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Development of Visual Preference for Own- Versus Other-Race Faces in Infancy

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Previous research has shown that 3-month-olds prefer own- over other-race faces. The current study used eye-tracking methodology to examine how this visual preference develops with age beyond 3 months and how infants differentially scan between own- and other-race faces when presented simultaneously. We showed own- versus other-race face pairs to 3-, 6-, and 9-month-old Chinese infants. In contrast with 3-month-olds' visual preference for own-race faces, 9-month-olds preferentially looked more at other-race faces. Analyses of eye-tracking data revealed that Chinese infants processed own- and other-race faces differentially. These findings shed important light on the role of visual experience in the development of visual preference and its relation to perceptual narrowing.

Keywords: face processing, other-race effect, development, infancy, culture

A fundamental question in visual perception is how faces are perceived and processed. Faces are a unique class of visual stimuli that populate our visual environment and contain rich sources of information regarding, for instance, age, gender, and race. Given the importance of faces in our lives, the investigation of the origins of face expertise has been a central focus of developmental scientists for the last 2 decades.

Infant and child visual experiences with different types of faces are not equivalent. During infancy, for example, infants typically see more human faces than nonhuman faces (e.g., Pascalis, de Haan, & Nelson, 2002), more female than male human faces (e.g., Quinn, Yahr, Kuhn, Slater, & Pascalis, 2002), and more own-race faces than other-race faces (e.g., Kelly et al., 2005). Such asymmetries in visual experience have profound impacts on the development of face processing expertise. Greater experience with one particular face type is found to be related to more advanced face processing abilities, whereas a lack of exposure to other types of faces relates to poorer face processing abilities (see Lee, Anzures, Quinn, Pascalis, & Slater, 2011, for a review).

A prime example of an asymmetrical experience that leads to differential processing is the processing of own- and other-race faces. It is well established that faces from other racial backgrounds that an individual has little experience with are processed differently from own-race faces. This tendency is known as the other-race effect (ORE) in the literature on adults' face processing (for a review and discussion, see Hugenberg, Young, Bernstein, & Sacco, 2010; Meissner & Brigham, 2001). Adults recognize own-race faces better than other-race faces, but categorize the former less efficiently than the latter (e.g., Ge et al., 2009). The difference

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in own- versus other-race face processing has also been demonstrated in early infancy (e.g., Anzures, Quinn, Pascalis, Slater, & Lee, 2010; Ferguson, Kulkofsky, Cashon, & Casasola, 2009; Hayden, Bhatt, Zieber, & Kangas, 2009; Kelly et al., 2005; Kelly, Liu et al., 2007; Kelly, Quinn, et al., 2007; Liu et al., 2011; Quinn, Anzures, et al., 2013; Sangrigoli & de Schonen, 2004; Wheeler et al., 2011; Xiao et al., 2013, 2014; for a review, see Anzures et al., 2013). Three-month-olds were shown to be able to recognize and discriminate between both other-race faces and own-race faces (Kelly, Quinn, et al., 2007; Kelly et al., 2009; Sangrigoli & de Schonen, 2004). However, by 9 months of age, infants could not discriminate and recognize faces of other races, whereas their ability to discriminate and recognize own-race faces was maintained. These findings suggest that the development of the ORE follows a trajectory called perceptual narrowing, reflecting a face processing transition from broad discrimination abilities at an early age to more focal discrimination abilities at older ages of infancy (Nelson, 2001; Scott, Pascalis, & Nelson, 2007; Slater et al., 2010). The face-processing system of infants seems to be tuned by increased experience with own-race faces and lack of experience with other-race faces so as to optimally process the most frequently encountered own-race faces.

Data on young infants' preference for own- versus other-race faces lend support to the claim that visual experience affects face processing in the first few months of life. Kelly et al. (2005) were among the first to study infants' visual preference for own- as opposed to other-race faces with the use of a standard visual preference task. In their study, White newborns and 3-month-old infants were presented with White-African, White-Asian, and White-Pakistani face pairings. Findings revealed that White 3-month-old infants preferred to look at White faces as opposed to faces from other racial groups. White newborns, however, did not display a preference for own-race White faces. These findings suggest that own- and other-race face representations are absent at birth, and three months of exposure to own-race faces are sufficient for infants to develop a visual bias toward own-race faces. Follow-up studies have extended this significant finding to 3-month-old infants from different racial backgrounds (Bar-Haim, Ziv, Lamy, & Hodes, 2006; Kelly, Liu et al., 2007). Using the same preferential looking paradigm, Bar-Haim et al. (2006) found that 3-month-old Ethiopian infants exposed mainly to African faces preferred to look at African faces more than White faces, whereas Ethiopian infants born in Israel who had similar experience with both African and White faces did not display any preference. In addition, when viewing the same face stimuli used in Kelly et al. (2005), Chinese 3-month-old infants showed a preference for Asian faces compared to White and African faces (Kelly, Liu et al., 2007). These results have consistently indicated that the stimuli are not the basis for performance, but rather it is the interaction between the participant population and stimulus category that is driving performance differences between same- and other-race faces.

In contrast to research on infants' own- versus other-race face recognition that spans the entire first year of life, evidence for the own-race *preference* has been limited to 3-month-olds. It is entirely unknown whether infants beyond 3 months of age will continue to show a preference for own-race faces relative to other-race faces. Moreover, it has yet to be decided whether experientially based tuning affects infants' development of visual preferences for own- versus other-race faces in the same manner as it does for perceptual narrowing in face recognition. Theoretically, the investigation of visual preferences for own- versus other-race faces in 3-, 6-, and 9-month-olds allows a comparison with the developmental course of face recognition, and thereby provides insight into the relationship between visual preference and perceptual narrowing in face recognition. According to the perceptual narrowing account, accumulated experience with own-race faces presumably leads to reduced discrimination abilities within other-race faces. That is, different other-race faces are not differentiated at the individual level as are own-race faces. Regarding the development of visual preference, one possibility is that older infants would continue to display a preference for own-race faces over other-race faces, because more visual attention is needed to process the identity information of own-race faces. On the other hand, it is possible that visual preference follows a different developmental trajectory as perceptual narrowing in face recognition. That is, the greater degree of experience that older infants have with own-race faces might result in more efficient processing of own-race faces, and hence drive their interest toward the unfamiliar other-race faces for which they have poorer processing efficiency. If this is the case, with increased age, older infants may show a spontaneous novelty preference for other-race faces compared to own-race faces. The present study, therefore, sought to test these two opposing hypotheses by examining 3- to 9-month-old infants' visual preferences for own-race versus other-race faces using the standard visual preference task.

