PAPER

Building biases in infancy: the influence of race on face and voice emotion matching

Margaret Vogel, Alexandra Monesson and Lisa S. Scott

Department of Psychology, University of Massachusetts, Amherst, USA

Abstract

Early in the first year of life infants exhibit equivalent performance distinguishing among people within their own race and within other races. However, with development and experience, their face recognition skills become tuned to groups of people they interact with the most. This developmental tuning is hypothesized to be the origin of adult face processing biases including the other-race bias. In adults the other-race bias has also been associated with impairments in facial emotion processing for other-race faces. The present investigation aimed to show perceptual narrowing for other-race faces during infancy and to determine whether the race of a face influences infants' ability to match emotional sounds with emotional facial expressions. Behavioral (visual-paired comparison; VPC) and electrophysiological (event-related potentials; ERPs) measures were recorded in 5-month-old and 9-month-old infants. Behaviorally, 5-month-olds distinguished faces within their own race and within another race, whereas 9-month-olds only distinguish faces within their own race. ERPs were recorded while an emotion sound (laughing or crying) was presented prior to viewing an image of a static African American or Caucasian face expressing either a happy or a sad emotion. Consistent with behavioral findings, ERPs revealed race-specific perceptual processing of faces and emotion/sound face congruency at 9 months but not 5 months of age. In addition, from 5 to 9 months, the neural networks activated for sound/face congruency were found to shift from an anterior ERP component (Nc) related to attention to posterior ERP components (N290, P400) related to perception.

Introduction

Infants develop within a social world where they learn to attend and respond to people within their environment. Perceiving the emotions of others is an important skill that is thought to develop over the first year of life. Previous findings suggest that young infants are able to discriminate among several facial expressions (e.g. Barrera & Maurer, 1981; Striano, Brenna & Vanman, 2002; Nelson & Dolgin, 1985; Schwartz, Izard & Ansul, 1985). By 3 months of age, a greater number of infants can tell the difference between their smiling and frowning mother than a smiling and frowning female stranger, suggesting that experience may drive development of facial emotion processing (Barrera & Maurer, 1981). Findings from several investigations also suggest that infants can categorize emotions across individuals sometime between 3 and 7 months of age (Bornstein & Arterberry, 2003; Ludemann & Nelson, 1988; Nelson & Dolgin, 1985; Kotsoni, de Haan & Johnson, 2001).

However, emotion detection typically occurs within a multimodal context and infants likely use both visual and auditory information to detect and recognize emotions. By at least 3.5 months of age, infants are able to successfully match emotion sounds (happy/sad) with appropriate static face images; however, this ability is limited to the faces and sounds of familiar people (e.g. the father) and does not generalize to unfamiliar people (Montague & Walker-Andrews, 2001). Recently, in a study aimed at examining the underlying neural responses to face and voice pairs, event-related potentials (ERPs) were recorded from infants in response to congruent and incongruent emotional face and word pairs (Grossmann, Striano & Friederici, 2006). In this study, infants watched a static facial expression while listening to a spoken word in a tone of voice that was either congruent or incongruent with the facial expression. These authors found that 7-month-old ERPs differentiated congruent and incongruent word–face pairs. Thus, although the development of emotion processing likely develops well beyond infancy, extracting emotion information from faces and voices appears to develop during the first year of life.

Although studies suggest that experience likely plays a role in the development of emotion processing (Barrera & Maurer, 1981; Montague & Walker-Andrews, 2001), it is currently unclear what specific role face experience plays in shaping emotion processing during infancy. Studies investigating the development of emotion processing have been limited to faces of people from groups

Address for correspondence: Lisa S. Scott, Department of Psychology, University of Massachusetts Amherst, 413 Tobin Hall/135 Hicks Way, Amherst, MA 01003, USA; e-mail: lscott@psych.umass.edu

in which infants are highly familiar. Researchers have long debated whether facial emotion perception and recognition abilities vary by culture or are universal (Ekman, 1994; Izard, 1994). Within this debate, some have hypothesized that in-group familiarity increases perception and recognition of emotions expressed and perceived by members of the same racial or cultural group (Kilbride & Yarczower, 1983; Markham & Wang, 1996). Results from a meta-analysis examining 97 separate studies revealed that although emotions were universally recognized at above chance levels, there was a pervasive in-group advantage in emotion recognition accuracy (Elfenbein, Mandal, Ambady, Harizuka & Kumar, 2002). This advantage decreased when participants lived in more diverse regions or reported increased out-group experience (see Matsumoto, 2002, for criticisms of this meta-analysis). More recently, adults were found to confuse the facial expressions of 'fear' and 'disgust' when viewing faces within another culture (Jack, Blais, Scheepers, Schyns & Caldara, 2009). In this previous investigation, East Asian observers were impaired at differentiating emotions expressed by Western Caucasian faces. Moreover, eye-tracking results suggested that Eastern and Western observers use different visual strategies when fixating in-group and out-group emotion faces (Jack et al., 2009). These results suggest that emotion perception and recognition may be influenced by experience with certain groups of faces. If experience plays a critical role in the development of emotion perception, one would expect to find developmental differences during a time when infants are actively building expert representations for faces and using faces and voices to make inferences about emotions.

During the first year of life, face representations become tuned to environmentally salient faces (e.g. own-race faces) relative to less salient or less frequently encountered faces (e.g. other-race faces), a process called 'perceptual narrowing' (Kelly, Quinn, Slater, Lee, Ge & Pascalis, 2007; Kelly, Liu, Lee, Quinn, Pascalis, Slater & Ge, 2009; Nelson, 2001; Pascalis, de Haan & Nelson, 2002; Pascalis, Scott, Kelly, Shannon, Nicholson, Coleman & Nelson, 2005; Scott & Monesson, 2009; Scott, Pascalis & Nelson, 2007; Sugita, 2008). It has been suggested that perceptual narrowing is the origin of adult other-race biases, often called the 'other-race effect' (ORE) (Nelson, 2001). The ORE is characterized by increased difficulty recognizing or differentiating among faces from within another racial group (for review see Meissner & Brigham, 2001). Although the other-race bias is not present at birth (Kelly, Quinn, Slater, Lee, Gibson, Smith, Ge & Pascalis, 2005), it is present by the end of the first year of life (Anzures, Quinn, Pascalis, Slater & Lee, 2010; Hayden, Bhatt, Joseph & Tanaka, 2007, Kelly et al., 2007, 2009; Ferguson, Kulkofsky, Cashon & Casasola, 2009; Liu, Quinn, Wheeler, Xiao, Ge & Lee, 2011).

