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A Novel Human Sex Difference: Male Sclera Are Redder and Yellower than Female Sclera

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Abstract
In a seminal study, Kobayashi and Kohshima (1997) found that the human sclera—the white of the eye—is unique among primates for its whitish color, and subsequent work has supported the notion that this coloration underlies the human ability to gaze follow. Kobayashi and Kohshima also claimed that there is no significant sex difference in sclera color, though no data were presented to support the claim. We investigated sclera color in a standardized sample of faces varying in age and sex, presenting the first data comparing male and female sclera color. Our data support the claim that indeed there is a sex difference in sclera color, with male sclera being yellower and redder than female sclera. We also replicated earlier findings that female sclera vary in color across the adult lifespan, with older sclera appearing yellower, redder, and slightly darker than younger sclera, and we extended these findings to male sclera. Finally, in two experiments we found evidence that people use sclera color as a cue for making judgements of facial femininity or masculinity. When sclera were manipulated to appear redder and yellower, faces were perceived as more masculine, but were perceived as more feminine when sclera were manipulated to appear less red and yellow. Though people are typically unaware of the sex difference in sclera color, these findings suggest that people nevertheless use the difference as a visual cue when perceiving sex-related traits from the face.

Keywords Eye · Face · Sexual dimorphism · Age · Aging · Face perception · Sclera

Introduction

The eyes are widely believed to play an important role in social communication. Yet the role of the sclera—the visibly white part of human eyes—has been investigated primarily with regards for its utility as a sign of health or disease. Yellowness of the sclera, i.e., jaundice, has long been associated with liver pathology (Roche & Kobos, 2004), and the sclera can appear red when the blood vessels in the conjunctiva above the sclera become dilated, due to irritation, fatigue, or infection (Leibowitz, 2000; Murphy et al., 2007). There are also numerous ocular conditions resulting in changes to the coloration of the sclera (Watson & Hazleman, 1976).

While the sclera is long recognized as signaling health, recent work using quantitative physical measurements of sclera color has discovered other social signals conveyed by the sclera. Sclera color is associated with age, with older adults having sclera that are less white (Gründl et al., 2012). Specifically, the sclera of older adults are yellower, redder, and slightly darker than those of younger adults (Russell et al., 2014). There is also evidence from studies using manipulated images that humans use sclera color as a cue for perceiving age from the face (Provine et al., 2013a, 2013b; Russell et al., 2014). Similarly, sclera color affects the perception of health and attractiveness from faces, with redder and yellower sclera looking less healthy and less attractive (Provine et al., 2011, 2013a, 2013b; Russell et al., 2014). Sclera color also affects the perception of emotions (Provine et al., 2013a, 2013b).

In an earlier article, Kobayashi and Kohshima (1997) demonstrated that humans are unique among primate species in having white sclera, making it easier for conspecifics to perceive gaze direction. Subsequent studies have supported and refined these claims (Ando, 2002, 2004; Kobayashi & Kohshima, 2001; Mayhew & Gómez, 2015), and the work has been used to support theories about the function of eye gaze in social behavior (Kobayashi & Hashiya, 2011; Tomasello et al., 2007). In the seminal 1997 article, Kobayashi and Koshima wrote that they did not detect any significant sexual differences in human sclera color. However, they presented no data to support the conclusion. To our knowledge, there are no published data comparing male and female sclera color.

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Related to the physical question of whether there are sex differences in sclera color, the perceptual question of whether sclera color is a cue for perceiving sex-related traits from the face has not been addressed. Also, published studies investigating the relationship between sclera color and age have only measured female eyes (Gründl et al., 2012; Russell et al., 2014), meaning that it is unknown whether sclera color is associated with age in male faces in the same ways as in female faces. We sought to address these questions in the current research.

In Study 1, we investigated whether there are sex differences in sclera color. We also investigated whether sclera color is associated with age in male as well as female faces. Toward this end, we measured sclera color in a well-controlled set of images of male and female faces with a wide range of adult ages. The data contain significant sex differences in the redness and yellowness of the sclera. In Study 2, we sought to determine experimentally whether people use sclera color as a cue related to sex classification, specifically for judgments of the masculinity or femininity of faces.