The recent eye-tracking methodology provides a more fine-grained understanding of where and how infants look during face processing. To examine infants' scanning patterns of own- and other-race faces, Liu et al. (2011) presented videos showing a single moving White or Chinese face stimulus to 4- to 9-month-old Chinese infants. They reported that infants' fixation time on the nose of the Chinese faces did not change with age, but their time spent fixating on the nose of the White faces decreased with age. Wheeler et al. (2011) used the same paradigm to study how 6- to 10-month-old White infants scan own- and other-race faces. They found that, with age, White infants spent more time fixating on the eyes and less time fixating the mouth of own-race faces; however, fixation time on the internal features of other-race faces did not change with age. Gaither, Pauker, and Johnson (2012) were the first to investigate the issue of how infants' scanning patterns related to their face discrimination abilities. They habituated 3-month-olds with different individual faces from either own- or other-race categories and then tested infants' preference for a novel face from the same race category presented during habituation. The degree of novelty preference in own-race face discrimination was found to be positively correlated with the visual transitions between the top (eye region) and bottom (mouth region) halves of own-race faces during habituation. However, no such correlation was found for other-race face discrimination. Xiao et al. (2013) analyzed 6- to 9-month-olds' scan paths among the internal features of own- versus other-race faces. Their results revealed that infants shifted their fixation more frequently between the eyes of own-race faces than between the eyes of other-race faces. It may be that infants are focusing on different second-order relations when processing own- versus other-race faces.

The evidence from these studies taken together suggests that when viewing own- or other-race faces individually (i.e., one by one), infants attend to different features of own- and other-race faces differentially. With the influence of experience, infants as early as 3 months of age already have acquired specific visual skills to process the faces they are mostly exposed to, which may in turn shape their discrimination abilities and develop into visual advantages for recognizing own-race faces. What has not yet been explored is how infants' attention to specific features of faces differs between own- and other-race faces during the visual preference task when own- and other-race faces are presented side by side. The eye-tracking data collected from the visual preference paradigm would enhance our understanding of the underlying mechanism driving the development of visual preference. The particular question we asked here was whether more attention directed to one type of face over another occurs correspondingly with one specific scanning strategy as opposed to another strategy for the other type of face.

The aims of the current study were twofold: (a) to examine how infants' visual preference for own- versus other-race faces develops with age, and (b) to explore infants' visual scanning patterns for own- and other-race faces when both faces are displayed side by side, and more specifically inquire about what features infants differentially fixate and how fixations shift between faces and between features. To meet these goals, we recruited 3-, 6-, and 9-month-old Chinese infants who lived in a city consisting of nearly 100% Chinese individuals and who were exposed only to Chinese own-race faces. The participants completed an eye-tracking study comprising a standard visual preference paradigm with pairs of Asian-White and Asian-African faces. We chose to study Chinese infants in particular to validate a cross-cultural model of visual preference development with a group of non-Western participants. Since only one race of participants was tested, it was possible that the visual preference responses of Chinese infants reflected the inherent contrast of the paired faces, but not the real ORE. Knowing this limitation, we used the same set of face stimuli that had been used in previous visual preference studies (Kelly et al., 2005; Kelly, Liu et al., 2007) because the earlier findings suggested 3-month-olds consistently preferred own-race over other-race faces regardless of the race of the participants when viewing the same set of stimuli. We also included a salience analysis of the stimuli to understand better the contrast in salient features for different face categories and its relation to visual attention.

To determine infant scanning patterns for own- and other-race faces, we used a multimethod approach to analyze the eye-tracking data. First, we used the area-of-interest (AOI) approach to examine the fixation distribution for different facial features of own- versus other-race faces. Second, we computed raw fixation maps using the iMap Matlab toolbox (Caldara & Miellet, 2011) in order to provide a more detailed picture of infants' differential scanning patterns for own- and other-race faces. Unlike AOI analyses, iMap does not require the a priori segmentation of the face images into AOIs. With iMap, fixation data are first smoothed to generate three-dimensional fixation maps, and an appropriate statistical approach is applied to assess significant fixation spots and differences across the fixation maps for different types of faces. Therefore, this procedure is capable of revealing statistically significant differences between areas that would otherwise go unnoticed by the AOI technique.

Third, we used a ScanPath analysis to examine visual transitions between the two paired faces and between the internal features of each face. This analysis provides information about how frequently infants shift attention between two faces as opposed to shifts within either face. Based on existing findings that infants from young ages are sensitive to the second-order relations within a face (e.g., Bhatt, Bertin, Hayden, & Reed, 2005; Cohen & Cashon, 2001; Ferguson et al., 2009; Leo & Simion, 2009; Quinn & Tanaka, 2009), they might be less inclined to use a feature-to-feature scanning strategy than a strategy that scans the internal features of one face first and then those of the other. However, with improved face processing skills in general, they might shift their attention between the two faces more frequently with increased age. Furthermore, we obtained specific scan paths between key features within each face, for example, the scan paths between the eyes, between the eyes and mouth, and between the eyes and nose. Specifically, the frequency of these scan paths were compared when viewing own- versus other-race faces. Such analysis should be informative in identifying the development of scan paths essential for successfully perceiving configural cues.

Method

Participants

The participants were 100 healthy, full-term infants (58 boys) from 3 to 9 months of age ($M = 177.53$ days, $SD = 73.06$, range: 89–295 days). Fifty-one infants were tested in the African-Asian face pairing condition ($M = 176.43$ days, $SD = 73.76$, range: 89–295 days). Forty-nine infants were tested in the White-Asian face pairing condition ($M = 178.67$ days, $SD = 73.06$, range: 92–295 days). All participants were of native Chinese origin and were recruited from a community hospital in Southeastern China. Infants were brought to the hospital for routine wellness check-ups. All parents indicated that the infants had no regular exposure to either White or African faces. An additional 26 infants were excluded due to failure to complete the calibration procedure, incomplete data capture, experimenter distraction, or parental interference.

