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ORIGINAL PAPER

Sexual Dimorphism in Facial Contrast: A Case from Central Africa

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Abstract
Apart from morphological differences, male and female faces also vary in color, especially in overall lightness and facial contrast, i.e., the contrast between the luminance and color of facial features (eyes, lips, or brows) and luminance and color of the surrounding skin. In many populations, it has been demonstrated that women tend to be lighter than men. Other differences were found in facial contrast: women have a higher contrast between the lightness of their eyes and lips and the surrounding skin. Manipulation of this contrast in an artificial genderless face can result in a masculine or feminine appearance. So far, however, this phenomenon has been studied mostly in Euro-American and East Asian samples, with little evidence from populations with darker facial tone. We explored natural sexual dimorphism in both facial contrast and lightness in an African, namely Cameroonian, sample, and compared it with results for a European, in particular Czech, population. Our findings showed that sexual differences in luminance contrast of eyes and brows were in both studied populations similar but in the Cameroonian sample, significant difference in lips contrast was absent. These results indicate that sex differences in facial contrast are a side effect of the sex differences in skin color and can be used as a proxy for skin color perception.

Keywords Sexual dimorphism · Sex typicality · Skin color · Facial contrast

Introduction

Human sexual dimorphism is apparent in a wide variety of traits, both physical and behavioral. Apart from overall height, many physical differences between the sexes manifest themselves in the facial area. Sexual dimorphism in facial morphology has been widely studied (Kleisner et al., 2021; Komori et al., 2011; Mitteroecker et al., 2015; O'Toole et al., 1998), in part possibly because it is directly influenced by differing hormone levels in men and women (Fink et al., 2005; Johnston et al., 2001; Thornhill & Gangestad, 1999). In fact, facial morphology has been used to define sex typicality. Nevertheless, apart from morphological differences, male and female faces also vary in color (Tarr et al., 2001; van den Berghe & Frost, 1986), and it has been confirmed in a wide range of populations that women have a lighter skin than men do (for a review, see Jablonski & Chaplin, 2000; van den Berghe & Frost, 1986). Similar differences have been found in facial contrast, where women, being lighter, have a higher contrast between the luminance of eyes and lips and the surrounding skin (Russell, 2003, 2009). Men, on the other hand, have a higher contrast between brows and surrounding skin (Jones et al., 2015), which is probably due to men having on average darker hair (Frost, 2014; Shekar et al., 2008) and higher density of eyebrows (Jones et al., 2015).

It has been shown that color and luminance play a key role in face detection (Bindemann & Burton, 2009) as well as recognition of gender (Bruce et al., 1993; Bruce & Langton, 1994; Dupuis-Roy et al., 2009; Hill et al., 1995; Nestor & Tarr, 2008). Frost (1988) suggested that among many human populations, sexual dimorphism in skin luminance has traditionally been the main source of skin color variation. It could, therefore, be used as a cue for perceiving sex from the face. Manipulation of facial contrast in an artificially genderless face can result in a masculine or feminine appearance (Russell, 2009). This effect remains strong even when controlled for overall skin lightness, which led Russell (2009) to a conclusion that facial contrast should not be treated as merely an epiphenomenon of women's lighter complexion. Facial contrast is further exaggerated by the use of cosmetics, which tend to enhance not only the appearance of sex typicality (Jones et al., 2015; Russell,

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2009) but also of youth (Porcheron et al., 2013; Russell et al., 2014) and health (Russell et al., 2016).

Recently, more attention has been paid to sexual dimorphism in skin color. Tarr et al. (2001) brought forth evidence on sexual dimorphism in the red–green color channel, where men tend to be redder than women. Moreover, it seems that this difference is significant enough to facilitate rapid sex classification. Stephen and McKeeganh (2010) revised previous findings of Russell (2003, 2009) with respect to the color contrast between lips and the surrounding skin. Their study showed that redder lips increased women's perceived sex typicality, while in men, the same effect was achieved by the opposite manipulation. They also found a difference in the amount of yellow in the lips but in this case, the sex difference consisted in the extent rather than direction of the change: in short, they found that women's lips are more yellow.

