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ORIGINAL ARTICLE

Facial Contrast Declines with Age but Remains Sexually Dimorphic Throughout Adulthood

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Abstract Facial contrast – the difference in coloration between facial features and the surrounding skin – is an important cue for several aspects of face perception, including the perception of age and sex. However, previous work showing age declines in facial contrast has investigated only female faces, and studies demonstrating sex differences in facial contrast have only used young adult faces as stimuli. In the present work we examined whether age related declines in facial contrast are similar in both female and male faces, and whether sex differences in facial contrast are similar across the adult lifespan. In a sample of 151 male and female faces, drawn from three age groups (young adult, middle-aged, older adult), we analyzed contrast around three facial features: eyebrows, eyes, and lips, in each of the three channels of CIEL*a*b* color space. We replicated the finding that feature contrasts decline with age in female faces, and found similar declines with age in facial contrast in male faces. We also found that the sex differences in luminance contrast around the facial features were present throughout the adult life span. Our findings demonstrate that age differences in facial contrast generalize to both sexes, and that sex differences in facial contrast generalize to all adult ages, indicating the general relevance of facial contrast cues. These findings also have implications for the understanding of facial beauty and of beautification practices such as makeup.

Keywords Face perception · Facial contrast · Gender · Sex · Age

Faces are a rich source of information, containing visual cues to critical social attributes such as identity (Sheehan and Nachman 2014), attractiveness (Rhodes 2006), and sex (Farkas and Munro 1987). Researchers have mostly focused on the role of facial shape

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and structure when examining how the face conveys aspects of sex (Perrett et al. 1998), attractiveness (Langlois and Roggman 1990), and age (George and Hole 1995; Yamaguchi and Oda 1997). Though most face perception research has focused on shape cues, surface reflectance cues to facial appearance such as skin texture and coloration also provide critical information for social perception. Surface reflectance is very important for perceptions of health, with both skin texture (Fink et al. 2001; B. C. Jones et al. 2004) and skin color (A. L. Jones et al. 2016; Stephen et al. 2011, 2009) playing prominent roles. Indeed for attractiveness judgments, surface reflectance properties are actually *more* important than shape properties (O'Toole et al. 1999; Torrance et al. 2014). Similarly, sex classification relies more on reflectance properties than on shape properties (Hill et al. 1995). Facial age perception also relies critically on surface reflectance information (O'Toole et al. 1999), which changes with age (Burt and Perrett 1995).

Facial contrast—the luminance and color contrasts between internal facial features and the surrounding skin—is a group of reflectance cues that are relevant for many aspects of face perception. Particular aspects of facial contrast are linked with attractiveness (Russell 2003), are sexually dimorphic, and are used as perceptual cues for judgments of masculinity and femininity (Russell 2009), while other aspects of facial contrast decline with age and are used as perceptual cues to facial age (Porcheron et al. 2013), or are linked with perceived health (Russell et al. 2016). Regarding the sex difference in facial contrast, female faces have greater luminance contrast around the eyes and lips than do male faces because female skin is lighter than male skin (Frost 2005; Jablonski and Chaplin 2000), but the luminance of the eyes and lips does not much differ between sexes (A. L. Jones et al. 2015; Russell 2009). The pattern of contrast around the eyebrows is reversed, with more contrast around the brows in male faces than female faces, because male eyebrows are much darker than female eyebrows (A. L. Jones et al. 2015). For all of these features (eyebrows, eyes, lips), the sex differences in facial contrast are confined to luminance—there are no sex differences in facial contrast in either the a^* (redness) or b^* (yellowness) color dimensions of the CIE $L^*a^*b^*$ color space (A. L. Jones et al. 2015). Luminance contrast around the features is a powerful cue to gender; manipulation of facial contrast alone is sufficient to make an androgynous face appear male or female (Russell 2009).

