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PAPER

Biracial and monoracial infant own-race face perception: an eye tracking study

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Abstract

We know that early experience plays a crucial role in the development of face processing, but we know little about how infants learn to distinguish faces from different races, especially for non-Caucasian populations. Moreover, it is unknown whether differential processing of different race faces observed in typically studied monoracial infants extends to biracial infants as well. Thus, we investigated 3-month-old Caucasian, Asian and biracial (Caucasian-Asian) infants' ability to distinguish Caucasian and Asian faces. Infants completed two within-subject, infant-controlled habituation sequences and test trials as an eye tracker recorded looking times and scanning patterns. Examination of individual differences revealed significant positive correlations between own-race novelty preference and scanning frequency between eye and mouth regions of own-race habituation stimuli for Caucasian and Asian infants, suggesting that facility in own-race face discrimination stems from active inspection of internal facial features in these groups. Biracial infants, however, showed the opposite effect: An 'own-race' novelty preference was associated with reduced scanning between eye and mouth regions of 'own-race' habituation stimuli, suggesting that biracial infants use a distinct approach to processing frequently encountered faces. Future directions for investigating face processing development in biracial populations are discussed.

Introduction

The face is a vital clue to a person's identity, and face processing is an essential skill needed to gather information about people in the social environment. During the first few days after birth, infants demonstrate visual preferences for schematic face-like patterns (Goren, Sarty & Wu, 1975; Simion, Farroni, Cassia, Turati & Dalla Barba, 2002; Valenza, Simion, Macchi Cassia & Umiltà, 1996), preferences for their own mother's face over a stranger's face (Bushnell, Sai & Mullin, 1989; Pascalis, de Schonen, Morton, Deruelle & Fabre-Grenet, 1995), discrimination between faces within their own ethnic group (Pascalis & de Schonen, 1994), and discrimination of attractive versus unattractive faces from facial features (Slater, Bremner, Johnson, Sherwood, Hayes & Brown, 2000; Slater, von der Schulenburg, Brown, Badenoch, Butterworth, Parsons & Samuels, 1998). These findings imply that newborns form face representations quickly and that they use internal facial features as cues for learning about faces.

There is now increasing evidence that the infants' face processing is strongly influenced by the social and visual environment (de Schonen & Mathivet, 1989; Nelson, 2001). For example, 3-month-old infants acquire a preference for faces linked both to the gender (Quinn, Yahr, Kuhn, Slater & Pascalis, 2002) and race of their primary caregiver (Kelly, Quinn, Slater, Lee, Gibson, Smith, Ge & Pascalis, 2005), and distinguish own-race faces but not other-race faces (Sangrigoli & de Schonen, 2004), known as the other-race effect (ORE), which is also seen in adults. Thus, infants exhibit visual preferences and recognition biases for faces they are most frequently exposed to in their environment. Upon their emergence, such biases remain malleable or flexible depending on environmental input. For example, short-term exposure to three other-race face exemplars (Sangrigoli & de Schonen, 2004) and perceptual training using picture books of other-race faces beginning at 6 months of age (Heron-Delaney, Anzures, Herbert, Quinn, Slater, Tanaka, Lee & Pascalis, 2011) both reduced the ORE seen in Caucasian infants, providing evidence for the plasticity in infants' ability to process both own-race and other-race faces based on one's continuing visual experiences.

Indeed, one popular explanation for the ORE is racial exposure – adults who have more contact with faces of one particular group tend to show a level of expertise for distinguishing faces within that group (Brigham & Malpass, 1985; Gauthier & Nelson, 2001; Golby, Gabrieli, Chiao & Eberhardt, 2001; Nelson, 2001). But

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this differential-experience hypothesis has not yet been fully explored for minority infant populations. The majority of studies that have explored the ORE in infants have used Caucasian populations (e.g. Kelly, Quinn, Slater, Lee, Gibson, Smith, Ge & Pascalis, 2007b; Kelly, Liu, Lee, Quinn, Pascalis, Slater & Ge, 2009; Quinn, Uttley, Lee, Gibson, Smith, Slater & Pascalis, 2008; Sangrigoli & de Schonen, 2004). These findings may not necessarily apply to other racial groups, especially since the social environment for infants from other racial backgrounds can vary drastically in comparison to that of Caucasian infants. Although Kelly *et al*. (2009) used a sample of Chinese infants, these infants were all raised in a homogenous Chinese environment. To our knowledge, there is no published study to date regarding ORE biases for infants who are normally exposed to racial outgroup members.