Both high luminance and high facial contrast are considered attractive in female faces (Coetzee et al., 2012; Russell, 2003, 2009; van den Berghe & Frost, 1986), and it has been shown that femininity is closely linked to female attractiveness (Perrett et al., 1998; Rhodes et al., 2000). Although masculinity might not be similarly linked to male attractiveness, sex classification is facilitated by attractiveness ratings, as shown by Hoss et al. (2005). The process of gender recognition, or at least female recognition, should be therefore approached as a type of quality assessment, not just a neutral distinction.

Facial contrast, its social perception, and sexual dimorphism have so far been studied mostly in Euro-American and East Asian samples. Both these populations are light-skinned, which means that conclusions from such studies cannot be simply generalized to all human populations. Porcheron et al. (2017) show that facial contrast can be an important cue for age perception across populations, including dark-skinned African ones. Gender recognition is also possible across cultures, even very different ones, which indicates that it is a process that might rely on universal cues to sex differences. One can therefore expect that aside from facial shape, skin luminance and skin color play a significant role as cues to sexual dimorphism in African populations as well. Recently, it has been shown that people of European origin have a higher level of sexual dimorphism in facial morphology than Africans do (Kleisner et al., 2021) but little is known about sexual dimorphism in the luminance contrast of facial features and surrounding skin in Africans.

The main aim of the current study is to examine whether previous findings based on faces of European origin can be unproblematically extrapolated to a Central African population. To this purpose, we compared sexual dimorphism in luminance, color, and facial contrasts of these variables in two distant populations, namely Cameroonians and Czechs.

Method

We used facial photographs of 113 Cameroonians (50 men, 63 women, mean age $\pm$ SD = 21.74 $\pm$ 3.09) and 119 Czechs (64 men, 55 women, mean age $\pm$ SD = 23.91 $\pm$ 4.13). Participants were mostly undergraduate students from Buea (Cameroon) and Prague (Czech Republic). They were recruited via flyers, social networks, or approached personally. All individuals involved in this study provided informed consent. Participants were given a uniform black t-shirt and were asked to remove all jewelry and cosmetics. We seated them in front of a white background and instructed them to adopt a neutral facial expression. Photographs were taken with a Canon 6D camera using an 85-mm lens, studio flash, and a reflection screen. Distance between the lens and participant's face was 1.5 m.

All photographs were then postprocessed in Adobe Photoshop Lightroom 4. White balance, exposure, and color were calibrated using X-Rite color checker passport. Afterward, we cropped the photographs using Photoshop CS6 so that the eyes were all at the same absolute height and identical length of the neck was visible. All photographs were resized to 1165 × 1476 pixels.

Then, we applied the Color Transformer 2 plugin in ImageJ. Eye, lips, brows, and surrounding skin areas were selected using the freehand selection tool (Fig. 1) and skin patches from the forehead and the right cheek were selected

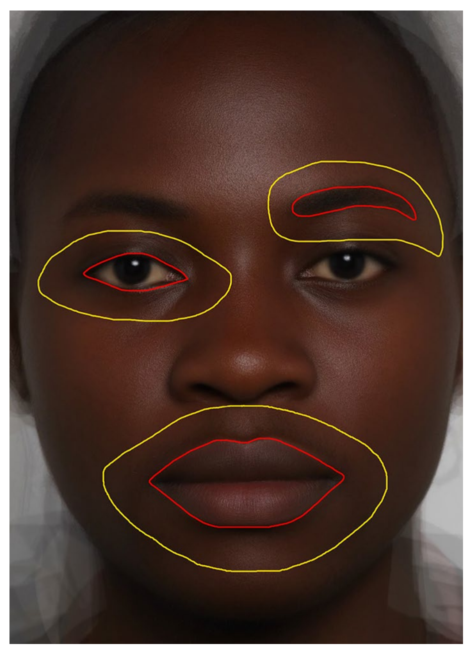

Fig. 1 An example of feature and skin area selection. Red lines show how features (lips, eyes, and brows) were selected, yellow lines show how areas of surrounding skin were selected. This image presents an artificial face (Color figure online)