Investigations of the other-race effect overwhelmingly suggest that this bias is dependent on differential experi-ence with own- versus other-race faces (e.g. Chiroro & Valentine, 1995; de Heering, de Liedekerke, Deboni & Rossion, 2010; Rennels & Davis, 2008, Sangrigoli, Pallier, Argenti, Ventureyra & de Schonen, 2005). Recently, parents reported their infants' experiences with people during a one-week period (Rennels & Davis, 2008). Rennels and Davis (2008) found that infants primarily interact (92% of the time) with their primary caregiver (typically the mother) and other same-race individuals. Moreover, children raised in mixed-race environments have been found to show little to no other-race bias (Bar-Haim, Ziv, Lamy & Hodes, 2006; de Heering et al., 2010) or a reversal of the other-race bias (Sangrigoli et al., 2005) and infants trained with other-race faces exhibit a reduction of the other-race bias (Heron-Delaney, Anzures, Herbert, Quinn, Slater, Tanaka, Lee & Pascalis, 2011). Finally, the other-race bias, and other face processing biases, have been found to arise because infants do not typically learn to individuate faces (i.e. to match an individual-level proper name with an individual face) from unfamiliar groups (Scott & Monesson, 2009). When infants were trained to associate individual labels (e.g. 'Fiona') with individual monkey faces, from 6 to 9 months of age, they maintained the ability to tell the difference between individual monkey faces. However, training with category-level labels (e.g. all faces labeled 'Monkey') or exposure to faces without labels led to perceptual narrowing (Scott & Monesson, 2009). These results suggest that the other-race bias is influenced by individual-level experience with faces during development but researchers have yet to determine whether this experience influences aspects of face processing beyond perceptual differentiation, including face-related emotion processing.

The purpose of the present investigation was to examine whether the decline in ability to recognize other-race faces during the first year of life influences the ability to accurately match emotion sounds with images of faces expressing congruent or incongruent emotional expressions. Behavioral (visual-paired comparison (VPC)) and electrophysiological (ERP) measures were recorded in 5-month-old and 9-month-old infants. For the behavioral portion we set out to replicate previous studies (Kelly et al., 2007, 2009; Pascalis et al., 2002, 2005; Scott & Monesson, 2009) using a set of female faces in which low-level perceptual differences were reduced across races. We predicted that, similar to previous investigations, 5-month-old infants would differentiate faces within both races, whereas 9-month-olds would only differentiate faces within their own race.

Infants also completed an emotion sound and face matching task previously found to index emotion processing in infants (Grossman et al., 2006). For this task, infants passively heard and viewed randomized sound/face pairs including a short sound clip of a happy or sad sound and either a African American and Caucasian face expressing an incongruent or congruent emotion. ERPs were recorded in response to the emotion face. Infant ERP components previously found to index face per-

ception and general attentional capacities were examined at both ages for own- and other-race congruent and incongruent emotion sound/face pairs.

ERPs reflect the activity of simultaneously active populations of neurons in the cerebral cortex that result in electrical signals that propagate from the brain to the surface of the scalp and can be recorded, non-invasively, by the electrodes embedded in a net placed on the head (Luck, 2005; for review of using ERPs in infant populations see Johnson, de Haan, Oliver, Smith, Hatzakis, Tucker & Csibra, 2001; DeBoer, Scott & Nelson, 2007). In infants, face processing is indexed by two ERP components, the N290 and P400 (de Haan, Pascalis & Johnson, 2002b; Halit, de Haan & Johnson, 2003; Scott & Nelson, 2006; Scott, Shannon & Nelson, 2006; Scott & Monesson, 2010). These components are modulated by different emotional expressions (Kobiella, Grossmann, Reid & Striano, 2008; Leppänen, Moulson, Vogel-Farley & Nelson, 2007) and by experience with faces (Scott et al., 2006; Scott & Monesson, 2010). Previously, ERPs were recorded while 9-month-old infants viewed familiar and unfamiliar monkey or human faces in two different orientations (frontal view, side view) (Scott et al., 2006). Although faces modulated both the N290 and P400 components, the P400 exhibited a more specific response to human faces relative to monkey faces. In another study, infants were trained for 3 months with monkey faces that were labeled with individual-level proper names (Scott & Monesson, 2010). After training, an inversion effect was found for upright versus inverted monkey faces during the transition from the N290 to the P400 component. Critically, this inversion effect was not present before training, after category-level labeling (all faces labeled 'monkey'), or after simple exposure to monkey faces. These findings suggest that the P400, and to a lesser extent the N290, are influenced by previous face experience. Given these previous results, we expected race to also modulate the P400 component in infants.

ERPs have also been used to investigate the development of emotion processing. The amplitude of the negative central component (Nc), an infant ERP component related to attention (Reynolds, Courage & Richards, 2010) differentiates fearful relative to happy faces (Nelson & de Haan, 1996) and fearful relative to angry faces (Kobiella et al., 2008). Recently, the infant Nc component was found to be greater in response to emotionally incongruent face–word pairs compared to congruent pairs in 7-month-olds, suggesting that infants integrate emotion face/sound pairs using their attentional systems (as indexed by the Nc) (Grossman et al., 2006). However, it is unclear whether or not infants exhibit similar cross-modal integration when viewing and hearing face/sound pairs for unfamiliar face groups.

For the present investigation, it was predicted that the development of the other-race effect would impair infants' processing of voice and face emotion matching (consistent with Elfenbein et al., 2002; Jack et al., 2009). More specifically, we expected to find similar processing

of emotion sound/face pairs for other- and own-race faces in 5-month-old infants and impaired processing of emotion sound/face pairs for other-, but not own-race faces, in 9-month-old infants. However, it is possible that emotion processing develops independent of perceptual narrowing and the other-race bias. If this is the case we expected to see either no change or a general increase in matching emotion sound/face pairs from 5 to 9 months that is not influenced by the race of the face. Finally, it was predicted that both attention-based (Nc) and perceptually based (N290; P400) neural networks would be engaged while infants completed this task and that 9-month-olds would exhibit race-specific perceptual processing as indexed by the P400 component.

Methods

Participants

Each infant came to the lab for a single one-hour session, during which s/he completed both a behavioral VPC and an electrophysiological task. Each parent received $10 for participation, and his or her infant received a small toy. All parents reported their infants having had little to no previous experience with African American or other Black individuals (e.g. Black Caribbean or Black Africans). All infants included in the final behavioral and electrophysiological analyses were Caucasian. Due to the demanding nature of the tasks, overlapping, but separate groups of infants contributed to the behavioral and electrophysiological analyses. Thus, some of the infants included in the behavioral analyses were not included in the electrophysiological analyses and vice versa.

Participants for the behavioral portion of the study included 24 5-month-old infants ($M = 154.67$ days, $SD = 9.12$ days; 15 male, 9 female) and 24 9-month-old infants ($M = 275.33$ days, $SD = 12.08$ days; 15 male, 9 female). Of the 48 infants included for VPC analyses, 19 also contributed data to the electrophysiological analyses.[1] For the behavioral analysis, an additional 43 infants were excluded due to experimenter or technical error ($n = 8$), because they became fussy during testing ($n = 1$), because they exhibited a side looking bias ($n = 14$), because they failed to fixate both images during one of the test trials ($n = 18$), or because the infant was not Caucasian[2] ($n = 2$).

For the electrophysiological analyses, participants included 15 5-month-old infants ($M = 155.67$ days, $SD = 8.57$ days; 8 males, 7 females) and 17 9-month-old infants

[1] Every infant who came into the lab first completed the behavioral task and then the ERP task. However, both the behavioral and ERP data were not always usable.

[2] Only Caucasian and African American face stimuli were used in this investigation, so if parents reported their infant's race as anything other than Caucasian or African American we were unable to assign them to 'own' or 'other' race conditions and they were therefore excluded from analyses. No African American infants participated in this investigation.