Studies have explored the impact of racial exposure on the ORE in older minority populations. For example, Korean children adopted by an other-race family (and thus who live in a homogenous outgroup environment) appear to exhibit a reversal in the typical ORE in adulthood (Sangrigoli, Pallier, Argenti, Ventureyra & de Schonen, 2005). These results may depend on the amount of exposure children have to outgroup faces in childhood, however (de Heering, de Liedekerke, Deboni & Rossion, 2010). Similarly, Black children's ORE is reduced for those attending an integrated school, and in some cases reversed for those also living in a primarily outgroup neighborhood (Feinman & Entwisle, 1976). Therefore, the social environment has been shown to directly impact face processing and ORE biases in older minority children when the environment is clearly homogeneous, but the effects of more heterogenous exposure to racial outgroups on infants' developing own- and other-race face processing abilities remains an open question. More hetereogenous exposure does appear to affect what faces infants attend to in their environment. Whereas African and Caucasian infants growing up in ingroup homogenous environments exhibit own-race visual preferences, 3-month-old African infants exposed to both African and Caucasian faces do not show a visual preference for either type of face (Bar-Haim, Ziv, Lamy & Hodes, 2006). Infants' early visual preference for faces to which they are frequently exposed in their environment has been hypothesized to be a starting point for the development of the ORE (Kelly, Liu, Ge, Quinn, Slater, Lee, Liu & Pascalis, 2007a), providing suggestive evidence that heterogenous exposure to outgroup faces may delay the emergence of the ORE.

Evidently, exposure to particular faces plays a fundamental role in how infants learn to distinguish both familiar and unfamiliar faces, but it is still unclear how infants actually process own- and other-race faces, particularly for infants from racially diverse environments or backgrounds. The manner in which infants explore own- and other-race faces (i.e. their actual visual processing of these faces) provides an important window into the development of ORE biases. Only two published studies to our knowledge have used eye tracking to examine how infants scan own-race and other-race faces. One study tested 4- to 9-month-old Chinese infants living in China and found that with increased age, the infants fixated significantly less on the noses of Caucasian faces but no changes were seen when scanning own-race Chinese faces across the age spectrum (Liu, Quinn, Wheeler, Xiao, Ge & Lee, 2011). The second tested 6- to 10-month-old Canadian Caucasian infants and found that with increased age, infants fixated more on the eyes of own-race faces and less on the mouths (Wheeler, Anzures, Quinn, Pascalis, Omrin & Lee, 2011). Neither of these studies reported results from infants who had been exposed to other races, however. These studies also did not specifically relate infants' scanning patterns to their ability to distinguish own- and other-race faces.

The aim of the current study, therefore, was twofold: (1) to investigate the ORE in monoracial majority, minority and biracial populations, all with heterogenous exposure to racial outgoups, and (2) to examine how infants' own- and other-race face processing relates to the own- and other-race discrimination. The evidence as to when the ORE emerges is equivocal. Although some studies have established that infants exhibit the ORE as early as 3 months (Sangrigoli & de Schonen, 2004; see also Hayden, Bhatt, Joseph & Tanaka, 2007), others have shown that 3-month-olds exhibit comparable recognition for own- and other-race faces and that the ORE does not emerge until at least 6 months (Kelly *et al*., 2007b; Kelly *et al*., 2009), and some studies have even argued that a robust ORE does not develop until 9 months of age (Kelly *et al*., 2007b). We chose to start with the youngest population to show evidence of ORE biases, 3-month-old infants, and asked whether early experience with other-race faces, acquired through living in a diverse social environment, affects own- and other-race face processing and discrimination.

To address this question, 3-month-old monoracial Caucasian, monoracial Asian, and biracial Asian/Caucasian infants living in Los Angeles were recruited to complete an eye tracking study comprising a within-subject, infant-controlled habituation paradigm where infants viewed Caucasian and Asian female faces. We examined scanning patterns and looking times of 3-month-old monoracial infants toward own- and other-race faces (the youngest to date for this method) and compared the results to biracial infants (the first time to date to be used within a face perception study) who were exposed to two different races daily in their home environment. Due to the added exposure to two different race exemplars during their first 3 months after birth, we reasoned that biracial infants would be better at distinguishing both Caucasian and Asian faces in comparison to their monoracial counterparts and biracial infants would display different face processing techniques as reflected through different facial scanning patterns in comparison to both monoracial populations. Perhaps biracial infants' added exposure to two different racial exemplars gives them the ability to maintain discrimination abilities for multiple racial categories. In addition, it may be the case that even our monoracial infants may not display the traditional ORE due to the racial diversity of Los Angeles and daily heterogenous exposure to other races.