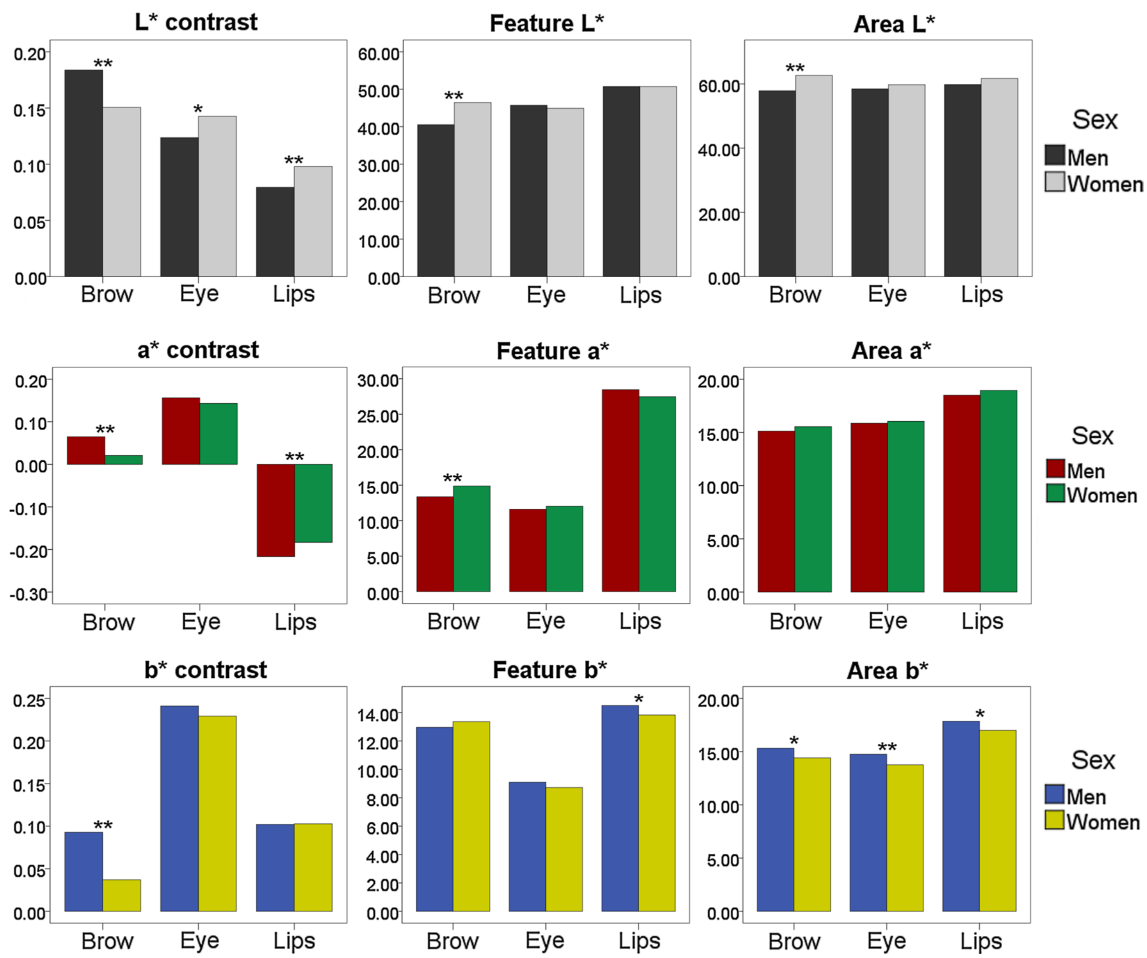

Fig. 2 Sex differences in lightness (L*), red–green channel (a*), and yellow–blue channel (b*) in the Czech population. * $p < .05$; ** $p < .01$ (Color figure online)

using the oval selection tool. Mean luminance and color of the selected areas were measured in CIE L*a*b* color space.

