Facial Contrast Is a Cue for Perceiving Health From the Face

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How healthy someone appears has important social consequences. Yet the visual cues that determine perceived health remain poorly understood. Here we report evidence that facial contrast—the luminance and color contrast between internal facial features and the surrounding skin— is a cue for the perception of health from the face. Facial contrast was measured from a large sample of Caucasian female faces, and was found to predict ratings of perceived health. Most aspects of facial contrast were positively related to perceived health, meaning that faces with higher facial contrast appeared healthier. In 2 subsequent experiments, we manipulated facial contrast and found that participants perceived faces with increased facial contrast as appearing healthier than faces with decreased facial contrast. These results support the idea that facial contrast is a cue for perceived health. This finding adds to the growing knowledge about perceived health from the face, and helps to ground our understanding of perceived health in terms of lower-level perceptual features such as contrast.

Keywords: health perception, face perception, facial color, facial contrast, appearance

Appearances matter. Perceived beauty affects more than just mating opportunities; it also affects how adults treat children, how employers choose job applicants, and how criminals are sentenced (Langlois et al., 2000). How old we look is not only related to a variety of ailments and health-related factors (Bulpitt, Markowe, & Shipley, 2001; Hwang, Atia, Nisenbaum, Pare, & Joordens, 2011), it is a better predictor of mortality than is our actual age (Christensen et al., 2004; Dykiert et al., 2012). Perceived health contributes to the appearance of attractiveness (Rhodes et al., 2007), and people perceived as healthy are more likely to be selected for leadership roles in a variety of contexts (Spisak, Blaker, Lefevre, Moore, & Krebbers, 2014). While perceived beauty and perceived age have been studied extensively, perceived health is a relatively new topic of research. Little is known about the visual cues that contribute to perceived health. Here we describe work investigating whether facial contrast—the luminance and color contrast between internal facial features and the surrounding skin—is a cue for perceived health.

The majority of research on facial health perception has focused on skin properties (but see also Coetzee, Perrett, & Stephen, 2009; Coetzee, Re, Perrett, Tiddeman, & Xiao, 2011; Rhodes, Chan, Zebrowitz, & Simmons, 2003; Rhodes et al., 2001). Skin texture is an important cue for health perception (Jones, Little, Burt, & Perrett, 2004), particularly skin homogeneity, with a more even skin tone considered healthier as well as younger and more attractive (Fink, Grammer, & Matts, 2006; Fink, Grammer, & Thornhill, 2001; Fink & Matts, 2008; Fink et al., 2012; Matts, Fink, Grammer, & Burquest, 2007). Overall skin color is also cue for health perception. People find skin that is lighter (Stephen, Coetzee, & Perrett, 2011; Stephen, Law Smith, Stirrat, & Perrett, 2009), yellower (Stephen et al., 2011), and redder (Stephen, Coetzee, Law Smith, & Perrett, 2009; Stephen, Law Smith et al., 2009) to appear more healthy.

While psychological studies of perceived health have focused on skin color and texture, numerous medical studies have investigated how the color of the facial features relates to health. From a perceptual standpoint, it is noteworthy that many of these relationships involve associations between poorer health and feature colors resulting in decreased contrast between the features and the skin. For example, graying or loss of eyebrow and eyelash hair decreases contrast with the surrounding skin. Premature graying of hair is related to specific health factors such as smoking (Mosley & Gibbs, 1996), and with the more general factor of oxidative stress (Trüeb, 2009). Further, the loss of either eyebrow or eyelash hair is related to a variety of specific diseases (Kumar & Karthikeyan, 2012). Similarly, increased redness or yellowness of the sclera results in decreased contrast between the eye and the surrounding skin. Scleral redness increases when blood vessels in the overlying conjunctiva become dilated, a result of irritation produced by fatigue, allergy, infection, and several ocular diseases (Leibowitz, 2000; Murphy, Lau, Sim, & Woods, 2007), and is a cue for perceiving emotion and attractiveness from the face

(Provine, Cabrera, Brocato, & Krosnowski, 2011; Provine, Cabrera, & Nave-Blodgett, 2013). Scleral yellowness (i.e., jaundice) is associated with liver pathology (Roche & Kobos, 2004). Both yellowness and redness of the sclera are cues for perceiving health as well as age and attractiveness from the face (Provine et al., 2013; Russell, Sweda, Porcheron, & Mauger, 2014).