(M = 276.47 days, SD = 10.03 days; 10 males, 7 females). Of these 32 infants, 19 also contributed data to the behavioral analyses. An additional 23 participants were excluded because their data contained a significant amount of noise (n = 7) or they did not complete enough trials (greater than 50 trials) to form an average (n = 16). All infants were born full-term and had no visual or neurological abnormalities.

Stimuli

For both the behavioral and electrophysiological procedure, face stimuli included eight different self-reported African American (four happy, four sad) and eight different self-reported Caucasian (four happy, four sad) female faces, from the MacArthur 'NimStim' face set (Tottenham, Tanaka, Leon, McCarry, Nurse, Hare, Marcus, Westerlund, Casey & Nelson, 2009). Four of the eight 'happy' faces were used for the behavioral VPC task (counterbalanced across subjects) and all eight faces ('happy' and 'sad') were used for the electrophysiological tasks. As reported in Tottenham and colleagues (2009), the faces used in the present experiment were from actors with kappas within the 'substantial' and 'almost perfect' range. All faces were cropped to exclude the hairline and neck and placed on a grey and white patterned background (see Figure 1 for examples of faces). The faces were converted to black and white and low-level perceptual differences (e.g. luminance and contrast) were reduced across faces by averaging dark and light pixel contrasts using a toolbox in MatLab called SHINE (Spectrum, Histogram, and Intensity Normalization and Equalization) (see Willenbockel, Fiset, Gosselin, Sadr, Horne & Tanaka, 2010, for more details). The SHINE toolbox was used to normalize and scale mean luminance and contrast differences across stimuli by equating the standard deviations of the luminance distribution. Individual faces were then edited for unnatural patches or distortions using Adobe Photoshop.

Auditory stimuli included 800 ms sound clips of female voices expressing happy (e.g. laughing) and sad (e.g. crying) sounds. These sounds were edited for length using a program called Audicity (GNU General Public License; GPL: Dominic Mazzoni). Adults (n = 8) participated in a pilot study in which they listened to several clips of a female voices laughing or crying and were asked to categorize the sounds. Of these clips, eight (four laughing, four crying) different sound clips were consistently categorized as either 'crying' or 'laughing' and were used for stimuli.

Procedure

All procedures were approved by the University Institutional Review Board and were conducted in accordance with this approval. At both ages, infants first completed a behavioral task designed to examine their ability to differentiate own- and other-race faces followed by an electrophysiological task designed to examine whether infants' neural responses differentiate sound/face emotion congruency for Caucasian and African American faces.

Behavioral procedure

We assessed 5- and 9-month-old infants' ability to distinguish among Caucasian and among African American female faces using the visual-paired comparison (VPC) procedure. Infants were seated on their caretaker's lap approximately 66.5 cm away from a computer monitor. Faces were presented on a 20-inch computer screen and were approximately 15.5 cm high and presented at a visual angle of approximately 13.50 degrees. A digital camera recorded the infants' looking behavior as they completed this task. Infants were first familiarized to two, side-by-side, images of the same smiling (i.e. 'happy') female face for an accumulated looking time of 30 seconds. The familiarized face was either African American or Caucasian. After familiarization, infants viewed the familiarized happy face paired, side-by-side, with a novel happy face of the same race as the familiarized face, for an accumulated looking time of 10 seconds. The side of stimulus presentation was switched after 5 seconds. After the first VPC task, infants completed a second task using faces from whichever race was not previously viewed. Order and race were counterbalanced across participants and only happy faces were used for the VPC task.

Behavioral analyses

To calculate duration of fixation to the novel and familiar stimuli, digital videos of infants were slowed to 20% of their normal speed, and visual fixations to each stimulus were coded using Noldus, The Observer XT (Version 7.0, Leesburg, VA). Two separate observers (inter-observer agreement was greater than 85% across participants), blind to the conditions, coded proportion looking to the familiar and novel images. Measures of looking time were averaged across the two 5-second test trials and then converted into percent fixation for the novel stimuli. Infants were excluded from analyses if they failed to fixate both side-by-side test trial images (i.e. zero looking to one of the pictures), or if 90% or more of their total test trial looking was to one side of the screen. Two-tailed t-tests determined whether percent time fixating the own-race novel face differed from percent time fixating the other-race novel face. In addition, one-tailed t-tests compared the percentage of time infants fixated the novel image to chance (50%) for both own- and other-race faces. Behavioral analyses were based on *a priori* hypotheses and therefore uncorrected p-values are reported.

Electrophysiological procedure

After completing the VPC task, infants were fitted with a 128-channel Geodesic Sensor Net (Electrical Geodesics,

Inc., Eugene, Oregon), connected to a DC-coupled 128-channel high input impedance amplifier (Net Amps 300, Electrical Geodesics). Infants sat on their caregiver's lap approximately 66.5 cm away from a computer monitor. After net placement, infants passively heard and viewed randomized pairs of incongruent (e.g. Happy Sound/Sad Face or Sad Sound/Happy Face) and congruent (e.g. Happy Sound/Happy Face or Sad Sound/Sad Face) African American and Caucasian face/voice pairs (see Figure 1). Experimenters viewed infants' fixation to the screen via a live video feed and presented trials only when infants were attending to and fixating the computer screen. Each trial began with a black fixation-cross presented on a gray and white patterned background. Once attending, infants were presented with an 800 ms sound clip of a female voice expressing either a happy (laughing) or sad (crying) emotion sound. Following the presentation of the sound, a fixation cross was presented on a gray and white patterned background for 1000 ms. After the fixation cross, either a happy or sad African American or Caucasian female face was presented for 500 ms. The inter-trial interval was at least 1000 ms, but the total duration varied depending on whether or not the infant was fixating the screen. If infants became distracted, an experimenter briefly tapped on the bottom of the computer monitor. If infants did not redirect their attention, the experimenter viewing the infant via live video feed paused the experiment and presented digital images/sounds of 'Elmo' until they fixated the screen.

Amplified analog voltages (100 Hz lowpass) were digitized at 500 Hz. Individual electrodes were adjusted until impedances were less than 50 kΩ. Post-recording processing was completed using Netstation 4.3 (Electrical Geodesics, Inc., Eugene, OR). EEG was digitally low-pass filtered at 40 Hz. ERPs were segmented to the presentation of the face and baseline corrected with respect to a 100 ms pre-stimulus recording interval. An average reference was used to minimize the effects of reference site activity and accurately estimate the scalp topography of ERPs recorded from a high-density electrode montage (Dien, 1998). Trials were discarded from analyses if they contained more than 12 bad channels (changing more than 300 microvolts within the entire segment). Individual channels that were consistently bad (off-scale on more than 70% of the trials) were replaced using a spherical interpolation algorithm (Srinivasan, Nunez, Tucker, Silberstein & Cadusch, 1996).