Luminance (L*) contrast was calculated using Russell's (2009) adapted Michelson contrast calculated as $C_f = (L_s - L_f)/(L_f + L_s)$, where L_f stands for feature (eye, brow, lips) luminance, L_s stands for skin luminance, and C_f is the feature/skin contrast. Resulting values can vary from − 1 to 1, with 0 meaning no contrast. Values above 0 indicate the feature is darker than the skin, values below 0 indicate the feature is lighter than the skin. The same process was applied to the red–green channel (a*), where values above 0 mean the skin is redder than the feature and values below 0 mean the feature is redder than the skin, and the yellow–blue channel (b*), where values above 0 mean the skin is yellower than the feature and values below 0 mean the feature is yellower than the skin.

Subsequent statistical analysis was performed in SPSS Statistics 20. Luminance contrast means were compared by a one-way ANOVA to test for sex differences. Absolute feature luminance and absolute skin luminance were added as covariates to test for skin color dimorphism bias. Sex differences in feature luminance and skin luminance separately were tested with a one-way ANOVA. The same setup was then, again separately, applied to the red–green (a*) and yellow–blue (b*) channels.

Results

Results based on our European sample corroborated the differences in facial contrast reported by Russell (2003, 2009), namely that women have higher facial contrast around the eyes and lips and lower facial contrast around the eyebrows (Fig. 2). Analysis of the Cameroonian sample revealed similar differences in luminance contrast in the eye and brow area but not in the lips area (Fig. 3).

