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Five-year-old children show cooperative preferences for faces with white sclera

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A B S T R A C T

The cooperative eye hypothesis posits that human eye morphology evolved to facilitate cooperation. Although it is known that young children prefer stimuli with eyes that contain white sclera, it is unknown whether white sclera influences children's perception of a partner's cooperativeness specifically. In the current studies, we used an online methodology to present 5-year-old children with moving three-dimensional face models in which facial morphology was manipulated. Children found "alien" faces with human eyes more cooperative than faces with dark sclera (Study 2) but not faces with enlarged irises (Study 1). For more human-like faces (Study 3), children found human eyes more cooperative than either enlarged irises or dark sclera and found faces with enlarged irises cuter (but not more cooperative) than eyes with dark sclera. Together, these results provide strong support for the cooperative eye hypothesis.

Introduction

Compared with other primates, human eyes have a unique morphology. Not only are human eyes elongated horizontally, but they are also characterized by a distinct lack in scleral pigmentation,

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making them particularly pale compared with the eyes of our closest primate relatives (Kobayashi & Kohshima, 1997). Importantly, although human and primate eye morphologies are more similar than scientists assumed for a long time (Caspar et al., 2021), recent research suggests that in a variety of ecologically relevant contexts (e.g., forest shading) the paleness relative to the rest of our eye morphology causes the direction of humans' gaze to be particularly discernible during social interactions (Kano, Furuichi, et al., 2022). Therefore, it has been argued that the lack of pigmentation in human eyes evolved specifically as an adaptation in an environment where cooperation was a prerequisite for survival and reproduction (i.e., the cooperative eye hypothesis; see Emery, 2000; Kobayashi & Hashiya, 2011; Kobayashi & Kohshima, 1997, 2001; Tomasello et al., 2007; Yorzinski & Miller, 2020). That is, having eyes from which gaze can easily be discerned facilitates collaborative interactions in which individuals need to coordinate their behavior as well as their mental states.

The importance of humans' capacity to track others' gaze has been demonstrated by a large body of literature examining its pivotal role in social development. Children's capacity to track gaze in joint attention interactions has been shown to be a crucial milestone in their development of cultural learning (Tomasello, 2000, 2014; Tomasello et al., 2005), communication and language (Baldwin, 1995; Eilan, 2005), social bonding (Wolf & Tomasello, 2020a, 2020b), normativity and morality (Tomasello, 2016, 2020), and cooperation (Siposova et al., 2018; Tomasello, 2009, 2014).

The wide variety of social domains in which discerning gaze plays a crucial role early in human development not only demonstrates how fundamental this process is for humans as a species but also implies a particular human sensitivity for cues and signals related to gaze direction in our species. Even newborns are already sensitive to face-relevant stimuli, including the specific light/dark polarity in the region around the eyes (Farroni et al., 2005, 2006). Furthermore, this sensitivity indeed seems particularly strong in humans compared with our closest primate relatives, the great apes, as demonstrated by a study showing that human children followed eyes rather than head direction in order to infer gaze, whereas great apes did the opposite (Tomasello et al., 2007).

If white sclera in humans indeed evolved because individuals with this trait were considered more valuable social partners, then this would imply not only a high sensitivity to eyes with white sclera but also a preference to interact with individuals who possess this trait. Previous research has shown that indeed human adults and children (but not children with autism spectrum disorder) like stuffed animals with white sclera more than stuffed animals with a different eye morphology (Segal et al., 2016). However, in the light of the cooperative eye hypothesis, one would expect this preference to be a preference for that individual specifically as a cooperative partner. Yet no research has directly tested this hypothesis empirically.

In the current research, therefore, we tested whether children would prefer to cooperate with a partner whose eyes show white sclera compared with partners who do not have visible white sclera in their eyes. To do so, we presented 5-year-old children with videos and pictures of highly controlled, computer-generated three-dimensional (3D) faces that either had white sclera or did not. For each stimulus, we then asked children three questions about their preference to cooperate with the individuals shown on these pictures/videos. In particular, we wanted to examine the degree to which the effect of white sclera on partner evaluation was specific to cooperativeness relative to other positive traits that might influence motivation to interact with a partner. Specifically, changing eye morphology might affect participants' evaluation of a stimulus face's youthfulness or "babyfacedness," which has been shown to, even in young children, attract gaze and make them appear "cuter" (Borgi et al., 2014; McCall & Kennedy, 1980). For every stimulus face in all three of our studies, therefore, we also asked children to give their cuteness preferences in addition to their cooperation preferences and examined whether their answers followed similar patterns.

In addition, we addressed several other important issues. First, previous studies on children's preferences for faces with eyes with white sclera have been done with stuffed animals (Segal et al., 2016). The upside of this approach is that potentially salient group markers and cues indicating similarity between the stimulus and the perceiver are removed from the stimulus. However, recent research has suggested that the social value of human eye morphology does not manifest isolated from the morphology of the rest of the face but rather interacts with it. For example, the degree to which white sclera is visible to others in various contexts depends on the color of the skin it contrasts with (Kobayashi & Kohshima, 2001). In the current research, therefore, we exposed children to stimuli faces with blue (alien) skin color (Studies 1 and 2) as well as to faces that had neutral human skin color (Study 3).

Second, the amount of (visible) white sclera in a face's eyes can be reduced in different ways. One can enlarge the irises, changing the properties of individual components of humans' natural eye morphology while leaving the other physical characteristics of these components relatively intact. This results in an eye morphology where the sclera is hidden when one sees the eyes from the front, but some white sclera is visible when the eyes are turned (similar to the eye morphology found in some gorillas and bonobos; see Caspar et al., 2021). One can, however, also change the pigmentation of the sclera (i.e., make the sclera darker), making the eye morphology more similar to that of chimpanzees (Caspar et al., 2021). This is a more salient deviation from a typical human face (i.e., adding a different color to the eyes), causing the face to appear less human (Seyama & Nagayama, 2007). To see whether these different degrees of deviation from a typical human face (i.e., the degree of "humanness") would influence 5-year-olds' preferences, we conducted one study in which we compared faces with normal human eyes with faces with eyes with enlarged irises (Study 1) and one study in which we compared faces with normal human eyes with faces with eyes with dark sclera (Study 2). In addition, in Study 3 we directly contrasted these two eye morphologies in faces with human skin color.