Method

Participants

In total, 68 full-term healthy 3-month-old infants were recruited from the Los Angeles metropolitan area by sending a letter to new parents who returned a postcard indicating interest in participating. Among the infants, eight were excluded due to fussiness (n = 4), incomplete data capture (n = 3), or technical errors (n = 1). The final sample consisted of 60 infants (M_{age} = 3.13 months): 21 Caucasian (10 female), 19 Asian (nine female) and 20 biracial Asian/Caucasian (10 female). All infant groups were from similar socioeconomic backgrounds and lived in similar regions of the Los Angeles area. All parents completed a demographic questionnaire and were asked to report the amount of time their infant spent with each parent (i.e. two separate percentages based on weekly exposure) and their infant's exposure to other races (i.e. 'What percentage of time do you spend with people not of your same race and/or culture? Please specify which racial/ethnic groups if possible'). Analyses of these racial exposure data revealed that infants in all groups were readily exposed to other races (overall M = 40.96%, SD = 19.80; Caucasian infants: M = 30.00%, SD = 8.49; Asian infants: M = 38.67%, SD = 16.20; biracial infants: M = 54.44%, SD = 23.51), the majority reporting exposure to Asian, Latino and Caucasian individuals.[1] Thus, these infants represent a distinct participant population – one that has considerable heterogenous exposure to other racial groups – relative to populations observed in past infant ORE studies which only included infants that had very little to no exposure to other races.

Materials

Color photographs of faces of 10 women (five Caucasian and five Asian) from the NimStim Set were pretested with adults to ensure that they were judged as Caucasian or Asian respectively (Tottenham, Tanaka, Leon, McCarry, Nurse, Hare, Marcus, Westerlund, Casey & Nelson, 2009). Female faces were used because children tend to be more receptive to females (Lee, Anzures, Quinn, Pascalis & Slater, 2011). A black mask was applied to the pictures to block out the hairline because hair can be used as an identifying feature (e.g. Maurer, 1983), and the images were cropped to 21.6 × 31.8 cm (20.4 × 29.6° visual angle), and shown to infants' at a viewing distance of 60 cm. Data were collected with a Tobii 1750 eye tracker with a sampling rate of 50 Hz and a screen resolution of 1280 × 1040. During test trials, the two paired images were 8.7 cm apart (8.3°).

Procedure

Infants were seated on a parent's lap in front of the eye tracker. The point of gaze was calibrated with a target-patterned stimulus that appeared at five locations (the four corners and the center) across the screen, one at a time.

Stimuli were presented following methods adapted from Sangrigoli and de Schonen (2004). Infants completed two consecutive within-subject infant-controlled habituation sessions testing discrimination of either Caucasian or Asian faces. In each session, a single photograph of a face (Caucasian or Asian) was presented for habituation and was followed by two 20-second test trials. Within each session one of the five possible faces from each racial category was selected at random to be used as the habituation stimuli. Order of the two sessions was counterbalanced across participants. Infants were judged to be habituated when the duration of looking time during any sequence of three consecutive trials added to 50% or less of the total looking time of the first three trials with a maximum limit of 12 trials. Before each trial an attention getter was used to center the infant's gaze. After habituating, infants completed two 20-second test trials comprising paired stimuli (Pascalis, de Haan, Nelson & de Schonen, 1998) in which the same (familiar) photograph and a novel face of the same race were shown side-by-side. The right–left positions of the paired stimuli were reversed between the first and second presentations and the initial right–left positions of the stimuli were randomly determined. Looking times and scanning patterns were recorded by the eye tracker.

Results

No effects of sex or order of stimuli presentation were found in preliminary analyses so the data were collapsed across these variables in subsequent analyses.

We examined looking time toward novel and familiar own- and other-race faces and infants' patterns of fixations (i.e. facial transitions) for own- and other-race faces. In order to quantify infants' patterns of fixations, we outlined four Areas of Interest (AOIs): habituation faces were divided into upper (eye region) and lower (mouth region) halves so transitions between the areas of the face during habituation could be measured while the test trial faces were outlined as either the novel or familiar face for looking time purposes. Fixations were

[1] Not all parents specified which racial/ethnic groups their child had exposure to outside of their own group, so we were unable to analyze the amount of exposure children had to specific racial out-groups.

defined as having a minimum radius of 30 pixels and a minimum duration of 100 ms.