Study 1

Method

Materials

To examine differences in sclera color between the sexes and across ages, we used images from the FACES database (Ebner et al., 2010). The FACES database is a well characterized set of 171 Caucasian faces with varying emotional expressions. The faces are in three age bands labeled as young (19–34 years), middle-aged (35–59 years), and older (60–80 years). Critically, all of the photographs in the set were taken under identical lighting and exposure conditions in the same studio with the same camera. We used images of faces displaying neutral emotions, and selected only those faces in which the eyes were fully visible and not occluded by hair, and were not wearing obvious cosmetics, yielding a final sample of 148 faces. These faces included 67 women (24 young, 19 middle-aged, 24 older) and 81 men (25 young, 30 middle-aged, 26 older). A priori power analyses using G*Power Version 3.1.9.2. found that for the sex difference comparisons, sample sizes of 787, 128, or 52 total images (with equal numbers of male and female images) would be required to reach power ($1-\beta$) of 0.80 for small, medium, or large effect sizes ($\eta^2=0.01$, 0.06, or 0.14, respectively). This indicates that our sample size of 148 items is adequately powered only for medium or large effect sizes, but not for small effect sizes.

Procedure

The labeling of the sclera was performed using MATLAB 7.8.0 (R2010a), using the same general approach as Russell et al. (2014). Each image was individually labeled to define regions corresponding to the sclera on both sides of the iris. An example of the sclera labeling can be seen in Fig. 1. In this image set, specular reflections are found over the iris but not the sclera, so we did not need to modify our labeling to avoid the reflections. However, we did avoid including any thick eyelashes or obvious shadows in the sclera labeling. To measure the luminance and color of the eyes, we used the $L^*a^*b^*$ color space which corresponds roughly to the color channels of the human visual system. The $L^*a^*b^*$ 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^*). The values of all the pixels within the sclera (on both sides of the iris) were averaged separately for each of the three color dimensions. Thus, for each face we calculated three values: the average L^* (luminance or light–dark) value of the sclera, the average a^* (red–green) value of the sclera, and the average b^* (yellow–blue) value of the sclera. These values could range from 0 (black for L^*, green for a^*, blue for b^*) to 255 (white for L^*, red for a^*, yellow for b^*).

Results

Scatterplots showing the L^*, a^*, and b^* values of the sclera as a function of age and sex are shown in Fig. 2. Each point represents an individual face. To investigate possible differences in sclera color as a function of sex or age, we conducted separate Analyses of Variance (ANOVA) for each of the three color dimensions, with sex (male, female) and age group (young, middle-aged, older) as between-groups factors. There were no significant interactions between sex and age group for the L^* dimension, $F(2, 142)=0.07$, $p=.935$, $\eta^2=.001$, or for the a^* dimension, $F(2, 142)=0.34$, $p=.711$, $\eta^2=.003$. However, there was a significant interaction for the b^* dimension, $F(2, 142)=3.48$, $p=.034$, $\eta^2=.027$. This indicates that there were not different associations between sclera color and age in male and female faces in the luminance and redness/greenness of the sclera, but there were in the yellowness/blueness of the sclera.

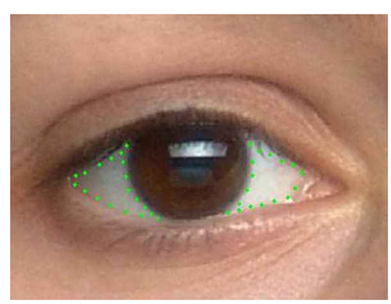

Fig. 1 Example image illustrating how the sclera was defined. The small dots placed around the sclera are in the location where the boundary of the sclera was placed