Work to date investigating sex differences in facial contrast has been performed only with young adult faces. However, certain aspects of facial contrast are now known to decline with age, at least in female faces (Porcheron et al. 2013). Unlike the sex differences in facial contrast, the declines in facial contrast with age are not limited to the luminance channel. There are also changes with age in contrast around the eyes and around the lips in the a^* (redness) and b^* (yellowness) color dimensions. The changes with age in facial contrast occur because the brows decrease in luminance, facial skin around eyes becomes less red and yellow while the eyes themselves (specifically the sclera) become more red and yellow with age, and the lips lose their redness. These changes with age in contrast across multiple features and color channels are also used as cues for judgments of age perception from the face. Those aspects of facial contrast are correlated with perceived age, and artificially increasing those contrasts makes a face appear younger (Porcheron et al. 2013).

These previous studies investigating facial contrast have held as constants the demographic variables not under study, both because of the limited availability of appropriate stimulus sets, and in order to minimize extraneous variables. The two published studies that have investigated sex differences in facial contrast only measured young adult faces (A. L. Jones et al. 2015; Russell 2009), and the one published study finding age differences in facial contrast measured only female faces (Porcheron et al. 2013). Thus, there is a clear need to determine the generalizability of these findings by extending them to other age groups and to both sexes.

Here we sought to test the hypotheses that age-related changes in facial contrast are present in male as well as female faces, and that the sex differences in facial contrast are found throughout adulthood. Toward this end, we measured facial contrast from a large, controlled set of facial photographs taken of men and women with a wide range of adult ages. We predicted that male as well as female faces would show declines with age in facial contrast. We also predicted that older and middle-aged as well as young adult faces would show sex differences in facial contrast of the luminance channel.

Method

Materials

In order to examine differences in facial contrast across ages and between sexes, we used images from the FACES database (Ebner et al. 2010). The FACES database consists of a set of 171 Caucasian faces with varying emotional expressions, split into younger, middle aged, and older age groups. All photos were taken under identical lighting and exposure conditions in the same studio with the same camera. We used only the stimuli in which the facial features were fully visible and not occluded by hair, and were not clearly wearing cosmetics, yielding a final sample of 151 faces, comprised of 50 younger faces (19–31 years; 24 females, age $M = 24.00$, $SD = 3.53$; 26 males, $M = 24.69$, $SD = 3.21$), 49 middle aged faces (39–55 years; 21 females, $M = 49.52$, $SD = 3.54$; 28 males, $M = 48.43$, $SD = 4.11$) and 52 older faces (69–80 years; 25 females, $M = 74.24$, $SD = 3.19$; 27 males, $M = 72.33$, $SD = 2.22$). While younger and middle aged faces did not differ in age, in the older age group the females were slightly older than the males, $t(50) = 2.52$, $p = .015$, $d = 0.69$. For each identity, we selected one of the images in which the face displayed a neutral expression.

Image Analysis

We used the same approach for measuring facial contrast as previous investigations of facial contrast (A. L. Jones et al. 2015; Porcheron et al. 2013; Russell 2009; Russell et al. 2016). Each face was manually labelled using MATLAB (Version R2010a) to define the facial features and regions around them. Specifically, we labelled the eyes—including the band of skin around the eyelashes, the eyebrows, the lips, an annulus of skin surrounding the eyes, an annulus of skin surrounding the eyebrows, and an annulus of skin surrounding the lips. These regions are demonstrated for one face in Fig. 1.

We used MATLAB to convert images into 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

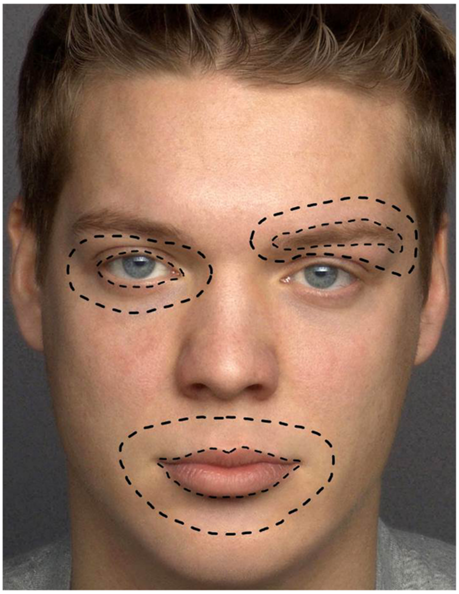

Fig. 1 The *dashed lines* illustrate the labeling of the facial features and the skin surrounding them

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**). This color space yields information about skin color in perceptually relevant terms and is ideal for addressing questions regarding perceptions of human skin coloration (Weatherall and Coombs 1992).