For biracial infants there is no clear 'own-race' and 'other-race' group. In fact, it may be the case that biracial adults view both racial groups that their parents belong to as 'own-race' (Pauker & Ambady, 2009). For monoracial infants, their own-race group is of course their racial ingroup, but it is also most often the group to which they have the most exposure. Thus, for purposes of comparison between groups in the current analyses, we decided to denote an 'own-race' group for biracial infants based on familiarity. To do this, we first calculated how much time each infant group spent with each of their parents based on responses from the demographic questionnaire. Paired samples *t*-tests within each infant group revealed that all infant groups spent significantly more time with their mothers than their fathers: Caucasian infants M_{mom} = 89.11%, SD = 12.07, M_{dad} = 39.44%, SD = 29.69, $t(17) = 7.01$, $p < .001$, $r = .86$; Asian infants M_{mom} = 81.88%, SD = 22.20, M_{dad} = 41.33%, SD = 20.13, $t(14) = 5.45$, $p < .001$, $r = .80$; biracial infants M_{mom} = 85.00%, SD = 13.72, M_{dad} = 31.56%, SD = 17.39, $t(15) = 11.48$, $p < .001$, $r = .95$.[2] Thus, Caucasian infants spent the most time with Caucasian female faces, Asian infants with Asian female faces, and biracial infants with Asian female faces (all of our biracial infants had Asian mothers). In order to explore the ORE as it relates to infants' highest level of racial exposure, for the rest of the analyses presented 'own-race' for biracial infants will be denoted as the faces to which they had had the most exposure: Asian females for this sample (also recall our stimuli were female faces).

Other-race effect

To examine the ORE, a novelty preference score was calculated for each infant for each test session (Caucasian and Asian) by dividing looking times to the novel face by total looking times (familiar plus novel). We ran one-tailed *t*-tests to compare infants' preference scores to .50. A novelty preference score significantly above .50 would reflect discrimination, and greater discrimination for own-race compared to other-race faces would reflect an ORE. Neither the Caucasian nor the Asian groups showed a novelty preference for either Caucasian or Asian faces, but the biracial infants showed a significant novelty preference for Caucasian faces only: *Caucasian session*: Caucasian infants $M = .47$, $SD = .14$, $t(20) = -.796$, $p = .44$, *ns*; Asian infants $M = .51$, $SD = .23$, $t(18) = .18$, $p = .85$, *ns*; Biracial infants $M = .62$, $SD = .20$, $t(19) = 2.62$, $p = .02$; *Asian session:* Caucasian infants $M = .51$, $SD = .20$, $t(20) = .264$, $p = .79$, *ns*; Asian infants $M = .42$, $SD = .23$, $t(18) = -1.54$, $p = .14$, *ns*; Biracial infants $M = .47$, $SD = .21$, $t(19) = -.711$, $p = .47$, *ns.*

Comparing the novelty preference scores for the Caucasian and Asian sessions with paired-samples *t*-tests again revealed a null effect for monoracial Caucasian and Asian infants, but a significant difference for the biracial infants, showing that they were better at distinguishing Caucasian faces than Asian faces: Caucasian infants $t(20) = .70$, $p = .49$, *ns*; Asian infants $t(18) = -1.74$, $p = .26$, *ns*; Biracial infants $t(19) = -2.23$, $p = .04$.

Despite the fact that we used similar presentation methods as Sangrigoli and de Schonen (2004) with the same age group of infants, the traditional ORE was not found in this study for Caucasian, Asian or biracial infants, perhaps due to the added other-race exposure these infants have all had across their first 3 months after birth. Alternatively, the null effects for monoracial infants found in the present study could also be due to the fact that we used color images rather than black and white. Indeed, past work with adults has shown that color can affect how some faces are processed (e.g. Bar-Haim, Saidel & Yovel, 2009). Our results showed an additional unexpected effect: biracial infants were better at distinguishing Caucasian faces, which represent the race to which they had significantly less exposure in their home environment.

Facial transition patterns during habituation

To examine the manner in which infants processed own- and other-race faces during habituation, and to address the possibility that oculomotor scanning patterns predicted test trial looking times (i.e. own- and other-race face discrimination), we computed two sets of analysis. First, we tallied the number of visual transitions or saccades between the top (eye region) and bottom (mouth region) halves of the faces during habituation trials. Each transition was defined by a new recorded fixation. A repeated measures ANOVA showed that the interaction between these transitions (i.e. the number of internal face transitions infants made between the top and bottom regions of the face) and the race of stimuli was not significant, $F(2, 57) = .28$, $p = .76$, *ns*, and there were also no main effects by participant race, $F(2, 57) = .13$, $p = .88$, *ns*.