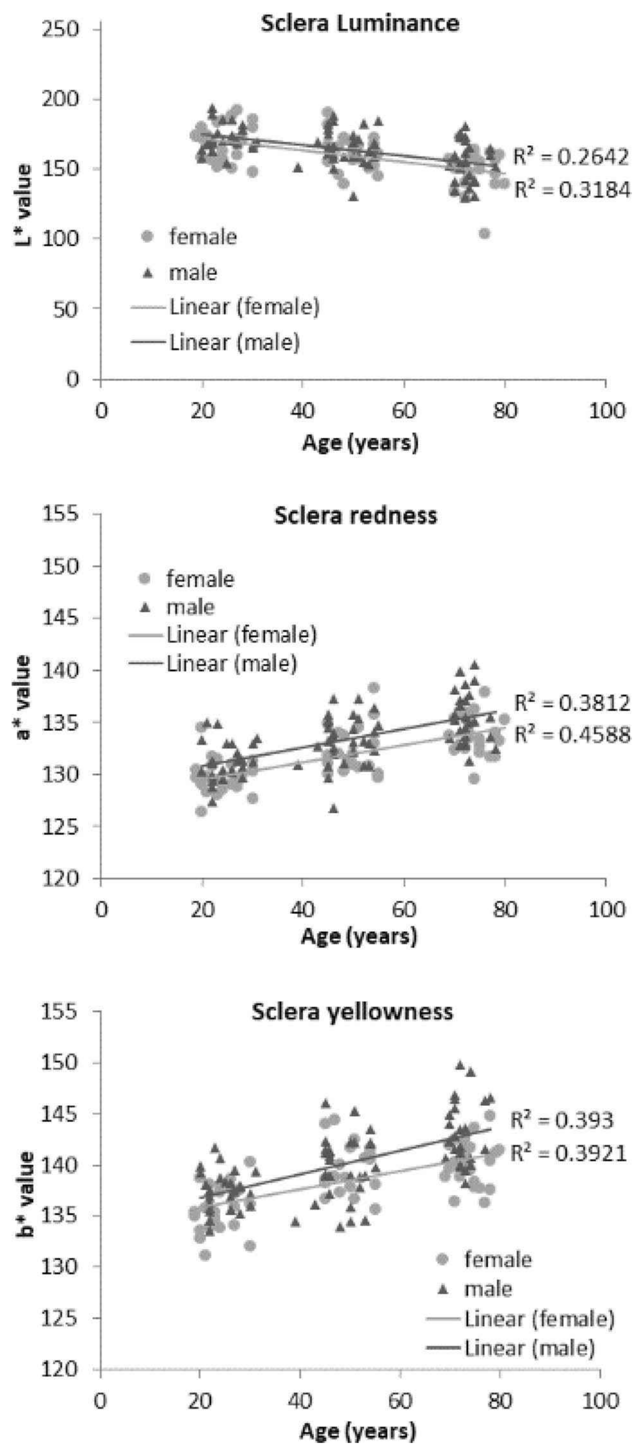

Fig. 2 Sclera color plotted as a function of the age and sex of the face

Sex Differences

There were significant main effects of sex in both the a^* dimension, $F(1, 142) = 14.77$, $p < .001$, $\eta^2 = .057$, and the b^* dimension, $F(1, 142) = 13.86$, $p < .001$, $\eta^2 = .054$. However, there was not a significant main effect of sex in the L^* dimension, $F(1, 142) = 3.03$, $p = .084$, $\eta^2 = .015$. The male sclera had higher a^* and b^* values, meaning that they were redder and yellower than female sclera, which were greener and bluer. There was no evidence of a sex difference in the luminance of the sclera.

Age Differences

There were significant main effects of age group in all three color dimensions. L^* was negatively associated with age, as the older age groups had darker sclera than younger age groups, $F(2, 142) = 30.82$, $p < .001$, $\eta^2 = .297$. a^* was positively associated with age, as the older age groups had redder sclera than younger age groups, $F(2, 142) = 51.00$, $p < .001$, $\eta^2 = .391$. b^* was positively associated with age, as older age groups had yellower sclera than younger age groups, $F(2, 142) = 46.40$, $p < .001$, $\eta^2 = .360$.

Discussion

In Study 1, we found that sclera color is associated with age in both male and female participants. The pattern of association with age was the same as that found previously with a different sample of female faces: older adult faces have sclera that are darker, redder, and yellower than younger adult faces (Russell et al., 2014). Thus, we have replicated this association between sclera color and age in female faces and extended it to male faces.

