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Similarity and difference in the processing of same- and other-race faces as revealed by eye tracking in 4- to 9-month-olds

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Abstract

Fixation duration for same-race (i.e., Asian) and other-race (i.e., Caucasian) female faces by Asian infant participants between 4 and 9 months of age was investigated with an eye-tracking procedure. The age range tested corresponded with prior reports of processing differences between same- and other-race faces observed in behavioral looking time studies, with preference for same-race faces apparent at 3 months of age and recognition memory differences in favor of same-race faces emerging between 3 and 9 months of age. The eye-tracking results revealed both similarity and difference in infants' processing of own- and other-race faces. There was no overall fixation time difference between same race and other race for the whole face stimuli. In addition, although fixation time was greater for the upper half of the face than for the lower half of the face and trended higher on the right side of the face than on the left side of the face, face race did not impact these effects. However, over the age range tested, there was a gradual decrement in fixation time on the internal features of other-race faces and a maintenance of fixation time on the internal features of same-race faces. Moreover, the decrement in fixation time for the internal features of other-race faces was most prominent on the nose. The findings suggest that (a) same-race preferences may be more readily evidenced in paired comparison testing formats, (b) the behavioral decline in recognition memory for other-race faces corresponds in timing with a decline in fixation on the internal features of other-race faces, and (c) the center of the face (i.e., the nose) is a differential region for processing same-versus other-race faces by Asian infants.

Keywords

Face perception; Infants; Other-race effect; Eye tracking; Face features; Visual perception

Introduction

Recent work examining the ontogenesis of face perception in infants has revealed that infants are sensitive to gender and race information based on differential experience with female versus male faces and same- versus other-race faces (Lee, Anzures, Quinn, Pascalis,

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& Slater, in press). For example, in the case of gender, 3- and 4-month-olds reared by female caregivers prefer female faces over male faces and also represent female faces at the level of individuals, with male faces being represented at the summary category level (Quinn, Yahr, Kuhn, Slater, & Pascalis, 2002). That the female preference is experientially based is evidenced by the fact that 3- and 4-month-olds reared by male caregivers and newborn infants do not display the preference (Quinn et al., 2002, 2008).

In the case of race, infants as young as 3 months of age, but not newborns, prefer same-race faces over other-race faces (Bar-Haim, Ziv, Lamy, & Hodes, 2006; Kelly et al., 2005, 2007a) and also show an advantage in recognizing structural changes to same-race faces over other-race faces (Hayden, Bhatt, Joseph, & Tanaka, 2007). However, at 3 months of age, the recognition advantage appears to be fragile enough such that it can be overcome by laboratory training involving brief exposure to as few as three other-race faces (Sangrigoli & de Schonen, 2004). In two large-scale studies of recognition of same-and other-race faces, including African, Asian, and Caucasian faces, and Asian versus Caucasian participants, same-race recognition advantages were observed to emerge during the period between 3 and 9 months of age (Kelly et al., 2007b, 2009). The combined results suggest that the representation of faces by infants may initially be unspecified but becomes tuned to the gender of the primary caregiver and the predominant race of faces encountered during the initial months of life.

Further evidence for tuning into social category information in faces is evident in a study that investigated how infants between 6 and 9 months of age respond to race category information (Anzures, Quinn, Pascalis, Slater, & Lee, 2010). In particular, 9-month-old Caucasians differentiated categories of female Caucasian and Asian faces (i.e., they generalized to novel instances of the familiarized race category and responded differentially to novel instances of the novel race category), whereas 6-month-old Caucasians did not. The 6-month-olds showed differential responsiveness (i.e., a significant increase in looking) to Caucasian faces after familiarization with Asian faces, but they showed no such increase in looking at Asian faces after familiarization with Caucasian faces. This pattern of responsiveness is consistent with the idea that 6-month-old performance in the racial categorization task was influenced by the spontaneous preference for own-race faces. Infants' spontaneous preference for own-race faces could have driven the observed increase in looking at own-race faces after familiarization with other-race faces and would have interfered with increased looking at the less preferred other-race faces after familiarization with own-race faces.