Next, because we were particularly interested in how visual scanning patterns during habituation related to the ability to discriminate faces during test trials, we regressed participants' own-race novelty preference score on participant race (dummy coded), participants' visual transitions between the top and bottom halves of own-race faces during habituation (mean-centered), and their interaction. Neither participant race nor visual transitions predicted own-race novelty preference (ps > .15), but importantly the interaction between participant race and visual transitions was significant, $F(2, 54) = 4.19$, $p = .020$. The slope for biracial infants was significantly

[2] These percentages are only for time spent with parents and not other caregivers. Percentages adding to more than 100% denote overlapping time spent with both parents.

different from that of Caucasian (B = .01, $t(54) = 2.07$, $p = .043$) and Asian infants (B = .01, $t(54) = 2.57$, $p = .013$). The slopes for Caucasian and Asian infants were not significantly different (B = .00, $t(54) = -.07$, $p = .95$) (see Figure 1). Both Caucasian and Asian infants showed a positive relation between visual transitions between the eye and mouth regions of own-race faces during habituation and own-race novelty preference scores: Caucasian infants $r = .44$, $p = .046$; Asian infants $r = .38$, $p = .11$. Biracial infants, however, showed the opposite effect: a negative correlation between scanning 'own-race' (Asian) faces and own-race novelty preference scores, $r = -.34$, $p = .15$, demonstrating that biracial infants are clearly using a different technique (e.g. less scanning between eye and mouth regions) to aid in own-race face discrimination in comparison to their monoracial counterparts. We ran the same analyses for other-race faces. The regression analyses revealed that neither participant race (*p*s > .12), nor visual transitions ($p = .71$), nor their interaction (*p*s > .76) predicted other-race novelty preference. Similarly, scanning of other-race faces during habituation was not related to other-race novelty preference for any of the infant groups (*ps* > .69). Thus, both monoracial and biracial infants appear to be using specific scanning patterns to aid in own-race face discrimination, but this same pattern of scanning eye-mouth regions in other-race faces does not seem to aid in their discrimination.

Discussion

Our findings represent the first infant ORE study to recruit infants who were routinely exposed to multiple races in their social environments as well as the first to include a biracial population of participants. We found that monoracial Caucasian and Asian infants exposed to a diverse social environment do not seem to develop an ORE by 3 months, but biracial infants showed a novelty preference for Caucasian faces, despite the race of their mother (Asian) to which they were more frequently exposed. It is not clear why the biracial infants in our sample seem to be better at Caucasian face discrimination, but we posit that the ORE may not develop as early for infants who grow up in racially diverse environments compared to infants from more racially homogeneous environments. The Caucasian population represents the majority race in the cities surrounding UCLA (racial makeup: Caucasian 62.53%, Asian 23%, Hispanic 7%, Black 2.10%), but not an overwhelming majority. Thus, infants in this area are most frequently exposed to Caucasian and Asian faces, but also a variety of other racial groups as well, which may be why infants in this study seem to perform almost equally well for both Caucasian and Asian faces. For infants who are exposed to a hetereogeneous outgroup population, it may be difficult to determine based on environmental input which faces are most important to learn, and this may affect the development of traditional ORE preferences (i.e. better own-race discrimination than other-race discrimination).

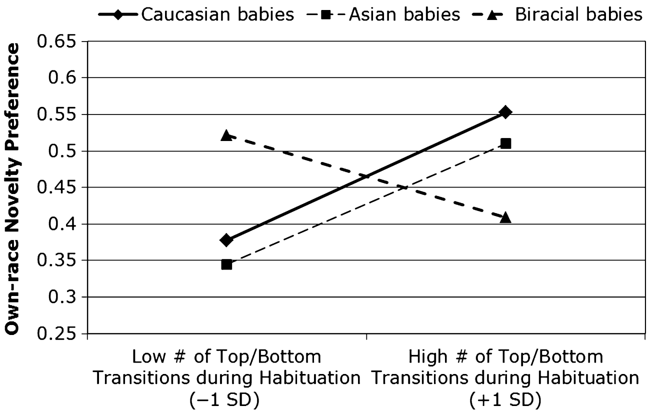

Figure 1 *The relation between scanning of internal facial features (between the eye and mouth regions) of own-race faces during habituation trials and infants' own-race novelty preference. For monoracial infants, a greater number of transitions between the eye and mouth regions during own-race habituation trials is positively related to own-race face discrimination, whereas for biracial infants a lower number of transitions is related to in 'own-race' (Asian) face discrimination.*

Infants in our sample did not exhibit own-race face discrimination, which has been documented previously in 3-month-olds (Kelly *et al.*, 2005, 2009; Sangrigoli & de Schonen, 2004). One major difference between past studies and the current study is that past studies typically recruited infants with little exposure to other racial groups. Thus, we still do not fully understand the development of own-race face discrimination for infants who are frequently exposed to other races. Indeed, in a study on infants' early face preference, which may be developmentally antecedent to own-race discrimination advantages (Kelly *et al.*, 2007a), 3-month-old African infants did not show a visual preference for either own- or other-race faces; in contrast, infants with homogenous exposure to their in-group exhibited a clear preference for own-race faces (Bar-Haim *et al.*, 2006). Thus it may be the case that more heterogeneous exposure may delay the onset of preferential attention toward highly prevalent stimuli in the environment (since the pattern of exposure is not as clear) and may ultimately affect the emergence of the ORE.

