

**THE INFLUENCE OF PERCEPTIONAL NARROWING ON EMOTION
PROCESSING DURING INFANCY**

A Thesis Presented

by

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ABSTRACT

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FEBURARY 2012

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During the first year of life, infants' capacities for face processing are shaped by experience with faces in their environment; a process known as perceptual narrowing. Perceptual narrowing has been found to lead to a decline in infants' abilities to identify and differentiate faces of other races. In the current study, it is hypothesized that this decline may also lead to differential processing of emotion information in own- versus other-race faces. In the current research, we recorded electrophysiological data (Event-related potential; ERP) from 5- and 9-month-old infants while they were presented with paired emotion non-verbal sounds and faces. ERPs in response to the sounds suggest that both 5- and 9-month old infants differentiate happy and sad sounds. The pattern of results, however, is different across ages. ERPs in response to the faces suggest that whereas 5-month-olds exhibit differential responses to happy and sad faces for both the N290 and P400 components, 9-month-olds did not differentiate happy and sad faces. Nine-month old infants did exhibit a great P400 in response to own- relative to other-race faces. These results suggest that although both 5- and 9-month olds differentiate happy and sad emotional sounds, their processing of emotion faces differs.

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CHAPTER I

OBJECTIVES AND BACKGROUND

Introduction

From the first minutes of life, infants are bombarded with faces expressing emotions. Infants immediately express a preference for faces or face-like stimuli and patterns relative to other visual stimuli (Fantz, 1963; Goren et al., 1975; Johnson et al., 1991). Although infants prefer faces at birth, face processing with unfamiliar groups of faces becomes increasingly difficult as infants age (e.g., monkey faces; Pascalis, de Haan & Nelson, 2002). This process, known as perceptual narrowing, leads to a face processing bias whereby infants show a decrease in their ability to distinguish among faces within unfamiliar groups (i.e., other-race faces; Kelly et al., 2007; 2009). In addition, faces convey salient information about emotions, which guide infants' social development and their interactions with the environment (e.g. social referencing of caregivers; Moses, Baldwin, Rosicky & Tidball, 2001). However, it is currently unclear whether infants process the facial emotions of familiar and unfamiliar groups differently. The present study will investigate whether the development of perceptual narrowing affects the processing of emotional sounds and faces.

Understanding whether or not humans differentially process faces and emotions of people of other races has important implications for society. For example, perceptual biases in adults can lead to inaccuracies identifying faces of other races in eyewitness testimony (Slone, Brigham, & Meissner, 2000). The current research may provide insight into the development of perceptual biases, such as the other-race effect, which

may in turn lead to deficits in emotion processing and recognition of unfamiliar groups of faces.

The present study uses electrophysiological measures to investigate the development of sound and face emotion processing. Event-Related Potentials (ERPs) measure brain activity in response to discrete stimuli such as a sounds or visual images. ERPs have been used to examine recognition, perception, attention, and memory for faces and sounds in both infants and adults (DeBoer, Scott & Nelson, 2007). ERPs are particularly advantageous in research with non-verbal populations because they provide an index of the neural basis of abilities without the need for manual or verbal responses (DeBoer et al., 2007).

Face-processing abilities, such as face discrimination, change with age and experience (Pascalis et al., 2002; 2005). The theory of perceptual narrowing proposes that the development of face processing abilities during infancy becomes gradually more specific to face groups with which infants have experience (for review see Scott, Pascalis & Nelson, 2007). Pascalis and colleagues (2002) conducted a study examining 6-month-old and 9-month-old infants' and adults' perception of monkey and human faces. Using a visual paired comparison task (VPC), 6-month-olds were found to discriminate amongst both monkey and human faces. Nine-month-old participants and adults were only able to discriminate amongst familiar human faces, but not the monkey faces, a phenomenon known as the other-species effect (Pascalis et al., 2002; 2005; Scott & Monesson, 2009; 2010). These results suggest a decline in the ability to discriminate among unfamiliar face groups from 6 to 9 months of age. This decline in face processing ability is mediated by experiences learning to individuate faces for some face groups relative to other face

groups (e.g., learning at an individual level for each face) and prevented this perceptual decline in monkey face processing (Scott & Monesson, 2009) from 6 to 9 months of age.

To further examine the role of experience in the other-species effect, a two part training study was conducted with 6- and 9-month-old infants (Scott & Monesson, 2009). Six-month-old infants were given training experience with unfamiliar faces (e.g., monkey faces) and were tested on their ability to differentiate between trained and untrained monkey faces before and after training (Scott & Monesson, 2009). Infants were randomly assigned to individual, category, or exposure training conditions for a 3-month period between 6 and 9 months of age. The individual-trained group received books with six monkey faces, each given a unique name. The category-trained infants received books with the same six monkey faces that were all labeled “monkey.” The exposure-trained infants received books with the six monkey faces without labels. Prior to all training, 6-month-olds discriminated among monkey faces in a VPC task. After three months of training, infants in the individual group did not exhibit perceptual narrowing for monkey faces; in other words, they maintained the ability to discriminate between the monkey faces exhibited at 6 months of age. In contrast, the category and exposure trained groups showed no evidence of discrimination between monkey faces at the age of 9 months (Scott & Monesson, 2009). These results suggest that individuation experience with faces is necessary for maintaining face discrimination abilities.