The findings of Anzures and colleagues (2010) suggest that younger infants' racial categorization may be influenced by a spontaneous preference for the category of faces with which they have the most experience, whereas older infants are able to separate categories of own- versus other-race faces. However, there was also an important sense in which even the older infants' representations for same- and other-races were not symmetrical. Specifically, at 9 months of age, same-race faces were discriminated, suggesting that they were *categorized* (where a category refers to a grouping together of discriminably different entities that are responded to equivalently). By contrast, at the same age, other-race faces were not discriminated, suggesting that they were represented through *categorical perception* (where the perception is of similar exemplars that are difficult to discriminate). This pattern of results in turn implies that same- and other-race faces are, by 9 months of age, represented by different category structures.

The contrasts between how infants represent male versus female faces and same- versus other-race faces may represent an expert–novice difference during early perceptual–cognitive development. Over the past 15 years, a literature has arisen on how perceptual expertise can emerge in adults (Bukach, Gauthier, & Tarr, 2006; Tanaka, 2001; Tanaka & Gauthier, 1997). One of the hallmark characteristics of perceptual expertise is that objects within an expert domain tend to be recognized at a specific subordinate level rather than at a generic category level. For example, a bird expert is likely to identify a sparrow as a “sparrow” rather than as a “bird.” The subordinate-level recognition observed for female and same-race faces suggests that gender and race are stimulus domains where expertise-like effects have already become evident in infants.

A second manifestation of expertise observed in the adult literature is the tendency for objects to be perceived holistically (Gauthier & Tarr, 2002). This mode of perceptual encoding emphasizes that there are performance advantages associated with processing the whole as opposed to processing individual parts. Consistent with the idea that infant responding to same- versus other-race faces is an expertise-like effect, Ferguson, Kulkofsky, Cashon, and Casasola (2009) reported that by 8 months of age (although not at 4 months of age), Caucasian infants processed same-race faces holistically (i.e., when habituated to two same-race faces, the infants dishabituated to “switch” faces consisting of the internal features of one face embedded in the external contour and hairstyle of the other face) but processed other-race (i.e., African) faces featurally. The finding that there are featural versus holistic processing differences between same- and other-race faces by infants is in accord with holistic processing advantages for same- over other-race faces observed in adults (Michel, Rossion, Han, Chung, & Caldara, 2006; Tanaka & Farah, 1993). It is also in accord with adult work showing that although both shape (physiognomic) features and skin tone (pigmentation) contribute to differences in perceiving same- versus other-race faces (Balas & Nelson, 2010), shape features rather than skin tone may be the primary basis for the same-race recognition advantage (Bar-Haim, Saidel, & Yovel, 2009). Moreover, research examining “pop-out” of same- and other-race faces in 9-month-olds provides even further consistency by demonstrating that a single other-race face can be detected from an array of same-race faces even when skin tone differences between the races are eliminated (Hayden, Bhatt, Zieber, & Kangas, 2009).

With the findings indicating that (a) infants in the time frame between 3 and 9 months of age manifest various processing advantages (which include enhanced visual attention, superior individuation ability, and holistic perception) for same-race faces over other-race faces based on differential experience and that (b) adult recognition and infant detection of face race are driven by physiognomic features, we undertook an eye-tracking study. Specifically, we investigated infant fixation on same-versus other-race faces, with emphasis on how infants scan the whole of the faces as well as the major internal features (i.e., eyes, nose, and mouth). In addition, given evidence that 3- to 7-month-old Caucasians presented with same-race female faces respond more readily to both featural and configural changes around the eyes than around the mouth (Quinn & Tanaka, 2009) and that infants are believed to prefer face-like arrangements of features based on their top-heaviness (Cassia, Turati, & Simion, 2004), a secondary analysis was performed to determine whether infants responded differently to the upper half versus lower half of same- and other-race faces. Finally, given evidence in adults that at least some social category distinctions are more readily detected on the right side of the face than on the left side of the face—that is, the diagnostic information for gender recognition resides on the right side of the face or on the left side of the vertical midline from the viewer’s perspective (Schyns, Bonnar, & Gosselin, 2002)—we believed that it was important to conduct a tertiary analysis examining infant fixation on the left versus right side of same- and other-race faces. The participants were Asians between 4 and 9 months of age who were reared by Asian female caregivers and exposed almost exclusively to Asian faces. The stimulus faces were Asian and Caucasian female faces.

