture that was defined by the left and right outer eye corners, the tops of the brows, and the lower lip. This window then was divided in n horizontal 1-pixel-wide slices. Each slice was then moved over the face until a symmetry point was reached. For every step, the difference of the gray values of the pixels between the left and right half was calculated. The symmetry point is reached when the difference between the two halves of each slice reaches a minimum. Thus, n symmetry points were calculated as the minimum difference between the sum of pixels of the left and the right half of the respective slice. In an ideal symmetrical face, the line through all symmetry points is a straight line and equals the distance between the top of the brows and the lower lip. The symmetry index was calculated as the length of the symmetry line divided by the height of the window.

Results

Because not all ratings and measurements were normally distributed, we used nonparametric statistical tests to analyze results (Spearman rho correlation). Probabilities are reported as two-tailed and a probability of 5% ($p = .05$) or less is considered statistically significant. Table 1 shows the correlations between the seven texture features.

Original Faces (Set A)

Table 2 illustrates the relationship between texture and color parameters of the original (unprocessed) faces and their attractiveness. Homogeneity and contrast features as well as color parameters did not correlate significantly with attractiveness. On average, the faces were rated 3.70 ($SD = 1.20$). Actual ratings may be obtained from Bernhard Fink.

Warped Faces (Set B)

Through the standardization of the stimulus faces by digital image warping, the second set of stimulus faces differed only in texture and not in shape. Texture parameters of the warped faces, with the exceptions of energy and inverse difference moment, were significantly positively correlated with attractiveness ratings. The exceptional correlations were also positive and of values of about .40 (see Table 3). In contrast to previous studies (Frost, 1988; Van den Berghe & Frost, 1986), we did not find a positive correlation between light skin (value) and attractiveness. It seems that the reverse may be considered attractive ($r = .44$, *ns*), a pattern supported by a significant positive relation between color saturation and attractiveness (see Table 3). On average, the faces were rated 3.79 ($SD = 1.16$).

As predicted, green and blue were negatively correlated with attractiveness, and red was positively correlated with attractiveness; however, only the correlation for blue reached statistical

Table 1
Spearman Correlations Between Texture Features

Texture feature	1	2	3	4	5	Correlation
Energy	.810**	.966**	.470*	.608**	.233	−.682**
1. Homogeneity		.906**	.514*	.622*	−.269	−.523*
2. IDM			.456*	.590*	.085	−.659**
3. CS				.979**	−.096	.078
4. CP					−.085	−.063
5. Contrast						−.060

Note. See the Appendix for a description of texture features. IDM = inverse difference moment; CS = cluster shade; CP = cluster prominence.
* $p < .05$, ** $p < .01$, two-tailed.

Table 2
Spearman Correlations of Mean Attractiveness Ratings With Texture and Color Features for the Original Faces (n = 20)

Feature	Correlation with attractiveness
Texture	
Homogeneity	
Energy	.057
Homogeneity	.126
IDM	.147
CS	.117
CP	.150
Contrast	
Contrast	.102
Correlation	.159
Color	
Red	.080
Green	−.036
Blue	−.083
Hue	.114
Saturation	.214
Value	−.198

Note. $M = 3.70$, $SD = 1.20$ for attractiveness. IDM = inverse difference moment; CS = cluster shade; CP = cluster prominence.

significance. None of the variables that we correlated with attractiveness were significantly correlated with age in our sample of warped faces. Therefore, we did not statistically partial out age in the correlations we report.

One might consider an influence of warping on texture or color in the images. However, correlations between the textural and color features of the original faces and the warped images were high (see Table 4), and thus warping itself probably did not introduce any serious confounds.

Symmetry as Confounding Factor

Original faces as well as warped faces were very symmetric and showed a limited range of symmetry values (Set A: Minimum = 431, Maximum = 986, *Mdn* = 962, *SD* = 123.25; Set B: Minimum = 456, Maximum = 988, *Mdn* = 954, *SD* = 130.11). Symmetry of the original faces (Set A) did not correlate significantly with attractiveness ratings ($r_s = -.088$, *ns,* two-tailed). Likewise, symmetry measurements for the warped faces (Set B) did correlate positively but not significantly with attractiveness ($r_s = .188$, *ns,* two-tailed) and health. Because symmetry had no significant influence on the judgment of attractiveness in our sample of faces, we did not analyze partial correlations to control the influence of symmetry on attractiveness ratings. A correlation of $r_s = .768$ ($p < .01$, two-tailed) between the symmetry of the original faces (Set A) and the processed ones (Set B) shows that the standardization for shape did not greatly alter facial symmetry.