In another investigation, infants’ electrophysiological responses were recorded before and after individual, category, and exposure training with monkey faces (Scott & Monesson, 2010). Results of this study suggested that 9-month-old infants with three months of individual training exhibited neural responses to the monkey faces similar to

what is typically found in response to human faces. Nine-month-olds, however, with three months of category or exposure training exhibited neural responses similar to what is typically found for objects, but not faces (Scott & Monesson, 2010). These results support that individual experience with faces is necessary for specialization of neural regions subserving face processing. In general, these behavioral and electrophysiological results from training infants with monkey faces suggest that experience with different types of faces shapes face-processing ability during infancy.

In addition to the other-species effect, perceptual narrowing is also manifested as the other-race effect, or the impaired ability to discriminate faces from a different racial group (Anzures, Quinn, Pascalis, Slater & Lee, 2010; Kelly et al., 2007; 2009). For example, infants' ability to tell the difference between other-race faces diminishes between the ages of 3 and 9 months (Kelly et al., 2007; 2009). Kelly and colleagues examined Caucasian infants' (2007) and Chinese infants' (2009) ability to discriminate between two same-race faces and two other-race faces at 3, 6, and 9 months of age. Caucasian and Chinese 3-month-old infants were able to discriminate familiar from novel faces regardless of the race of the face. However, 6-month-olds were only able to differentiate (2007) and marginally differentiate (2009) between faces that were Chinese or Caucasian, but showed no evidence of discrimination when viewing African faces (2007; 2009) or Middle Eastern faces (2007). Nine-month-old infants did not discriminate among faces within any other races, including African (2007; 2009), Middle Eastern (2007), Caucasian (2009) and Chinese (2007), but did maintain the ability to tell the difference between two own-race faces. These findings are consistent with previous research using monkey faces, and suggest that perceptual narrowing occurs between 6

and 9 months of age (Kelly et al., 2007; 2009; Pascalis et al., 2002; 2005; Scott & Monesson, 2009; 2010). Furthermore, these results suggest that 6-month-old infants demonstrated perceptual biases for other-race faces, (such as African or Middle Eastern faces) which are fully present in 9-month-old infants.

Other researchers have recently replicated this behavioral perceptual decline in discrimination among faces within other races from 5 to 9 months of age (Vogel, Monesson & Scott, in revision). Using a visual paired comparison task (VPC), 5- and 9-month-old Caucasian infants were tested on their ability to discriminate between same- (i.e., Caucasian) and other-race (i.e., African-American) faces. Five-month-old infants demonstrated a significant novelty preference for both same- and other-race faces, while 9-month-old infants did so only for same-race faces (Vogel, Monesson & Scott, in revision). In another study, 9-month-old infants were found to form racial categories of both own- and other-race faces; however infants did not show evidence of discrimination between other-race faces (Anzures et al., 2010).

Taken together, these results suggest that 9-month-olds can categorize own- and other-race faces, but have difficulty individuating among faces of other races (Anzures et al., 2010; Kelly et al., 2007; 2009; Vogel, Monesson & Scott, in revision). The developmental trajectory of the other-race effect has been studied for faces; however, it is currently unclear how the other-race effect will influence an infant's ability to extract emotional information from facial expressions.

Infants' ability to process emotions has primarily been investigated in two modalities, auditory and visual emotional expressions. Infants have demonstrated the ability to discriminate between positive and negative emotional sounds within a language

context (Walker-Andrews & Grolnick, 1983; Walker-Andrews & Lennon, 1991; Grossmann, Striano & Friederici, 2005; Grossmann, Oberecker, Kosch, & Freiderici, 2010). In an ERP investigation, 7-month-old infants heard words spoken in a neutral, angry, or happy prosody (Grossmann et al., 2005). Seven-month-old infants' ERP response was greater to angry prosody relative to neutral and happy prosody. In this previous investigation, the authors examined emotion prosody within a language context. However, the development of non-verbal emotion sound processing is currently unknown.

Behavioral research using looking-time paradigms has demonstrated that infants are also able to discriminate between positive and negative emotional facial expressions (Barrera & Mauer, 1981; Field, Woodson, Greenberg & Cohen, 1982; Ludemann, 1991; Leppenan, Richmond, Vogel-Farley, Moulson & Nelson, 2009). For example, newborn infants as young as 36 hours were found to discriminate between happy, sad and surprised emotional expressions (Field et al., 1982). In addition, Barrera and Maurer (1981) found that 3-month-old infants were able to distinguish between smiling and frowning faces of strangers and their mothers. Taken together, these results suggest that infants as young as newborns visually discriminate between facial expressions of both familiar and unfamiliar faces.

In addition to behavioral methods, recent developmental investigations have used ERPs to examine the development of face processing during infancy. Results of these investigations have identified posterior occipital and temporal ERP components, including the N290 and the P400, which index the perception of faces across the first year of infancy (de Haan & Nelson, 1999; de Haan, Pascalis, & Johnson, 2002; de Haan,

Johnson, & Halit, 2003; Halit, Csibra, Volein & Johnson, 2004; Scott, Shannon & Nelson, 2006; Scott & Monesson, 2010). The N290 ERP component peaks between 290 and 350 ms after stimulus onset and is found between the ages of 3 and 12 months (for review see: Halit, de Haan & Johnson, 2003). The P400 is a second infant perceptual ERP component that is also found between the ages of 3 and 12 months old and peaks between 390 to 450 ms after stimulus onset (Halit et al., 2003). Experimental studies have also shown that the P400 component differentiates between human faces and objects, displaying a shorter latency in response to faces than objects (de Haan & Nelson, 1999).