Though the color of facial skin and the facial features are both related to health, it remains to be determined whether the *contrast* between the skin and these features is used as a cue for perceiving health from the face. However, recent work has shown that contrast around these features is an important cue for other aspects of face perception. "Facial contrast"—the color and luminance contrast between facial features and the surrounding skin—or similar forms of contrast are known to be used by observers as a cue for face detection (Ohayon, Freiwald, & Tsao, 2012; Sinha, 2002), for perceiving facial attractiveness (Russell, 2003; Stephen & McKeegan, 2010), for categorizing faces by sex or making judgments of sex typicality (Jones, Russell, & Ward, 2015; Russell, 2009; Stephen & McKeegan, 2010), and for perceiving age from the face (Porcheron, Mauger, & Russell, 2013). Importantly, manipulation of either skin color or feature color can have similar perceptual effects (Russell, 2003, 2009, in press), supporting the idea that it is the contrast between the two regions that is the relevant perceptual feature. Because of this, and because the color of facial skin and the facial features are related to perceived health, it seems likely that facial contrast may also be a cue for perceiving health from the face.

The role in health perception of one aspect of facial contrast—contrast around the lips—was tested by Stephen, Law Smith, and colleagues (2009) in their study of the role of skin color in perceived health. In their study, participants were asked to change skin color to make the face appear as healthy as possible. In one condition, participants when varying the skin color also varied lip color with the result that contrast did not change when skin color changed, while in another condition the lip color was fixed, with the result that contrast around the lips was changed when skin color was changed. There was no difference in the amount of a^* (red-green) and L^* (light-dark) contrast added by the participants in these two conditions. However, subjects changed the b^* (yellow-blue) value of the skin more when the lips changed along with the skin than when they did not change, consistent with the idea that greater b^* contrast around the lips looked less healthy. Because only one of the three aspects of contrast around the lips was related to perceived health, and because there was no sex difference in the effect of manipulating or not manipulating the lips, Stephen and colleagues proposed three possible accounts that would reconcile their findings with other work (Russell, 2003, 2009) showing that facial contrast is sexually dimorphic and has opposite effects on attractiveness in male and female faces: "(1) Russell's use of black and white photographs may have eliminated important color information from his images. (2) The contrast between the features and the facial skin may be important for attractiveness and sexual dimorphism perception, but not for health perception. (3) The effects found by Russell (2003) may be attributable to the contrast between the eyes and the skin instead of the lips and the skin" (Stephen, Law Smith et al., 2009, p. 854). Recent work has contradicted account 1 (with regards to sexual dimorphism) but supported account 3 by showing that the sex difference is greater for contrast around the eyes than around the lips (Jones

et al., 2015). The current work will allow us to evaluate account 2 of Stephen and colleagues, that facial contrast is unimportant for health perception.

Here we directly tested the hypothesis that facial contrast is a cue for the perception of healthiness. In the first study, we measured the facial contrast of a set of carefully controlled face images, and determined whether facial contrast predicted ratings of the perceived health of these faces. After finding that facial contrast was correlated with perceived health, we conducted two experiments with images of faces whose facial contrast was artificially manipulated. One experiment used a forced-choice, paired-comparison design, while the other involved ratings of individually presented images. In both experiments, we found strong effects of facial contrast on perceived health.

Study 1

In this study, we sought to determine whether facial contrast predicts ratings of perceived health. Toward this end, we collected a sample of carefully controlled face images and measured facial contrast from these images. A group of participants then rated how healthy the faces appeared.

Stimuli

We sought to minimize differences between stimuli in terms of nonhealth variables by selecting a group of target faces that did not vary in terms of age, sex, or race. By holding constant these other variables that have been shown to predict facial contrast (Jones et al., 2015; Porcheron et al., 2013; Russell, 2009), we sought to isolate the relationship between facial contrast and perceived health. Having decided for this reason to use a narrow age range, we chose to collect and use a sample of somewhat older rather than younger adults from the belief that there should be greater variation in actual and apparent health among people who have had more time to experience the effects of health-related environmental and genetic variation. Toward this end, full face images of 146 Caucasian women aged 56–60 (mean: 58.1, SD: 1.4) were acquired using a closed photographic system that allows accurate and reproducible positioning of the subjects as well as controlled lighting conditions. All subjects signed an informed consent stating that "their facial images could be used by CERIES for research purposes or used for research under the CERIES responsibility." CERIES is the healthy skin research center of Chanel PB.

The height of the camera (Canon EOS-1 Ds Mark II, 17 MP) was adjusted to the height of the face. Each face was illuminated by three flashes: one in front of the face (diffuse light), the height of this flash was adjusted to the height of the subject's face; and two flashes illuminating the face from a 45 angle (direct light), the height of these flashes was fixed. These lighting conditions were defined in order to avoid cast shadows and to minimize variation from shading on the faces. The subjects wore no makeup or adornments. Subjects' eyes were open, and they were asked to keep a neutral expression and gaze directly into the camera. Faces wearing permanent makeup or colored contact lenses were excluded. The images were cropped to leave the face contour visible.