To calculate contrast values, we averaged the pixel values within both eye regions, within both brow regions, and within the lip region. We separately averaged the values within the annulus surrounding the eyes, the annulus surrounding the brow, and the annulus surrounding the lips. Pixel values ranged from 0 (*L**, black; *a**, green; *b**, blue) to 255 (*L**, white; *a**, red; *b**, yellow). The contrast of each feature was calculated as C_F = (skin color - feature color)/(skin color + feature color) using the averaged values for each feature and its corresponding annulus. Resulting values can range from −1 to 1. Positive values indicate that surrounding skin has a higher color value than the feature and negative values indicate the reverse. These calculations were repeated separately for each CIE *L*a*b** color channel for each feature.

Results

Age-Related Differences

Our first aim was to replicate the findings of Porcheron et al. (2013) with female faces and extend them to male faces, by examining the decline in facial contrasts that occur with age in male as well as female faces. Toward this end we conducted Pearson correlations to analyze the relationships between age, as a continuous variable, and the three color contrasts of each of the three facial features for each sex. These correlations are presented in Table 1. To facilitate comparison, the results of Porcheron et al. (2013) Study 1 are also presented in Table 1 (a^* and b^* contrast around the brows were not measured in that study). As the average a^* contrast of the lips was negative across all faces and age groups ($M = -.022$, $SD = .008$), indicating the lips are redder than the surrounding skin, we treat this variable in absolute values for this analysis. All other contrast values were positive.

In the luminance (L^* channel), age was negatively correlated with brow contrast in the male faces (and the female faces of the Porcheron et al. study), but curiously not with the female faces. Age was not significantly correlated with L^* contrast around the eyes or lips. In the redness (a^*) channel, age was not significantly correlated with brow contrast but was negatively correlated with contrast around the eyes and lips for both sexes. In the yellowness (b^*) channel, age was negatively correlated with brow contrast in the male faces but not the female faces, negatively correlated with eye contrast in both sexes, and not correlated with lip contrast (though age was *positively* correlated with lip contrast in the Porcheron et al. study).

In addition to carrying out these correlations, we conducted statistical tests on the correlation strengths to see if they differed between females and males – that is, do the contrasts of certain features decline more for females or males with age? To test this, we converted the correlation coefficients into Z-scores via Fishers r-to-z transform, and compared their values to standard Z-score criteria for significance ($\geq \pm 1.96$). As reported in Table 1, the L^* and b^* contrasts of brows differed between sexes, declining more with age in male faces than female faces.

Overall, we found evidence that male as well as female faces show declines in facial contrast with age, with most of the declines being consistent between the sexes. Many aspects of facial contrast showed significant negative relationships with age, and there were no significant positive relationships. Further, the pattern of results was largely similar to that of Porcheron et al. (2013).

Table 1 Pearson correlations between age and feature contrast

Channel	Feature	r values		Significance of sex difference (p)	r values from Porcheron et al. (2013), Study 1. Female faces ($n = 289$)
		Female faces ($n = 70$)	Male faces ($n = 81$)		
L^*	Brows	-.05	-.37*	.042*	-.50*
	Eyes	.02	.20	.271	-.11
	Lips	.12	.15	.857	.03
a^*	Brows	.14	.11	.857	*n/a*
	Eyes	-.32*	-.29*	.842	-.32*
	Lips[a]	-.41*	-.47*	.653	-.29*
b^*	Brows	.10	-.28*	.019*	*n/a*
	Eyes	-.41*	-.36*	.726	-.24*
	Lips	-.10	-.17	.667	.16*

[a] These correlations are with the absolute values of a* lips contrast, * $p < .05$