Following artifact detection, each trial was visually inspected for noise and was rejected if a significant amount of noise or drift was present. Five-month-olds completed an average of 95.93 (SD = 13.71) sound/face pair trials and an average of 22.40 (SD = 4.85) trials were included in the Caucasian congruent condition, 21.20 (SD = 4.30) trials were included in the African American congruent condition, 20.00 (SD = 5.18) trials were included in the Caucasian incongruent condition, and 21.53 (SD = 5.68) trials were included in the African
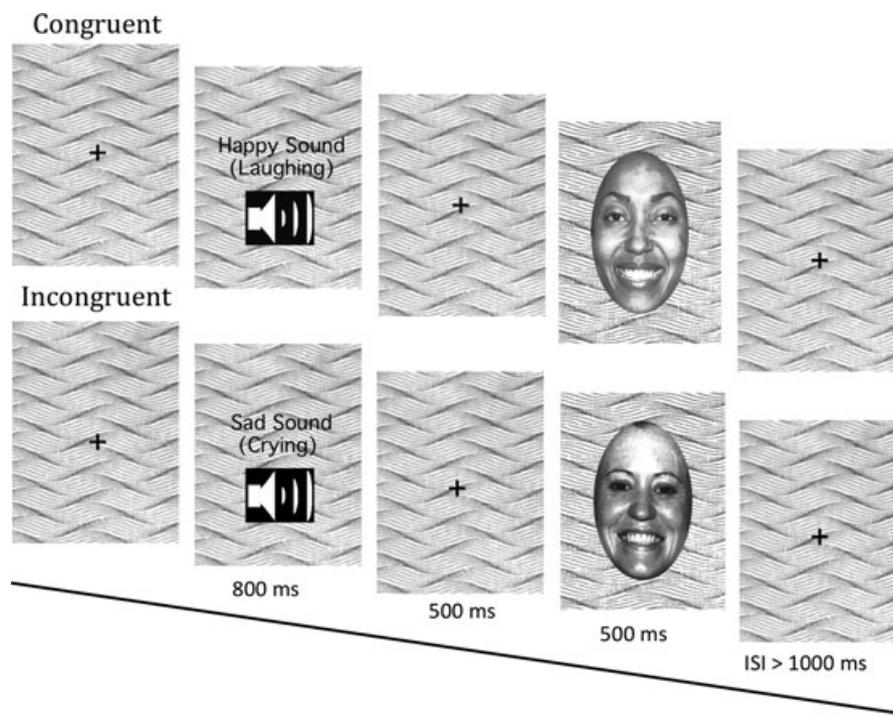
Figure 1 *Event-related potential Emotion Sound/Face Congruency Task. This figure shows two example ERP trials. Infants were presented with a fixation cross until they directed their attention to the screen. Then they were presented with either a laughing or crying sound followed by a second fixation cross, which was followed by either an African American or a Caucasian face. Sound/face pairs were either congruent (emotion of the sound and face matched) or incongruent (emotion of the sound and face did not match).*

American incongruent condition. Nine-month-olds completed an average of 92.28 (*SD* = 19.69) sound/face pair trials and an average of 19.47 (*SD* = 5.22) trials were included in the Caucasian congruent condition, 21.00 (*SD* = 7.43) trials were included in the African American congruent condition, 21.88 (*SD* = 7.00) trials were included in the Caucasian incongruent condition, and 20.65 (*SD* = 7.13) trials were included in the African American incongruent condition.

Electrophysiological analyses

Responses to happy and sad faces were collapsed across conditions (due to low trial counts) and analyses focused on determining whether the race of the face influenced infants' electrophysiological responses to congruent and incongruent sound/face pairs. Analyses examined mean amplitude and peak latency differences for the face, in response to own- and other-race congruent and incongruent sound/face pairs within each age group for the N290, P400, and Nc components. For the N290 and P400, electrodes within three occipital-temporal regions were averaged for analyses (Left Occipital-Temporal Region: 64, 69, 63, 68, 73; Middle Occipital Region: 70, 75, 83, 74, 82; Right Occipital-Temporal Region: 95, 89,

99, 94, 88) (see Figure 2). These regions were chosen based on previous reports of these components (de Haan *et al.*, 2002b; Scott & Monesson, 2010; Scott & Nelson, 2006; Scott *et al.*, 2006) and visual inspection of the component topography. Based on visual inspection and previous reports of the Nc component (Courchesne, Ganz & Norcia, 1981; Grossman *et al.*, 2006; Grossmann, Striano & Friederici, 2007; Webb, Long & Nelson, 2005) electrodes within frontal (16, 11, 12, 5; corresponding to Fz) and central (6, 7, 106, REF; corresponding to Cz) regions were averaged for analyses (see Figure 2).

Windows for analyses were chosen based on previous infant ERP reports of these components (Courchesne *et al.*, 1981; de Haan & Nelson, 1997, 1999; Grossman *et al.*, 2006; Halit *et al.*, 2003; Hoehl & Striano, 2008; Leppänen *et al.*, 2007; Reynolds *et al.*, 2010; Scott & Monesson, 2010; Scott *et al.*, 2006; Stahl, Parise, Hoehl & Striano, 2010; Webb *et al.*, 2005; Webb & Nelson, 2001) and on an examination of the peak of each component across participants. Mean amplitude of the N290 was measured between 200 and 320 ms after stimulus onset for 5-month-olds and 210–290 ms after stimulus onset for 9-month-olds. Mean amplitude of the P400 was measured 320–450 ms after stimulus onset for
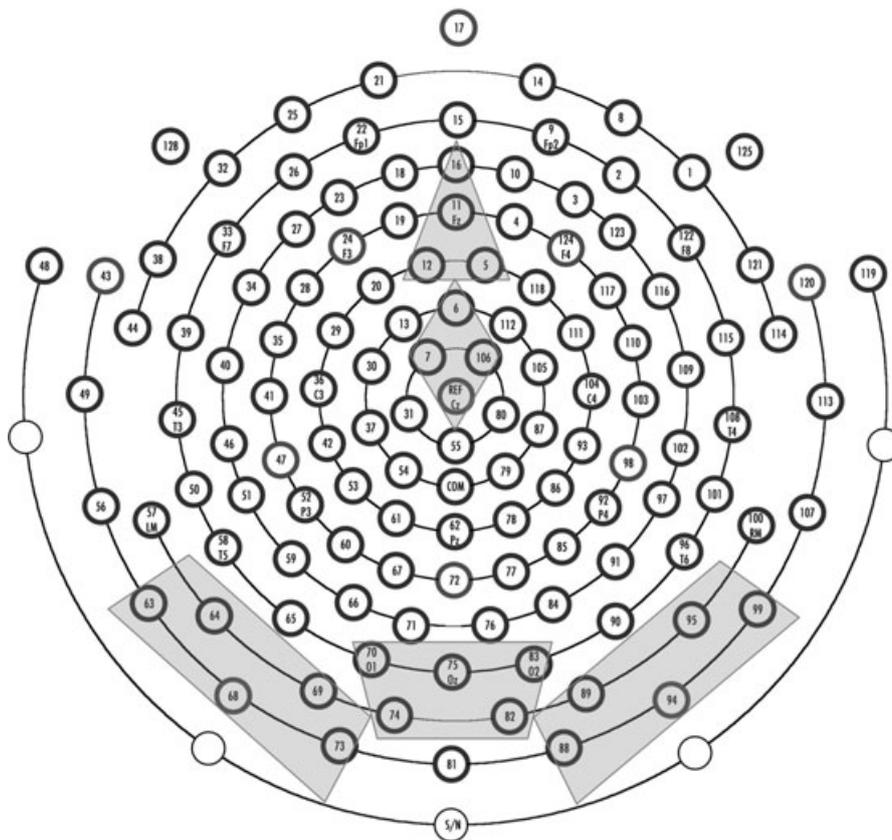
Figure 2   *Regions selected for ERP analyses for the Nc (frontal and central regions) and the N290 and P400 (left occipital-temporal, middle occipital, right occipital-temporal) components.*

5-month-olds and 340–420 ms for 9-month-olds. Mean amplitude and latency of the Nc component were measured within the window of 380–700 ms after stimulus onset for 5-month-olds and 300–570 ms after stimulus onset for 9-month-olds.