Third, to disentangle the effect of eye-specific changes in face morphology from the effect of a more general sense of perceived "humanness," Studies 1 and 2 also included an additional third stimulus face in which the eyes were identical to those of the human face but in which the ears (and forehead) were unnaturally large. Thus, this control condition also constituted a departure from a typical human morphology (i.e., the difference in ear and forehead size was salient) while leaving the sclera of the eyes intact to get a better idea of how changes in eye morphology compare with changes in other parts of a face's morphology.

Study 1

Method

Participants

For Study 1,[1] a power analysis in G*Power with an expected effect size of.25 (Segal et al., 2016) and.80 power for a repeated-measures analysis of variance (ANOVA) with a within-factors effect showed a required sample size of 28 participants. However, to fully counterbalance the order of the model gender, the order of the sets of questions, and the placement of the models on the screen, the sample needed to be divisible by $(2 \times 2 \times 6) = 24$. As such, for all three studies we aimed for the smallest sample size larger than 28 that was still divisible by 24, which is 48.

Participants were recruited via e-mail through the university's pool of birth records from the surrounding counties as well as through social media and listservs. In Study 1, which was approved by the university's institutional review board, 58 children aged 5 years (29 female; M_{age} = 5.49 years, SD =.28) participated over Zoom in the presence of a parent or guardian. We chose this age group specifically because we estimated 5-year-olds to be the youngest children to still understand the questions we would be asking them. Participants joined the Zoom call from their homes. Of the original sample, 10 children were excluded because they failed the manipulation check (n = 8), refused to participate (n = 1), or had problems with their internet connection (n = 1). Thus, our final sample consisted of 48 children (24 female; M_{age} = 5.51 years, SD =.28). Most parents (n = 31) reported to have an income above $100,000. In addition, parents indicated that their children's ethnic background was Caucasian/White (n = 33), African American/Black (n = 6), Asian or Asian American (n = 3), Hispanic (n = 3), or mixed (n = 3).

[1] Pre-registration link for Study 1: https://osf.io/f56qa/?view_only=0f08015213e34f84b7b998a11d55057c.

Materials

To assess participants' preferences, we created a boy stimulus face and a girl stimulus face with neutral facial expressions[2] using Reallusion software, specifically the Character Creator 3 and iClone applications (Reallusion, San Jose, CA, USA). All the eyes had light brown irises because previous research has shown that dark areas make gaze following more difficult (Yorzinski et al., 2021). Next, we used this baseline human face to create a second face with reduced white sclera. Specifically, in this face we enlarged the irises of the eyes while keeping both the pupil size and the size of the eyes overall constant. In addition, we also used the human baseline face to create a stimulus face with enlarged ears and a slightly widened forehead. As such, we ended up with three boy stimuli and three girl stimuli, which hereafter are referred to as *human, eyes* (i.e., manipulated eyes), and *ears* (i.e., manipulated ears). See Fig. 1 for an overview of the still stimuli and Supplementary Online Material 1 (SOM 1) for examples of the video stimuli.

Finally, we used the software to create moving images of these faces. Because it has been hypothesized that white sclera is particularly helpful when following gaze, we made the faces in the moving images look around in the environment. Importantly, however, we made sure that the stimuli never looked directly at the camera/participant to reduce potential unintended consequences of the participant making eye contact with the stimulus face (Kleinke, 1986; Siposova et al., 2018).

Procedure and design

Participants participated in a within-participants design. Prior to the study, parents read and signed a consent form and demographic questionnaire via Qualtrics. The study itself was conducted online through Zoom. All participants logged into the Zoom call through a computer (i.e., not a tablet or smartphone). At the start of the Zoom call, the experimenter confirmed that both Qualtrics surveys had been completed and asked participants whether they had any questions regarding the forms. The experimenter then shared the experimenter screen with the participants and their parents, showing the stimuli through a PowerPoint presentation. The experimenter instructed the parents to turn off self-view on their Zoom screen to prevent the participants from being distracted by their own images and to place the experimenter video centered and on top of the screen to keep it from obstructing any stimuli. The experimenter then gave a brief overview of the study and asked the parents or guardians to refrain from influencing their children's choices. The participants were told that there were no right or wrong answers to the questions in the study and to pick the options they felt like choosing.

After the introduction, the participants completed a warm-up aimed at familiarizing them with the procedure in which they needed to choose an object in response to a question they were asked. Specifically, we asked them 3 practice questions about food items: chips, broccoli, and cake. They were asked (1) "Which one would you choose to have as a snack?"; (2) "Which one is the sweetest?"; and (3) "Which one is the greenest?".

After the participants had demonstrated that they understood the response format, the experimenter introduced them to the study narrative, designed to keep the participants engaged while also providing a cover story as to why the faces in the stimuli had blue skin. During this section, the participants were invited to go on an adventure to outer space. On-screen animations showed a rocket ship leave Earth, travel through space, and land on a new planet. The experimenter then asked the participants whether they wanted to go explore the planet. Once the participants left the spaceship, they were introduced to the first three stimuli, which were either all male or all female.

To avoid overwhelming the participants, each stimulus first appeared by itself. That is, the first video stimulus appeared, looked around for about 10 s while the experimenter introduced the participants to the stimulus (i.e., Morp, Zorp, and Florp for male stimuli or Merp, Zerp, and Flerp for female stimuli). The stimulus then disappeared, after which the second stimulus appeared. This sequence of events was then repeated until all three stimuli had been individually introduced.

After the introductions, the experimenter asked the participants 6 questions. Of these, 3 questions were aimed at measuring how cooperative the participants considered the aliens: (1) "Which one

[2] During initial pilots with friendly faces, many children mentioned that they felt all three faces looked very friendly and, therefore, they liked them equally. To reduce the probability of the friendliness of a smile interfering with the effect of eye/face morphology, we decided to give the stimuli neutral facial expressions instead.