Critically, we also found sex differences in sclera color, with female sclera appearing less red and less yellow than male sclera. We did not find evidence for a difference in sclera luminance. However, our sample of faces was not large enough to detect small effect sizes, therefore it is possible that there is a small sex difference in sclera luminance that our study could not detect because of inadequate power. The sex differences in sclera redness and yellowness are a novel finding. The sex differences in sclera redness (Cohen's $d = 0.49$) and sclera yellowness (Cohen's $d = 0.48$) observed here are similar in size to other known physical sex differences, including facial contrast (Cohen's $d = 0.55$ and $d = 0.60$, Russell, 2009) and 2D:4D digit ratio (Cohen's $d = 0.38$ for the left hand and $d = 0.46$ for the right hand, Hönekopp & Watson, 2010). However, the sex differences in sclera color are substantially smaller than the age differences, as reported above.

Study 2

Having found evidence for sex differences in sclera color in Study 1, we sought in Study 2 to determine whether people use sclera color as a cue for face perceptions related to sex. We performed experiments using stimulus face images with manipulated sclera color. In order to overcome limitations of any one procedure, we performed two separate experiments with different procedures. In the first experiment (Study 2a), participants performed a forced-choice task indicating which of two faces looked more masculine. Critically, the two faces in each stimulus pair were physically identical except for sclera color. The images were otherwise perceptually androgynous. In the second experiment (Study 2b), we collected ratings of masculinity and femininity of male and female faces that were unmanipulated except for sclera color. In both experiments, we used face images derived from the FACES set, which included young, middle-aged, and older adult faces, allowing us to determine whether sclera color is a cue to sex across this wide range of adult ages.

Study 2a

In Study 2a, we created perceptually androgynous images using morphing software. The sclera color of these images was then manipulated to create two versions of each face image that differed from each other only in terms of sclera color. Participants then made forced-choice judgments of which of the two faces appeared more masculine. Because sclera color was the only feature that differed between the images in each pair, any deviation from chance selection (i.e., equal selection of the two alternatives) must be due to the use of sclera color as a cue to masculinity.

Method

A total of 175 people (109 female, 66 male; $M = 19.3$-years-old, $SD = 1.2$) participated in the study. Ninety-three participants were recruited through the Gettysburg College study pool and received course credit. The other 82 participants were recruited as part of another study and received $5 for their participation. Participants gave informed consent and the research was approved by the Gettysburg College Institutional Review Board.

We used JPsychomorph (Tiddeman et al., 2001) to create perceptually androgynous faces by morphing together male and female faces. This was done separately for each of the three age groups of the FACES set: young, middle-aged, and older. For example, to create a perceptually androgynous young face, we morphed together the young female faces to create a young female average and separately morphed together the young male faces to create a young male average. These two average images were then morphed together, and an androgynous-looking point along the morph continuum was selected by the two authors and a third observer.

We then used Adobe Photoshop to manipulate the sclera color of this perceptually androgynous face. The image was transformed to $L^*a^*b^*$ color mode, and the lasso tool was used to select the four visible sclera regions (one region on either side of the iris, in both eyes). We then made two versions of the face, one with both the a^* and b^* levels of the sclera increased (hence appearing more red and yellow), and another with both the a^* and b^* levels of the sclera decreased (hence appearing less red and yellow). This process was repeated for the young, middle-aged, and older age groups, creating three pairs of images.

The three pairs of images with manipulated sclera color were presented in randomized order such that different participants viewed the three age groups in different orders, and the left–right ordering of the two images in each pair was counterbalanced across participants. The three stimulus image pairs can be seen in Fig. 3; each set is shown with only one of the two possible left–right orders. The participants' task was to select which of the two faces appeared more masculine. In this way, each participant made three dichotomous responses, one for each age group.

Results

The number of people choosing the face with redder/yellower sclera (a^* and b^* increased) or greener/bluer sclera (a^* and b^* decreased) as appearing more masculine is shown in Fig. 4. For each of the three stimulus pairs, we performed a chi-square test of independence to examine the relationship between sclera color and perceived masculinity. The relationship was significant for the young faces, $\chi^2(1, N = 175) = 8.69, p = .003$, and the middle-aged faces, $\chi^2(1, N = 175) = 4.80, p = .028$. However, the relation between sclera color and perceived masculinity was not significant for older faces, $\chi^2(1, N = 175) = 0.96, p = .326$.

When presented pairs of young or middle-aged faces that differed only in terms of their sclera color, people were significantly more likely to select the face with redder and yellower sclera as appearing more masculine. There was no significant effect of sclera color on perception of masculinity in the older faces.