For the N290 and P400, mean amplitudes and peak latencies were submitted to separate 2 × 2 × 3 MANOVAs for each age group, including 2 levels of Congruency (Congruent sound/face pair, Incongruent sound/face pair), 2 levels of Race (Own race, Other race), and 3 levels of region (Right, Middle, Left). For the Nc, mean amplitudes and peak latencies were submitted to separate 2 × 2 × 2 MANOVAs for each age group, including 2 levels of congruency (same as above), 2 levels of race (same as above), and 2 levels of region (Frontal, Central). Follow-up analyses of significant interactions were conducted using paired-sample t-tests. P-values of paired-sample t-tests were Bonferroni corrected. Only significant ($p < .05$) and marginally significant ($p < .07$) results are reported.

Results

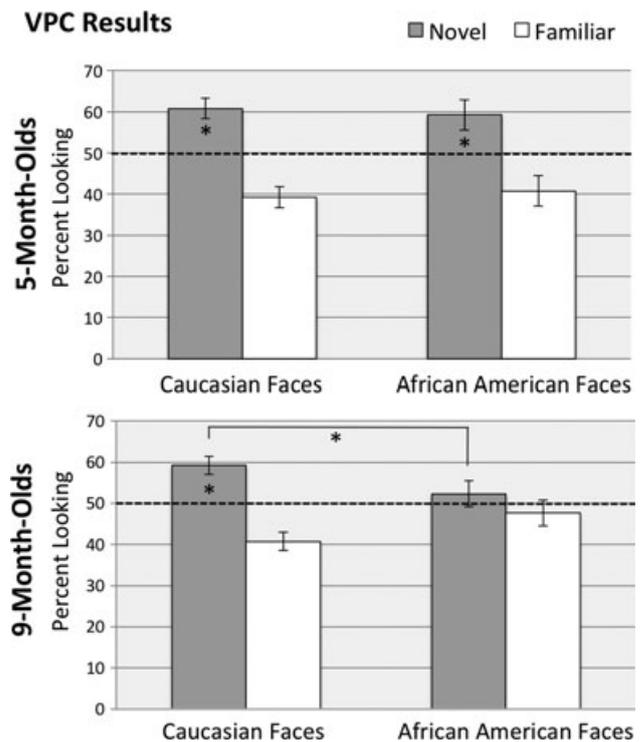### Visual paired comparison (VPC) results: 5- and 9-month-old infants

Within each age group, planned paired t-tests were conducted to determine whether the percent looking toward the novel stimulus was significantly different for own- versus other-race faces. The results of these analyses showed no difference in percent novelty preference for own-race and for other-race faces at 5 months of age ($t(23) = 1.56$, $p = .74$). However, 9-month-old infants exhibited a significantly greater novelty preference for own-race faces relative to other-race faces ($t(23) = 6.92$, $p < .05$) (see Figure 3).

One-tailed t-tests were also used to compare the percent fixation toward the novel stimulus with chance (50%) for both the own-race and other-race trials. Five-month-olds exhibited novelty preferences for both own- ($M = 60.8\%$, $SE = 2.5\%$; $t(23) = 4.3$, $p < .001$) and other- ($M = 59.2\%$, $SE = 3.6\%$; $t(23) = 2.5$, $p < .05$) race faces. Nine-month-old infants exhibited a novelty preference for own-race faces ($M = 59.2\%$, $SE = 2.2\%$; $t(23) = 4.3$, $p < .001$) but not for other-race faces ($M = 52.3\%$, $SE = 3.2\%$, $t(23) = .73$, $p = .47$) (see Figure 3).

Electrophysiological results: 5- and 9-month-old infants

N290: 5-month-old infants

For 5-month-olds, amplitude analyses demonstrated a significant main effect Region ($F(2, 13) = 9.84$, $p < .01$; $\eta^2 = .60$) due to a more negative amplitude N290 recorded over the right and left hemispheres relative to the middle occipital region ($ps < .05$). No significant latency effects were found for the N290 for 5-month-old infants.
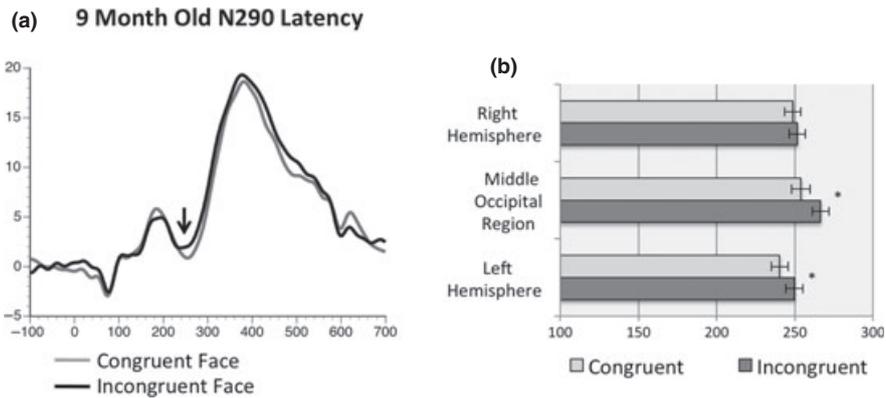
Figure 3 *Behavioral visual-paired comparison (VPC) results. All infants completed one VPC task for Caucasian faces and a second VPC for African American faces. Pictured is mean percent looking (±SE) toward the novel and familiar stimuli after 30 seconds of familiarization to the familiar face. Whereas 5-month-old infants looked longer to the novel Caucasian and African American faces, showing evidence of discrimination for both races, 9-month-old infants only looked longer to novel Caucasian faces.*

N290: 9-month-old infants

Nine-month-olds exhibited a significant main effect of Region ($F(2, 15) = 22.44$, $p < .05$; $\eta^2 = .75$) due to a more negative amplitude N290 recorded over the left and the right hemispheres relative to the middle occipital region ($ps < .05$). Latency analyses of the N290 revealed a main effect of Congruency ($F(1, 16) = 7.03$, $p < .05$, $\eta^2 = .31$) and a main effect of Region ($F(2, 15) = 5.82$, $p < .01$, $\eta^2 = .44$). The main effect of Congruency was due to a faster latency to peak N290 for incongruent versus congruent sound/face pairs (see Figure 4a) and the main effect of Region was due to a faster latency to peak in the left occipital relative to the middle occipital region. Analyses also showed a marginal interaction between Congruency and Region ($F(2, 15) = 3.23$, $p = .07$, $\eta^2 = .30$) due to a faster latency to peak N290 for incongruent relative to congruent sound/face pairs in the left hemisphere ($t(16) = -2.10$, $p < .05$) and the middle occipital region ($t(16) = -2.92$, $p < .05$), but not in the right hemisphere (see Figure 4b).