The N290 and P400 components have also been found to differentiate facial expressions (Hoehl & Striano, 2008; Kobiella, Grossmann, Reid & Striano, 2008; Leppanen, Moulson, Vogel-Farley & Nelson, 2007). Seven-month-old infants have exhibited a larger N290 response to angry relative to fearful faces (Kobiella et al., 2008). In addition, a larger P400 was found in response to angry faces relative to neutral faces (Hoehl & Striano, 2008). Seven-month-old infants were also found to have larger P400 amplitudes in response to fearful faces compared to neutral faces (Leppanen et al., 2007). These results suggest that the N290 and P400 respond differently to emotional expressions.

In a recent ERP investigation, 7-month-old infants were found to integrate cross-modal emotional information from voices and images of Caucasian female faces (Grossmann et al., 2006). Infants were presented with emotionally congruent and incongruent face-voice pairs while ERPs were recorded in response to the voice. Infants' ability to integrate cross-modal emotional information was indexed by two ERP

components. The Nc amplitude in response to the word was larger for emotionally incongruent than congruent prosody. Conversely, the amplitude of the PSW was greater in response to emotionally congruent than incongruent prosody (Grossmann et al., 2006). These findings suggest that 7-month-olds are able to integrate emotional information across multiple modalities for familiar, same-race faces (Grossmann et al., 2006).

Recently, infants' abilities to detect congruent sound/face emotion pairs in an ERP task for other-race faces was found to be impaired in 9-month-old, but not 5-month-old infants (Vogel, Monesson & Scott, in revision). The current investigation used the same data set as Vogel, Monesson & Scott (in revision) to follow-up findings reported in this previous paper. For this study (Vogel, Monesson, & Scott, in revision), Caucasian infants were presented with short clips of happy sounds (e.g., laughing) or sad sounds (e.g., crying) followed by either a happy or a sad African-American or Caucasian face. Infants' ERP responses were recorded in response to the emotional face. Results revealed that 5-month-old infants showed no evidence of processing race differentially for the Nc, N290, and P400 ERP components. However, 5-month-old infants did differentiate congruent and incongruent sound face pairs, independent of race. Nine-month-old Caucasian infants differentiated congruent and incongruent sound face pairs for Caucasian but not African-American faces for the N290 and P400 components (Vogel, Monesson & Scott, in revision). These results suggest that infants match emotion sounds with emotion faces at both 5- and 9-months of age. However, this processing is influenced by the race of the face at 9-, but not 5-, months of age. In this previous report, researchers did not examine the neural response to the sound, or the response to happy versus sad facial expressions. In order to understand the development of emotion

processing it is important to examine infants' responses to both happy and sad emotional sounds and faces.

The current research predicted three main findings. The first prediction was that both 5- and 9-month-old infants would exhibit greater amplitude in response to sad sounds relative to happy sounds, based on previous research (Grossmann et. al., 2005; 2006; Walker-Andrews & Grolnick, 1983; Walker-Andrews & Lennon, 1991). The second prediction was that, consistent with previous reports (Hoehl & Striano, 2008; Kobiella et al., 2008; Leppanen, et al., 2007), both 5- and 9-month-old infants would show larger amplitude in response to sad facial expressions as compared to happy facial expressions. For the third prediction, it was anticipated that there would be an interaction between emotion and race for 9-month-old infants. For 5-month-olds, consistent with the other-race effect research (Anzures et al., 2010; Kelly et al., 2007; 2009), it was anticipated that there would be no difference between the neural response to African-American and Caucasian emotional faces. Additionally, it was predicted that 9-month-old infants would demonstrate the other-race effect (Kelly et al., 2007; 2009) by only showing amplitude differences in response to Caucasian, but not African-American, happy and sad faces.

CHAPTER II

THE INFLUENCE OF PERCEPTUAL NARROWING ON EMOTION PROCESSING DURING INFANCY

Experimental Procedures

The University of Massachusetts Amherst Institutional Review Board approved all methods and procedures used in this study.

Participants

The final sample included 15 5-month-old (mean age=153.33 days, SD=8.69 days) infants (8 males, 9 females) and 16 9-month-old (mean age=275.86 days, SD=9.3 days) infants (10 males, 6 females) that were born full-term (38 weeks) with no visual or auditory deficits or neurological abnormalities. An additional 23 participants were excluded because their data contained noise (n=7) or they did not have enough trials per condition (n=17). Infants were tested within 2 weeks of their 5-month or 9-month birthdays. Families were compensated \$10 for their time and travel and infants were given a small toy for their participation.

Materials and Apparatus

Based on previous findings suggesting that infants prefer to look at female faces, the stimuli included only female faces (Quinn, Yahr, Kuhn, Slater & Pascalis, 2002). The stimuli consisted of eight randomized different Caucasian female faces (4 happy, 4 sad) and eight randomized different African-American female faces (4 happy, 4 sad) from the MacArthur NimStim face database (Tottenham et al., 2009). Each face was presented in grayscale, and low-level perceptual cues (e.g., luminance and contrast) were equalized to

the best of our abilities using MatLab's "Shine" program (Willenbockel et al., 2010). Each individual image was 15.5 cm high and 12.5 cm wide, and was presented at approximately 13.6 degrees. All images were presented on a patterned white and gray background.