Sex Differences

Our second aim was to replicate the findings of Russell (2009) and Jones et al. (2015) with young adults, and extend them to middle-aged and older faces by examining whether the sex differences in facial contrast of the luminance channel are found throughout adulthood. Toward this end, we conducted a 3 (Feature: Eyebrows, Eyes, Lips) × 2 (Sex: Female, Male) × 3 (Age Group: Young, Middle, Old) mixed model ANOVA, using the items as the unit of analysis, and Feature as the sole repeated measure. Because previous work has found sex differences in facial contrast only in the luminance channel (A. L. Jones et al. 2015), we examined only luminance contrasts here. A sex difference in the pattern of facial contrast would be indicated by a significant interaction between Feature and Sex. A three-way interaction between Feature, Sex, and Age Group would contradict our prediction that older and middle-aged as well as younger faces would show sex differences in facial contrast. However, the lack of such an interaction would indicate that sex differences in facial contrast do *not* vary with age, indicating that the two-way interaction between Feature and Sex does not significantly differ between the age groups.

The three-way interaction between Feature, Sex, and Age Group was not significant, $F(4, 290) = 2.21$, $p = .068$, $\eta_p^2 = .03$, but the two way interaction between Feature and Sex was significant, $F(2, 290) = 15.75$, $p < .001$, $\eta_p^2 = .10$. This indicates that the pattern of sex differences in facial contrast do not differ by Age Group. This overall pattern of sex differences in facial contrast, shown in Fig. 2, consists of greater luminance contrast around the eyes and lips in females, and greater contrast luminance contrast around the eyebrows in males, as has been found previously (A. L. Jones et al. 2015; Russell 2009). There was a significant sex difference for each of these features. Female eyes (M = .145, SE = .005) had significantly more contrast than male eyes (M = .118, SE = .004), $p < .001$, $d = 0.72$. Female lips (M = .095, SE = .003) had significantly more contrast than male lips (M = .081, SE = .003), $p = .001$, $d = 0.53$. Male brows (M = .139, SE = .006) had significantly more contrast than female brows (M = .117, SE = .006), $p = .014$, $d = 0.39$.

Even though the three-way interaction between Feature, Sex, and Age Group was not significant, we present the contrast data for each feature for each sex and each age group in Fig. 3 and in Table 2. Because this is the only study to investigate sex differences in facial contrast in different age ranges, these data may be helpful for

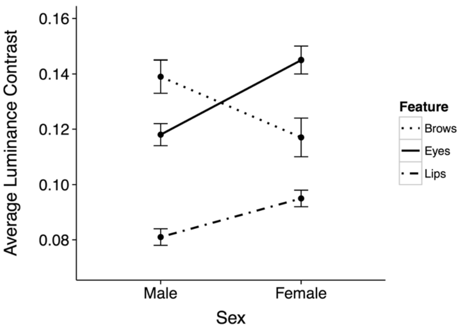

Fig. 2 The interaction between feature and sex, collapsed across age group. Error bars represent ±1 *SEM*

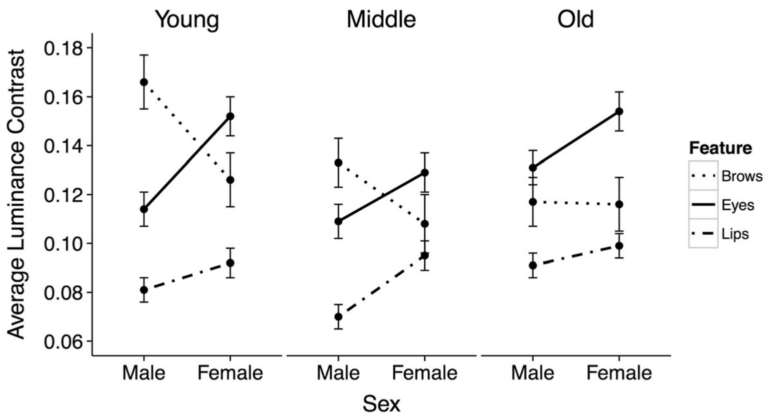

Fig. 3 An illustration of the full interaction between feature, sex, and age group. The full comparison between each sex, in each age group, for the brows, eyes, and lips contrasts are provided in Table 2. Error bars represent ±1 *SEM*

comparisons with future samples. Consistent with the lack of a three-way interaction, the general qualitative pattern of sex differences seen in Fig. 2 and found elsewhere (A. L. Jones et al. 2015; Russell 2009) can be observed in each of the three age groups, with female faces having greater luminance contrast around the eyes and lips, but male faces having greater luminance contrast around the brows.