Materials

Stimuli were comprised of six images of male and female adult faces (age range = 25–29) from three distinct racial groups (Asian, White, and African). Faces of the same gender were paired as White-Asian and African-Asian. An example stimulus pairing is shown in Figure 1. The face images were presented as colored photographs in the tests. All faces were cropped to remove the neck and background details from the original image and then mounted on a uniform gray background. All stimuli were resized identically to ensure uniformity. Faces from all racial groups were rated on a scale of 1 to 10 for attractiveness and distinctiveness by 8 independent Chinese observers (4 male, 4 female). The faces in each pair were then matched on the two dimensions. Since only Chinese infants were tested in the current study, we used the same faces that had been used in previous race preference studies (Kelly et al., 2005; Kelly, Liu et al., 2007) to make our results comparable to the earlier data and to help rule out the possible effect of

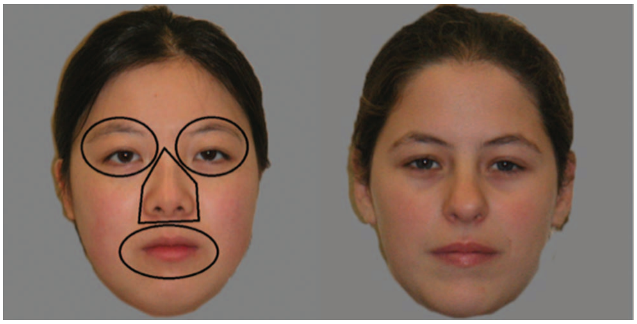

Figure 1. Example of stimulus presentation and area of interest plots. The authors received signed consent for the individuals' likenesses to be published in this article. See the online article for the color version of this figure.

low-level stimulus characteristics in any differential responding that is observed.

Procedure

First, the purpose of the study was explained to parents. Parents then gave written consent for their child to participate. Infants were secured in a car seat that was placed in a three-quarter semireclining position before a Tobii 1750 eye tracker (data sampling rate was 50 Hz). The resolution of the screen was 1024 × 768 pixels. The eye-tracking screen was positioned at an angle parallel to the incline of the infant, with a viewing distance of 60 cm. A female Chinese experimenter sat behind the infant to adjust the position of the car seat during the calibration procedure. If an infant was inattentive for more than 3 s during the experimental session, the experimenter sitting behind would redirect the infant's gaze onto the screen. The data points when infants were distracted by the presence of the experimenter were excluded from analyses.

Infants were first shown a cartoon character to attract their attention to the screen display before calibration began. Infants then saw another cartoon character sequentially pop up at five locations across the screen: the four corners and the center. If insufficient data were collected during the initial calibration, then the same calibration procedure was repeated until successful, or for up to four failed attempts.

Each infant was then randomly assigned to either one of the two race pairs (White vs. Asian or African vs. Asian). For each pairing, the gender of the two faces was matched. Each infant saw two face pairings, one male and one female, with the presentation order counterbalanced for gender and left versus right positioning of images across trials. When displayed on the screen, each face image was measured 18 cm × 18 cm (14° visual angle) and the distance between the two paired images was 9 cm. Each pair of images was presented until infants had looked at the stimuli for a cumulative 10 s or infants spent a cumulative 10 s looking away from the screen. Therefore, the total presentation time varied between both infants and face pairings. This procedure was exactly the same as in Kelly et al. (2005).

Data Analysis

Three analytic approaches were used to examine the data. First, the traditional AOI approach was used to explore the differential scanning patterns of own- versus other-race faces. Six AOIs were designated: whole face, left eye (the right eye of the photographed face, as observed by the viewer), right eye, nose, mouth, and the rest of the face area without these face features (see Figure 1 for examples; throughout the paper, left and right positions refer to the left and right side of the viewed face from the viewer's perspective). The AOIs were drawn individually for each face. A fixation was defined as a continuous period of looking at an AOI with a minimum radius of 30 pixels for at least 100 ms. All fixations during a presentation period, which lasted until the infant's attention was diverted away from the screen, were counted. Due to the fact that the length of presentation periods varied across infants, proportional fixation durations were computed by dividing total fixation time on each featural AOI by total fixation time on the whole face AOI (excluding fixations on areas beyond the oval overlaid on the face).

Second, a data-driven approach was conducted using iMap Matlab toolbox (Caldara & Miellet, 2011) in order to generate the fixation distribution maps for the paired own- and other-race faces in separate age groups. The iMap Matlab toolbox computed statistical maps of fixations by summing fixation location coordinates (x, y) across time and smoothing the resulting fixation distribution with a Gaussian kernel. Then, fixation maps for all participants belonging to the same age group were pooled together and separated by face race. Next, group fixation maps were Z scored. Finally, a statistical random field theory approach was applied to assess both significant fixation spots and any differences between the 3D fixation maps for each condition.

Third, a ScanPath analysis procedure was used to count the number of times participants shifted their gaze from one face to the other. These paths denoted shifts in visual attention from the own-race face to the other-race face and vice versa. The length of the fixation period prior to each visual shift between faces was measured in order to examine whether infants shifted their attention from one face to the other after fixating for an extended or short period. The frequencies of fixation transition between the internal features were also calculated and compared across face races.

Results

Preliminary analyses revealed no significant gender difference for face stimuli or participants. There was neither an order of presentation effect nor a right versus left position effect. Therefore, data were collapsed across genders, presentation orders, and positions for all subsequent analyses.

Proportional Fixation Duration for Own- and Other-Race Faces

To determine if there was an overall preference to attend to one face type over the other, we computed the proportional fixation durations on each face (with hair excluded) relative to the sum of looking time on both faces in the three age groups and in the White-Asian and African-Asian paring conditions (see Table 1). A 2 (Face Race: own vs. other) × 2 (Face Pairing: White-Asian vs. African-Asian) × 3 (Age: 3 months, 6 months, or 9 months) repeated-measures ANOVA was performed with face race (own vs. other) as a within-subject variable, face pairing and participant age as between-subjects variables, and proportional on-face fixation duration as the dependent variable. Only the interaction between face race and age was found to be significant, $F(2, 94) = 3.58$, $p = .032$, $\eta^2 = .07$. Neither the main effect for face pairing nor the three-way interaction among face race, face pairing, and age was significant. Hence, data for White-Asian and African-Asian face pairing conditions were collapsed. A planned contrast was conducted to compare the proportion of fixation time on the own- and other-race faces for each age group. Results (as displayed in Figure 2) showed that 3-month-olds looked marginally more at own-race faces than other-race faces (own: 55.39% vs. other: 44.61%), $t(35) = 1.79$, $p = .082$,[1] 6-month-olds spent similar amounts of time on own- and other-race faces (own: 51.56% vs. other: 48.49%), $t(36) = 0.72$, $p = .475$, while 9-month-olds looked significantly more at other-race faces versus own-race faces (own: 45.74% vs. other: 54.22%), $t(26) = 2.63$, $p = .014$.