Alternatively, one could also argue that the infants in our sample are too young to exhibit an ORE. This argument is consistent with a number of studies that have not found the ORE in 3-month-olds (e.g. Kelly *et al.*, 2007b; Kelly *et al.*, 2009). Thus, the results of the present study are consistent with the possibility that robust ORE biases may not appear until later in infancy. Future studies should examine older monoracial and biracial infant populations (e.g. 6 months and 9 months in particular) who are also frequently exposed to racial outgroup members using similar methodology as the current study to measure visual processing and face discrimination. This would enable us to more fully understand the trajectory of the development of own-race face processing for all types of infant populations, since we still know little about how infants who grow up in a homogeneous versus heterogeneous environments compare in their face perception abilities.

Only one other face perception study to our knowledge included a biracial sample of children. This study found that 5–12-year-old biracial Black/Caucasian children recognized faces in the same way that monoracial Black and Caucasian children did (Goodman, Sayfan, Lee, Sandhei, Walle-Olsen, Magnussen, Pezdek & Arredondo, 2007). The present experiment included a much younger population and revealed that biracial infants used a distinct pattern of visual scanning in comparison to monoracial infants to aid in discrimination of faces to which they had a greater amount of exposure. Increased internal transitions on own-race faces during habituation led to a deterioration in own-race (Asian in this study) face discrimination for biracial infants, but an advantage in own-race face discrimination for monoracial infants. One recent study involving 3-month-olds found that varying the duration and type of exposure to a novel female face resulted in the same distinguishing abilities later during test trials, but the neural processes were reversed between the two exposure groups, suggesting that the amount of visual exposure to a given face can alter the neural correlates and processing used during face recognition while still resulting in the same outcome (Moulson, Shannon & Nelson, 2011). Perhaps the end result in perceiving faces is the same for both monoracial and biracial infants, but the pathway or process biracial children take to get to that end point in face recognition is what differs. Future studies should aim to examine this difference further.

It also may be that biracial infants, due to their in-home exposure to two different race exemplars on a regular basis, begin to scan and learn about faces in a different manner from monoracial infants. For example, bilingual infants and children are often seen as delayed concerning each learned language in comparison to their monolingual counterparts, but this difference disappears when the performance abilities of both learned languages are considered together (Pearson, Fernández & Oller, 2006). This is possibly what is happening regarding face perception for biracial infants. It is known that as infants get older, their face processing patterns begin to resemble adults' patterns, using shorter and fewer fixations when scanning new faces and images across the first several postnatal months (Bronson, 1994; Hunnuis & Geuze, 2004). So perhaps, biracial infants are more 'advanced' face processors who begin to resemble adult-like scanning patterns earlier than monoracial infants and this difference in face processing abilities may also influence their abilities to recognize certain emotions or even read lips as it relates to language learning. Certainly, future studies are needed to more fully evaluate these possibilities. In addition, it will be important for future research to examine monoracial and biracial infants' scanning patterns of male faces, since we used exclusively female faces in the current study.

Finally, the trends seen in visual transitions predicting discrimination of faces to which infants are most readily exposed may serve as a window into the visual processes that lead to the development of ORE biases. The present data show that both monoracial and biracial infants used specific scanning patterns to aid in own-race, but not other-race, face discrimination. Perhaps during their first 3 months infants acquire skills specific to processing faces they encounter most frequently based on their social environments, which in turn shape own-race discrimination abilities and lead to the visual advantages seen in the ORE literature.

Overall, our data are consistent with a differential-experience model of face processing, which argues that cognitive specialization develops in infancy due to environment interactions and inputs during critical developmental time points (Nelson 2001, 2003; Turati, Valenza, Leo & Simion, 2005). Infants in our sample did not exhibit better recognition for own-race compared to other-race faces, highlighting the possibility that differences in face discrimination may emerge for infants who grow up in more diverse social environments. We did find, however, that biracial infants who are regularly exposed to two different racial exemplars within their home environment employ a different strategy from monoracial infants to aid in own-race face discrimination. Thus, biracial infants utilized a different cognitive process from monoracial infants for the same outcome, which perhaps stems from their unique pattern of racial exposure. Infants' scanning processes of faces has been defined as an ongoing transition toward adult-like scanning (Bronson, 1994). Our findings demonstrate that early differences in racial exposure within the first months after birth may shape the *way* in which infants use their developing face processing skills.