Fig. 1. Stimuli for Study 1.

would you choose to play a game with?"; (2) "Which one would you choose to build a puzzle with?"; and (3) "Which one would you ask to help you with your jacket?" In addition, 3 questions were asked to assess how cute the participants found the stimuli: (1) "Which one looks the cutest?"; (2) "Which one looks the cuddliest?"; and (3) "Which one would you choose to give a hug?" The order of these questions within each set was fixed in the order listed above. The children were asked each question twice, first about all three stimuli and then again about the two remaining stimuli, so that for each question a rank ordering was created. For each question (6 questions in total), there was a separate slide on which (nonmoving) pictures of the stimuli were shown. The placement of these pictures (i.e., left, right, or center; six possible placement combinations) was counterbalanced across the 6 questions, where the order of the placement was randomized across participants. This was aimed at reducing primacy or recency effects. The placement of the videos was always identical to the placement of the pictures in the first question the children received.

To avoid Zoom fatigue and maintain the participants' attention, there were short breaks in between each of the 6 sets of questions as well as a longer break between the boy and girl stimuli. During these breaks, the experimenter asked the participants questions to keep the conversation going without being presented to stimuli. For example, after the question related to playing a game, the experimenter asked "What's your favorite game?", and the question with regard to being helped with a jacket was set up by the experimenter saying "Brr! Did you feel that? It just got really cold on this planet. But it's hard to put on a jacket by yourself overtop of a space suit. You might need some help.".

After answering the first 6 questions, this exact procedure was repeated for the second set of stimuli (with the opposite gender). Everything in this second session (including the order of questions) was identical to the first session except for the placement of pictures. The six possible placement combinations were randomized again for the second set of stimuli. The order of the gender of the stimuli faces and the order of the 2 sets of questions were counterbalanced across participants.

At the end of the procedure, the participants completed the manipulation check, which consisted of asking them to point out the differences between the stimuli. If the participants could not indicate the differences between the stimuli, they were excluded from the study. Because the independent measure was contingent on the fact that the differences in physiology between the stimuli were noticeable, the manipulation check ensured that the participants recognized these differences.

Data coding and compiling

After each question, the participants indicated which picture they preferred most in the context of the question, usually verbally by indicating placement (e.g., left) or order (e.g., last). The experimenter would then use the cursor on the screen to confirm their choice and say "This one?" to make sure the experimenter had understood them correctly. Occasionally, the children would point to the screen and the parents would tell us which picture the children were pointing at. Here also, the experimenter then confirmed this by hovering the cursor over the picture and asking "This one?" We also recorded all the sessions so that if the experimenter missed an answer or felt that it was ambiguous, the experimenter could rewatch the session to take a closer look at the response. For each question, the first picture pointed to by the children was coded as a 1, the second as a 2, and the third as a 3. Next, for each question, we calculated the average rank order across the male and female stimuli. Finally, we compiled these average rankings for each question into two composite scores[3] containing the average rankings for cooperativeness and cuteness, respectively, with a minimum possible score of 1 and a maximum possible score of 3.

Data availability

The data for this study can be found in the corresponding Open Science Framework (OSF) database (https://osf.io/wtceh/?view_only=11c739a1f39045209ba60054c4fb8c14).

Results

To assess the difference in average rank-ordered preferences between the different face morphologies for both the cooperativeness and cuteness questions, we conducted a Bayesian generalized linear mixed model (GLMM)[4] (Gaussian, link identity, 2000 burnin, 3 chains, 100,000 iterations) in JASP (Marsman & Wagenmakers, 2017) with the participants as a random effects grouping factor,[5] each face morphology (human, ears, or eyes) per set of questions (cooperativeness and cuteness) as a fixed effect variable, and the average rank order as the dependent variable. We then looked at specific contrast of interests in order to compare the relative preference for individual morphologies per set of questions separately. For each contrast, we looked at whether the 95% Bayesian high-density interval (HDI) of the contrast estimate overlapped with zero. If this was not the case, children on average picked the stimulus with the lower score earlier (i.e., had a stronger preference for this stimulus) than the stimulus with the higher score. See Table 1 for the means and standard deviations and Fig. 2 for the distribution of the average preferences across conditions.

Our analyses showed that children did not show a cooperative preference between (1) the human face and the face with the enlarged irises (contrast estimate posterior mean =.014, 95% HDI = −.155,.177), (2) the human face and the face with the enlarged ears (contrast estimate posterior mean = −.149, 95% HDI = −.312,.019), and (3) the face with the enlarged irises and the face with the enlarged ears (contrast estimate posterior mean = −.161, 95% HDI = −.330,.003). This suggests that the children in this study did not show a cooperative preference for any of the three faces.

[3] For the Cronbach's alpha of the cooperativeness and cuteness scales for all three studies, see Supplementary Online Material 4 (SOM 4).

[4] For Study 1, we had initially preregistered a Bayesian within-participants ANOVA. However, post-registration discussions with our colleagues about the research design made us realize that a Bayesian GLMM was a more appropriate model for the average rank order type data in the current study. The results of the study did not meaningfully change by using Bayesian GLMMs. We also addressed this issue for Study 2 by preregistering Bayesian GLMMs as our intended analysis.

[5] The number of observations was too small to estimate individual differences in participant responses.

Table 1
Means and standard deviations for each type of stimulus per set of questions for Study 1.

	Cooperation			Cuteness		
	White sclera	Enlarged iris	Enlarged ears	White sclera	Enlarged iris	Enlarged ears
Mean	1.94	1.96	2.10	1.92	1.86	2.21
SD	0.405	0.471	0.444	0.415	0.409	0.367
Min	1	1	1	1	1	1.333
Max	2.67	3	3	2.67	3	3

Note. A lower value means that this stimulus was picked first more often. This means that children had a stronger preference for this stimulus and thus considered it more cooperative/cute. The minimum possible score was 1, and the maximum possible score was 3.