P400: 5-month-old infants

Analyses of the P400 revealed a main effect of Region ($F(2, 13) = 8.53$, $p < .01$; $\eta^2 = .57$) due to a smaller P400

(a)   **9 Month Old N290 Latency**

(b)

Congruent Face
Incongruent Face

Right Hemisphere
Middle Occipital Region
Left Hemisphere
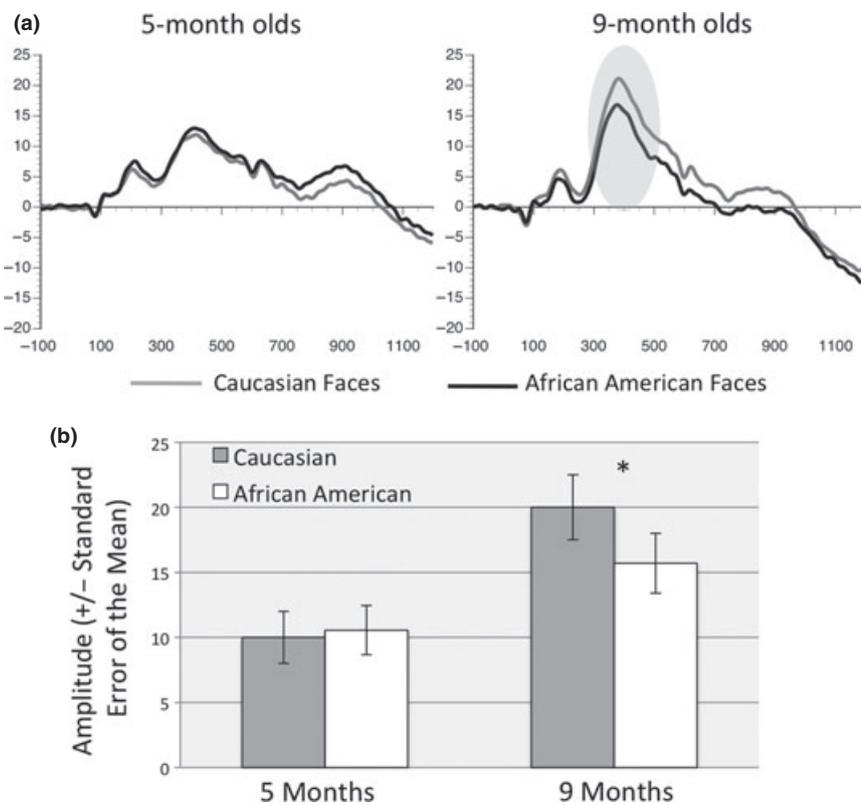
Congruent   Incongruent

Figure 4   *N290 component in 9-month-old infants: (a) ERP response to congruent versus incongruent faces. The response to congruent faces peaked earlier than the response to incongruent faces. (b) This earlier peaking N290 was primarily driven by latency differences recorded over in the left hemisphere and middle occipital regions.*

in the left hemisphere relative to the middle occipital region ($p < .05$) and a marginally smaller P400 in the left relative to the right hemisphere ($p < .09$). No other significant main effects or interactions were found for this component. No significant latency effects were found for the P400.

P400: 9-month-old infants

Amplitude analyses for 9-month-old infants showed significant main effects of Race ($F(1, 16) = 5.12$, $p < .05$;

$\eta^2 = .24$) and of Region ($F(2, 15) = 4.35$, $p < .05$; $\eta^2 = .36$). The main effect of Race was due to a larger P400 amplitude in response to Caucasian faces compared to African American faces (see Figure 5). The main effect of Region was due to a greater P400 amplitude recorded over the middle occipital region relative to the right hemisphere ($p < .05$). Latency analyses for the P400 showed a main effect of Region ($F(2, 15) = 7.25$, $p < .01$; $\eta^2 = .49$), due to a faster latency to peak P400 in the right relative to the left hemisphere. In addition, 9-month-olds exhibited an interaction between

(a)   5-month olds   9-month olds

Caucasian Faces   African American Faces

(b)

Amplitude (+/– Standard Error of the Mean)

Caucasian
African American

5 Months   9 Months

Figure 5   *Perceptual processing of own- and other-face faces. (a) P400 component in response to African American and Caucasian faces, collapsed across congruent and incongruent trials. The P400 response to Caucasian faces was significantly greater than the response to African American faces in 9- but not 5-month-old infants (shaded area denotes significant amplitude difference). (b) Mean amplitude (±SEM) for the P400 for both ages.*

Congruency and Race (F(1, 16) = 6.43, p < .05, η^2 = .29) and between Race and Region (F(2, 15) = 3.88, p < .05, η^2 = .34). The interaction between Congruency and Race was due to a faster latency P400 peak for Caucasian incongruent compared to Caucasian congruent face/sound pairs (t(16) = 2.24, p < .05; Figure 6). No differences were found between African American congruent and incongruent sound/face pairs. The interaction between Race and Region was due to a slower latency P400 to Caucasian faces in the left hemisphere relative to the middle occipital region (t(16) = 2.70, p < .05) and right hemisphere (t(16) = 4.35, p < .05). No differences were found for African American faces.