To measure the luminance and color contrast of the face, we used the CIE $L^*a^*b^*$ color space, whose dimensions correspond roughly to the color channels of the human visual system. $L^*a^*b^*$

color space was designed such that differences between coordinates of stimuli are predictive of perceived color difference between the stimuli (Brainard, 2003). The three orthogonal dimensions of this color space are light-dark (L^*), red-green (a^*), and yellow-blue (b^*).

Following acquisition, the images were color calibrated with the goal of minimizing color differences between the different images in the set. This was done in order to compensate for possible illumination variation between images and to make color comparisons between images more accurate. All photographs included a color chart with 48 color patches including 12 patches designed to be similar to a range of skin tones (the charts were cropped out of the images shown to the subjects, such as the example in Figure 1). The $L^*a^*b^*$ parameters were measured for each color patch in each image. For each $L^*a^*b^*$ parameter of each of the 48 colors, the median value for the set of images was calculated. The color difference (ΔE 1976) was calculated for each color patch of each

Figure 1. Labeling of facial regions. The black lines demonstrate how the features and surrounding skin were defined. In the study, both eyebrows and both eyes were defined; in this image, we see the definition of only the left eyebrow and the right eye in order to avoid clutter. The individual appearing here consented for her likeness to be published in this article. See the online article for the color version of this figure.

image relative to the corresponding median value. The mean ΔE 1976 value across the 48 color patches was calculated for each image. The image with the lowest global ΔE 1976 value was selected as the reference image, and its color chart was set as the reference color chart. Finally, the colors of each image were registered to the reference image by minimizing the differences between the image color chart and the reference image color chart. After registration, all of the ΔE 1976 values for comparisons between individual image color patches and reference image color patches were 0.3 or less—well below the just-noticeable difference—indicating that the images were successfully color calibrated to each other.

The labeling of facial regions and the measurement of the contrast was performed using MATLAB 7.8.0 (R2010a) using roughly the same procedure used by Porcheron et al. (2013). Each image was individually 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, the eyebrows, annuli surrounding the eyebrows (with the approximate width of the eyebrows but not including the eyes), annuli surrounding the eyes (with the approximate width of the eyes but not including the eyebrows), and an annulus surrounding the lips (with the approximate width of the mouth). The definitions of these regions are shown for an example face in Figure 1. The person shown in the figures signed an informed consent stating that she authorized the CERIES to use her facial images to illustrate the results of the study in a scientific, peer-reviewed journal.

Luminance values of all pixels within the eyes were averaged, as were all the pixels in each of the other features and the annuli surrounding each feature. In this way, a single mean pixel value for each face region (whether a feature or the surrounding skin) was measured for each of the three color channels. This yielded 18 measured values per face (three color channels, L^*, a^*, and b^*, each for six distinct regions—eyebrows, eyes, lips, eyebrow annuli, eye annuli, lip annuli). Because the calculations were implemented in MATLAB, they were actually performed in "icclab" color space, which differs from the CIE $L^*a^*b^*$ color space insofar as the L^* dimension is on a 0–255 scale rather than a 1–100 scale. Skin and feature luminance, both being the averages of 8-bit pixel values, could range from 0 (black) to 255 (white). The contrast was calculated for each feature as C_f = (skin luminance—feature luminance)/(skin luminance + feature luminance). This is an adapted version of Michelson contrast, which varies from -1 to 1, with higher absolute values indicating greater contrast, and 0 indicating no contrast. The same method was applied to measure red-green and yellow-blue facial contrast, with a^* ranging from 0 (green) to 255 (red) and b^* ranging from 0 (blue) to 255 (yellow). Consistent with other investigations of facial contrast (Jones et al., 2015; Porcheron et al., 2013; Russell, 2009), the contrast values for all of the features and color channels were positive, indicating that the features are darker, less red, and less yellow than the surrounding skin. The one exception to this is the red-green contrast around the mouth, which is negative, indicating that the lips are more red than the surrounding skin.
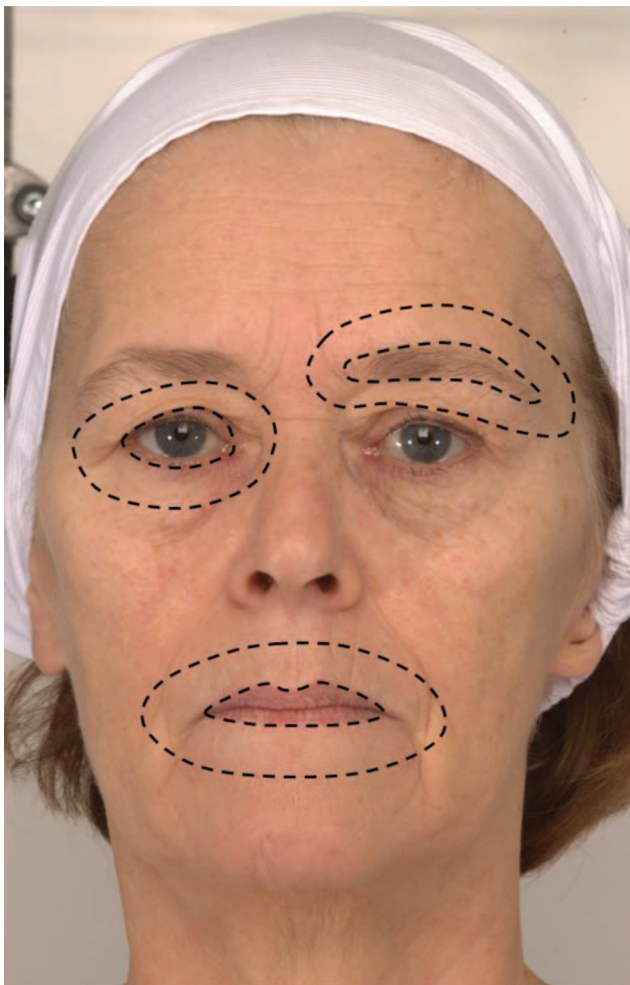
Participants and Procedure