Discussion

This study provides evidence that women's facial skin texture affects (male) judgment of women's facial attractiveness and that homogeneous (smooth) skin is most attractive. The results suggest that skin-texture features are evaluated in addition to the characteristics of age and facial shape (hormone markers) in judgments of facial beauty. All homogeneity features we derived from warped faces that correlated positively with attractiveness ratings. High values of energy, homogeneity, inverse difference moment, cluster

Table 3
Spearman Correlations of Mean Attractiveness Ratings With Texture and Color Features for the Warped Faces (n = 20)

Feature	Correlation with attractiveness
Texture	
Homogeneity	
Energy	.402
Homogeneity	.496*
IDM	.391
CS	.463*
CP	.462*
Contrast	
Contrast	−.016
Correlation	.011
Color	
Red	.023
Green	−.282
Blue	−.462*
Hue	.044
Saturation	.504*
Value	−.437

Note. $M = 3.79$, $SD = 1.16$ for attractiveness ratings. IDM = inverse difference moment; CS = cluster shade; CP = cluster prominence.
* $p < .05$, two-tailed.

Table 4
Spearman Correlations Between Texture and Color Features for the Original Faces and the Warped Faces

Feature	*r*
Texture	
Homogeneity	
Energy	.893**
Homogeneity	.755**
IDM	.727**
CS	.961**
CP	.944**
Contrast	
Contrast	.968**
Correlation	.828**
Color	
Red	.955**
Green	.955**
Blue	.989**
Hue	.992**
Saturation	.983**
Value	.983**

Note. *r* denotes the correlation between the calculated parameters in an original face and a warped face. IDM = inverse difference moment; CS = cluster shade; CP = cluster prominence.
** $p < .01$, two-tailed.

shade, and cluster prominence are an expression of a homogeneous surface (i.e., neighboring pixels have the same gray value, and clusters of these pixels are distributed uniformly over the whole face). This can be the case only when the structure of the skin is homogeneous and does not show any disturbances that can be caused by dermatoses, any other kind of lesions, or variable facial hair growth. Parameters that measure coarseness in an image (contrast, correlation) were uncorrelated with attractiveness.

Our findings did not support the hypothesis that men prefer women with paler skin because this may be an indication of fertility (Van den Berghe & Frost, 1986). Color parameters that indicate a light skin (value) as well as the blue and green component in a face correlated negatively with attractiveness, but only the correlation with blue was statistically significant. In contrast, saturation showed a significant positive correlation with attractiveness. The red component showed a positive but statistically insignificant correlation with attractiveness. We interpreted this finding in terms of the suggestion that slightly reddish skin is considered attractive and healthy. The preference for dark skin indicated by the correlation between saturation and attractiveness may be explicable in terms of a preference for suntanned skin, which is sometimes described as healthy. However, it has also been suggested that tanned skin may be an honest signal of status when it is obtained through the luxury of leisure time (Etcoff, 1999).

We were not able to replicate previous studies that found a statistically significant positive correlation between attractiveness and symmetry (Grammer & Thornhill, 1994; various studies are reviewed by Thornhill & Gangestad, 1999). Facial attractiveness is influenced by a lot of variables (Thornhill & Gangestad, 1999), and experimental studies indicate that variables such as facial hormone makers often must be controlled to show an effect of symmetry on attractiveness. Hence, symmetry's insignificant effect may stem from other variables masking symmetry's relationship with attractiveness. In the present study, the problem of limited range of symmetry values may contribute to the lack of symmetry effect. Original as well as warped faces were (in general) highly symmetric.

We conclude that skin texture transmits information relevant to attractiveness and possibly mate choice. However, what kind of information lies in female skin texture that makes it important for the male observer?