We also analyzed first fixations at which faces infants looked, but no effect for own- versus other-race faces was found.

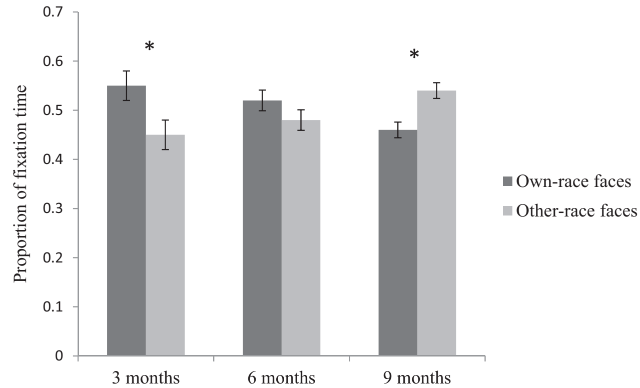

Figure 2. Proportion of fixation time on own- and other-race faces as a function of age group (standard error bars are shown, * $p < .05$, one-tailed, and ** $p < .05$, two-tailed).

Proportional Fixation Duration of Individual AOIs

To further examine how infants' visual attention to specific features varied across face race and age group, we used an AOI analysis. Four major featural AOIs were defined: the right eye (from the viewer's perspective), left eye, nose, and mouth. Preliminary analyses showed no significant effects for face pairing conditions. Therefore, the data in these two conditions were combined in the following analyses. However, there were differences in the looking times on the right versus left eyes. Therefore, we reported the separate results for the right and left eyes. The amount of time spent fixating each AOI relative to the total amount of time spent fixating each face was calculated to obtain proportional fixation times. A 2 (Race: own vs. other) × 4 (Feature: left eye, right eye, nose, mouth) × 3 (Age: 3, 6, 9 months) repeated-measures ANOVA was performed using the proportion of fixation time as the dependent variable. The three-way interaction was significant with a correction for nonsphericity applied, $F(4.77, 231.18) = 2.88$, $p = .017$, $\eta^2 = .06$. The two-way interaction between feature and race was also significant, $F(2.38, 231.18) = 4.15$, $p = .012$, $\eta^2 = .04$, indicating the distributions of attention to different facial features were different between own- and other-race faces. There was additionally a significant main effect for feature, $F(2.33, 226.40) = 33.88$, $p < .001$, $\eta^2 = .26$. In general, infants attended to the mouth area significantly less than the other three AOIs. The main effect for age was significant, $F(2, 97) = 6.84$, $p = .002$, $\eta^2 = .12$. Infants increased their looking time on faces significantly from 3 to 6 months and there was no difference in overall looking time between 6- and 9-month-olds.

To explore the significant 3-way interaction, follow-up analyses were performed by conducting a 2 (Face Race: own vs. other) × 3 (Age: 3 months, 6 months, or 9 months) repeated-measures ANOVA with the proportional fixation time for each AOI as the dependent variable. Table 2 shows the descriptive results for the proportional fixation time for each major AOI for both the own- and other-race faces. There was a significant main effect of face type for proportional fixation time on the left eye (from the viewer's perspective), $F(1, 97) = 8.33$, $p = .005$, $\eta^2 = .08$. The interaction between face type and age group was also significant, $F(2, 97) = 4.36$, $p = .015$, $\eta^2 = .08$. Planned contrasts revealed that 3-month-olds attended more to the left eye of own-race faces (from the viewer's perspective) relative to that of other-race faces, $t(35) = 3.27$, $p = .002$, whereas 6- and 9-month-old infants spent similar amounts of time scanning the left eye of own- and other-race faces.

No significant results were found for the proportion of fixation time on the right eye. The results of proportional fixation time on the nose revealed a significant main effect for age, $F(2, 97) = 5.83$, $p = .004$, $\eta^2 = .11$. Post hoc analysis showed that 3-month-olds spent significantly less time fixating on the nose of own- and other-race faces ($M = .13$) than 6- and 9-month-olds ($M = .20$ and $M = .23$). A significant main effect was found for proportional fixation time spent on the mouth with both age, $F(2, 97) = 5.28$, $p = .007$, $\eta^2 = .10$, and with face type, $F(1, 97) = 12.62$, $p = .001$, $\eta^2 = .12$. Post hoc analyses showed that 6- and 9-month-olds looked longer at the mouth than 3-month-olds regardless of face race and infants in general fixated more on the mouth of other-race faces than on the mouth of own-race faces regardless of age. Although the effect size was small, the significant findings were replicated in the following iMap analysis.

Table 1
Means (and SDs) of Proportion of Fixation Time for Own- and Other-Race Faces in White-Asian and African-Asian Conditions

	White-Asian		African-Asian	
	Other	Own	Other	Own
3 Months	.43 (.20)	.57 (.20)	.46 (.17)	.54 (.17)
6 Months	.47 (.12)	.53 (.12)	.50 (.14)	.50 (.14)
9 Months	.53 (.09)	.47 (.09)	.56 (.08)	.44 (.08)

Note. Proportional fixation time on whole face was calculated by the fixation duration on each face stimulus (with hair excluded) divided by the overall looking time on both faces (with hair excluded).

[1] It should be noted that had a one-tailed criterion been used, which is justifiable given that three prior reports from two different labs have reported same-race preference in infants at 3 months of age (Bar-Haim et al., 2006; Kelly et al., 2005; Kelly, Liu et al., 2007), the effect would be significant ($p = .041$).

Table 2
Mean (and SD) Proportion of Fixation Time on Each AOI for Own- and Other-Race Faces

	Own-race faces			Other-race faces		
	3 Month	6 Month	9 Month	3 Month	6 Month	9 Month
Left eye	.25 (.19)	.17 (.15)	.19 (.15)	.13 (.18)	.17 (.14)	.16 (.15)
Right eye	.15 (.13)	.18 (.15)	.22 (.17)	.20 (.19)	.18 (.17)	.17 (.15)
Nose	.14 (.12)	.20 (.15)	.20 (.14)	.12 (.13)	.20 (.15)	.25 (.14)
Mouth	.00 (.13)	.03 (.06)	.02 (.05)	.01 (.04)	.06 (.10)	.06 (.10)
Other part of face	.47 (.18)	.42 (.16)	.37 (.18)	.53 (.25)	.39 (.16)	.36 (.15)

Note. AOI = area of interest. Proportional fixation time on each feature was calculated by the fixation duration located on the specific feature divided by the looking time for that particular face.