The auditory stimuli included ten different sound clips (5 happy, 5 sad) of females expressing happy (e.g., laughing) and sad (e.g., crying) sounds. Clips were presented for 800 msec and were edited using a program named Audacity (GNU General Public License (GPL: Dominic Mazzoni; <http://audacity.sourceforge.net/>). The combination of sound type, facial expression, and race resulted in 8 different types of trials.

Procedure

Parents of all infants gave informed consent prior to the experimental testing session. All infants were recruited from names maintained in a participant database. This database consists of names of families obtained from the Massachusetts Registry of Vital Records and Statistics.

Each infant was seated in their parent's lap approximately 60 cm away from a computer screen. Infants were shown approximately equal numbers of all eight different types of trials presented in random order. Infants completed an average of 94.46 (SD =18.05) trials across all conditions. Each trial began with a black fixation cross on a gray and white patterned background. The infant was then presented with either a happy or sad sound for 800 ms, followed by another fixation cross, with an inter-trial interval ranging from 1000 to 1500 ms. Next, the infant saw a smiling or frowning Caucasian or African-American female face for 500 ms (See Figure 1). An experimenter monitored infant

attention to the computer screen and only presented stimuli when the infant was attending to the screen.

Electrophysiological Procedures

ERPs were collected from a 128-channel Geodesic Sensor net connected to a DC-couple 128-channel, high input impedance amplifier (Net Amps 300, Electrical Geodesics). The amplified analog voltages (.1-100 Hz bandpass) were digitized at 500 Hz. Individual electrodes were adjusted until impedances were less than 50 k Ω .

Post-recording processing was completed using Netstation 4.3 (Electrical Geodesics Inc., Eugene, OR). All 128-scalp electrodes were referenced online to the Cz scalp electrode (located at the vertex) and then referenced offline to the average reference. 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) and low pass filtered at 30 Hz. Stimulus locked ERPs to both the emotional sounds and faces were baseline-corrected with respect to a 100 ms pre-stimulus interval. These ERP segments were 1200 ms in duration. Netstation 4.3 scanned each recording channel during artifact detection in order to detect large amplitude changes (>300 microvolts) and rejected that particular electrode channel within that 1200 ms segment. If a recording channel was marked with an artifact in more than 30% of all segments, the channel was marked bad. Bad channels were replaced using a spherical interpolation algorithm (Srinivasan, Inunez, Silberstein, Tucker & Cadusch, 1996). Following artifact detection, each trial was visually inspected for noise and rejected if a significant amount of noise or drift was present. Trials from participants

were discarded from data analysis if there were more than 12 bad channels in each trial. Participants were excluded if they contributed an average of fewer than 15 artifact-free trials per condition.

For 5-month-olds, an average of 96.27 trials (SD=15.60) were completed, for the average number of trials completed in individual sound (See Table 1) and face (See Table 2) conditions. For 9-month-olds, an average of 92.65 trials (SD=20.5) were completed for the average number of trials completed in individual sound (See Table 1) and face (See Table 2) conditions.

ERP Statistical Analyses

Based on previous research (Grossmann et al., 2006; Scott et al., 2006; Scott & Monesson, 2010; Vogel, Monesson & Scott, in revision) and an examination of mean amplitudes and peak latencies, groups of electrodes exhibiting the components of interest were combined and averaged for analyses.

Visual inspection of the response to the sound revealed a sustained amplitude response beginning between 120 and 150 ms. These sustained responses were evident over frontal and central scalp regions. Groups of electrodes exhibiting this response were averaged for analyses. These electrode groups were based on visual inspection and previous investigations (Grossmann et al., 2005; 2006) and included the following: Frontal (F) 15,18,16,10; corresponding to the Fz: Central (C): 7, 106, REF, 55; corresponding to the Cz (See Figure 2). Mean amplitude was measured within the time window of 120-1200 ms for 5-month-olds and 150-1200 ms for 9-month-olds after visual stimulus onset for both age groups.

Groups of electrodes were chosen over occipital temporal regions for the N290 and P400 components, based on previous research (de Haan & Nelson, 1999; Scott & Nelson, 2006; Scott, Shannon, & Nelson, 2006) and visual inspection of the data. Thus, all of the following electrodes and electrode groupings were included in N290 and P400 analyses: Left (L): 63, 64, 68, 69, 73; Middle (M): 70, 74, 75, 83, 82; Right (R): 89, 88, 94, 95, 99 (See Figure 2). Mean amplitude and latency were measured for the N290 within the window of 200-320 ms for 5-month-olds and 210-290 ms for 9-month-olds. The window for the P400 was within 320-450 ms for 5-month-olds and 340-420 ms for 9-month-olds.

Sound and Face ERP Response Measurements and Analysis

For each component we completed two calculations. First, the average amplitude and peak latency of each component were calculated for each participant within each condition. The mean amplitude for each component was measured as the average amplitude across each time window corresponding to the component.

The response to the sound was analyzed using a 2 (Emotion: Happy, Sad) x 2 (Region: Frontal, Central) repeated measures ANOVA. Mean amplitude in response to the face for the N290 and P400 components was analyzed using a 2 (Emotion: Happy, Sad) x 2 (Race: Caucasian, African-American) x 3 (Region: Left, Middle, Right) repeated measures ANOVA. Follow-up analyses of significant interactions were conducted using paired-sample t-tests corrected for multiple comparisons.