Method

Participants

The participants were 23 healthy, full-term infants (15 boys and 8 girls) from 4 to 9 months of age (mean age = 206 days, range = 122–284). All were native Chinese. One additional infant was tested but did not complete the procedure due to unsuccessful calibration.

Stimuli

The stimuli consisted of 10 videos. Each video contained an adult female face (five of the faces were Caucasian and the other five were Chinese) looking directly into the camera with neutral expression and counting forward for 30 s against a uniform light-colored background. Each video was presented without sound. A still frame from one of the same-race face videos is presented in Fig. 1.

Procedure

Each infant was placed in a car seat in a three-quarters semi-reclining position before a Tobii 1750 eye tracker with a viewing distance of 60 cm. The eye-tracking screen was positioned at an angle parallel to the incline of the infant. An experimenter sat directly behind the infant to adjust the car seat as required during the calibration procedure and to reorient the infant's gaze if necessary.

Infants were first shown an attention-grabbing cartoon character to attract their attention to the display before calibration (courtesy of Scott P. Johnson). During the calibration procedure, infants would see another cartoon character pop up at five locations (the four corners and center) on the screen sequentially. If insufficient data were collected to complete the initial calibration task, then it was repeated up to three times for a total of four attempted calibrations. Infants were presented with two video clips on the eye-tracking screen while fixation data were captured. Each infant saw one own-race female face and one other-race female face. The particular female exemplar from each race was chosen randomly, and the order of the two videos was counterbalanced across infants.

Data analysis

Fixation duration was computed for each of eight areas of interest (AOIs). The 8 AOIs were whole face, eyes, nose, mouth, upper half, lower half, left side of vertical midline from the viewer's perspective (i.e., left visual field or right side of face), and right side of vertical midline from the viewer's perspective (i.e., right visual field or left side of face). The AOI of whole face was defined by the outline of the face with the hair excluded. Splitting the whole face AOI at the center point created the AOIs of the face halves/sides. Horizontal splitting created upper and lower halves, and vertical splitting created left and right sides. The eyes, nose, and mouth were then outlined with a small buffer area to allow for feature/head movement during the recording. The AOIs of one of the other-race faces are shown in Fig. 2. The buffer zone for the nose and eyes was approximately 0.5 cm, whereas the buffer zone for the mouth was extended to approximately 1 cm to allow for lip movement during talking. The mean area of the whole face AOI was 63,512 pixels, which covered 20.67% of the video area. The resolution of the screen was 1024 × 768 pixels. Fixations were defined as having a minimum radius of 30 pixels and a minimum duration of 100 ms.

Results

Preliminary analyses revealed no main effects or interactions for participant gender. Therefore, data were collapsed across this factor for all further analyses. The comparisons of the face race (same vs. other) were conducted on the whole face, facial features, upper versus lower half, and left versus right side of vertical midline from the viewer's perspective. The dependent variable was fixation duration (in seconds).

Whole face, upper versus lower half, and left versus right side of vertical midline

We first examined whether infants preferred looking at same-race faces or other-race faces on the basis of whole face area, upper versus lower half, and left versus right side of the vertical midline from the viewer's perspective (i.e., right vs. left side of the face). Preliminary analyses failed to reveal a significant effect of age (in days); thus, the data for infants from all ages were combined for these analyses.

For the whole face, mean fixation duration for the same-race faces was 14.95 s ($SD = 6.70$), and for the other-race faces, it was 16.25 s ($SD = 7.19$). The fixation duration data were analyzed through a one-way repeated-measures analysis of variance (ANOVA) with face race (own and other) as the repeated measure. The race effect was not significant.

We then compared the effects of face race on fixation duration for the upper versus lower half of the face and the left versus right side of the vertical midline. A 2 (Face Race: own or other) × 2 (Face Half: upper or lower) × 2 (Face Side: left or right of vertical midline) repeated-measures ANOVA was performed on the fixation length data. The results indicated that there was a main effect of face half, $F(1, 22) = 9.692$, $p < .005$, $\eta^2 = .306$, with the difference favoring the upper half of the face ($M = 10.97$, $SD = 6.20$) over the lower half of the face ($M = 4.74$, $SD = 5.00$). There was also a marginal effect of face side, $F(1, 22) = 4.13$, $p = .054$, $\eta^2 = .158$, with fixation time trending higher on the left side of the vertical midline ($M = 9.79$, $SD = 6.05$) than on the right side of the vertical midline ($M = 5.82$, $SD = 4.71$). The face race effect was not significant, nor was the interaction between face half and face side.