Study 2b

In Study 2b, we manipulated the sclera color of otherwise unaltered face images of men and women. Participants viewed these images with manipulated sclera color one at a time and rated the masculinity of the male faces and rated the femininity of the female faces.

Method

A total of 90 participants were recruited through the Gettysburg College study pool and received course credit. Two participants did not complete the study, yielding eighty-eight participants (51 female, 37 male; $M = 19.2$-years-old, $SD = 1.5$) that were included in subsequent analyses. Participants gave informed consent, and the research was approved by the Gettysburg College Institutional Review Board.

30 male and 30 female faces were selected from the FACES set, a third from each of the three age groups (young, middle-aged, older). We then used Adobe Photoshop to manipulate the sclera color of these target faces. The images were transformed to Lab color mode, and the lasso tool was used to select the four visible sclera regions (one region on either side of the iris, in both eyes). We then made two versions of each face, one with both the

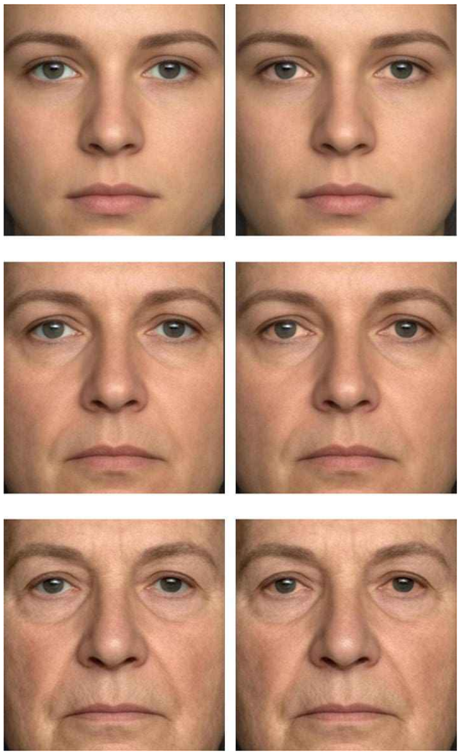

Fig. 3 Stimulus image pairs for Study 2a. The top image pair shows the young stimuli, the middle image pair shows the middle-aged stimuli, and the bottom image pair shows the older stimuli. In each image pair the left image has greener/bluer sclera, while the right image has redder/yellower sclera. Left–right ordering of the sclera manipulation was counterbalanced across subjects

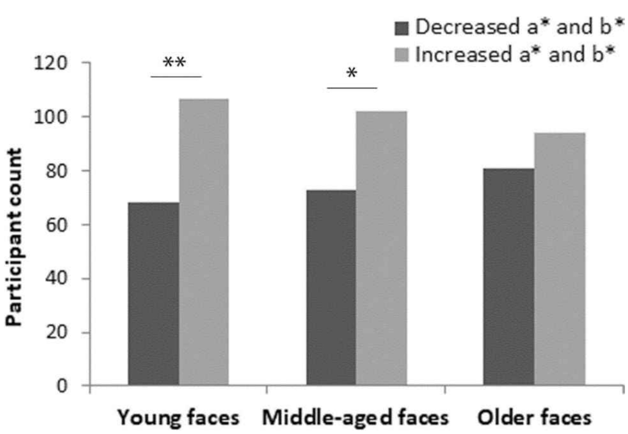

Fig. 4 Count of participants selecting faces with bluer-greener or redder-yellower sclera as appearing more masculine (* indicates $p < .05$; ** indicates $p < .01$)

a^* and b^* levels of the sclera increased (hence appearing more red and yellow), and another with both the a^* and b^* levels of the sclera decreased (hence appearing less red and yellow).

Participants were first shown the male faces one at a time and asked to judge their masculinity on a 7 point Likert scale and then were shown the female faces one at a time and asked to judge their feminitiy on a 7 point Likert scale. Both versions [a^* and b^* increased, a^* and b^* decreased] of each face were shown separately. Example stimuli are shown in Fig. 5.

Results

Femininity ratings of the female faces and masculinity ratings of the male faces are presented in Fig. 6. We conducted 2 × 3 within-subject analyses of variance (ANOVAs) separately on the ratings of femininity and masculinity. Sclera color [a^* and b^* increased, a^* and b^* decreased] and age group [young, middle-aged, older] were the within-subject independent variables. When Mauchly's test of sphericity was significant, we used the Greenhouse–Geisser correction.