Results: Electrophysiological Responses to the Emotion Faces

N290: 5-month-old infants

Analyses of amplitude revealed a significant main effect of emotion $F(1, 14) = 6.91, p = .02, \eta^2 = .33$. This main effect of emotion was driven by larger negative amplitude N290 in response to happy relative to sad faces (See Figure 5).

P400: 5-Month-Old Infants

For 5-month-olds, analyses revealed a main effect of emotion $F(1, 14) = 4.77, p = .05, \eta^2 = .25$; see Figure 5). This main effect was due to a greater positive amplitude P400 in response to sad relative to happy faces (See Figure 5). In addition, a main effect of region was found $F(2, 13) = 10.74, p < .01, \eta^2 = .62$ due to a greater positive amplitude P400 response over the middle occipital region relative to the left and right regions (p 's $< .01$).

N290: 9-Month-old Infants

For 9-month-olds, a main effect of region was found for the N290 amplitude $F(2, 14) = 17.8, p < .01, \eta^2 = .72$. This main effect was driven by a greater negative N290 response recorded over the left and right hemispheres (p 's $< .01$) relative to the middle occipital region.

P400: 9-Month-Old Infants

Analyses of amplitude revealed a main effect of race $F(1, 15) = 4.56, p = .05, \eta^2 = .24$; see Figure 6). This main effect was driven by a larger P400 in response to Caucasian faces as compared to African-American faces.

In summary, 5-month-old infants exhibited a more negative N290 in response to happy faces relative to sad faces and a more positive P400 in response to sad faces

compared to happy faces. Nine-month-olds, on the other hand, did not exhibit any emotion face differences, but did show a greater P400 to own-race relative to other-race faces.

Discussion

The current research used electrophysiological techniques to examine the neural correlates of emotion processing from vocalizations and emotional expressions during infancy. In addition, the current ERP study examined whether perceptual narrowing and the other-race effect differentially influenced 5- and 9-month-old infants' neural processing in response to same- and other-race emotion faces.

The results of the electrophysiological analyses revealed three important findings in regards to the development of emotion processing during infancy. First, the current study found that 5- and 9-month-old infants exhibited different patterns of neural responses to happy and sad emotional sounds. Five-month-olds neurally discriminated between happy and sad sounds and exhibited an enhanced frontal region response to happy sounds relative to sad sounds. Nine-month-olds had differential regional responses to sad, but not happy sounds with a greater response in the frontal compared to the central region. Second, 5-month-old, but not 9-month-old infants exhibited differential neural processing in response to emotional expressions for the N290 and P400 components. Third, the current study found that 5-month-olds infants' processing of facial expressions for both the N290 and P400 were independent of race. Furthermore, 9-month-old infants did not exhibit any differential neural processing of emotion, but did show an enhanced response to own-race faces relative to other-race faces.

The first prediction of the current investigation was that both 5- and 9-month-old infants would exhibit greater sustained amplitude in response to sad sounds relative to happy sounds. The results for five-month-old infants were inconsistent with this prediction and previous research (Grossmann et al., 2005; 2006). The current study found that 5-month-old infants had a larger sustained amplitude in response to happy relative to sad non-verbal sounds. The current investigation revealed that 9-month-old infants exhibited a greater sustained amplitude response to sad sounds recorded over the frontal region compared to the central region. These results are not consistent with the previous prediction that 9-month-old infants did not neurally differentiate between happy and sad sounds. Instead, 9-month-old infants showed enhanced processing of sad sounds only, specifically in the frontal region. The inconsistency in both the 5- and 9-month-old infants' results may be due to the use of non-verbal emotional expressions, whereas Grossmann and colleagues (2005) used spoken words in angry, happy and neutral prosodies.

Five-month-olds' neural differentiation of sustained responses to happy and sad sounds suggests that 5-month-old infants are differentially processing emotional sounds in both a non-verbal and a language context as found by Grossmann and colleagues (2005). Nine-month-olds' enhanced response to sad sounds may be due to a specialization of processing sad non-verbal sounds as an artifact of their increased experience with sad emotion expression in their environment. Thus, 9-month-olds may be more attuned to sad sounds because of their greater understanding of this emotion. On the contrary, 5-month-olds have more limited experience with emotion expression and thus may have not ascribed as much significance to sad sounds as 9-month-olds.

These results suggest that between the periods of 5 and 9 months of age infants develop an enhanced processing of sad sounds over the frontal region. In addition, these developmental changes in processing emotion sounds also suggest that 5-month-olds' ability to differentiate between emotional sounds and enhanced response to happy sounds is reflective of their more limited emotional experience with their environment. Therefore, the changes in neural response to happy and sad sounds from 5 to 9 months of age may be a result of specialization in the neural mechanisms that process emotional sounds. In summary, this study has demonstrated that 5- and 9-month-old infants neurally process happy and sad non-verbal emotion differentially.

The second prediction was that both 5- and 9-month-old infants would show larger amplitude responses to sad facial expressions as compared to happy facial expressions. Five-month-old infants' results both contradicted and supported this hypothesis by exhibiting enhanced N290 amplitude to happy faces and a greater P400 amplitude to sad faces (See Figure 5). Nine-month-old infants did not show any differential neural processing of happy and sad emotional expressions in the N290 and P400 components.