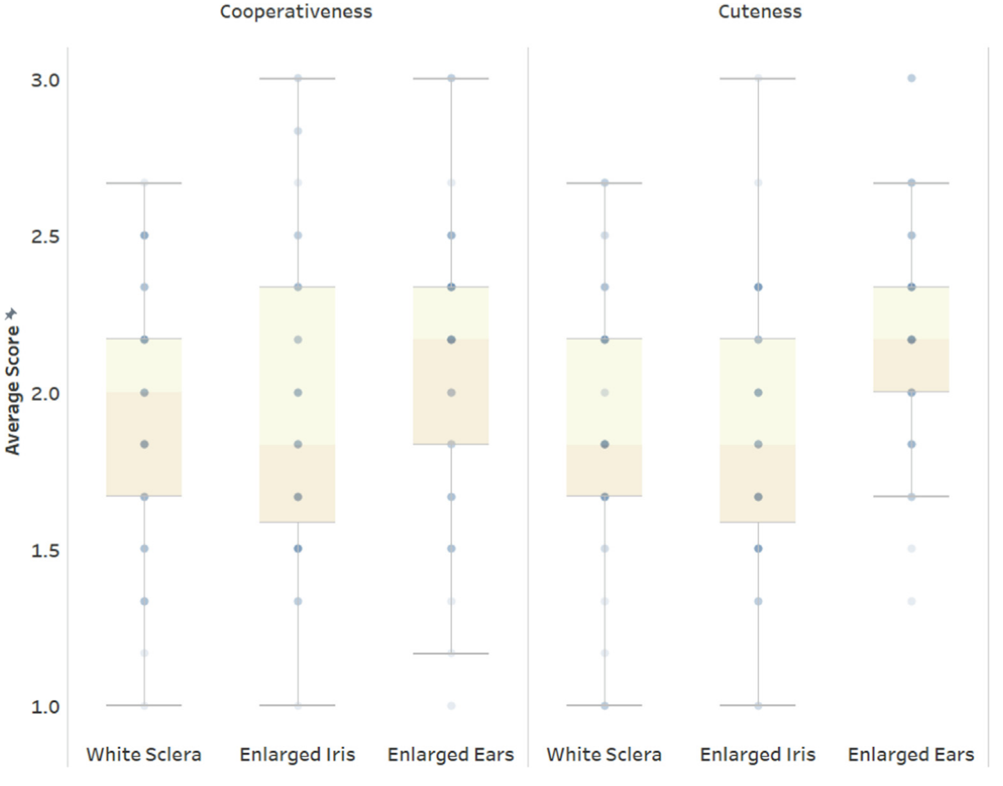

Fig. 2. Distributions of average cooperativeness and cuteness preferences across stimuli in Study 1. A lower value means that this stimulus was picked first more often. This means that children had a stronger preference for this stimulus and thus considered it more cooperative/cute. The minimum possible score was 1, and the maximum possible score was 3.

With regard to children's preferences in terms of cuteness, we also did not find a difference between the human face and the face with the enlarged irises (contrast estimate posterior mean = −.046, 95% HDI = −.217,.119). However, in this case we did find differences between the human face and the face with enlarged ears (contrast estimate posterior mean = −.330, 95% HDI = −.500, −.164) and between the face with the enlarged eyes and the face with the enlarged ears (contrast estimate posterior mean = −.284, 95% HDI = −.453, −.121). In other words, although children did not show a preference between the human face and the face with enlarged eyes, they did seem to prefer both those faces over the face with the enlarged ears when it came to cuteness.

Study 2

Method

Participants

Like in Study 1, we aimed to test 48 children after exclusions for Study 2,[6] which was also approved by the institutional review board of the university. In total, we tested 62 5-year-old children (M_{age} = 5.46 years, *SD* =.28) through Zoom in the presence of a parent or guardian. Recruitment was conducted the same way as in Study 1. We made sure that children who had participated in Study 1 did not participate in Study 2 because the study procedures and stimuli for Study 2 were so similar to those for Study 1. In total, 14 children were excluded for not passing the manipulation check (n = 13) or due to connection problems and experimenter error (n = 1).

Thus, our final sample consisted of 48 children (27 female; M_{age} = 5.50 years, *SD* =.29). Most parents (n = 34) reported to have an income above $100,000. In addition, parents indicated that their children's ethnic background was Caucasian/White (n = 37), Asian or Asian American (n = 3), Hispanic (n = 1), or mixed (n = 6), with 1 participant not indicating the ethnic background of the child.

Materials

The materials of Study 2 were identical to those of Study 1 in all respects but one. In the stimulus faces where we manipulated the eyes, instead of giving the faces large irises to hide the sclera, we gave the faces eyes with human proportions but with dark sclera (i.e., increased sclera pigmentation) instead of white sclera. The other two stimuli for each gender were unchanged. These stimuli were made with the same software and manner as in Study 1. See Fig. 3 for an overview of the still stimuli and SOM 2 for examples of the video stimuli.

Procedure

The procedure for Study 2 was identical to that of Study 1.

Data availability

The data for this study can be found in the corresponding OSF database (https://osf.io/wtceh/?view_only=11c739a1f39045209ba60054c4fb8c14).

Results

To assess the average preference of children for the different stimuli, we analyzed the mean rank orders of each type of stimulus face per set of questions (i.e., cooperativeness and cuteness) using the exact same statistical model as in Study 1. See Table 2 for the means and standard deviations and Fig. 4 for the distribution of the average preferences across conditions.

Our analyses on the cooperation question set showed that, in contrast to Study 1, children in Study 2 did prefer the human face (i.e., with white sclera) over the face with dark sclera instead of enlarged irises (contrast estimate posterior mean = −.232, 95% HDI = −.422, −.044). They also preferred the face with white sclera over the face with the enlarged ears (contrast estimate posterior mean = −.246, 95% HDI = −.432, −.056). In addition, children showed no difference in cooperative preference between the face with dark sclera and the face with the enlarged ears (contrast estimate posterior mean = −.014, 95% HDI = −.200,.179).

We found similar results with regard to the question set about the faces' cuteness; children preferred the human face with white sclera over the face with dark sclera (contrast estimate posterior mean = −.232, 95% HDI = −.424, −.044) and over the face with the enlarged ears (contrast estimate posterior mean = −.392, 95% HDI = −.581, −.204). For this question set, we also did not find a difference in preference between the face with dark sclera and the face with the enlarged ears (contrast estimate posterior mean = −.159, 95% HDI = −.349,.028).