Thirty-nine adults (20 female, 19 male) aged 30–65 (mean: 42.8, *SD*: 10.3) were recruited from the local community and were

compensated $10 for participation in the study. Participants were asked to rate all 146 face images on a 7-point Likert scale, with a response of 1 indicating that the face looked very unhealthy, and a response of 7 indicating that the face looked very healthy.

Analysis

Because perceived health was rated on a 7-point Likert scale, we performed multinomial regression models with repeated measurements to investigate the effect of each aspect of facial contrast on the likelihood of choosing a higher value on the scale, with faces and participants as repeated random effects. Analyses were adjusted for the faces' chronological age. Because participants evaluated several faces, and faces were evaluated by several participants, we used the method of generalized estimating equations (GEE) to account for correlations among observations from the same participant and also of the same face. Liang and Zeger (1986) introduced GEE as a method of dealing with correlated data when the data can be modeled as a generalized linear model, such as correlated binary and count data. The GEEs provide a practical method with reasonable statistical efficiency to analyze correlated data arising from repeated measurements, as the normality assumption is not accurate when the responses are discrete and correlated. The GEE method estimates the regression parameters assuming that the observations are independent, uses the residuals from this model to estimate the correlations among observations from the same face or from the same participant, and then uses the correlation estimates to obtain new estimates of the regression parameters. This process is repeated until the change between two successive estimates is very small. For facial contrast, the relationship with perceived health was described with the direction (positive, negative, or none).

Results

The relationships between facial contrast and perceived health, with perceived health (rated on a 7-point Likert scale) treated as a categorical variable, are presented in Table 1. Nearly all of the feature contrasts were significantly related to perceived health. The only exceptions to this were a^* contrast around the eyebrows and b^* contrast around the mouth, which were not significantly associated with perceived health. All but one of the significant relationships were positive. The exception was L^* contrast around the mouth, which was negatively related to perceived health. L^* and b^*

contrast around the eyebrows, all three color channels around the eyes, and a^* contrast (absolute value) around the lips were positively related to perceived health. Because almost all the feature contrasts were positively associated with perceived health, this means that higher contrast around the features generally predicted a healthier appearance. The adjusted odds ratios are a measure of effect size, and were calculated using a step increase of half of the range of the contrast values. Thus, the odds ratio of 1.72 for L^* contrast around the eyes indicates an increase of L^* contrast equivalent to [1/2] the range of observed L^* contrast values is associated with a 1.72 times greater likelihood of receiving one point higher rating of perceived health on the 7-point Likert scale.

We also sought to replicate previous findings that overall skin color predicts perceived health. To measure skin color, we calculated the average pixel values from the five annulus regions (the skin surrounding the two eyebrows, the two eyes, and the mouth), a rectangle in the forehead, and two in the cheeks. This yielded three skin color values (L^*, a^*, and b^*) for each face, which we then used as a factor in a linear model to predict perceived health. Skin color significantly predicted perceived health in all three color dimensions. Faces were perceived as healthier when the skin was lighter ($\chi^2 = 21.62$, $p < .0001$), redder ($\chi^2 = 38.06$, $p < .0001$), and yellower ($\chi^2 = 106.73$, $p < .0001$), consistent with previous work (Stephen, Coetzee et al., 2009; Stephen et al., 2011; Stephen, Law Smith et al., 2009).