Facial features

The next set of analyses were performed on the fixations of the internal features (eyes, nose, and mouth), which are perceptually the high-contrast regions of faces and important for recognition (e.g., Schyns et al., 2002) and which are also thought to convey substantial social information for inter-personal communication (e.g., Hadjikhani, Hoge, Snyder, & de Gelder, 2008). A 2 (Face Race: same or other) × 1 (Participant Age: days [continuous variable]) repeated-measures ANOVA with the first factor as the repeated measure was performed on the combined fixation duration of the eyes, nose, and mouth. We observed a significant interaction between face race and age, $F(1, 21) = 5.801$, $p = 0.025$, $\eta^2 = 0.216$, which is illustrated in Fig. 3. To interpret the interaction, we computed the Pearson correlations between the combined fixation durations for the three key face features and age (in days). Although the correlation for the own race was not significant ($r = .004$, *ns*), the correlation for the other race was significant ($r = -.45$, $p = .031$). Thus, with increased age, infants' combined fixation duration for the internal features of other-race faces decreased but was maintained for the internal features of same-race faces.

To further explore whether infants fixated on the three major face features differently, we performed three separate 2 (Face Race: same or other) × 1 (Participant Age: months [continuous variable]) repeated- measures ANOVAs with the first factor as the repeated measure on the fixation duration for eyes, nose, and mouth, respectively. For fixation on the nose, there was a significant face race by age interaction, $F(1, 21) = 6.80$, $p = 0.016$, $\eta^2 = 0.25$, which is depicted in Fig. 4. To interpret the interaction, we computed the Pearson correlations between the fixation durations for the nose and age (in days). Although the correlation for the own race was not significant ($r = -.011$, *ns*), the correlation for the other race was significant ($r = -.50$, $p = .014$). Thus, with increased age, infants' fixation duration for the nose of other-race faces decreased but was maintained for the nose of same-race faces. In the eyes and mouth areas, there were no main effects or interactions, suggesting that infants spend relatively the same time gazing at these areas for same-race faces as for other-race faces across the age range tested.

Discussion

The current investigation examined fixation duration for same-race (i.e., Asian) and other-race (i.e., Caucasian) female faces, their internal features (eyes, nose, and mouth), and their halves and sides (upper vs. lower and left vs. right) by Asian infant participants between 4 and 9 months of age. This is the same age range over which prior processing differences between same- and other-race faces have been observed, with spontaneous preference for same-race faces appearing at 3 months of age (Kelly et al., 2005, 2007a) and recognition memory differences in favor of same-race faces emerging between 3 and 9 months of age (Kelly et al., 2007b, 2009). Both similarities and differences in the processing of same- and other-race faces were revealed through the eye-tracking procedure.

Similarities in face race processing

In terms of similarity of processing face race, there was no overall fixation duration difference for same- and other-race faces on the whole face stimuli. In addition, although there were advantages in fixation time for the upper half of the face over the lower half of the face and for the left side of the vertical midline over the right side of the vertical midline (i.e., right side of the face over left side of the face), neither of these region differences was impacted by face race. The fixation time advantage for the upper half of the face over the lower half of the face is in accord with prior reports of upper region processing advantages in infants (Cassia et al., 2004; Quinn & Tanaka, 2009). Also, the fixation time tendency for the right side of the face over the left side of the face is in accord with a bias to attend to the right side of the face over the left side of the face that has been reported for adults (Schyns et al., 2002), although to our knowledge this is the first report of such a right side of the face fixation bias in infants. However, the effect should be interpreted with caution given its marginal significance.