We suggest that the condition of the skin surface provides an indication of the quality of the immune system of the respective individual. A reduced immune defense provides the possibility of a more aggressive attack by micro- and macroparasites (Grammer & Thornhill, 1994), which may be indicated in skin surface textures. Organisms with a higher resistance against parasites are favored in contests for a mate (Hamilton & Zuk, 1982). Mehrabian (1972) mentioned that the face holds the main part of information being processed during social interactions. Not only does the human face transmit emotions and language, but it also has a specific appearance. If this appearance is indeed a result of sexual selection, it would bear a series of signals for fitness. Accordingly, these signals are decisive for nonverbal communication. In particular, the face is the most frequently exposed part of the body and therefore always visible to others.

With respect to the color of the skin, Zahavi and Zahavi (1997) noted that a healthy red coloring of the cheeks in climatically cold regions could be interpreted as a signal for health and could thus be considered beautiful. This is explained by the fact that peripheral blood vessels usually contract when it is cold, which indicates a hypocirculation of blood. A red coloration of the skin under extreme environmental conditions demonstrates that the carrier is bearing a physiologically expensive feature. This leads us to the problem of delusion in human communication.

It is vital for the receiver of a signal to know whether the signal is true or false because deception may occur. Symmetry and shape of a face can be little modified by the individual. In traditional human societies, the texture and color of the face cannot be changed very much either. The use of makeup in modern societies may be functional and deceptive. On one hand, humans try to fake a homogeneous skin surface. On the other hand, humans attempt to set up the healthy taint by slight red coloring.

References

Andersson, M. (1994). *Sexual selection.* Princeton, NJ: Princeton University Press.

Apple Computer, Inc. (1995). *Advanced color imaging on the MacOS.* New York: Addison Wesley.

Barber, N. (1995). The evolutionary psychology of physical attractiveness: Sexual selection and human morphology. *Ethology and Sociobiology, 16,* 395–424.

Beier, T., & Neely, S. (1992). Feature-based image metamorphosis. *Computer Graphics, 26,* 35–42.

Bookstein, F. L. (1997). *Morphometric tools for landmark data: Geometry and biology.* Cambridge, England: Cambridge University Press.

Conners, R. W., Trivedi, M. M., & Harlow, C. A. (1984). Segmentation of a high-resolution urban scene using texture operators. *Computer Vision, Graphics, and Image Processing, 25,* 273–310.

Dabbs, J. M. (2000). *Heroes, rogues, and lovers.* New York: McGraw-Hill.

Darwin, C. (1871). *The descent of man and selection in relation to sex.* London: John Murray.

Davis, L. S., Johns, A., & Aggarwal, J. K. (1979). Texture analysis using generalized co-occurrence matrices. *IEEE Transactions on Pattern Analysis and Machine Intelligence, PAMI-1, 3,* 251–259.

Dhawan, A. P., & Sicsu, A. (1992). Segmentation of images of skin lesions using color and texture information of surface pigmentation. *Computerized Medical Imaging and Graphics, 16,* 163–177.

Eibl-Eibesfeldt, I. (1984). *Die biologie des menschlichen verhaltens* [Human ethology]. München, Germany: Piper.

Etcoff, N. (1999). *Survival of the prettiest.* New York: Doubleday.

Fiedler, M., Meier, W.-D., & Hoppe, U. (1995). Texture analysis of the surface of the human skin. *Skin Pharmacology, 8,* 252–265.

Frost, P. (1988). Human skin color: A possible relationship between its sexual dimorphism and its social perception. *Perspectives in Biology and Medicine, 32,* 38–58.

Gomes, J., Darsa, L., Costa, B., & Velho, L. (1999). *Warping and morphing of graphical objects.* San Francisco: Morgan Kaufmann.

Grammer, K., & Thornhill, R. (1994). Human (*Homo sapiens*) facial attractiveness and sexual selection: The role of symmetry and averageness. *Journal of Comparative Psychology, 108,* 233–242.

Hamilton, W. D., & Zuk, M. (1982). Heritable true fitness and bright birds: A role for parasites? *Science, 218,* 384–387.

Haralick, R. M. (1979). Statistical and structural approaches to texture. *Proceedings of the IEEE, 67,* 786–804.