Five-month-olds' greater P400 amplitude to sad faces is consistent with previous research studies in that 5-month-old infants exhibited a greater response to negative emotional expressions relative to other emotions. It has been found in previous research that 7-month-old infants exhibited enhanced P400 responses to angry facial expressions compared to neutral faces (Hoehl & Striano, 2008). The current results suggest that 5-month-old infants neurally differentiate between happy and sad facial expressions

The N290 and P400 responses of 9-month-old infants are not consistent with previous emotion ERP results found in 7-month-old infants (Hoehl & Striano, 2008; Kobiella et al., 2008; Leppanen et al., 2007). In the current investigation 9-month-old infants did not demonstrate neural differences in their response to happy and sad facial expressions. While these results are unexpected, the lack of neural differentiation between happy and sad faces may be due to an interaction with the race of the faces. These N290 and P400 results suggest that 9-month-old, but not 5-month-old infants may have been processing other aspects of the emotional faces, such as race.

In summary, the emotion analyses appear to suggest that 5-month-old infants when viewing emotional faces are attuned to extracting the emotional information, but not other facial features including race. On the other hand, 9-month-old infants may have developed an enhanced sensitivity to race, such that it affects their neural responses to emotional expressions.

The third and final prediction in the current research evaluated whether the race of the face would influence the neural responses to happy and sad faces in 5- and 9-month-old infants. Specifically, it was predicted that 5-month-old infants would show neural differentiation independent of race, whereas 9-month-olds would only exhibit enhanced responses to Caucasian, but not African-American emotional expressions.

Five-month-old infants' responses were consistent with the predicted response, in that their neural differentiation of emotion was independent of race. Results for 9-month-old infants were also consistent with previous research examining the other-race effect (Anzures et al., 2010; Kelly et al., 2007; 2009; Vogel, Monesson & Scott, in revision). Nine-month-old infants showed a greater P400 amplitude in response to Caucasian

relative to African-American faces (See Figure 6). In addition, these P400 amplitude results are consistent with behavioral findings of 9-month-old infants' enhanced differentiation between same race faces only (Anzures et al., 2010; Kelly et al., 2007; 2009; Vogel, Monesson & Scott, in revision).

These results suggest that 5-month-old infants' neural processing of emotion is not influenced by the race of the face. On the contrary, 9-month-old infants appear to be more attuned to race as opposed to emotion. Furthermore, these findings may imply that there are developmental changes from 5 to 9 months of age. These changes may include a neural specialization such that race rather than emotion becomes more salient in face processing. Overall these results suggest that extraction of emotional information may be influenced by the race of the face around 9 months of age, however future research needs to investigate this face processing phenomenon further to examine how perceptual biases influence the development of emotion processing.

Future Research

One proposed direction of future research could examine neural processing of emotion sounds alone. As found in the current study with 5- and 9-month-old infants adults have also shown rapid differential ERP amplitude responses to non-verbal emotion sounds, including both happy and sad emotions (Sauter & Eimer, 2010). Sauter and Eimer (2010) not only examined ERP responses to happy and sad vocalizations, but also included a broader range of emotions. It is currently unknown whether infants neurally process more subtle and complex emotional valences. A potential developmental ERP investigation could employ a broader a range of emotion valences (e.g., happy, sad, angry, frustrated, fearful, neutral) that were expressed through non-verbal sounds. This

potential study could examine the distribution and developmental differences between infants' and adults' rapid neural discrimination between auditory non-verbal emotion sounds (Sauter & Eimer, 2010). Furthermore, this investigation would address the development of emotion processing expressed across different emotional valences.

A second direction for future research could examine the relationship between emotion processing and the other-race effect. For example, future research could include a broader participant sample to examine whether the other-race effect is also present for 9-month-old African-American infants in response to Caucasian emotion faces. Furthermore, the stimuli could include more faces of other races (e.g., Asian, Middle Eastern, etc.) to examine whether this is consistent across all other-race faces relative to own-race face. Finally, future investigations should include a broader range of emotion, including a neutral condition to compare with both positive and negative emotional valences. The addition of a neutral emotion would provide a better control and comparison to further the understanding of the development of emotion processing in infants and how this interacts with face processing biases.

Table 1: Mean Number and Standard Deviation of ERP Trials in Response to Happy and Sad Sounds for 5- and 9-Month-old Infants.

	<u>All Sounds</u>	<u>Happy Sounds</u>	<u>Sad Sounds</u>
5-month-olds	85.40(7.52)	41.77(6.22)	43.73(8.82)
9-month-olds	86.38 (11.94)	41.31(12.33)	45.06(11.54)

Table 2: Mean Number and Standard Deviation of ERP Trials in Response to African-American and Caucasian Faces for 5- and 9-Month-old Infants.