Discussion

While previous research had found evidence for sex-and age-related variation in facial contrast, the generalizability of these findings was limited. Specifically, sex differences in facial contrast had only been investigated in young adult faces, and age-related

Table 2 Means, standard deviations, and direct comparisons between sex for luminance contrasts of each feature in each age group

Age Group	Feature	Sex		Direct comparison statistic
		Female	Male	
Young	Brows	.126 (.061)	.166 (.049)	$t(48) = 2.56$, $p = .014$, $d = 0.74$
	Eyes	.152 (.037)	.114 (.029)	$t(48) = 4.12$, $p < .001$, $d = 1.19$
	Lips	.092 (.024)	.081 (.028)	$t(48) = 1.40$, $p = .167$, $d = 0.40$
Middle	Brows	.107 (.036)	.133 (.058)	$t(47) = 1.77$, $p = .082$, $d = 0.52$
	Eyes	.128 (.042)	.109 (.039)	$t(47) = 1.65$, $p = .107$, $d = 0.48$
	Lips	.095 (.017)	.069 (.025)	$t(47) = 3.98$, $p < .001$, $d = 1.16$
Older	Brows	.116 (.053)	.117 (.061)	$t(50) = 0.05$, $p = .960$, $d = 0.00$
	Eyes	.154 (.037)	.131 (.043)	$t(50) = 2.05$, $p = .046$, $d = 0.58$
	Lips	.099 (.033)	.091 (.032)	$t(50) = 0.93$, $p = .359$, $d = 0.26$

Standard deviations appear in parentheses differences in facial contrast had only been investigated in female faces. We sought here to replicate these findings and also to extend them to other demographic groups, by using a large, carefully-controlled set of images of male and female faces of a very wide range of adult ages. We found declines with age in facial contrast in male as well as female faces that were nearly identical to those found elsewhere with female faces (Porcheron et al. 2013). We also found sex differences in facial contrast across the adult lifespan. The pattern of sex differences that we found here was the same as that found previously in young adults (A. L. Jones et al. 2015; Russell 2009).

We first examined the change in facial contrast with age in male and female faces. We found that there are declines in facial contrast with age in men as well as women, that were very similar to those found in a previous study with only female faces (Porcheron et al. 2013). With age, red-green and yellow-blue contrast around the eyes decreases in part because the sclera becomes redder and yellower with age (Gründl et al. 2012; Russell et al. 2014). We also observed a decrease of the absolute value of red-green lips contrasts in both female and male faces. With age, lips lose their redness, becoming a similar redness to the surrounding skin. This contrast is important for perceptions of femininity in female faces, and attractiveness in faces of both sexes (Stephen and McKeegan 2010). Given that it decreases with age in both sexes, lip redness may be a cue to youth for both sexes. The use of cosmetics to increase this contrast (A. L. Jones et al. 2015) may be related to the importance of youth as a cue to female attractiveness (D. Jones 1996). We found a decrease in the luminance contrast around the brow in male faces, consistent with the decrease found in female faces previously (Porcheron et al. 2013). Curiously we did not find this decrease in the female faces of the current set. Given the changes that occur with age in hair color and hair density that should cause a decrease in luminance contrast around the brow, this was a surprising finding. Future work with other samples will be useful for confirming whether this is indeed a consistent age-related change.

We next examined sex differences in luminance contrast around the facial features. In a sample of faces that ranged from 19 to 80 years of age, we found the same pattern of sex differences that has been reported previously (A. L. Jones et al. 2015; Russell 2009; Stephen and McKeegan 2010). Specifically, female faces have greater luminance contrast around the eyes and lips than do male faces, while male faces have greater luminance contrast around the brows than do female faces. This pattern of sex differences did not interact with the age band of the faces, suggesting that this pattern of sex differences is largely consistent across the adult lifespan.