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References

Bar-Haim, Y., Saidel, T., & Yovel, G. (2009). The role of skin colour in face recognition. *Perception*, **38**, 145–148.

Bar-Haim, Y., Ziv, T., Lamy, D., & Hodes, R.M. (2006). Nature and nurture in own-race face processing. *Psychological Science*, **17**, 159–163.

Brigham, J.C., & Malpass, R.S. (1985). The role of experience and contact in the recognition of faces of own- and other-race persons. *Journal of Social Issues*, **41**, 139–155.

Bronson, G.W. (1994). Infants' transitions towards adult-like scanning. *Child Development*, **65**, 1243–1261.

Bushnell, I.W., Sai, F., & Mullin, J.T. (1989). Neonatal recognition of the mother's face. *British Journal of Developmental Psychology*, **7**, 3–15.

de Heering, A., de Liedekerke, C., Deboni, M., & Rossion, B. (2010). The role of experience during childhood in shaping the other-race effect. *Developmental Science*, **13**, 181–187.

de Schonen, S., & Mathivet, H. (1989). First come, first served: a scenario about the development of hemispheric specialization of face recognition during early infancy. *European Bulletin of Cognitive Psychology*, **9**, 3–44.

Feinman, S., & Entwistle, D.R. (1976). Children's ability to recognize other children's faces. *Child Development*, **47**, 506–510.

Gauthier, I., & Nelson, C.A. (2001). The development of face expertise. *Current Opinion in Neurobiology*, **11**, 219–224.

Golby, A.J., Gabrieli, J.D.E., Chiao, J.Y., & Eberhardt, J.L. (2001). Differential fusiform responses to same- and other-race faces. *Nature Neuroscience*, **4**, 845–850.

Goodman, G.S., Sayfan, L., Lee, J.S., Sandhei, M., Walle-Olsen, A., Magnussen, S., Pezdek, K., & Arredondo, P. (2007). The development of memory for own- and other-race faces. *Journal of Experimental Child Psychology*, **98**, 233–242.

Goren, C.C., Sarty, M., & Wu, P.Y.K. (1975). Visual following and pattern discrimination of face-like stimuli by newborn infants. *Pediatrics*, **56**, 544–549.

Hayden, A., Bhatt, R.S., Joseph, J.E., & Tanaka, J.W. (2007). The other-race effect in infancy: evidence using a morphing technique. *Infancy*, **12**, 95–104.

Heron-Delaney, M., Anzures, G., Herbert, J.S., Quinn, P.C., Slater, A.M., Tanaka, J.W., Lee, K., & Pascalis, O. (2011). erceptual training prevents the emergence of the other race effect during infancy. *PLoS ONE*, **6**, e19858.

Hunnius, S., & Geuze, R.H. (2004). Developmental changes in visual scanning of dynamic faces and abstract stimuli in infants: a longitudinal study. *Infancy*, **6**, 231–255.

Kelly, D.J., Liu, S., Ge, L., Quinn, P.C., Slater, A.M., Lee, K., Liu, Q., & Pascalis, O. (2007a). Cross-race preferences for same-race faces extend beyond the African versus Caucasian contrast in 3-month-old infants. *Infancy*, **11**, 87–95.

Kelly, D.J., Liu, S., Lee, K., Quinn, P.C., Pascalis, O., Slater, A.M., & Ge, L. (2009). Development of the other-race effect during infancy: evidence toward universality? *Journal of Experimental Child Psychology*, **104**, 105–114.

Kelly, D.J., Quinn, P.C., Slater, A.M., Lee, K., Gibson, A., Smith, M., Ge, L., & Pascalis, O. (2005). Three-month-olds, but not newborns, prefer own-race faces. *Developmental Science*, **8**, F31–F36.

Kelly, D.J., Quinn, P.C., Slater, A.M., Lee, K., Gibson, A., Smith, M., Ge, L., & Pascalis, O. (2007b). The other-race effect develops during infancy: evidence of perceptual narrowing. *Psychological Science*, **18**, 1084–1089.

Lee, K., Anzures, G., Quinn, P.C., Pascalis, O., & Slater, A. (2011). Development of face processing expertise. In: A.J. Calder, G. Rhodes, M.H. Johnson, & J.V. Haxby (Eds.), *Handbook of face perception* (pp. 753–778). Oxford: Oxford University Press.