Discussion

For the most part, facial contrast was found to be positively associated with perceived health, indicating that faces with higher facial contrast look healthier than faces with lower facial contrast. Several of these aspects of facial contrast have previously been found to be negatively associated with age (Porcheron et al., 2013), specifically L^* contrast around the eyebrows, contrast in all three color channels around the eyes, and a^* contrast (absolute value) around the mouth. This is probably not accidental, as attributes that make a face look older are likely to also make it look less healthy, particularly for faces in this age range (56–60 years) or older. However, the pattern of results comparing facial contrast with perceived health was not the same as with age. In particular, L^* contrast around the mouth was negatively associated with perceived health but was not associated with age, while b^* contrast around the mouth was not associated with perceived health but was positively associated with age. Also, L^* contrast around the eyes

Table 1
Relationships Between Facial Contrast and Perceived Health

Feature	Contrast	χ^{b}	p	Relationship with perceived health	Adjusted odds ratio	[95% CI[b]]
Brows	L^*	23.79	<.0001	positive	1.32	[1.18–1.47]
Brows	a^*	.74	.3896	none	1.05	[.94–1.19]
Brows	b^*	4.61	.0318	positive	1.14	[1.01–1.30]
Eyes	L^*	93.51	<.0001	positive	1.72	[1.54–1.92]
Eyes	a^*	40.25	<.0001	positive	1.48	[1.31–1.67]
Eyes	b^*	61.37	<.0001	positive	1.58	[1.41–1.76]
Lips	L^*	26.90	<.0001	negative	.69	[.59-.79]
Lips	a^{*a}	22.33	<.0001	positive	1.35	[1.19–1.53]
Lips	b^*	2.88	.0897	none	1.13	[.98–1.30]

[a] Absolute value. [b] Confidence interval.

was quite strongly associated with perceived health, but not significantly associated with age. The association between eye L^* contrast and perceived health may be due to the impact of dark circles around or below the eyes, which look unhealthy but can appear in both younger and older faces (Roh & Chung, 2009). Thus, age or perceived age cannot be the sole explanation of the current results. In the case of a^* and b^* contrast around the eyes, it seems likely that the positive association with perceived health may be related to the association of redness and yellowness of the sclera with specific aspects of health, as well as with age (Provine et al., 2013; Russell et al., 2014).

Study 2

Having found evidence in Study 1 for an association between facial contrast and perceived health, we sought in Study 2 to test the hypothesis that facial contrast plays a causal role in the perception of health. Toward this end, we used an experimental design with stimuli in which facial contrast was digitally increased or decreased, and participants had to select which of these versions of the face looked healthier.

Stimuli

Thirty images from Study 1 were selected for use in Study 2. This subset was randomly selected and had similar age characteristics (aged 56–60 years, mean years: 58.2, SD: 1.4) as the larger set of faces used in Study 1. Each of these 30 faces was manipulated to create two new versions, one with the facial contrast increased and the other with it decreased. Only those aspects of facial contrast that were found to significantly vary with perceived health in Study 1 were manipulated in the current set. Specifically, we manipulated the L^* contrast around the eyebrows, eyes, and lips, the a^* contrast around the eyes and lips (but not the eyebrows), and the b^* contrast around the eyebrows and eyes (but not the lips). Because of the known relationship between skin color and perceived health, we sought to test the effect of facial contrast on perceived health independent of skin color. Toward this end, we manipulated contrast around a feature by manipulating the feature but leaving unchanged the surrounding skin (i.e., we increased or decreased the luminance of the eyebrows and lips, the redness of the eyes and lips, and the yellowness of the eyebrows and eyes). In this way, we were able to manipulate facial contrast but not skin color. The L^* eye contrast was an exception to this rule. For the L^* eye contrast, we manipulated the luminance of the skin surrounding the eye rather than the eye itself. We manipulated the luminance of the skin around the eyes rather than the eye itself because the eye region contains several different subregions (e.g., eyelashes, eye border, sclera, iris, pupil) that each vary differently as a function of age and health (Russell et al., 2014). The burn tool in Adobe Photoshop was used to selectively darken the eyebrows, and the dodge tool was used to selectively lighten the eyebrows. To manipulate all other feature contrasts (i.e., the size of the b^* contrast between the eyebrows and the surrounding skin, the a^*, and b^* contrast between the eyes and the surrounding skin and the L^* and a^* contrast between the mouth and the surrounding skin), we individually manipulated the L^*, a^*, or b^* channel (0 to 255) of the relevant feature without changing the rest of the face. For instance, increasing the a^* value of the lips made the lips redder

and led to an increase of the absolute value of the a^* contrast between the lips and the skin surrounding the lips. The direction of contrast change was consistent across all features, except for the L^* change around the lips, which unlike the other features was negatively correlated with perceived health. For example, in the condition where contrast around all the other features was increased, it was decreased for L^* contrast around the lips.