Though our findings here did not investigate the perception of age and sex from the face, a recent study that also used images from the FACES database investigated facial sex categorization as a function of aging (Kloth et al. 2015). That study found that sex categorization was not worse for older faces, which is consistent with our finding that the sex difference in facial contrast does not decline with age. There was a sex difference, however, with participants being slower and less accurate at classifying older faces as female, and slower and less accurate at classifying younger faces as male. This finding is broadly consistent with our findings that higher facial contrast is typical of female and younger faces, while lower facial contrast is typical of male and older faces. Further, Kloth and colleagues found that this younger-female older-male bias was preserved when faces were low-pass filtered or inverted. As facial contrast is largely preserved in those manipulations, this finding is also consistent with the idea that facial contrast plays a role in this younger-female older-male bias.

The current data supports the idea that there is variation in facial contrast with age and with sex, but that these sources of variation do not interact with each other. This suggests the possibility that the causes of these two forms of variation are distinct. Indeed, the sex differences in facial contrast are believed to be due primarily to the sex difference in skin color (Russell 2009), while the age-related differences in facial contrast are believed to be due primarily to the color of the features (Porcheron et al. 2013). However, it is important to note that while the current data set is large overall (151 faces), it is not especially large for testing this interaction—individual age-gender groups ranged in size from 21 to 28 faces. Because of this, replication with larger samples would be helpful, although quite difficult to organize logistically. Along these lines, it will also be helpful to investigate the physiological underpinnings and possible adaptive nature of the age and sex differences in facial contrast, keeping in mind that they are likely distinct.

Makeup has been found to increase some of the aspects of facial contrast that decline with age, as well as the aspects of facial contrast that are naturally higher in female faces than male faces (Etcoff et al. 2011; A. L. Jones et al. 2015). This is consistent with the findings that makeup increases the perceived health (Nash et al. 2006) and femininity (Graham and Jouhar 1981; J.E. and Johnson 1991; Law Smith et al. 2006) of faces, and with the idea that makeup functions in part by exaggerating the perceived femininity and youthfulness of female faces (Russell 2010). While it has been found that makeup causes a larger increase in perceived attractiveness in older women than younger women (Huguet et al. 2004), studies investigating the effect of makeup on perceived health and femininity have only used younger women as targets. Our finding that sex differences in facial contrast are present in middle-aged and older faces suggests that makeup should increase femininity throughout the adult lifespan. Also, the finding that male faces also experience a decline in facial contrast with age may be useful in guiding the development of cosmetics intended to rejuvenate the appearance of middle-aged or older male faces.

The current work expands the generalizability of the findings that aspects of facial contrast vary with age and that others are sexually dimorphic, yet many questions remain. It is unknown how facial contrast changes with age from birth to adulthood, and whether sex differences in facial contrast are present from birth or begin at puberty or some other age. Similarly, facial contrast has only been studied in Caucasian and East Asian faces, and age differences in facial contrast have only been described in Caucasian faces. Future research will also need to determine why aspects of facial contrast change with age. This will involve determining the physiological factors underlying these changes, and whether they are due to intrinsic or extrinsic factors of aging. To address these questions it will be necessary to associate face images with lifestyle data relevant to extrinsic aging such as smoking behavior and sun exposure, as well as physiological measures related to intrinsic aging.

We have examined several aspects of facial contrast to understand how this facial cue changes throughout the lifespan. We found evidence that the contrasts that decline with age generally decline similarly for both sexes. The contrasts that change with age are, with the exception of luminance contrast around the brows, not the same as the contrasts that are sexually dimorphic. We found evidence that these sex differences in facial contrast are found throughout adulthood. In summary, several aspects of facial contrast decline with age in both sexes but the sex differences in luminance contrast around the features remain through adulthood.

Compliance with Ethical Standards

Conflict of Interest Richard Russell receives research grants from Chanel PB, a cosmetics company.

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