For ratings of femininity, there was a significant interaction between sclera color and age group, $F(2, 174) = 10.54$, $p < .001$, partial $\eta^2 = .108$. There were also significant main effects of both sclera color $F(1, 87) = 19.88$, $p < .001$, partial $\eta^2 = .186$, and age group $F(1.25, 108.74) = 204.54$, $p < .001$, partial $\eta^2 = .702$. To explore the significant interaction between sclera color and age, we conducted simple effects of sclera color for each of the three age groups. There were significant effects of sclera color for both young faces, $F(1, 87) = 24.21$, $p < .001$, partial $\eta^2 = .218$, and middle-aged faces, $F(1, 87) = 16.16$, $p < .001$, partial $\eta^2 = .157$. However, for older faces there was no significant effect of sclera color, $F(1, 87) = 1.57$, $p = .214$, partial $\eta^2 = .018$.

For ratings of masculinity, there was a significant main effect of age group $F(1.19, 103.29) = 88.01$, $p < .001$, partial $\eta^2 = .503$. However, there was no significant main effect of sclera color $F(1, 87) = 1.65$, $p = .202$, partial $\eta^2 = .019$, and no significant interaction between age group and sclera color $F(2, 174) = 1.40$, $p = .250$, partial $\eta^2 = .016$.

Discussion

In Study 2a and 2b, there were significant effects of sclera color on sex-related perceptions of faces. These effects were specific to the young and middle-aged faces; there were no such effects

Fig. 5 Example stimuli. A young female is pictured with greener/bluer sclera on the left and redder/yellower sclera on the right. Stimuli were rated for femininity one image at a time

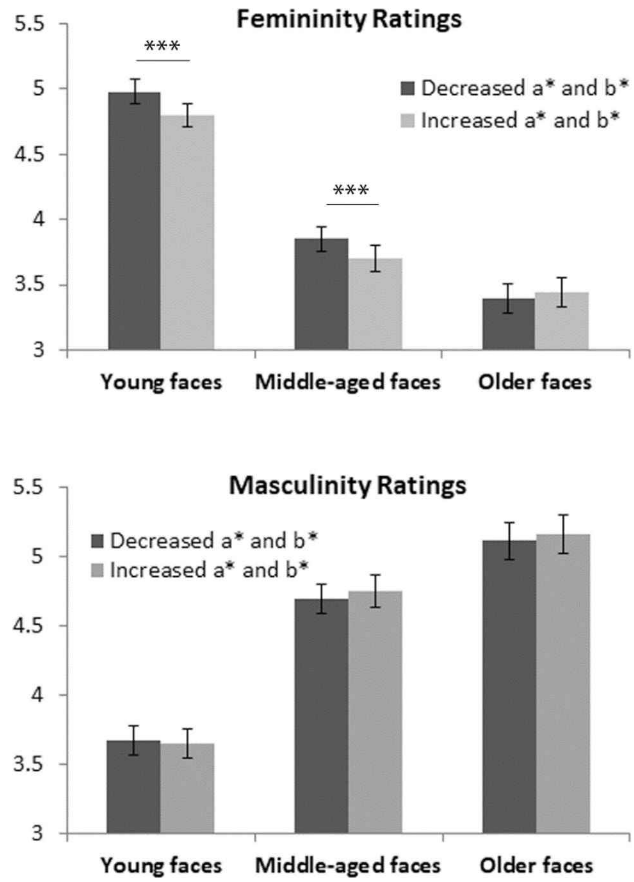

Fig. 6 Mean femininity and masculinity ratings as a function of manipulation (decreased a^* and b^*, increased a^* and b^*) and age group (young, middle, old) (*** indicates $p < .001$)

in the older faces. Specifically, in Study 2a, participants were significantly more likely to indicate that the face with redder and yellower sclera looked more masculine than the otherwise identical image with greener and bluer sclera, but only for the young and middle-aged face pairs. In Study 2b, participants rated the female faces as appearing more feminine when they had greener and bluer sclera than when they had redder and yellower sclera, but only for the young and middle-aged faces. However, participants did not rate the male faces as appearing any more or less masculine as a function of their sclera color. Overall, the results of these two experiments are consistent with the notion that people use sclera color as a cue for perceiving the sex-related traits of masculinity and femininity, at least for young and middle-aged adults.