For the present study, our goal was to determine whether these aspects of facial contrast played any role in health perception. We chose the magnitude of each manipulation with an eye toward maximizing the effect of the manipulation on apparent health while keeping the changes subtle and naturalistic. These magnitudes were the same for most faces, but were weakened for some features of some faces in order to maintain a naturalistic appearance. The critical point is that the direction of change was consistent across all faces. Only the manipulated faces (low/high contrast) were presented to the participants. Example stimuli are shown in Figure 2. We conducted two versions of the experiment, one in which participants viewed both the high and low contrast versions of each face at the same time and indicated which looked healthier (Study 2a), and one in which a different group of participants viewed the same set of faces one at a time, rating them for perceived attractiveness (Study 2b).

Study 2a

Participants and procedure. Thirty-nine adults (24 female, 15 male) aged 29–71 (mean: 46.6, SD: 11.4) were recruited from the local community and were compensated $10 for participation in the study. For each of the 30 stimulus faces, participants saw both the contrast-increased and contrast-decreased versions presented side-by-side (as in Figure 2) and indicated with a button press which of the two faces looked healthier. The sequence of identities was randomized for each participant, and the left-right ordering of high/low contrast versions was counterbalanced.

Figure 2. Contrast manipulated versions of a face. The left image shows one of the target faces with facial contrast increased, and the right image shows the same face with facial contrast decreased. The individual appearing here consented for her likeness to be published in this article. See the online article for the color version of this figure.

Results. The participants selected the increased contrast version of the face on 91% of the trials, $\chi^2 = 462$, $p < .001$, odds ratio = 9.63, 95% confidence interval = [7.68–12.10]. This effect was consistent for all of the faces, with participants selecting the higher contrast version as appearing healthier in the vast majority of trials. This overwhelmingly large effect clearly indicates that participants used facial contrast as a cue for perceiving health.

Study 2b

Participants and procedure. Twenty-six adults (18 female, 8 male) aged 20–60 (mean: 40.8, *SD*: 12.4) were recruited from the local community and were compensated $10 for participation in the study. The high and low contrast versions of each of the 30 stimulus faces were split into two blocks. Within each block, each face appeared once in a given contrast condition (high or low). Participants indicated with a mouse click how healthy the face looked on a 7 point Likert scale, with a response of 1 indicating that the face looked very unhealthy, and a response of 7 indicating that the face looked very healthy. Faces were presented in a random order within each block, and the ordering of each block was counterbalanced across participants.

Results. Figure 3 shows the percentage of responses made at each level of the 7-point scale for increased and decreased contrast images. We analyzed the data with a generalized linear model for a multinomial distribution of ratings. The model was adjusted on faces' chronological age, and faces and participants were considered as repeated random effects. The participants gave significantly higher ratings of perceived health to the increased contrast faces than the decreased contrast faces, $\chi^2 = 231.8$, $p < .001$, adjusted odds ratio = 3.36, 95% confidence interval = [2.96–3.95].

Discussion. The results of Study 2b replicate the findings from Study 2a, with a different task as well as different partici-

Figure 3. Ratings of perceived health for faces with increased or decreased facial contrast. Data is presented in terms of the percentage of responses that were given to each Likert scale value, for each of the two contrast conditions.

pants. While Study 2a used a task in which participants directly compared the apparent health of two versions of each face with different contrast levels, Study 2b required participants to consider the apparent health of faces individually, akin to method of Study 1. In both versions of Study 2, there was a large effect of facial contrast on perceived health. Together, these studies show that participants used facial contrast as a cue for perceiving health, and causally implicate facial contrast in the perception of health from the face.

General Discussion

In two studies, we have found evidence supporting the idea that facial contrast is a cue for perceived health. In Study 1, we found that several aspects of facial contrast are correlated with perceived health. Almost all of these aspects of facial contrast were correlated *positively* with perceived health, meaning that higher facial contrast looks healthier. In Study 2, we manipulated those aspects of facial contrast that were found to correlate with perceived health. We found that faces were perceived as healthier when their facial contrast was increased as compared with when it was decreased, which shows that facial contrast plays a causal role in judgments of healthiness made from face images. Together, these results clearly implicate facial contrast as a cue for the perception of health from the face.