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[6] Pre-registration link for Study 2: https://osf.io/a8tdq/?view_only=fc05eaf578f8411f815781b36bbd1ae6.

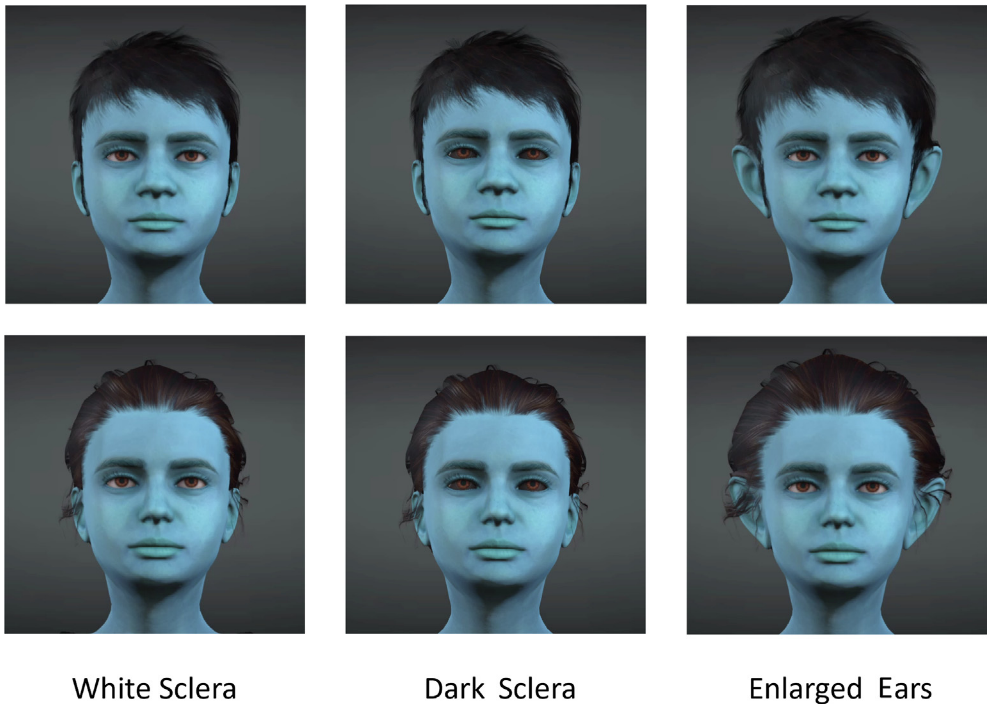

Fig. 3. Stimuli for Study 2.

Table 2
Means and standard deviations for each type of stimulus per set of questions for Study 2.

	Cooperation			Cuteness		
	White sclera	Dark sclera	Enlarged ears	White sclera	Dark sclera	Enlarged ears
Mean	1.840	2.184	2.087	1.792	2.024	2.184
SD	0.417	0.452	0.508	0.415	0.384	0.545
Min	1	1	1	1	1	1
Max	2.667	3	3	2.667	3	3

Note. A lower value means that this stimulus was picked first more often. This means that children had a stronger preference for this stimulus and thus considered it more cooperative/cute. The minimum possible score was 1, and the maximum possible score was 3.

Study 3

Method

Participants

As in Studies 1 and 2, we aimed to test 48 children after exclusions for Study 3,[7] which was also approved by the institutional review board of the university. In total, we tested 52 5-year-old children (M_{age} = 5.50 years, *SD* =.31) through Zoom in the presence of a parent or guardian. Recruitment was

[7] Pre-registration link for Study 3: https://osf.io/q82na/?view_only=d6bc3b1e62de421eb23abb776f05c098.

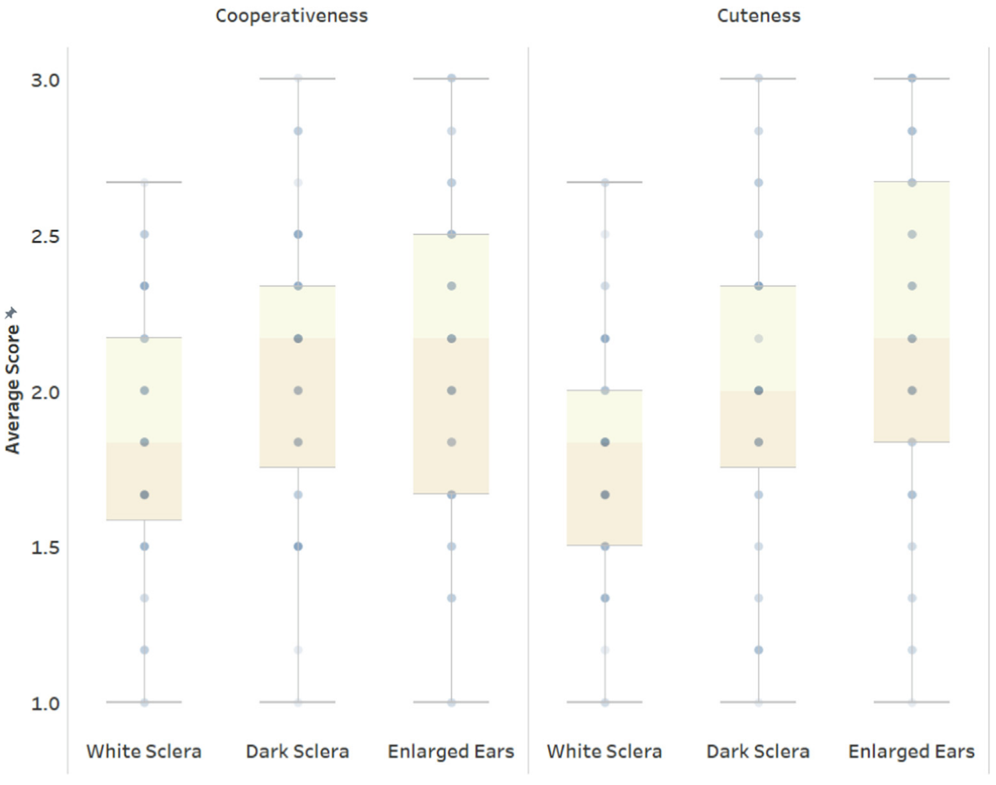

Fig. 4. Distributions of average cooperativeness and cuteness preferences across stimuli in Study 2. A lower value means that this stimulus was picked first more often. This means that children had a stronger preference for this stimulus and thus considered it more cooperative/cute. The minimum possible score was 1, and the maximum possible score was 3.