Raw Fixation Distribution and Difference Maps

The iMap toolbox (Caldara & Miellet, 2011) was used to generate statistical fixation maps of eye movements, which can directly reveal where infants looked when own- and other-race faces were presented side by side. These fixation distribution maps are shown in Figure 3. Areas that infants spent significantly greater time fixating at an above-chance level are marked by white borders ($p < .001$, corrected). Differences between the two types of faces are calculated by subtracting the fixation map for other-race faces from that of own-race faces. Areas found to be significantly different are marked by white borders ($p < .001$, corrected). As seen from the figure, 3-month-old infants fixated on own- and other-race faces differentially. Specifically, they fixated significantly more on the left eye region of own-race faces (from the viewer's perspective) and more on the nose bridge (between the eyes) of other-race faces. By 6 months, infants attended more on the right eye region of own-race faces and more on the nose bridge and left eye of other-race faces. Further, the iMap of the 3-month-old fixations on the own-race faces was similar to that of the 6-month-old fixations on the other-race faces, suggesting a delay in fixation distribution for other-race faces relative to own-race faces. The fixation patterns of 9-month-olds were similar to those of 6-month-olds, more on the right eye of own-race faces (from the viewer's perspective), but more on the nose bridge and left eye of

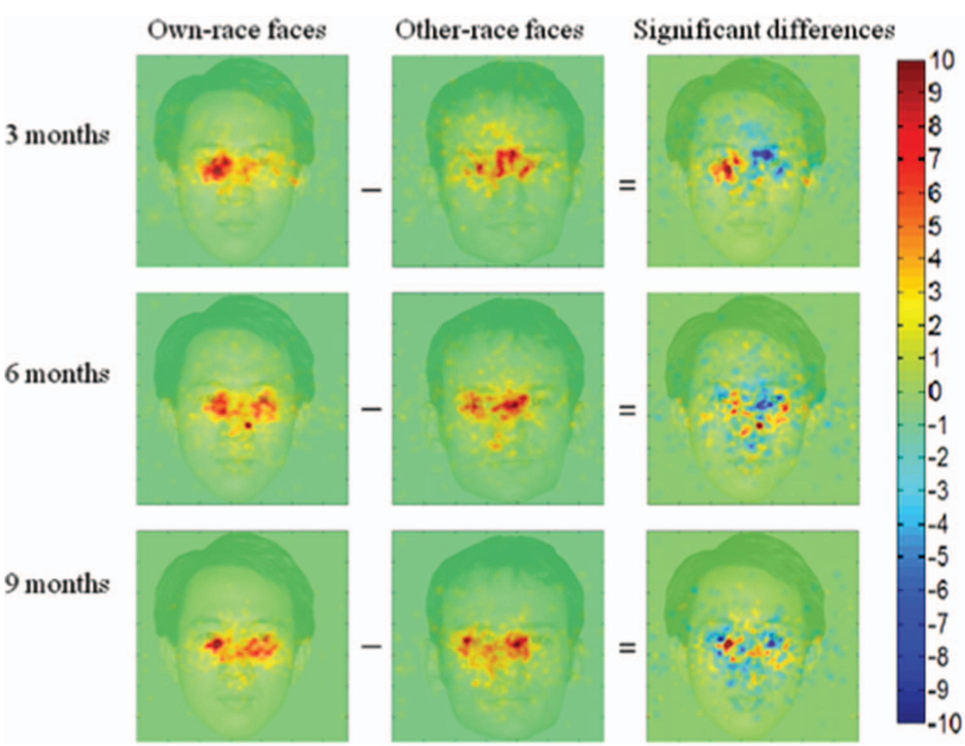

Figure 3. Mean heat maps for own-race faces and other-race faces and the difference map at each age group. The colors represent *Z* scores of the fixation duration, with warm colors denoting longer fixation duration and cold colors denoting shorter fixation duration. The white contours in the difference maps indicate the regions of significant difference ($p = .001$, two-tailed, corrected). The authors received signed consent for the individuals' likenesses to be published in this article. See the online article for the color version of this figure.

other-race faces (from the viewer's perspective). It is also noteworthy that when scanning the eyes of own-race faces, the infants actually focused on the lower edge of the eyes. Overall, the results revealed that infants scanned own- and other-race faces differentially even when the two types of faces were presented together and the differential patterns changed from 3 to 6 months of age.

Scan Paths Between and Within Faces

Another aim of the present study was to explore how infant visual attention shifted between own- and other-race faces. Frequencies of fixation paths were assessed. A fixation path was defined as a fixation on one of the faces followed by a shift in attention resulting in either a fixation on the other face or a different fixation within the same face. To categorize these fixation paths, we used two variables: starting face (from own- or other-race face) and shift type (within the same face or between the two faces). Hence four types of fixation shifts were identified: own-other between-faces, other-own between faces, own-own within-faces, and other-other within-faces. Then, the proportional frequency for each type of fixation path relative to the overall frequency of fixation changes was assessed. A 2 (Start: own-race face vs. other-race face) $\times$ 2 (Shift: within-faces vs. between-faces) $\times$ 3 (Age: 3 months, 6 months, or 9 months) repeated-measures ANOVA was performed with the proportional frequency of fixation paths as the dependent variable. No significant main effect was found for starting face, nor did it interact with other variables, so all data were collapsed regardless of which face the fixation path started from.

A 2 (Shift: within-faces vs. between-faces) $\times$ 3 (Age: 3 months, 6 months, or 9 months) repeated-measures ANOVA was performed for the proportional frequencies. A significant main effect for shift type was found, $F(1, 97) = 737.55$, $p < .001$, $\eta^2 = .88$. Infants scanned different features within the same face significantly more than they shifted between the two faces. There was also a significant interaction between age and shift type, $F(2, 97) = 33.54$, $p < .001$, $\eta^2 = .41$. A planned contrast analysis revealed that with increased age, infants became less likely to maintain their attention within one particular face, but instead shifted their attention more frequently between the faces from the two races (see Figure 4).