sound/face pair and Region (F(1, 14) = 5.80, p < .05; η^2 = .30). The main effect of Region was due to a more negative amplitude Nc recorded over frontal, relative to the central, regions. The interaction between Congruency and Region was driven by a more negative Nc in response to congruent relative to incongruent sound/face pairs recorded over frontal scalp regions (t(14) = −2.33, p < .05; see Figure 7 and Table 1) and by a more negative Nc to congruent sound/face pairs over the frontal compared to central scalp regions (t(14) = −3.79, p < .01). No significant effects of race were found for this component and no significant latency differences were found.
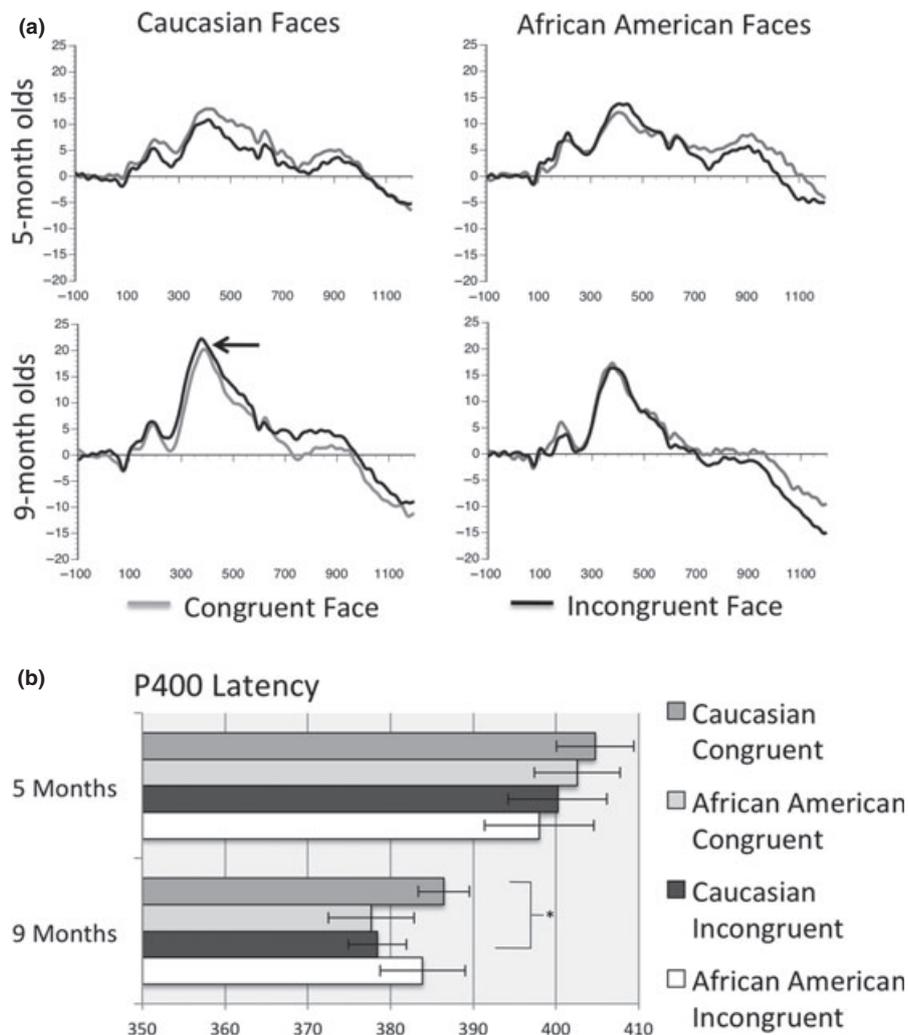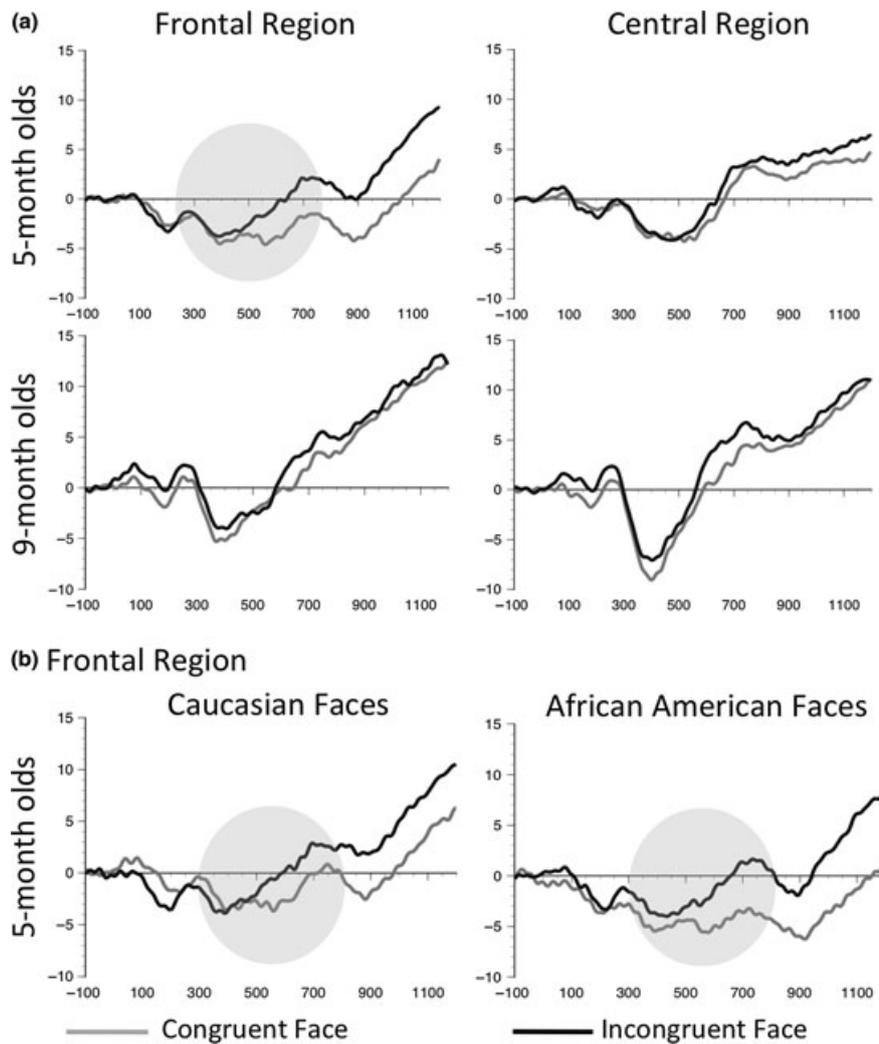
Nc: 5-month-old infants

Analyses of the Nc component showed a significant main effect of Region (F(1, 14) = 9.05), p < .01; η^2 = .40) and a significant interaction between Congruency of the

Nc: 9-month-old infants

Amplitude analyses revealed a significant main effect of region (F(1,16) = 6.42, p < .05; η^2 = .27) due to a larger amplitude Nc recorded over the central compared to

Figure 6 *Perceptual processing of congruency. (a) Illustrates the P400 component in response to African American and Caucasian congruent and incongruent sound/face pairs in 5-month-old and 9-month-old infants (arrow denotes significant latency differences). (b) Mean Latency (±SEM) for the P400, across conditions, for both ages. In 9-month-old infants the latency in response to the Caucasian incongruent condition peaked faster than the Caucasian congruent condition. No differences were found for 5-month-old infants.*

Figure 7 *Negative central (Nc) component. (a) Illustrates the Nc component in 5- and 9-month-old infants. Five-month-old infants exhibited a more negative Nc response, over the frontal region, to congruent relative to incongruent faces (shaded area denotes significant differences). No significant differences were found for 9-month-olds. (b) Illustrates the similar Nc response to Caucasian and African American faces in 5-month-olds.*

Table 1 *Nc component mean amplitude (SE)*

Condition/region	5-month-olds	9-month-olds
Frontal congruent	−2.75 (2.10)*	−3.5 (1.94)
Frontal incongruent	2.69 (1.67)*	−6.01 (1.64)
Central congruent	1.48 (1.31)	−2.38 (1.96)
Central incongruent	3.97 (1.10)	−4.77 (1.67)

Note: *$p < .05$

frontal region. No other significant amplitude or latency differences were found for the Nc component (see Figure 7).

Discussion

The present investigation was designed to determine whether perceptual narrowing and the development of the other-race effect influences the development of the ability to match emotion faces and sounds. Here we first replicated previous perceptual narrowing results (Pascalis *et al.*, 2002, 2005; Kelly *et al.*, 2007, 2009; Scott & Monesson, 2009) using a new set of own- and other-race stimuli in which low-level perceptual differences were reduced. We found that whereas 5-month-old infants discriminated faces within both races, 9-month-olds only discriminated faces within their own race.