conducted the same way as in Study 1. We made sure that children who had participated in Studies 1 and 2 did not participate in Study 3 because the study procedures and stimuli for Study 3 were so similar to those for Studies 1 and 2. In total, 4 children were excluded for not passing the manipulation check (n = 3) or because the child was not willing to cooperate (n = 1).

Thus, our final sample consisted of 48 children (20 female; M_{age} = 5.50 years, SD =.31). Most parents (n = 33) reported to have an income above $100,000. In addition, parents indicated that their children's ethnic background was Caucasian/White (n = 42), Asian or Asian American (n = 3), African American (n = 1), or mixed (n = 2).

Materials

The materials of Study 3 were identical to those of Studies 1 and 2 in all respects but two. First, the skin color of the stimuli was changed to reflect neutral human skin instead of blue alien skin. Second, we removed the large ear stimuli and instead presented children with a face with human eyes, a face with eyes with enlarged irises (similar to Study 1), and a face with eyes with dark sclera (similar to Study 2). These stimuli were made with the same software and in the same manner as in Studies 1 and 2. See Fig. 5 for an overview of the still stimuli and SOM 3 for examples of the video stimuli.

Procedure

The procedure for Study 3 was identical to that for Studies 1 and 2.

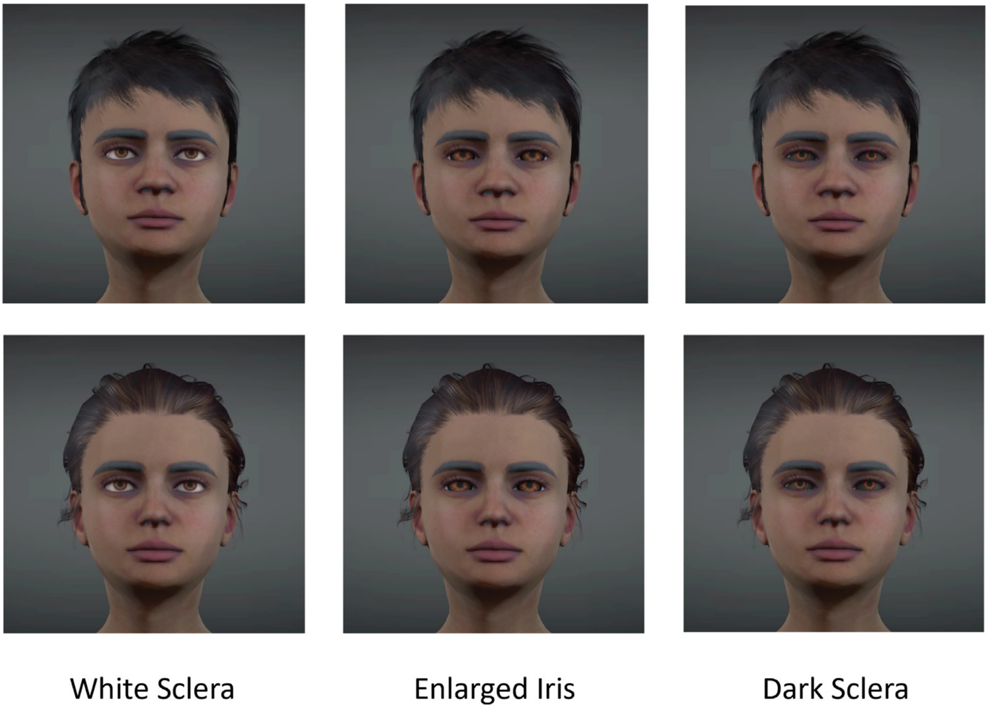

Fig. 5. Stimuli for Study 3.

Data availability

The data for this study can be found in the corresponding OSF database (https://osf.io/wtceh/?view_only=11c739a1f39045209ba60054c4fb8c14).

Results

To assess the average preference of children for the different stimuli, we analyzed the mean rank orders of each type of stimulus face per set of questions (i.e., cooperativeness and cuteness) using the exact same statistical model as in Studies 1 and 2. See Table 3 for the means and standard deviations and Fig. 6 for the distribution of the average preferences across conditions.

Our analyses on the cooperation question set showed that for faces with neutral human skin color, children showed a cooperative preference for the face with white sclera over the face with eyes with

Table 3

Means and standard deviations for each type of stimulus per set of questions for Study 3.

	Cooperation			Cuteness		
	White sclera	Enlarged iris	Dark sclera	White sclera	Enlarged iris	Dark sclera
Mean	1.69	2.11	2.20	1.64	2.09	2.26
SD	0.46	0.30	0.45	0.48	0.31	0.40
Min	1	1.667	1.333	1	1.333	1.333
Max	2.667	2.667	3	2.833	2.833	3

Note. A lower value means that this stimulus was picked first more often. This means that children had a stronger preference for this stimulus and thus considered it more cooperative/cute. The minimum possible score was 1, and the maximum possible score was 3.