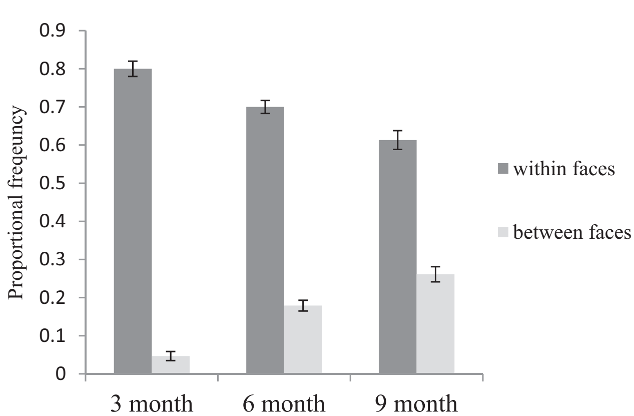

Figure 4. Proportional frequency of fixation shifts within faces and between faces as a function of age group (standard error bars are shown).

Scan Paths Between AOIs Within a Face

To analyze how infants differentially shifted their attention between AOIs when scanning own- or other-race faces, several fixation paths were identified (paths between eyes, left-eye–nose, left-eye–mouth, right-eye–nose, right-eye–mouth, nose–mouth). Mean frequencies for each type of path are shown in Table 3 and Figure 5. Because frequency distributions for these fixation paths were not normalized, we used a Poisson regression model to analyze frequency data. Face race was used as the predictor and the frequency of each defined fixation path was the dependent variable. Age was entered as a covariate. The results showed that above and beyond the age factor, infants scanned between the eyes more frequently for own-race faces than for other-race faces, odds ratio (OR) = 3.02, $p < .001$. Thus, infants were 3.02 times more likely to scan between the eyes of own-race faces than those of other-race faces.

As shown in Figure 5, infants scanned between the right eye (from the viewer's point of view) and nose, and between the right eye and mouth significantly more frequently for own-race faces than for other-race faces, $OR = 2.59$, $p < .001$, and $OR = 2.60$, $p = .042$. Infants were 2.60 times more likely to scan between the right eye and the mouth or nose of own-race faces than for other-race faces. However, there were significantly more fixation shifts between the nose and mouth of other-race faces than for own-race faces, $OR = 1.85$, $p = .020$. Infants were 1.85 times more likely to scan between the nose and mouth of other-race faces than for own-race faces. There was no significant difference in scanning frequency between own- and other-race faces for fixation paths between the left eye and nose or fixation paths between the left eye and mouth.

Stimulus Salience Analysis

One possible reason that infants scanned own- and other-race faces differently is that faces of different races might vary in perceptual salience. To test this hypothesis, we used the Saliency Toolbox developed by Walther and Koch (2006) to compare the saliency results for own- and other-race face photos. The toolbox calculates saliency based on a psychologically plausible neural network model assuming that more salient areas of the photo can draw more attention and lead to better recognition. As shown in Figure 6, the saliency result for each Asian face was spatially averaged to derive a mean saliency map for all own-race faces; the same procedure was used for each White and African face to derive a mean saliency map for all other-race faces. Then, the own- and other-race face salient regions were contrasted using the "gene mattest" procedure, an equivalent of independent t tests in Matlab 2010a.

Regarding the face photos, the saliency analyses showed that the own- and other-race faces were highly similar and both salient in the right and left corners of the face contour. Using Type I error FDR correction, there were no significant differences in saliency between the own- and other-race images, especially for the eyes, nose, and mouth regions. The results suggest that the face stimuli were inherently similar in terms of the saliency of their perceptual features. Infants' differential scan patterns of own- versus other-race faces cannot thus be explained by difference in perceptual salience of the face images.

Table 3
Mean Frequencies of Fixation Paths Between AOIs of Own- and Other-Race Faces

	Own race	Other race	*OR* [95% CI]	*p*
Between eyes	1.24	0.41	3.02 [2.17, 4.22]	<.001
Right-eye–nose	1.40	0.54	2.59 [1.89, 3.56]	<.001
Right-eye–mouth	0.13	0.05	2.60 [1.04, 6.52]	.042
Left-eye–nose	1.12	0.91	1.23 [0.83, 1.83]	.305
Left-eye–mouth	0.08	0.15	0.53 [0.23, 1.24]	.145
Nose–mouth	0.33	0.61	0.54 [0.32, 0.91]	.020

Note. AOI = area of interest; *OR* = odds ratio; CI = confidence interval.

Discussion

The present study investigated development of (a) visual preference for own- versus other-race faces and (b) visual scanning of paired own- and other-race faces. Our data showed that 3-month-old Chinese infants displayed a spontaneous preference to look at faces from their own race group when these faces were paired with two types of other-race faces, African and White. Furthermore, extending the previous findings in the literature that were limited to newborns and 3-month-olds, we found that the preference for own-race faces was not present at 6 months of age, and 9-month-old infants showed a preference for other-race faces. The early preference for own-race faces is consistent with previous findings from Kelly et al. (2005; Kelly, Liu et al., 2007) and Bar-Haim et al. (2006). As Kelly et al. (2005) reported, the own-race face preference is not present at birth, but is observed by 3 months of age, and marks the emergence of differential responding to own- versus other-race faces. This finding led the researchers to speculate that human perception of race-based face differences is acquired with visual exposure to faces encountered during early development. The data reported in the current study not only further validate previous findings with younger infants, but also reveal, strikingly, the decline and eventual reversal of own-race visual preference in older infants.

To our knowledge, our data are the first to document a developmental profile of visual preference for own- and other-race faces. With increased age, infants shift from familiarity preference (for own-race faces) to novelty preference (for other-race faces). Previous studies with nonface objects showed that infants have a tendency to shift their preference from a familiar to a novel stimulus with increasing exposure to the familiar stimulus (e.g., Houston-Price & Nakai, 2004). The developmental trend observed in the current study may thus possibly reflect exposure to own-race faces, with less exposure at an early age leading to familiarity preference and more exposure at an older age leading to novelty preference. The similar pattern of results obtained with faces in the current study and nonface objects in prior studies is consistent with the broader suggestion that at least some aspects of infant responding to faces may not be “special” when compared with infant responding to nonface objects (Quinn, Tanaka, Lee, Pascalis, & Slater, 2013).