The finding that facial contrast is a cue for facial health perception clearly contradicts account 2 of Stephen, Law Smith, and colleagues (2009, p. 854), that facial contrast is unimportant for health perception. Other recent work (Jones et al., 2015) has shown that there are *not* consistent sex differences in facial contrast in nonluminance color dimensions, contradicting account 1 of Stephen and colleagues, that the use of grayscale images by Russell (2003, 2009) eliminated important color information. However, the current work does add further support to the notion that color information is important for *health* perception. Jones et al. (2015) found a greater sex difference in luminance contrast around the eyes than around the lips, supporting account 3 of Stephen and colleagues, that contrast between the eyes and skin is more perceptually important than contrast between the lips and skin, in the context of sex classification. The current work also supports Stephen and colleagues' account 3, but in the context of *health* perception, with the finding from Study 1 that perceived health is more strongly linked to eye contrast (in all three color channels) than to lip contrast.

We propose two possible accounts for the finding of a stronger relationship between perceived health and eye contrast than lip contrast. The first account rests on the observation that eye contrast is more sexually dimorphic than lip contrast (Jones et al., 2015). Sexual dimorphism in facial appearance is associated with perceived health (Rhodes et al., 2003), and there is some evidence that femininity is linked to lower incidence of ill health (Gray & Boothroyd, 2012). This account predicts that unlike in female faces, in male faces, *lower* eye L^* contrast should appear healthier, as lower contrast is more masculine. The second account of the greater importance of eye contrast than lip contrast in health perception rests on the observation that the eye and eyebrow region is much more complex and contains more contrast information than the lip region. The eye is itself composed of differently colored parts, each independently related to perceived age
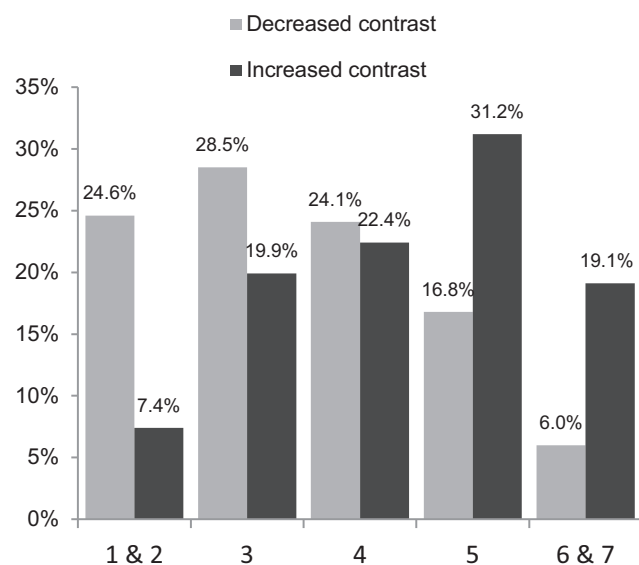
and health (Russell et al., 2014). Further, the nearby eyebrow may serve as a related contrast signal (Sadr, Jarudi, & Sinha, 2003). In this account, the greater importance of eye contrast to health perception is due to its general perceptual importance rather than any health-specific reason. This account predicts that *higher* eye L^* contrast should appear healthier in male faces, as the eye and eyebrow region is also more complex in males. Thus, these two accounts make different predictions about the relationship between perceived health and L^* contrast around the eyes in male faces.

Because the calculation of facial contrast involves skin color, a potential concern with our finding is that the relationship between facial contrast and perceived health could actually be due to the relationship between skin color and perceived health. However, this possibility is contradicted by the findings of Study 2. In Study 2, facial contrast was manipulated by changing feature color rather than skin color, with the exception of luminance contrast around the eyes. Faces with greater facial contrast—but identical skin color, aside from the luminance around the eyes—were perceived as healthier. These findings clearly show that facial contrast influences perceived health independently of skin color, and that facial contrast should be viewed as a cue for health perception that is separate from skin color.

An important caveat to our findings is that the sample of stimulus faces had fairly narrow selection criteria (female Caucasians aged 56–60 years old). While the large sample of relatively homogeneous faces allows greater confidence that the findings are not due to variation in gender, race, or age, it makes generalization to other demographic groups less certain. The restricted age range is the biggest concern in this respect, because both facial contrast and health are known to vary with age. It is possible that the relationship between facial contrast and perceived health is different in younger or older faces. In order to address this concern, subsequent research will need to investigate the relationship between facial contrast and perceived health in other demographic groups.