	Happy Faces		Sad Faces	
	<u>Caucasian</u>	<u>African-American</u>	<u>Caucasian</u>	<u>African-American</u>
5-month-olds	21.07(5.52)	21.00(5.67)	21.07(5.52)	21.73(3.97)
9-month-olds	20.94 (5.58)	22.13(7.55)	20.75 (7.55)	20.69(7.01)

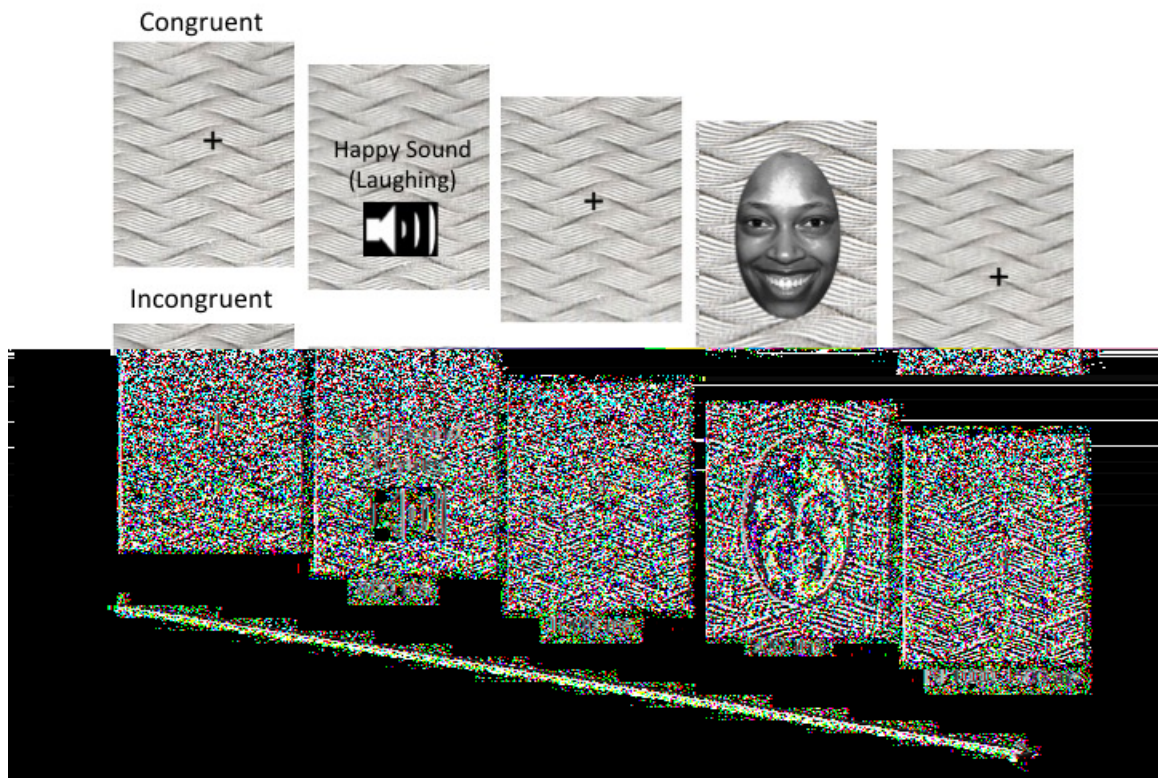


Figure 1: Design of Infant ERP Task. Each trial began when the infant is attending to the screen and started with a black fixation cross on a gray and white patterned background. Next, the infant heard a 800 ms sound clip of a female voice laughing or crying, which was followed by a 1000 ms black fixation cross on the same gray and white patterned background. Then, the infant was presented with a smiling or frowning African-American or Caucasian female faces for 500 ms. ERPs were recorded in response to both the sound and the face. The inter-trial stimulus varied randomly for 1000-1500 ms.

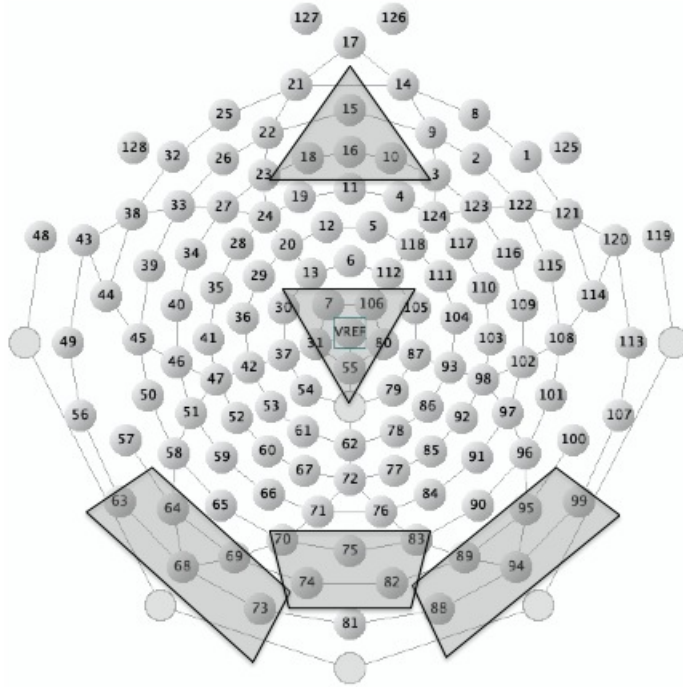


Figure 2: The electrode groupings chosen for anterior and posterior components in response to emotion stimuli. Electrode groups over the frontal and central regions were for the ERP sustained amplitude responses to the emotion sound and face. Electrode groups over the occipital region were used for the ERP response to Emotion faces for the N290 and P400 components.