The null preference observed in 6-month-olds suggests a developmental transition. It is additionally in line with other evidence that infants at the same age do not differ in looking time to their mother’s face versus a stranger’s face (de Haan & Nelson, 1999), even though the neural responses of the infants revealed differential processing for the two faces. It appears that even though the infants recognized the mother’s face, they did not look longer at her face than at the stranger’s face. As discussed by de Haan and Nelson (1999), a looking preference at this age might not provide a direct index of infants’ discrimination ability or recognition memory, and in the present case this may perhaps be due to the transitional nature of preference that is applied to stimuli in general (inclusive of nonface objects) at this particular age (Cohen, 2004; Hunter & Ames, 1988; Roder, Bushnell, & Sasseville, 2000; Rose, Gottfried, Melloy-Carminar, & Bridger, 1982; Shinskey & Munakata, 2010; Wetherford & Cohen, 1973).

Our findings raise interesting questions about the processes underlying visual preference and its developmental relations with the ORE. Although the visual preference for own-race faces in 3-month-olds is obviously not a demonstration of the ORE, the possibility that the two phenomena (own-race face preference and superior own-race face recognition) are interrelated cannot be dismissed. Quinn et al. (2002) reported that the same population of infants who showed a visual preference for female faces also demonstrated a recognition deficit for male faces, but not female faces, as measured by a visual paired comparison task involving familiarization with a category of male or female faces. Therefore,

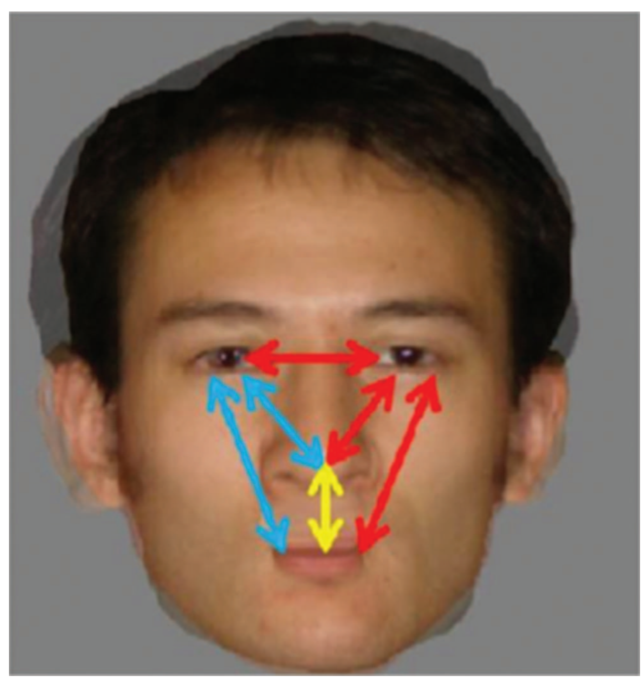

Figure 5. Mean fixation path maps for the difference between own- and other-race faces. The six lines in each map represent the paths between eyes, left eye (from the viewer’s perspective) and nose, right eye and nose, left eye and mouth, right eye and mouth, and nose and mouth, respectively. Lines in red indicate significantly more fixation path counts for own-race faces versus other-race faces ($p < .05$). The line in yellow indicates significantly more fixation path counts for other-race faces than own-race faces ($p < .05$). Lines in blue indicate that fixation path counts in other-race faces were not significantly different from those in own-race faces. The authors received signed consent for the individuals’ likenesses to be published in this article. See the online article for the color version of this figure.

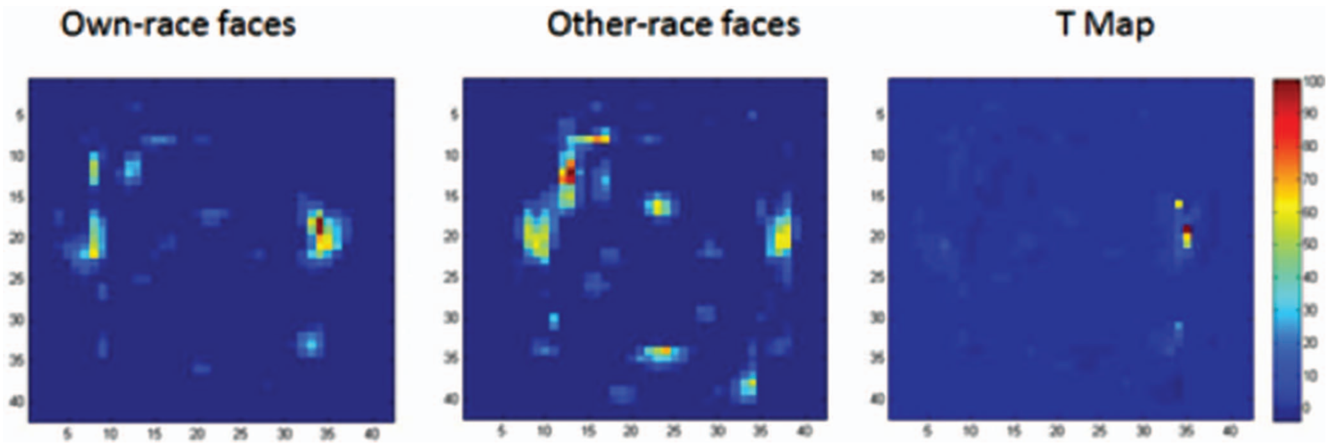

Figure 6. Mean saliency maps for the own- and other-race faces (White and African faces) and the significant difference *t* maps (own-race face saliency—other-race face saliency). See the online article for the color version of this figure.

it is conceivable that early own-race preference and the ORE may be related to each other in an as yet unidentified way. However, older infants' visual preferences for other-race faces should not be taken as evidence for an other-race face processing bias, given the finding that 9-month-olds have difficulty in recognizing other-race faces (Kelly, Liu et al., 2009; Kelly, Quinn, et al., 2007). Two possibilities may underlie these developmental changes: perceptual learning at younger ages and perceptual narrowing at older ages in infancy. Developing perceptual expertise for own-race faces may require younger infants to spend more time looking at own-race faces and learning their finer stimulus features. The shift from familiarity to novelty preference could be due to the fact that with experience, infants gradually become proficient at processing the familiar own-race faces such that they can afford to allocate more cognitive resources to process the less familiar other-race faces. In other words, other-race face preference in 9-month-olds may be associated with perceptual narrowing. This speculation can be tested with specifically designed future studies that assess infant visual preference for own- and other-race faces and their recognition of own- and other-race faces.