Liu, S., Quinn, P.C., Wheeler, A., Xiao, Ge, L., & Lee, K. (2011). Similarity and difference in the processing of same and other-race faces as revealed by eye tracking in 4- to 9-month- olds. *Journal of Experimental Child Psychology*, **108**, 180–189.

Maurer, D. (1983). The scanning of compound figures by young infants. *Journal of Experimental Child Psychology*, **35**, 437–448.

Moulson, M.C., Shannon, R.W., & Nelson, C.A. (2011). Neural correlates of visual recognition in 3-month-old infants: the role of experience. *Developmental Psychobiology*, **53**, 416–424.

Nelson, C.A. (2001). The development and neural bases of face recognition. *Infant and Child Development*, **10**, 3–18.

Nelson, C.A. (2003). The development of face recognition reflects an experience-expectant and activity dependent process. In O. Pascalis & A. Slater (Eds.), *The development of face processing in infancy and early childhood: Current perspectives* (pp. 79–97). New York: Nova Science.

Pascalis, O., de Haan, M., Nelson, C.A., & de Schonen, S. (1998). Long-term recognition memory for faces assessed by visual paired comparison in 3- and 6-month-old infants. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **24**, 249–260.

Pascalis, O., & de Schonen, S. (1994). Recognition memory in 3- to 4-day-old human neonates. *NeuroReport*, **5**, 1721–1724.

Pascalis, O., de Schonen, S., Morton, J., Deruelle, C., & Fabre-Grenet, M. (1995). Mother's face recognition in neonates: a replication and an extension. *Infant Behavior and Development*, **17**, 79–85.

Pauker, K., & Ambady, N. (2009). Multiracial faces: how categorization affects memory at the boundaries of race. *Journal of Social Issues*, **65**, 69–86.

Pearson, B.Z., Fernández, S.C., & Oller, D.K. (2006). Lexical development in blingual infants and toddlers: comparison to monolingual norms. *Language Learning*, **43**, 93–120.

Quinn, P.C., Uttley, L., Lee, K., Gibson, A., Smith, M., Slater, A.M., & Pascalis, O. (2008). Infant preference for female faces occurs for same- but not other-race faces. *Journal of Neuropsychology*, **2**, 15–26.

Quinn, P.C, Yahr, J., Kuhn, A., Slater, A.M., & Pascalis, O. (2002). Representation of the gender of human faces by infants: a preference for female. *Perception*, **31**, 1109–1121.

Sangrigoli, S., & de Schonen, S. (2004). Recognition of own-race and other-race faces by three-month-old infants. *Journal of Child Psychology and Psychiatry*, **45**, 1219–1227.

Sangrigoli, S., Pallier, C., Argenti, A.M., Ventureyra, V.A., & de Schonen, S. (2005). Reversibility of the other-race effect in face recognition during childhood. *Psychological Science*, **16**, 440–444.

Simion, F., Farroni, T., Cassia, V.M., Turati, C., & Dalla Barba, B. (2002). Newborns' local processing in schematic facelike configurations. *British Journal of Developmental Psychology*, **20**, 465–478.

Slater, A.M., Bremner, G., Johnson, S.P., Sherwood, P., Hayes, R., & Brown, E. (2000). Newborn infants' preference for attractive faces: the role of internal and external facial features. *Infancy*, **1**, 265–274.

Slater, A.M., von der Schulenburg, C., Brown, E., Badenoch, M., Butterworth, G., Parsons, S., & Samuels, C. (1998). Newborn infants prefer attractive faces. *Infant Behavior and Development*, **21**, 345–354.

Tottenham, N., Tanaka, J., Leon, A.C., McCarry, T., Nurse, M., Hare, T.A., Marcus, D.J., Westerlund, A., Casey, B.J., & Nelson, C.A. (2009). The NimStim set of facial expressions: judgments from untrained research participants. *Psychiatry Research*, **168**, 242–249.

Turati, C., Valenza, E., Leo, I., & Simion, F. (2005). Three-month-olds' visual preference for faces and its underlying visual processing mechanisms. *Experimental Child Psychology*, **90**, 255–273.

US Census Bureau (2010). State and county quick facts. Data derived from Population Estimates. Retrieved from: http://quickfacts.census.gov/qfd/states/00000.html

Valenza, E., Simion, F., Macchi Cassia, V., & Umiltà, C. (1996). Face preference at birth. *Journal of Experimental Psychology: Human Perception and Performance*, **22**, 892–903.

Wheeler, A., Anzures, G., Quinn, P.C., Pascalis, O., Omrin, D.S., & Lee, K. (2011). Caucasian infants scan own- and other-race faces differently. *PLoS ONE*, **6** (4), e18621.

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