Haralick, R. M., Shanmugam, K., & Dinstein, I. (1973). Textural features for image classification. *IEEE Transactions on Systems, Man, and Cybernetics, SMC-3, 6,* 610–621.

Held, B. L., Nader, S., Rodriguez-Rigau, L. J., Smith, K. D., & Steinberger,

E. (1984). Acne and hyperandrogenism. *Journal of the American Academy of Dermatology, 10,* 223–226.
Jones, D. (1996). *Physical attractiveness and the theory of sexual selection.* Ann Arbor: Museum of Anthropology, University of Michigan.
Lorenz, K. (1943). Die angeborenen Formen möglicher Erfahrung. *Zeitschrift für Tierpsychologie, 5,* 235–409.
Lucky, A. W. (1995). Hormonal correlates of acne and hirsutism. *The American Journal of Medicine, 98,* 89–94.
Mehrabian, A. (1972). *Nonverbal communication.* Chicago: Aldine Atherton.
Morris, D. (1967). *The naked ape: A zoologist's study of the human animal.* New York: McGraw-Hill.
Ohanian, P. P., & Dubes, R. C. (1992). Performance evaluation for four classes of textural features. *Pattern Recognition, 25,* 819–833.
Perrett, D. I., May, K. A., & Yoshikawa, S. (1994, March 17). Facial shape and judgments of female attractiveness. *Nature, 386,* 239–242.
Pope, T. W., Williams, W. L., Wilkinson, S. B., & Gordon, M. A. (1996). Texture parameters based on the spatial gray level dependence method applied to melanocytic nevi. *Computers and Biomedical Research, 29,* 429–437.
Rosenfeld, A., & Kak, A. C. (1982). *Digital picture processing* (2nd ed). New York: Academic Press.
Schiavone, F. E., Rietschel, R. L., Sgoutas, D., & Harris, R. (1983). Elevated free testosterone levels in women with acne. *Archives of Dermatology, 119,* 799–802.
Sonka, M., Hlavac, V., & Boyle, R. (1993). *Image processing, analysis and machine vision.* London: International Thompson Computer Press.
Steinberger, E., Rodriguez-Rigau, L. J., Smith, K. D., & Held, B. (1981). The menstrual cycle and plasma testosterone level in women with acne. *Journal of the American Academy of Dermatology, 4,* 54–58.
Stoecker, W. V., Chiang, C.-S., & Moss, R. H. (1992). Texture in skin images: Comparison of three methods to determine smoothness. *Computerized Medical Imaging and Graphics, 16,* 179–190.
Symons, D. (1979). *The evolution of human sexuality.* Oxford, England: Oxford University Press.
Symons, D. (1995). Beauty is in the adaptations of the beholder: The evolutionary psychology of human female sexual attractiveness. In P. R. Abramson & S. D. Pinkerton (Eds.), *Sexual nature, sexual culture* (pp. 80–118). Chicago: University of Chicago Press.
Thornhill, R., & Gangestad, S. W. (1999). Facial attractiveness. *Trends in Cognitive Sciences, 3,* 452–460.
Thornhill, R., & Grammer, K. (1999). The body and face of woman: One ornament that signals quality? *Evolution and Human Behavior, 20,* 105–120.
Thornhill, R., & Møller, A. P. (1997). Developmental stability, disease and medicine. *Biological Reviews, 72,* 497–548.
Van den Berghe, P. L., & Frost, P. (1986). Skin color preference, sexual dimorphism and sexual selection: A case of gene-culture co-evolution? *Ethnic and Racial Studies, 9,* 87–118.
Winton, G. B., & Lewis, C. W. (1982). Dermatoses of pregnancy. *Journal of the American Academy of Dermatology, 6,* 977–998.
Wolberg, G. (1990). *Digital image warping.* Los Alamitos, CA: IEEE Computer Society Press.
Wong, R. C., & Ellis, C. N. (1984). Physiologic skin changes in pregnancy. *Journal of the American Academy of Dermatology, 10,* 929–943.
Zahavi, A., & Zahavi, A. (1997). *The handicap principle: A missing piece of Darwin's puzzle.* Oxford, England: Oxford University Press.