Even though the findings of the whole face analysis might at first glance appear to be surprising because there was no advantage in fixation duration for same-race faces over other-race faces, it is important to note that the same-race preferences reported in prior studies measuring overall looking time were observed only in paired comparison tasks where individual same- and other-race faces were contrasted simultaneously (Kelly et al., 2005, 2007a). The null effect of the race of the stimulus faces observed here in a sequential presentation format is actually consistent with the null effect of face race observed during the familiarization periods of both recognition memory and categorization tasks where same- versus other-race faces were presented in between-participants designs (Anzures et al., 2010; Kelly et al., 2007b, 2009). Paired comparison task contexts have previously been reported to be more sensitive than serial presentation procedures at revealing infant perception of differences between non-face object classes (Younger & Furrer, 2003), and a comparison of the current data with the prior reports suggests that this sensitivity difference may extend to social face categories. It may be that the paired comparison task in some sense forces a choice between looking at same-race faces and looking at other-race faces that is critical to revealing the same-race preference for whole face stimuli.

Differences in face race processing

With respect to differences in fixating faces based on race, the observed interaction between face race and participant age on fixation duration for the internal features provides new information regarding the processing of same- and other-race faces by infants. In particular, previous reports emphasized same-race preferences in 3-month-olds in the paired comparison task (Kelly et al., 2005, 2007a) and a gradual “tuning out” of other-race faces between 3 and 9 months of age as measured in recognition memory and processing tasks (Ferguson et al., 2009; Kelly et al., 2007b, 2009). The current report complements both findings in suggesting a possible basis for the decrement in recognition memory performance, namely, that infants are less likely to fixate (and process) the internal features of other-race faces in the time window between 4 and 9 months of age. Indeed, Kelly and colleagues (2007b) speculated that the spontaneous preference for same-race preference at 3 months of age and the decline in recognition memory performance between 3 and 9 months of age were related (see also Ferguson et al., 2009). Specifically, a preference for same-race faces based on differential experience results in greater visual attention to such faces, which in turn increases the likelihood that they will be processed at a deeper (i.e., subordinate) level. The current findings add to this account by suggesting that lesser experience with other-race faces may bring about decreases in looking time to the internal features of such faces, which in turn increases the likelihood that the faces will be processed at a more summary category level (i.e., Caucasian). In other words, if infants gradually come to spend less time fixating the internal features of other-race faces and there is important identifying information associated with those internal features (e.g., Schyns et al., 2002), then it stands to reason that the infants would become less skilled at individuating other-race faces from one another. It would also be the case that if infants are spending less time fixating the internal features of other-race faces, then they may be less capable of the more holistic integrative processing associated with perceiving same-race faces in an expert way (Ferguson et al., 2009; Michel et al., 2006; Schwarzer, Zauner, & Jovanovic, 2007).

The results showing that the decline in fixation duration for the internal features of the other-race faces is most prominent about the nose is consistent with the findings from one other eye-tracking study of infant face perception that showed that a change in the orientation of same-race faces from upright to inverted resulted in a decrease in fixation on the nose region for Caucasian 4-month-olds (Gallay, Baudouin, Durand, Lemoine, & Lecuyer, 2006). The decline in fixation on the nose for other-race faces is of further interest in light of the report by Blais, Jack, Scheepers, Fiset, and Caldara (2008) that adult Asian observers tend to fixate on the central regions of faces when scanning both same- and other-race faces, although the effect is less pronounced during recognition and categorization of other-race faces (see Fig. 3 in Blais et al., 2008). The findings with the adult Asian observers contrasted with the predominant featurally based triangular scanning pattern between the eyes and mouth observed in adult Caucasian observers scanning same- and other-race faces (Blais et al., 2008; Yarbus, 1967), although again, in Blais and colleagues’ (2008) study, the triangular pattern was not as robust for the processing of other-race faces. Thus, Blais and colleagues’ (2008) study suggests the importance of the center point of the face (which aligns with the nose) for scanning faces (especially same-race faces) by Asian adults, and the current study suggests that although the importance of that center point is maintained in the scanning of same-race faces by Asian infants, it declines in the scanning of other-race faces. The combined findings from Blais and colleagues’ (2008) study conducted with Asian adults and the current study conducted with Asian infants suggest that an important reference point for fixating faces (i.e., the center point) is being established during the infancy period.