Second, if face and sound emotion matching develops independent of face biases, such as the other-race effect, we would expect to find either an increase in facial emotion processing with age or no differences between the ages. However, when infants were presented with an emotion sound (laughing or crying) followed by an image of a static African American or Caucasian face expressing either a happy or a sad emotion, 9- and 5-month-olds exhibit differential neural processing of emotion congruency for own- and other-race faces. Findings revealed

race-specific perceptual processing of emotion-related face stimuli at 9 months, whereas 5-month-olds exhibited similar neural processing of both own- and other-race faces. In addition, the neural networks activated for sound/face congruency were found to shift from an anterior ERP component (Nc) to more posterior ERP components (N290, P400) from 5 to 9 months of age. The 5-month frontally distributed Nc response did not differ by race. However, the 9-month occipital-temporal response (P400) was race specific and only differentiated congruent versus incongruent sound/face pairs for own-race faces. The shift in neural processing with age occurs coincident with the decrease in ability to behaviorally discriminate among other-race faces.

Overall, the present findings suggest that perceptual narrowing and the development of the ORE influence the development of emotion processing during the first year of life. Here we report that although 5-month-old infants differentiated among faces from both their own race and the other race, 9-month-old infants only differentiated among own-race faces (see Figure 3). These results replicate previous findings from studies investigating the development of the ability to differentiate among faces within familiar versus unfamiliar groups during the first year of life (Anzures *et al.*, 2010; Kelly *et al.*, 2007, 2009; Pascalis *et al.*, 2002, 2005; Scott & Monesson, 2009). Notably, these effects were found after reducing low-level perceptual differences in color, contrast, luminance, and after excluding external facial features. These controls allow us to infer that the differences found were not due to low-level stimulus properties and suggest that, similar to adults (Bar-Haim, Saidel & Yovel, 2009) the 9-month-old ORE is not due to color differences across own- and other-race faces.

The results of the electrophysiological analyses allow us to make three important conclusions about the development of the ORE and its influence on emotion processing. First, consistent with current and previous behavioral findings described above, the neural response to own- and other-race faces, as indexed primarily by the P400, is differentiated in 9-, but not 5-month-old infants (see Figure 5). Second, coincident with the decline in ability to perceptually discriminate among other-race faces, infants also decline in the ability to match emotionally congruent sounds with other-race emotion faces. This is the first investigation of this effect in infancy and is consistent with previous behavioral research with children and adults suggesting that emotion recognition is less accurate for other-race relative to own-race faces (Elfenbein *et al.*, 2002; Jack *et al.*, 2009; Kilbride & Yarczower, 1983; Markham & Wang, 1996). Finally, electrophysiological results extend previous behavioral findings and reveal that 5- and 9-month-old infants are processing emotion sound/face congruency using distinct neural systems.

The infant N290 and P400 ERP components, found over occipital and temporal scalp regions, have previously been found to index infant face processing (de

Haan, Humphreys & Johnson, 2002a; Halit *et al.*, 2003; Scott & Monesson, 2010; Scott & Nelson, 2006). These components are thought to be precursors to the adult N170 (de Haan et al., 2002b; Scott & Nelson, 2006), but the exact nature of how the effects found across two components in infancy combine or shift into a single adult component is presently unknown. Here, the P400 race difference found for 9-month-old infants is consistent with N170 race effects in adults (Gajewski, Schlegel & Stoerig, 2008) and with previous findings suggesting that the infant P400 responds differentially to familiar versus unfamiliar face groups (Scott *et al.*, 2006). Although caution must be exercised when interpreting null results, 5-month-old infants did not exhibit differential neural processing for own- versus other-race faces for the N290 or the P400, suggesting a lack of specialized perceptual processing at this age.

In addition, the N290 in 9-month-old infants peaked earlier for incongruent versus congruent sound/face pairs. This main effect of congruency did not significantly interact with race, but it does appear to be driven by the own-race faces (see Figure 6a). The P400 component peaked significantly faster for own-race incongruent, relative to congruent, sound/face pairs but did not differentiate other-race incongruent and congruent sound/face pairs (see Figure 6a and b). Thus, unlike 5-month-olds, neural processing of emotion-related face information in 9-month-olds is influenced by the race of the face.

The infant Nc component is recorded over frontal and central scalp regions and is thought to originate from neural systems underlying general arousal and attention including the prefrontal cortex and the anterior cingulate cortex (Reynolds *et al.*, 2010). The Nc tends to be larger for novel or infrequently presented stimuli, but is also sensitive to task context and is larger during periods of attention compared to inattention (Richards, 2003). In a previous investigation, 7-month-olds were found to detect emotionally congruent and incongruent face–voice pairs using ERP measures (Grossman *et al.*, 2006). These researchers found that the infant Nc, in response to a word, was significantly more negative for incongruent compared to congruent face/word pairs. In our investigation, 5-month-olds exhibited a larger Nc, in response to the face, for congruent compared to incongruent sound/face pairs (see Figure 7). Although, the differential processing of congruent and incongruent emotional stimuli for the Nc is consistent across studies, the direction of Nc congruency effect reported here is opposite to that previously reported (Grossman *et al.*, 2006). This could be due to the fact that (a) the Nc in the present investigation was in response to the face and not a word, (b) here we examined younger infants, or (c) the context of the task led to increased attention toward congruent relative to incongruent sound/face pairs. Although more work is needed to resolve this discrepancy, the present results suggest that 5-month-olds are recruiting neural systems involved in sustained attention in order to detect congruent and incongruent sound/face pairs. In

contrast, the Nc in 9-month-olds did not significantly differentiate sound/face congruency or race information, suggesting that their perceptual systems (as indexed by the N290 and the P400) are processing this information without the help of more anterior brain regions. However, as can be seen in Figure 7a and Table 1, 9-month-olds exhibit small numerical (but not statistical) differences between congruent and incongruent sound/face pairs. These numerical differences are difficult to interpret but suggest that this task may still recruit anterior neural regions for 9-month-olds, but to a lesser extent than 5-month-olds. Regardless, these results imply that the neural networks used to process emotion sound/face congruency change during development. This regional shift is likely a influenced by perceptual narrowing and the development of highly specialized perceptual systems. This shift in neural activity is noteworthy because it suggests that perceptual narrowing may be the result of a shift in processing from a primarily attention-based system to a primarily perceptual based system not simply just a refinement of a single broad perceptual system.

Previous findings suggest that highly specialized perceptual systems are developing in response to faces that infants (Scott & Monesson, 2010) and adults (McGugin, McKeeff, Tong & Gauthier, 2010; Tanaka & Pierce, 2009) learn at the individual level. The current behavioral and ERP findings are consistent with these results and suggest that between 5 and 9 months of age infants are shifting their attention allocation to face groups for which they have more individuating experience. However, more research, including studies that train infants with other-race faces, is needed in order to directly link experience-based differences in individuating other-race faces with impairments in emotion processing for other-race faces.

Overall, the results of the present investigation replicated previous behavioral findings and revealed race-specific face processing by 9 months of age. Thus, similar to language development, infants come to this world with broad abilities to equally differentiate among faces within other-races (Anzures *et al.*, 2010; Kelly *et al.*, 2007, 2009) and other species (Pascalis *et al.*, 2002; Pascalis *et al.*, 2005; Scott & Monesson, 2009). However, by 9 months of age, these broad abilities subsequently narrow and become specific to faces within groups infants have experience individuating (Scott & Monesson, 2009). The present results suggest that the process of perceptual narrowing also influences the development of infants' face and sound emotion matching and that this processing shifts from anterior to posterior neural regions from 5 to 9 months of age.

Acknowledgements

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