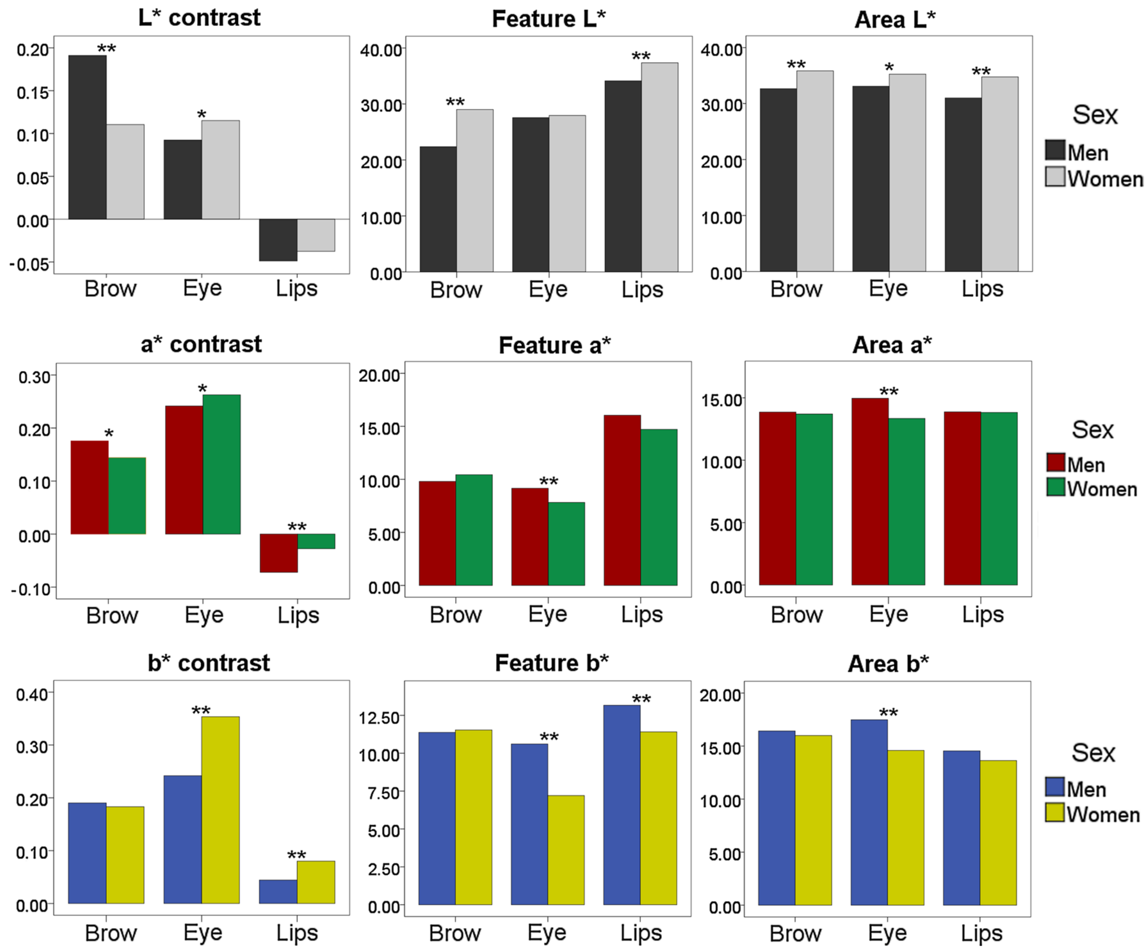

Fig. 3 Sex differences in lightness (L*), red–green channel (a*), and yellow–blue channel (b*) in the Cameroonian population. * $p < .05$; ** $p < .01$ (Color figure online)

Luminance

In the Cameroonian sample, men had a significantly darker skin than women in every measured area except for the cheeks ($F[1, 111] = 1.86$, $p = .176$, $R^2 = 0.016$). Men also had much darker brows ($F[1, 111] = 42.24$, $p < .001$, $R^2 = 0.276$) and lips ($F[1, 111] = 18.14$, $p < .001$, $R^2 = 0.140$). No significant difference was found in eye luminance ($F[1, 111] = 0.30$, $p = .584$, $R^2 = 0.003$). In the Czech sample, men had a significantly darker skin in the brow area ($F[1, 115] = 34.57$, $p < .001$, $R^2 = 0.231$) and significantly lighter skin in the cheek area ($F[1, 117] = 4.39$, $p = .038$, $R^2 = 0.036$). They had a darker skin also in other measured areas but this difference proved insignificant. There was no difference in the eye luminance ($F[1, 117] = 0.87$, $p = .35$, $R^2 = .007$) or lips luminance ($F[1, 117] < 0.01$, $p = .989$, $R^2 < 0.001$). Men had significantly darker brows ($F[1, 116] = 17.22$, $p < .001$, $R^2 = 0.129$).

Luminance Contrast

In the Cameroonian sample, men had a significantly higher brow contrast ($F[1, 111] = 55.63$, $p < .001$, $R^2 = 0.334$) and lower eye contrast ($F[1, 111] = 6.85$, $p = .01$, $R^2 = 0.058$). There was no significant difference between the sexes in the contrast between the lips and surrounding skin ($F[1, 111] = 3.32$, $p = .071$, $R^2 = 0.029$). In the Czech sample, we observed differences in luminance contrast in all three studied features. Men had a significantly higher brow contrast ($F[1, 115] = 7.20$, $p = .008$, $R^2 = 0.059$), lower eye contrast ($F[1, 117] = 6.20$, $p = .014$, $R^2 = 0.05$), and lower lips contrast ($F[1, 114] = 10.11$, $p = .002$, $R^2 = 0.081$).