Appendix

Description and Analysis of Texture

Image Texture

An image texture is described by the number and types of its primitives and the spatial organization or layout of its primitives. The spatial organization may be random, may have a pairwise dependence of one primitive on a neighboring primitive, or may have a dependence of n primitives at a time. Image texture can be qualitatively evaluated as having one or more of the properties of fineness, coarseness, smoothness, granulation, randomness, lineation, or being motled, irregular, or hummocky (Haralick, 1979). There are a lot of statistical approaches to the characterization and measurement of image texture, but compared with others, the co-occurrence-approach performed best in past studies (i.e., Pope, Williams, Wilkinson, & Gordon, 1996). The power of the co-occurrence approach is that it characterizes the spatial interrelationships of the gray tones in a textural pattern.

Co-occurrence Matrices

The formal definition of co-occurrence matrices is obtained as follows. Let f: $L_x \times L_y \Rightarrow G$ be a digital image with horizontal and vertical spatial domains $L_x = (1, 2, \ldots, n_x)$ and $L_y = (1, 2, \ldots, n_y)$, respectively, and gray levels $G = (0, 1, \ldots, m - 1)$. Let d be the distance that separates two pixels with the positions (x_1, y_1) and (x_2, y_2), respectively, and with gray values s and t, respectively. $d = 1$ means neighboring pixels, $d = 2$ means pixels that are separated by one pixel, and so forth. Furthermore, one chooses the neighboring pixels within the four angles (directions) of $\Theta = 0°$, 45°, 90°, and 135°. Thus, four co-occurrence matrices are obtained for a fixed d: $P0$, $P45$, $P90$, and $P135$. They are defined as follows (Haralick, Shanmugam, & Dinstein, 1973): $P0 = [p0(s, t)]$, $s = 0, \ldots, m - 1$, $t = 0, \ldots, m - 1$, with $p0(s, t)$ being the cardinality of the set of pixel pairs that has the properties $f(x_1, y_1) = s$, $f(x_2, y_2) = t$ and $|x_1 - x_2| = d$, $y_1 = y_2(1)$. For the definition of $P45$, condition (1) has to be replaced by $[(x_1 - x_2 = -d)$ and $(y_1 - y_2 = -d)] \vee [(x_1 - x_2 = d)$ and $(y_1 - y_2 = d)]$.

Texture Features

$P(i, j)$ represents the matrix of relative frequencies with which two neighboring pixels occur on the image, one with gray value i and the other with gray value j:

Energy:

$$M1 = \sum_i \sum_j p(i, j)^2.$$

This feature is a measure of the homogeneity of the image. The larger the value of $M1$, the more homogeneous the texture.

Contrast:

$$M2 = \sum_i \sum_j (i - j)^2 p(i, j).$$

The contrast is a measure of the variation of gray levels in an image. A smaller value of $M2$ results from a low-contrast image compared with an image with many variations in gray levels.

Homogeneity:

$$M3 = \sum_i \sum_j \frac{1}{1 + |i - j|} p(i, j).$$

The homogeneity measures the monotonicity of an image. The higher the value of $M3$, the more homogeneous the image.

Inverse Difference Moment:

$$M4 = \sum_i \sum_j \frac{1}{1 + (i - j)^2} p(i, j).$$

The inverse difference moment (local homogeneity) is clearly the opposite measure to contrast. $M4$ is high when similar gray levels are next to each other in the image.

Correlation:

$$M5 = \frac{\sum_i \sum_j (ij)p(i, j) - \mu_x \mu_y}{\sigma_x \sigma_y}.$$

The correlation is a measure of the dependence of the rows and columns of the co-occurrence matrix. The value of $M5$ is low for an inhomogeneous image.

Cluster Prominence:

$$M6 = \sum_i \sum_j [(i - \mu i) + (j - \mu j)]^4 p(i, j).$$

Cluster Shade:

$$M7 = \sum_i \sum_j [(i - \mu i) + (j - \mu j)]^3 p(i, j),$$

with $\mu i = \sum_i i \sum_j p(i, j)$

and $\mu j = \sum_j j \sum_i p(i, j)$.

Cluster prominence and cluster shade were introduced by Conners, Trivedi, and Harlow (1984) as new features for homogeneity to address a deficiency in past studies. Values of $M6$ and $M7$ are high for a homogeneous texture.

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