General Discussion

We tested the hypotheses that there are physical sex differences in sclera color and that people use sclera color as a cue for perceiving the sex-related traits of femininity and masculinity from the face. We found support for both hypotheses. In Study 1, we measured sclera color from carefully controlled photographs of male and female German faces of a range of adult ages, allowing for the first time the direct comparison of male and female sclera color. Across the age span, male sclera had higher a^* and b^* values than female sclera, meaning that the male sclera appear more red and yellow than the female sclera. In all age groups, there was no sex difference in the L^*, or luminance, dimension. Thus, we found clear evidence across the adult age span for sex differences in the redness and yellowness of the sclera, but not in the luminance of the sclera.

In Study 2, participants made judgments of the apparent masculinity or femininity of face images with manipulated sclera color (increased or decreased a^* and b^* values). In Study 2a, the target stimuli were perceptually androgynous morphed averages. The sclera color of these averaged images were then manipulated to appear either more red and yellow, or less red and yellow. Viewing both versions of the target stimuli, participants indicated that the version of the face with redder and yellower sclera appeared more masculine. This effect was found with the young and middle-aged, but not with the older faces. In Study 2b, the target stimuli were images of male and female faces from a range of ages that were unmanipulated aside from making the sclera color more red and yellow or less red and yellow. These images were viewed one at a time and participants rated the female faces for femininity and the male faces for masculinity. Participants did not rate male images as any more or less masculine with increased redness and yellowness. However, participants rated the female images as less feminine with increased redness and yellowness. As in Study 2a, the effect was found only for the young and middle-aged, but not the older faces. The lack of significant sex differences with older faces across both Study 2a and Study 2b may be due to the visible area of the sclera becoming smaller with age (Berry & McArthur, 1986) and hence less useful as a perceptual cue. Overall, we found evidence that sclera color is a cue for perception of sex-related traits from faces that are young or middle-aged, but not that are older.

The findings of Study 2 also provide indirect support for the existence of a physical sex difference in sclera color, which was directly supported by Study 1. The finding that faces with yellower and redder sclera look more masculine, and less feminine is likely explained by the notion that people have learned the natural image statistics associated with male and female sclera, thereby representing males as having redder and yellower sclera than females.

Why is there a sex difference in sclera color? This question has both proximal and distal levels. Proximally, what are the physical differences in the sclera and episclera that cause a difference in appearance? Distally, why is there a physical sex difference in the sclera and episclera? Regarding the physical differences in the sclera and episclera that cause a difference in appearance, we suspect that the sex difference in redness is in some way due to differences in the vascularization of the sclera and the overlaying episclera and conjunctiva. The sex difference in apparent yellowness may be due to one of the factors related to age-related change in sclera yellowness. These age-related factors include increased lipid deposits (Fraunfelder et al., 1976; Watson & Young, 2004) and changes in the elastic fibers caused by cumulative sun exposure (Gründl et al., 2012). Also, the sclera is believed to be thicker in men and in older adults (Watson & Young, 2004), the same groups that have been found to have redder and yellower sclera. Because the sclera is not completely opaque, this variation in thickness may play a role in the sex and age variations in sclera color.

The question of why there are physical sex differences in the sclera and episclera can be explained in two ways. Either the sex difference is adaptive, or it is an accidental consequence of some other sex difference. Regarding possible adaptive reasons for the sex differences, it is possible that there is sexual selection for cues to neoteny in females or maturity in males, since sclera color varies with age. Alternately, both the cooperative eye hypothesis (Tomasello et al., 2007) and the gaze-grooming hypothesis (Kobayashi & Hashiya, 2011) propose that patterns of primate eye coloration evolved to support or inhibit gaze following. Because of sex differences in the ways that prosocial behavior is expressed (Eagly, 2009), the sex difference in sclera color might yield a sex difference in the ease of gaze following.