Color

In the Cameroonian sample, men had significantly redder eyes ($F[1, 111] = 20.33$, $p < .001$, $R^2 = 0.155$) and eye area ($F[1, 111] = 14.40, $p < .001$, $R^2 = 0.115$) as well as significantly yellower eyes ($F[1, 111] = 47.39$, $p < .001$, $R^2 = 0.299$) and eye area ($F[1, 111] = 14.46$, $p < .001$, $R^2 = 0.115$). Men also had yellower lips ($F[1, 111] = 18.14$, $p < .001$, $R^2 = 0.067$) and the intersexual difference in lips redness was bordering on significant ($F[1, 111] = 3.62$, $p = .060$, $R^2 = 0.032$). In the Czech sample, we found no difference in the red–green channel (a*) in the measured skin patches. Women had redder brows ($F[1, 116] = 14.42$, $p < .001$, $R^2 = 0.111$) but there was no significant difference between eye and lip redness between the sexes. Men had a significantly yellower skin (b*) across all measured areas and yellower lips ($F[1, 117] = 4.45$, $p = .037$, $R^2 = 0.037$). With respect to the brows and eyes, there was no difference between the sexes in the yellow–blue channel.

Color Contrast

In the Cameroonian sample, men had a higher red contrast in brows ($F[1, 111] = 5.32$, $p = .023$, $R^2 = 0.046$). Women had a higher red contrast ($F[1, 111] = 5.36$, $p = .022$, $R^2 = 0.046$) and higher yellow contrast ($F[1, 111] = 41.04$, $p < .001$, $R^2 = 0.27$) in eyes. The lips were redder than the skin (negative values for a* contrast) in both sexes but men had a higher lips/skin contrast ($F[1, 111] = 23.60$, $p < .001$, $R^2 = 0.175$) due to having redder lips. Women had a higher b* contrast in the lip area ($F[1, 111] = 8.39$, $p = .005$, $R^2 = 0.07$) due to having bluer lips. In the Czech sample, men had a significantly higher both red ($F[1, 115] = 15.92$, $p < .001$, $R^2 = 0.122$) and yellow contrast ($F[1, 115] = 9.84$, $p = .002$, $R^2 = 0.079$) in the brows. There was no difference in eye contrast neither in the red ($F[1, 117] = 1.58$, $p = .211$, $R^2 = 0.013$) nor in the yellow ($F[1, 117] = 0.66$, $p = .417$, $R^2 = 0.006$) channel. In lips, men had a higher red contrast in negative values ($F[1, 114] = 19.73$, $p < .001$, $R^2 = 0.148$), meaning the lips were redder than the surrounding skin. There was no difference in the yellow–blue channel in the lips contrast ($F[1, 114] = 0.01$, $p = .932$, $R^2 < 0.001$).

Discussion

The main aim of this study was to find out whether previous findings on sexual dimorphism in facial contrast (based mostly on Europeans and East Asians) apply also to an African population. We observed significant sex differences both in (1) the luminance of brows compared to surrounding skin and in (2) the luminance of eyes compared to surrounding skin. Cameroonian men showed a higher contrast in the former case (brows), whereas women in the latter (eyes). These findings are consistent with previously published results from Euro-American and East Asian populations (Jones et al., 2015; Russell, 2009), as well as with our control group from the Czech Republic. Interestingly, though, we found that in the Cameroonian sample, the luminance contrast between the lips and surrounding skin showed no significant sex differences. This finding contradicts our expectations based on previous research, according to which women should have higher contrast in the mouth area.

In Cameroonians, values for lips/skin luminance contrast were negative in both sexes, which means that the lips are lighter than the surrounding skin. This is never the case in light-skinned individuals, such as Europeans and East Asians. West Africans and Europeans show the same direction of sexual dimorphism in skin color: men are darker than women. In Europeans, this difference is what causes the sexual dimorphism in lips/skin contrast because lips are equally dark in both sexes. In Cameroonians, whose lips are lighter than their skin, we would have expected the opposite effect in lips/skin contrast dimorphism, that is, men would have a higher contrast than women. Our results, however, showed no significant sexual dimorphism in lips/skin contrast. This was probably because Cameroonian men had significantly darker lips than women, which blurred the possible difference in lips/skin contrast.