The current eye-tracking data not only provide insights into infant distribution of attention between own- and other-race faces, but also shed light on how infants scan own- versus other-race faces. First, there were no differences found between African and White other-race faces. It seems that, in the visual preference paradigm, infants treated both of them as the other-race category and processed them in a similar way that contrasted with own-race Chinese faces. Second, using AOI and iMap analyses, we explored the development of looking time on different facial features of own- and other-race faces. Our AOI and iMap results revealed that with increased age, infants increasingly attended to the nose of both own- and other-race faces. This finding partly contrasts with the findings of Liu et al. (2011) who presented videos showing a single moving White or Chinese face stimulus to 4- to 9-month-old Chinese infants. Liu et al. reported that infants' fixation time on the nose of Chinese faces did not change with age, but their time spent fixating on the nose of White faces decreased with age. The reason for the discrepancy in looking time on other-race noses is unclear due to the fact that the two studies used different types of stimuli (static faces in the present study vs. talking and moving faces in Liu et al.) and different stimulus presentation paradigms (paired in the present study vs. sequential presentation in Liu et al.). Future studies need to systematically manipulate stimulus type and presentation paradigm to better gauge this age-related change in fixation on the nose.

Earlier adult studies (e.g., Blais, Jack, Scheepers, Fiset, & Caldara, 2008; Fu, Hu, Wang, Quinn, & Lee, 2012) revealed that Asian adults fixated on the nose of own- and other-race faces more than White adults. Blais et al. interpreted their findings in terms of an enculturation account in which Asian adults have been socialized to their culturally defined gaze norms that prohibit direct eye contact with others. Although our infants appeared to behave somewhat like the Asian adults in Blais et al., it is premature to infer that the Chinese infants might have already been socialized to attend to the nose of the faces. To test the enculturation hypothesis, additional studies are needed. For example, one must establish that White infants, when viewing the same faces used in the present study, would increasingly attend to the eyes, rather than the nose, of the own- and other-race faces with increased age. Further, one must observe infant-parent interactions among White and Chinese participants closely to ascertain whether Chinese parents indeed engage in interactions with their infants in ways that encourage nose-centric fixation strategies, whereas White parents interact with their infants in ways that promote eye-centric fixation strategies.

The ScanPath analyses offer further new insights into infants' processing of paired own- and other-race faces. We found for the first time that infants were more likely to shift their attention between the features within a face, as opposed to switching their attention between the features of two faces. More frequent fixation shifts between features within a face may indicate processing of second-order relational information. In contrast, fixation shifts between comparable features from the two faces may suggest featurally based face processing (e.g., a shift from the nose on the Asian face to the nose on the White face). Thus, our findings are consistent with the idea that second-order relational processing may be weighed more importantly than featural processing in young infants (Quinn & Tanaka, 2009). Furthermore, we also found that although infants generally shifted their gaze within a face more often than between two faces, older infants switched back and forth between own- and other-race faces more frequently than younger infants, perhaps an indication that older infants were more proficient at processing faces than younger ones. Thus, once they finished scanning between the features of one face, they had more opportunity to shift to the other face for scanning between its features.

With regard to scan paths between specific facial features within a face, we found that infants might focus on different second-order relations when processing more familiar own-race faces versus less familiar other-race faces. Regardless of age, infants scanned between the eyes of own-race faces more frequently than the eyes of other-race faces. The decrease in scanning frequencies between eyes of other-race faces, one of the most distinct features of faces, could lead to difficulty in extraction of the key featural and configural information essential for face recognition (Bukach, Le Grand, Kaiser, Bub, & Tanaka, 2008; Caldara, Zhou, & Miellet, 2010).

More frequent scan paths for own- over other-race faces were also found between the right eye and the nose as well as between the right eye and the mouth. Comparatively, fixation shifts between the nose and the mouth were more prominent in other-race face scanning than own-race face scanning. It appears that infants overall had an advantage in scanning the upper-region of own-race faces, whereas scan paths for other-race faces were directed more toward the lower-region. Similar findings were obtained from an investigation of White infants scanning own- and other-race faces presented serially. Xiao et al. (2013) used the same ScanPath analysis and showed that White infants scanned between the eyes of own-race faces more frequently than they did for other-race faces. Such upper region bias has previously been reported to be critical in infants' preference for own-race faces (Simion, Valenza, Cassia, Turati, & Umilta, 2002) and own-race face recognition (Quinn & Tanaka, 2009). The present findings thus suggest that infants may be using a more advanced strategy for scanning own-race faces, perhaps due to their extended experience with them.

Our eye movement results from the multimethod approach suggest that differential scanning patterns exist when infants view own- versus other-race faces. The observed differential pattern could not be explained by the perceptual salience of the Asian eyes and nose versus that of the White and African facial features. When we applied the saliency map procedure to the face stimuli, there were no significant differences between the Asian and other-race faces in perceptual salience.

However, there are several caveats regarding the current findings. First, the eye movement patterns for pairs of own- and other-race faces may differ from situations with only a single face (e.g., the faces of different races shown sequentially) or a pair of same-race faces shown concurrently. For future study, a control condition where face pairs of the same race are shown would help to identify whether the visual scanning patterns across face pairs interact with the race manipulations. Second, the present study only examined Chinese infants. How White 6- and 9-month-olds would react to the own- and other-race face pairings is unknown. It will thus be necessary to extend the results to infants from other racial groups to determine more conclusively whether the change-over in visual preference from own- to other-race reflects a cross-race effect. Also, in addition to using eye-tracking as a behavioral index for studying infant cognition, more psychophysiological measures (i.e., heart rate) should be used in conjunction to further our understanding of infants' face processing (Brez & Colombo, 2012).

In summary, the findings taken together suggest that infants' visual preferences for own- versus other-race faces develop in noticeably different manners. With age increased from 3 to 9 months, infants shifted from familiarity preference to novelty preference. It was speculated that with the development of perceptual narrowing, infants become more efficient in processing own- versus other-race faces and therefore shift their attention to the novel stimuli, other-race faces. Especially, when we applied a multimethod approach to analyze the eye-tracking data, we found that fixation distributions within individual facial features and scan paths between these features varied for own- versus other-race faces. These findings suggest that the underlying mechanisms of processing own- versus other-race faces are different. Overall, our results indicate that asymmetrical visual experiences with faces of different races produce significant effects on infants' preference for and differential visual scanning of own- versus other-race faces. Moreover, it is only through the concurrent examination of both behaviors that we may come to understand the interconnections between them.

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