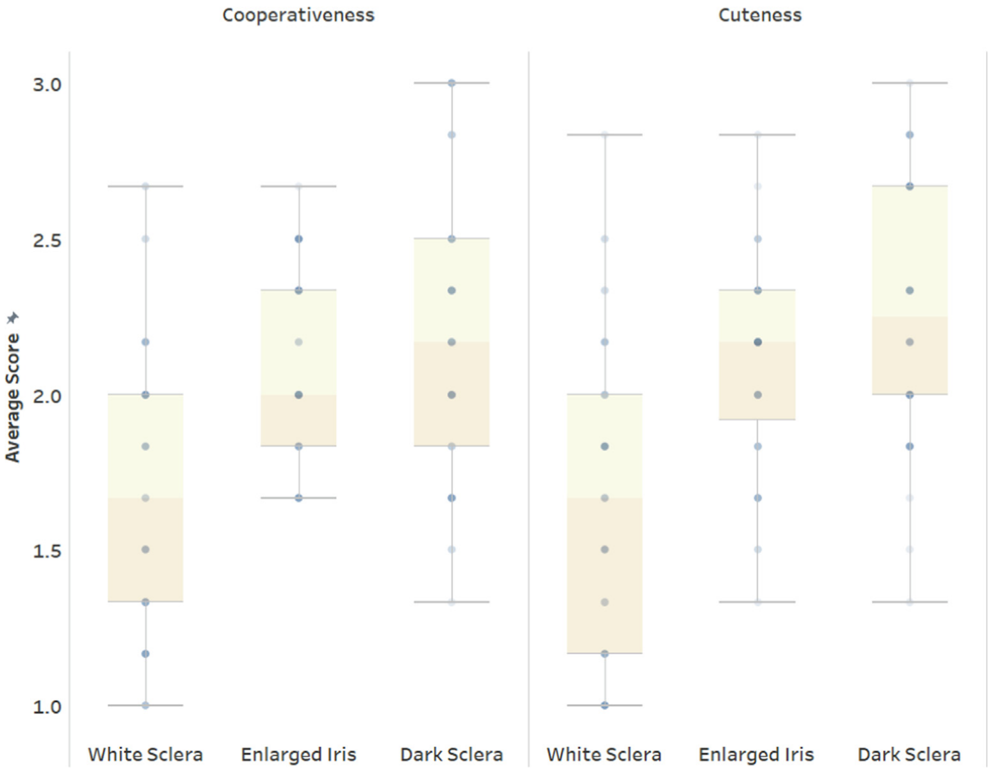

Fig. 6. Distributions of average cooperativeness and cuteness preferences across stimuli in Study 3. A lower value means that this stimulus was picked first more often. This means that children had a stronger preference for this stimulus and thus considered it more cooperative/cute. The minimum possible score was 1, and the maximum possible score was 3.

enlarged irises (contrast estimate posterior mean = −.43, 95% HDI = −.59, −.26) as well as the face with eyes with dark sclera (contrast estimate posterior mean = −.51, 95% HDI = −.68, −.35). In addition, children showed no difference in cooperative preference between the face with enlarged irises and the face with dark sclera (contrast estimate posterior mean = −.24, 95% HDI = −.24,.09).

For cuteness, we found that children had a similar preference for faces with white sclera and faces with enlarged irises (contrast estimate posterior mean = −.45, 95% HDI = −.61, −.28) and faces with eyes with dark sclera (contrast estimate posterior mean = −.62, 95% HDI = −.78, −.45). However, in contrast to children's cooperative preferences, with regard to cuteness children preferred the face with eyes with enlarged irises over the face with eyes with dark sclera (contrast estimate posterior mean = −.17, 95% HDI = −.33, −.01).

General discussion

These three studies together demonstrate children's social sensitivity to eyes with white sclera. More specifically, the results of Study 3 show that in faces with a human skin tone, children perceive human eyes with white sclera as more cooperative than faces with enlarged irises and/or dark sclera. This suggests that even at a young age, not only are children sensitive to faces with white sclera but also the whiteness of the sclera actually shapes the degree to which young children deem others desirable cooperative partners. As such, these results provide support for the cooperative eye hypothesis.

In addition, the results from all three studies together suggest that although perceptions of cuteness follow a similar pattern to children's cooperative preferences, they are not identical. In Study

3, eyes with enlarged irises were perceived as cuter, but not more cooperative, than faces with white sclera. In addition, in Study 1 we found that faces with white sclera were perceived as cuter, but not more cooperative, than faces with enlarged ears. Although it is difficult to draw strong conclusions about the nature of these differences between perceptions of cooperativeness and cuteness, it does suggest that eye morphology influences children's perceptions of cooperativeness in unique ways.

Finally, the results from our current studies also raise an important methodological point. Although children showed a cooperative preference for white sclera over dark sclera regardless of the skin color of the face presented to them, the skin tone of the stimulus face did seem to matter when examining the difference between faces with eyes with white sclera and faces with eyes with enlarged irises. For the alien stimuli with blue skin color, children did not seem to differentiate between faces with white sclera and enlarged irises (Study 1). However, they did do so for faces with human skin tone (Study 3). One of the reasons why children might have preferred faces with white sclera over faces with dark sclera in a wider variety of face morphologies is that dark sclera elicits a negative attitude in a perceiver for reasons other than making it more difficult to track gaze. Research has shown that having paler sclera causes one to be perceived as younger and more attractive, as well as healthier, in humans and great apes (Gründl et al., 2012; Perea-García et al., 2019; Russell et al., 2014), given that decreased paleness in an individual's sclera can be a symptom of a variety of ophthalmological conditions (e.g., Richards & Guzman-Cottrill, 2010; Sen et al., 2011). This is, however, not the case for faces with enlarged irises, which in combination with the blue skin might have just come across as "cartoonish" to the children.

Regardless of the explanation, the crucial methodological point here is that children (and potentially humans in general) judge the eyes of stimuli differently depending on whether the rest of the face has a human morphology or not. As such, caution is warranted when interpreting data about individuals' judgments of stimuli's eye morphology independently from whether the faces' overall morphology is human or not (e.g., Studies 1 and 2 in the current work; Segal et al., 2016). As Study 3 demonstrates, results most likely depend on whether participants feel the face as a whole (and not just the eyes) resembles a human morphology.