We did, however, find a significant difference in lips color in the Cameroonian sample, which manifested itself in a difference in contrast in both the red–green and yellow–blue color channel. These large and possibly visible differences could compensate for the lack of luminance contrast dimorphism in gender recognition.

In the red–green channel (a*), the contrast between the lips and the surrounding skin was significantly sexually dimorphic in both the Cameroonians and Czechs. Porcheron et al. (2017) showed that the a* contrast in the mouth area decreases with age in female faces across multiple cultures. The skin reddens with age, especially in men (Kelly et al., 1995), which also results in a lower a* contrast of lips. Our samples consisted mostly of young men and women, with little difference in the mean age (men: mean age ± SD = 23.05 ± 3.69; women: mean age ± SD = 22.66 ± 3.92). The difference we found can therefore hardly be explained by aging. It is more likely that it is a manifestation sexual dimorphism in skin color.

Our results did not show any significant differences in the red–green channel in the skin. This seems to contradict the findings of Tarr et al. (2001), who found that men are redder than women. On the other hand, we selected the skin patches for the purpose of facial contrast calculation and the values measured for them could differ from those for average skin color.

The CIELab a* channel, quantifying the red–green spectrum, is mostly associated with hemoglobin and is a cue for blood perfusion and oxygenation (Stephen et al., 2009, 2011). The L* (light/dark) and b* (yellow–blue) channels are affected by melanin content: L* mainly due by the dark eumelanin and b* by pheomelanin (Ito & Wakamatsu, 2003). The b* channel is furthermore affected by carotenoid levels in the skin (Stephen et al., 2011). Dark-skinned populations, such as Cameroonian ones, differ from light Europeans in their overall melanin concentration but tend to have a higher eumelanin/pheomelanin ratio (Alaluf et al., 2001; Karsten et al., 2013). Our results show a significant difference in skin L* values between the two studied samples, but a much smaller difference in b* values. Skin redness (a*) was slightly lower in the Cameroonians. This may have been due to the high content of eumelanin, the most visually significant pigment in the skin, overriding the effects of other sexually dimorphic skin colorants such as hemoglobin, myoglobin, and carotene.

Sexual dimorphism in the luminance of brows relative to surrounding skin was significant in both studied samples, i.e. both the Cameroonians and the Czechs. In Europeans, this difference can be explained by men either having on average darker hair (Frost, 2014; Shekar et al., 2008) or denser brows that show less of the underlying skin (Jones et al., 2015). With respect to the Cameroonians, we know of no evidence of sexual dimorphism in hair color. The observed difference in brow/skin contrast should be therefore due to men having denser brows, as indeed suggested by Jones et al. (2015). It remains to be seen whether this difference occurs naturally or is the result of some grooming behavior, such as brow plucking in women.

It remains to be observed whether facial contrast itself is a cue for perceiving sex typicality. Feminine women are considered attractive (Perrett et al., 1998; Rhodes et al., 2000), which is why it is difficult to clearly differentiate between sex typicality and female attractiveness. But attractiveness is also highly correlated with age and health and in some cases, such as the brow/skin contrast, sex typicality stands in opposition to health and age. For instance, it is part of general makeup routine in many cultures that women darken their brows using eyebrow pencils. This should increase their perceived health (Russell et al., 2016) and youthfulness (Jones et al., 2015; Porcheron et al., 2013) but not sexually dimorphic appearance. On the other hand, Jones et al. (2015) found that women in experimental conditions tend to decrease their brow contrast, increasing their sex typicality at the expense of their perceived age. A similar conflict can be found in lips/skin contrast. Women have a higher luminance contrast in the mouth region, which is negatively correlated with perceived health (Russell et al., 2016). Increasing sex typicality by darkening the lips should thus have a negative effect on perceived health. The actual aim of lipstick use might be to increase the a* contrast in the mouth area (Jones et al., 2015). That would manipulate the face into appearing younger (Porcheron et al., 2017) but in light of our current results, also less feminine. Increasing facial contrast with a possible negative effect on perceived attractiveness is an important hint to the importance of facial luminance and color contrast in gender recognition.