The discussion in Blais and colleagues’ (2008) study highlighted the importance of culture in determination of eye-tracking patterns of faces with mention of the possible avoidance of the eyes and the use of the central region as an optimal starting point for global processing in adult Asian observers. However, the findings reported here with infants under 1 year of age may be suggesting a different mechanism at work, namely, one that reflects the possibility that different features may be differentially useful in recognizing faces of different races.

Such a possibility would be consistent with Valentine's (1991; see also Caldara & Abdi, 2006) accounting of how the other-race effect comes about in face space (i.e., the tuning of the face processing system to features that maximize discrimination of same-race faces but not necessarily other-race faces). It would also be consistent with the finding that Asian faces have a different morphology in terms of their physiognomic features relative to Caucasian faces, one characterized by wider noses and smaller mouth widths (Le, Farkas, Ngim, Levin, & Forrest, 2002). These observations would suggest that a full accounting of how faces from different races are tracked by observers of different races may require understanding of both stimulus contributions operating during the short term of development (i.e., morphology differences in faces from different races that could be detected by infants during the first year of life) and observer contributions operating during the longer term of development (i.e., cultural differences). Further studies of the eye-tracking patterns of Caucasian infants for same- and other-race faces will be critical for evaluating these speculations.

Concluding summary

The findings from the current study suggest that although region biases and overall fixation time on whole faces presented sequentially were unaffected by race, another manifestation of the tuning out of other-race faces during infancy is a gradual decline in the fixations of the internal features between 4 and 9 months of age. The significance of this finding lies in its suggestion that prior reports of differential visual attention and recognition for same-versus other-race faces are linked, with less experience leading to less visual attention and a consequent decline in recognition for other-race faces.

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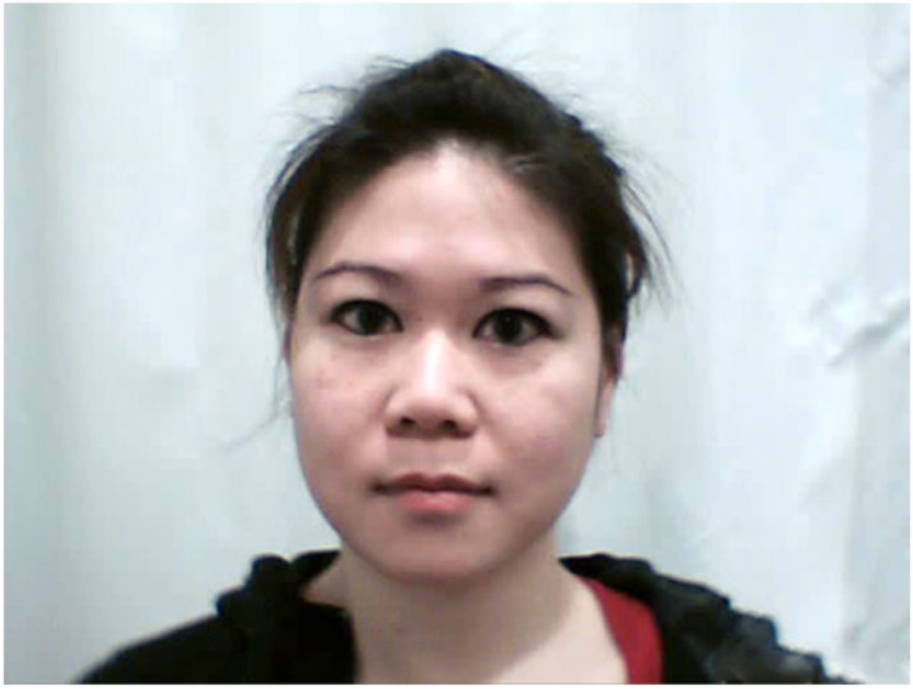

Fig. 1.
A still frame from one of the same-race videos presented to the infants.