In this regard, it is also difficult to interpret the data from the enlarged ear conditions of Studies 1 and 2. Although these conditions might give some insight into how general perceptions of humanness might influence children's judgments of cooperativeness and cuteness, it is difficult to draw specific conclusions from them because the effects of enlarged ears on perceptions of cooperativeness and cuteness might in fact be specific to that particular change in morphology rather than a general decrease in humanness. In itself, the question of whether manipulating various aspects of morphology (e.g., eyes, ears, nose, teeth) would show a similarly gradual change in attributions of cooperativeness and cuteness, and thus perhaps point to a more general social evaluative mechanism based on overall humanness, seems like a potentially valuable question to be addressed by future research. However, drawing strong conclusions about the meaning of children's responses to the enlarged ear stimuli (without manipulating further non-eye facial features) seems to go beyond the scope of the current research of testing the cooperative eye hypothesis specifically.

In the current research, we specifically aimed to test the effect of ecologically valid eye morphology on perceptions of cooperativeness in children, modeling the stimulus eyes after that of our closest living relatives, the great apes (Caspar et al., 2021). This does mean, however, that it becomes more difficult to assess the effects of specific morphologic dimensions of the eye on children's perceptions of cooperativeness and cuteness. Specifically, when comparing the enlarged iris and dark sclera stimuli, two morphological dimensions were manipulated simultaneously: the amount of visible white sclera and the color of the sclera. Although a direct assessment of the effect of these morphological dimensions was beyond the scope of the current research, future research should be aimed at assessing whether these morphological dimensions independently influence the degree to which children (and adults) perceive faces as more cooperative.

It is worth mentioning that the use of a neutral human skin tone in Study 3 might have evoked certain social ingroup or outgroup biases based on the degree to which the neutral skin tone reflected that of the participants (Quinn et al., 2019). Research has shown that already at 9 months of age, infants associate faces with different skin color with negatively valanced stimuli (Xiao et al., 2018). This might have affected how our mostly White sample judged the stimuli in Study 3.

One important limitation to note in the context of the current research is that the participants in this sample came from a predominantly WEIRD (Western, educated, industrialized, rich, and democratic) population (Henrich et al., 2010; Nielsen et al., 2017), meaning that many of them most likely have access to a variety of animated and computerized TV shows. This might be amplified by the fact that many families in our current sample were families who had relatively high socioeconomic status, with many of them indicating an income of more than $100,000 a year. Children in our sample, therefore, might have had relatively high exposure to variability in facial morphology (e.g., cartoon characters). As such, they might have been more familiar to, and thus potentially less affected by, the types of stimuli we used in the current study compared with children from certain non-WEIRD populations.

In addition, one potential alternative pathway through which our current results might be explained is that children judged faces with white sclera as more attractive and, therefore, as more cooperative. It is well known that white sclera positively influences perceptions of physical attractiveness in adults (Gründl et al., 2012; Provine et al., 2013). In addition, people often evaluate physically attractive others as more positive in general (Lorenzo et al., 2010) as well as more cooperative specifically (Mulford et al., 1998). There is, however, also evidence that for 5-year-old children conceptualizing and verbalizing physical attractiveness is not yet that straightforward, showing that only at 6 years of age children start to be able to rate the physical attractiveness of others in a reliable and consistent manner, at least verbally (Cavior & Lombardi, 1973). As such, it seems unlikely that incorporating (measurements of) attractiveness as a factor in the current research would have significantly (and/or reliably) changed the interpretation of the current results.

Overall, these results demonstrate that humans' social sensitivity to the lack of scleral pigmentation in our eyes seems to occur already early in ontogeny, suggesting that the visibility of the eyes of our fellow humans bears particular social value to our species. This corroborates the cooperative eye hypothesis, in which the central idea is that this adaptation has made it easier for us to cooperate (Emery, 2000; Kobayashi & Hashiya, 2011; Kobayashi & Kohshima, 1997, 2001; Segal et al., 2016; Tomasello et al., 2007; Yorzinski et al., 2021). Thus, although there is some recent debate about how uniquely discernible primate eyes are compared with human eyes, with some arguing that the eyes of other primates, such as chimpanzees, are in fact sufficiently conspicuous up to 10 m to engage in species-specific social activities (Bethell et al., 2007; Caspar et al., 2021; Kano, Furuichi, et al., 2022; Mayhew & Gómez, 2015; Mearing & Koops, 2021; Perea-García et al., 2019; Whitham et al., 2022a, 2022b), both humans and chimpanzees discriminate eye gaze better when eyes have uniformly white sclera (Kano, Kawaguchi, et al., 2022). This suggests that human eyes with white sclera seem relatively more effective at communicating gaze than the eyes of our closest primate relatives.

One possibility is that human white sclera not only might help us to establish a joint focus on something in the world relevant to our collaboration (as other primates seem capable of doing as well) but also might facilitate engaging in the communicative eye contact, which is a particularly difficult gaze pattern to infer (Vida & Maurer, 2012) yet plays a crucial role in human social life. Already early in their development, children use communicative eye contact to infer ostension and reference, thereby playing a crucial part in pedagogy and social learning (Csibra & Gergely, 2006, 2009). In addition, 5- and 7-year-old children already interpret communicative eye contact as a signal of commitment to cooperate (Siposova et al., 2018). Communicative eye contact also seems to hold special value in social bonding for young children (Wolf & Tomasello, 2020a), amplifying the effectiveness of bonding with others by simply going through a similar experience together (Haj-Mohamadi et al., 2018; Rennung & Göritz, 2015; Wolf et al., 2016; Wolf & Tomasello, 2019, 2020b). Future research, therefore, should look into whether the human eye morphology is particularly effective at establishing communicative eye contact relative to other types of (phylogenetically similar) eye morphologies.

Overall, our current results with regard to children's cooperative preferences for human faces with eyes with white sclera over eyes with enlarged irises and eyes with dark sclera show that even early in ontogeny children perceive white sclera to have unique cooperative value. As such, the current work provides further evidence for the special role of human eye morphology in our species' social evolution.

Data availability

Link with the OSF data repository is provided in the manuscript

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Author contributions

W.W., J.T., and M.T. developed the study together. J.T. collected the data under the supervision of W.W. and M.T. W.W. analyzed the data. J.T. wrote the Method sections under the supervision of W. W. and M.T. W.W. wrote the rest of the manuscript in collaboration with J.T. and M.T.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jecp.2022.105532.

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