Alternately, the sex differences in sclera color may not be adaptive, but arise as an accidental consequence of environmental or social differences associated with sex. For example, it is known that the sclera becomes yellower as a result of alcohol consumption (Roche & Kobos, 2004), the rates of which are higher in men than women (Wilsnack et al., 2000). Smoking is known to increase cataracts in smokers, as well as increased scleral redness, due to the irritation caused by smoke (Satyanarayana et al., 2013). Like alcohol consumption, smoking rates are higher in men than women (Bauer et al., 2007). These and other environmental toxins may also play a role in the age-related increases in sclera redness and yellowness.

Sclera color can now join the list of known sex differences in facial coloration. Overall skin color is another feature that varies by sex, with males having skin that is redder and darker than female skin (Frost, 2005; Jablonski & Chaplin, 2000). While female skin is lighter than male skin, the luminance of the eyes and lips is largely similar between the sexes. This results in the luminance contrast between the facial skin and the facial features—termed 'facial contrast'—being larger in female faces (Jones et al., 2015; Russell, 2009). A sex difference in contrast around the eyebrows is in the opposite direction—male eyebrows are darker than female eyebrows, resulting in greater luminance contrast around male eyebrows than female eyebrows (Jones et al., 2015).

The current findings add further weight to previous reports that sclera color changes with age (Gründl et al., 2012; Russell et al., 2014). In addition to replicating those earlier findings with a different set of female faces, the results of Study 1 extend the findings to male faces, showing that male sclera undergo similar changes with age. It is also interesting to consider the age and sex differences together, as redder and yellower sclera are more typical of both male faces and older faces. There are also several other features that are typical of both male and older faces, or of both female and younger faces, including overall 3D face shape (Bruce & Young, 2012), facial contrast (Russell et al., 2017), and skin texture (Kloth et al., 2015). Kloth et al. (also using the FACES database) found evidence that female faces are increasingly difficult to identify as female as they grow older, while the opposite pattern was found for male faces. That finding is broadly consistent with the results of Study 2b here. As is readily apparent in Fig. 6, age has very different effects on perceived femininity and masculinity. Older female faces were rated as less feminine, while older male faces were rated as more masculine. This adds further weight to the notion that perception of age and sex are related, at least in part because the age and sex variation in the facial features underlying these judgments are correlated (Fitousi, 2021).

Because this is the first study to report data on sex differences in sclera color, our claim that there is a physical sex difference in sclera color rests entirely on the data presented here. Thus, it will be critical for future work to investigate these questions using additional samples of face images. This work investigated a single database of face images of people living in Germany. Because sun exposure could be a relevant factor, it may be particularly important to measure sclera color in more equatorial populations. Also, while our stimulus set was carefully controlled, it was not color-calibrated. To our knowledge, no published research on sclera color has used color-calibrated images. Color calibration will be an important step for future work investigating sclera color. It is also important to note that our study of physical sex differences was underpowered to detect small effect sizes. Thus, we can claim on the basis of our data that there is a sex difference in sclera redness and yellowness, but we cannot claim that there is no sex difference in sclera luminance. It is possible that there is in fact a small sex difference in sclera luminance that our study was underpowered to detect.

In conclusion, we found evidence to support the notion that sclera color differs between male and female faces. Though the sclera of both sexes had an overall whitish color, female sclera were measurably more green and blue, while male sclera were more red and yellow. This contradicts the claim by Kobayashi and Kohshima (1997) that there is no sex difference in human sclera color. We also replicated the finding that female sclera are yellower, redder, and darker in older adulthood (Russell et al., 2014), and extended this finding to male sclera, which showed the same pattern. Finally, we found evidence that people use sclera color as a cue for making judgments of the apparent masculinity and femininity of faces. Though people are typically unaware that sclera color is sexually dimorphic, they nevertheless use it as a cue for making sex-related perceptual judgments of other people.

Authors' Contributions Both authors contributed to the study conception and design. Material preparation was performed by both authors. Data collection was performed by SSK. Analysis was performed by both authors. The first draft of the article was written by SSK. Both authors revised previous versions of the article. Both authors read and approved the final article.

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Availability of Data and Materials Materials were drawn from the FACES database (Ebner et al., 2010). Data are available for peer review at this link: https://osf.io/m7zep/?view_only=094cc3ac667a45cbac9f4134f6dd3762.

Code Availability Not applicable.

Declarations

Conflict of interest Not applicable.

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