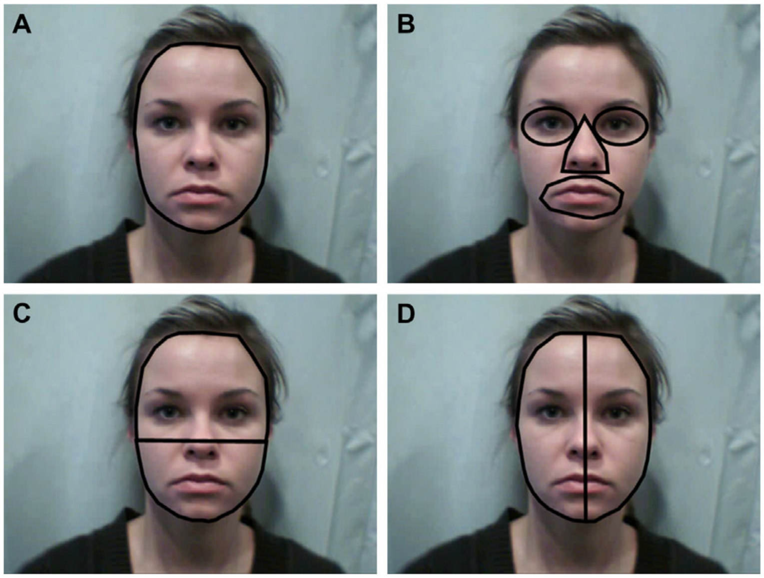

Fig. 2.

A display of the AOIs using a still frame from one of the other-race videos presented to the infants. Each quadrant depicts a different set of AOIs: (A) whole face; (B) eyes, nose, and mouth; (C) upper half and lower half; (D) left side of vertical midline from the viewer's perspective (i.e., left visual field or right side of face) and right side of vertical midline from the viewer's perspective (i.e., right visual field or left side of face).

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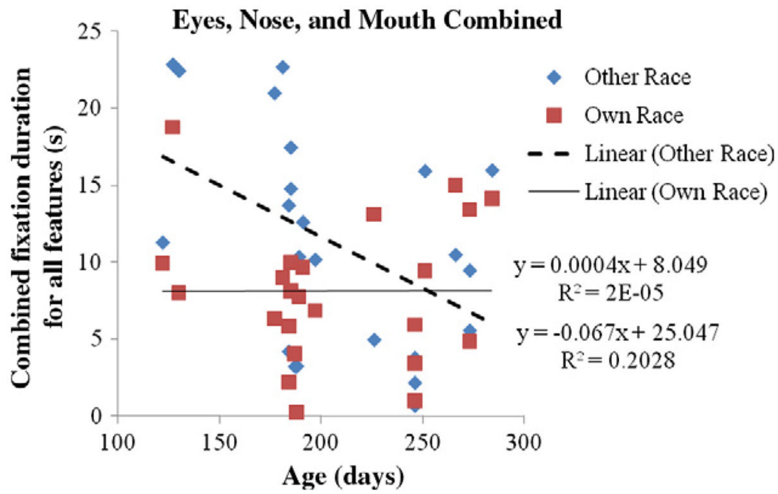

Fig. 3.

Fixation duration for the internal facial features area (eyes, mouth, and nose) plotted against participant’s age in the same- and other-race conditions.

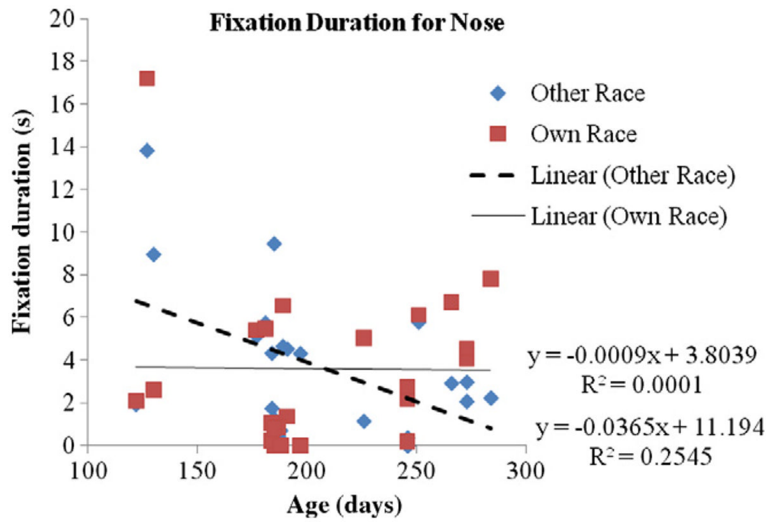

Fig. 4.
Fixation duration for nose area plotted against participant's age in the same- and other-race conditions.