Porcheron et al. (2013) found that several aspects of facial contrast decrease with age. Here we have found that several of the same aspects of facial contrast are also related to the perception of health. The relationships between perceived health and facial contrast are presumably due to the many ways that skin color varies with perceived health (Stephen, Coetzee et al., 2009; Stephen et al., 2011; Stephen, Law Smith et al., 2009) and facial feature color varies with health—for example, hair loss and graying of the eyebrow hairs (Chen et al., 2010; Mosley & Gibbs, 1996; Trüeb, 2009), variation in sclera color (Leibowitz, 2000; Murphy et al., 2007; Roche & Kobos, 2004), and lip color (Caisey et al., 2008; Lundsgaard & Van Slyke, 1923). However, it is also possible that some of the relationships between facial contrast and perceived health are due to an overgeneralization effect (Zebrowitz, 2003), with cues to age (i.e., specific aspects of facial contrast) being taken as a cue to a related judgment (perceived health). However, these two possibilities are not mutually exclusive. Because the overall pattern of aspects of facial contrast that were related to perceived health was different than the overall pattern related to age, we believe that overgeneralization between age and perceived can be at best a partial explanation of the relationships between facial contrast and perceived health.

Facial contrast is increased by typical application of cosmetics (Etcoff, Stock, Haley, Vickery, & House, 2011; Jones et al., 2015; Russell, 2009, 2010). For example, red shades of lipstick increase the luminance and redness contrast around the lips; eyeliner, mascara, and eyeshadow all increase the luminance contrast around the eyes; and eyebrow pencil increases the luminance contrast around the eyebrows. It has been suggested that makeup functions in part by exaggerating naturally occurring sex and age differences in facial contrast (Etcoff et al., 2011; Jones et al., 2015; Porcheron et al., 2013; Russell, 2003, 2009, 2010). The discovery that increased facial contrast makes a face look healthier suggests the possibility that cosmetics may also function by exaggerating a cue to perceived health, thereby making the wearer appear healthier.

The finding that facial contrast is a cue for face perception adds to the growing body of evidence that facial contrast is an important and pervasive component of the representation of faces by the human visual system. In addition to being used in judgments of health perception, facial contrast is a cue for face detection (Ohayon et al., 2012; Sinha, 2002), for perceiving facial attractiveness (Russell, 2003; Stephen & McKeegan, 2010), categorizing faces by sex or making judgments of sex typicality (Jones et al., 2015; Russell, 2009; Stephen & McKeegan, 2010), and perceiving age from the face (Porcheron et al., 2013). Facial contrast is also consistently increased by makeup (Etcoff et al., 2011; Jones et al., 2015; Russell, 2009, 2010). The presence of makeup on the face can influence the ability of humans (Ueda & Koyama, 2010) and automated systems (Dantcheva, Chen, & Ross, 2012) to recognize faces, which suggests the possibility that facial contrast also plays a role in face recognition. It has also been proposed that contrast negation impairs face recognition because it disrupts the ordinal contrast relations in the eye and eyebrow region, which is also consistent with the idea that facial contrast matters for face recognition (Gilad, Meng, & Sinha, 2009).

Further support for the idea that facial contrast may be relevant for face recognition comes from research into the role of spatial frequencies in face recognition. There is a body of evidence that contrast in the middle range of spatial frequencies is particularly critical (e.g., Hayes, Morrone, & Burr, 1986; Näsänen, 1999). Numerous psychophysical studies have shown that face identity is most efficiently processed from a narrow band of spatial frequencies in the range of 8 to 16 cycles per face width (see reviews by Ruiz-Soler & Beltran, 2006, and Keil, 2008). It has been argued that the bias toward these spatial frequencies is caused by the intrinsic spatial frequency content of the internal facial features (Keil, 2009). It has also recently been shown that facial identity information conveyed predominantly by *horizontal* visual structure, is processed by mechanisms tuned to these orientations (Dakin & Watt, 2009; Goffaux & Dakin, 2010; Pachai, Sekuler, & Bennett, 2013). Taken together, these studies suggest the importance of contrast around the horizontally oriented internal face features (eyebrows, eyes, mouth) for perceiving identity from the face. This raises the question of whether these same spatial frequency bands and orientations are also critical for those aspects of face perception for which facial contrast is important, including detection, attractiveness, sex classification, age perception, and now health perception.

In conclusion, we have presented evidence that supports the notion that facial contrast is a cue for perceiving health from the face. In a large, well-controlled sample of Caucasian female faces, we observed positive relationships between most aspects of facial

contrast and perceived health. In a subset of those images, we artificially manipulated those aspects of facial contrast that were found to vary with perceived health. In two experiments, the faces with increased facial contrast were perceived as healthier than the faces with decreased facial contrast, confirming that facial contrast is one of the visual cues used to determine perceived health. This adds to the list of visual cues known to affect the perception of health from the face. It also demonstrates how a low-level visual cue—contrast—can influence the perception of the people around us. This highlights the value of studying lower-level cues for grounding and informing higher-level perceptual processes such as perceived health.

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