This study has several limitations stemming from the methods used. First, it is not clear to what extent the contrast calculation used in our study reflects the natural perception of facial contrast. Overall lightness of human face could be perceived either in a holistic manner or as a sum of discrete facial areas. The areas of skin surrounding features which we observed (lips, eyes, brow) were chosen in a rather arbitrary manner and we noted some differences in skin color sexual dimorphism between forehead and cheeks. An area-based computation of facial contrast could therefore yield different results than the holistic approach. Secondly, the use of mean values for computing the lightness or color of the eyes may be problematic because it combines elements which are extremely light (sclera) with others that are dark (pupil, iris). Mean values thus need not be the best way of describing the contrast at the edge between the eyes and surrounding skin. Nevertheless, since we propose a modified approach based on a perception of relative skin luminance in the context of particular facial features, these limitations should have only a limited or no effect on our results. We cannot estimate to what extent specular reflections affected the luminance measurements in our samples. Since reflections are more prominent on dark surfaces, specular reflections might possibly bias some of the observed cultural differences.

Conclusion

In the current study, we found no sex difference in the mean luminance of eyes, neither in Cameroonians nor in Czechs. In both studied populations, observed differences in the luminance contrast between the eyes and surrounding skin can fully be explained by sexual dimorphism in overall skin luminance. The same applies to lips/skin luminance contrast in Czechs and partly also in Cameroonians, although in the latter case, sex difference did not reach the formal level of significance. It seems therefore that sexual dimorphism in the luminance contrast is a byproduct of the general luminance dimorphism described by van den Berghe and Frost (1986). Although it might be perceived independently, as suggested by Russell (2009), facial luminance contrast could serve as a proxy for assessing skin lightness. Since we cannot measure people's skin luminance in everyday social contact, we must perceive it relative to something that shares the same lighting conditions. Other facial features, such as eyes, lips, and possibly brows, are reference points available to us. As Nestor and Tarr (2008) had shown, skin color differences do affect gender recognition. On the other hand, people focus on facial features rather than the skin that is the bearer of the difference. We can thus conclude that sexual dimorphism in skin luminance and facial contrast should be treated as a single phenomenon. From this perspective, our findings from the Cameroonian population contradict neither the results from our control group, nor the results previously published by Russell (2009). In both African and European populations, women have a lighter skin relative to facial features (eyes and lips) than men do. It is therefore likely that the differences in color contrast described in our study have some functional role in facial perception and gender recognition. Exploration of gender recognition in dark-skinned Africans and the role of color dimorphism should be the aim of our future studies.

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Author Contributions SP wrote the initial draft of the manuscript; SP and KK collected data in studied populations; SP provided data analyses and designed the figures. Both authors discussed the results and contributed to the final manuscript.

Data Transparency All data are available for public access: https://osf.io/cxqwh/?view_only=019a1aba12634da582ff06d7499ab166.

Compliance with Ethical Standards

Conflict of interest All authors declare that they have no conflict of interest.

Ethical Approval This study was performed in line with the principles of the Declaration of Helsinki. All procedures mentioned and followed were approved by the Institutional Review Board of the Faculty of Science of Charles University (Protocol Ref. No. 06/2017). This study does not include information or images that could lead to the identification of a study participant. Informed consent was obtained from all individual participants included in the study.

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