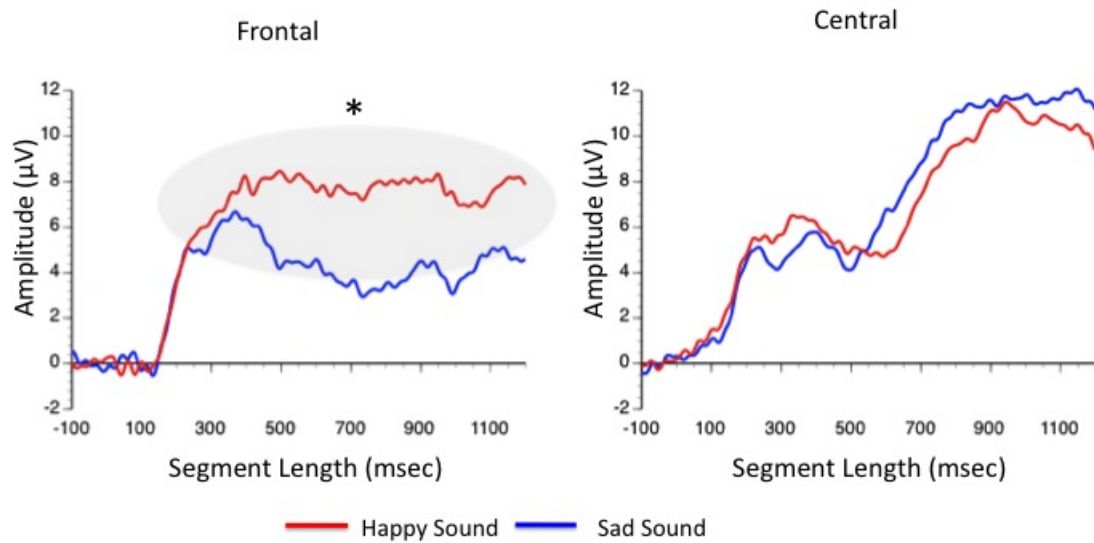


Figure 3: Five-month-olds' sustained amplitude interactions for emotion and region in response to the emotion sound. The sustained response amplitude was greater to sad relative to happy sounds over the frontal region.

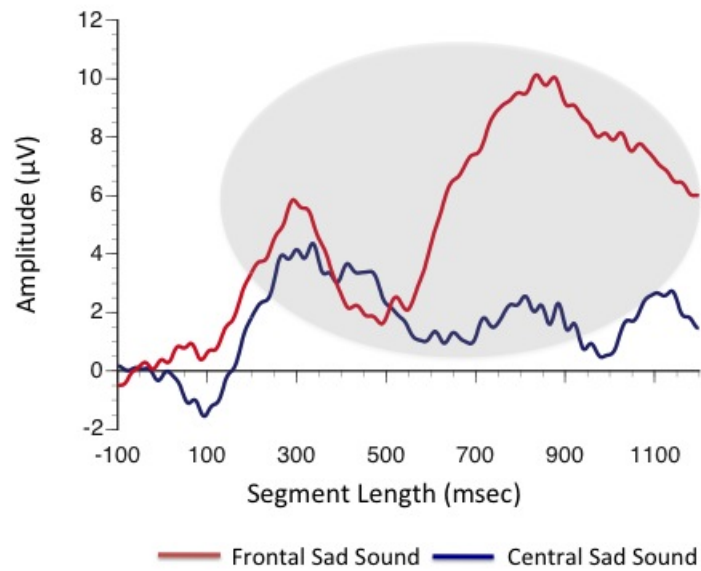


Figure 4: Nine-month-olds' interaction of emotion and region for the sustained amplitude response to sad emotion sounds. The sustained amplitude response interaction was driven by greater amplitude in response to sad sounds recorded over the central relative to the frontal region.

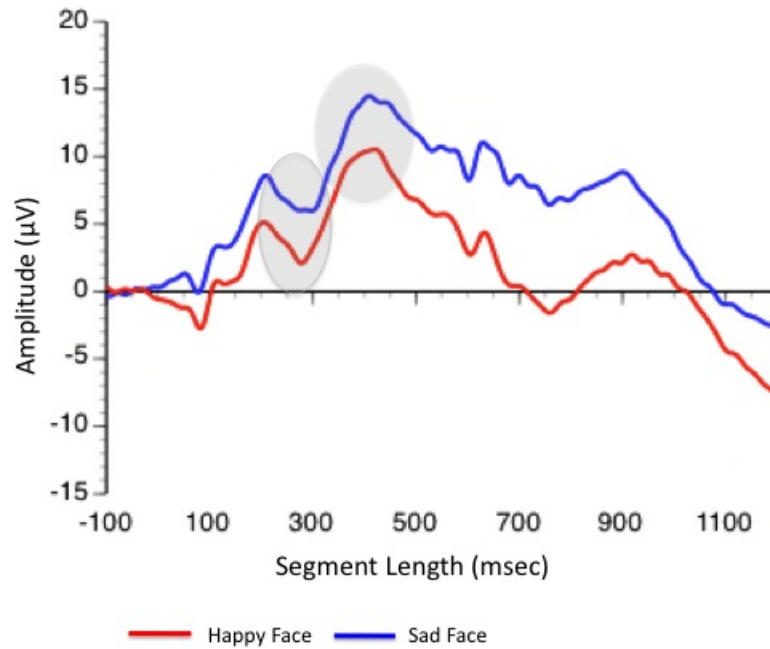


Figure 5: Five-month-olds’ main effect of emotion in the N290 and P400 amplitude in response to the emotion face. The N290 amplitude elicited by happy faces was greater than the response for sad faces. The P400 amplitude in response to sad faces was greater relative to happy faces.

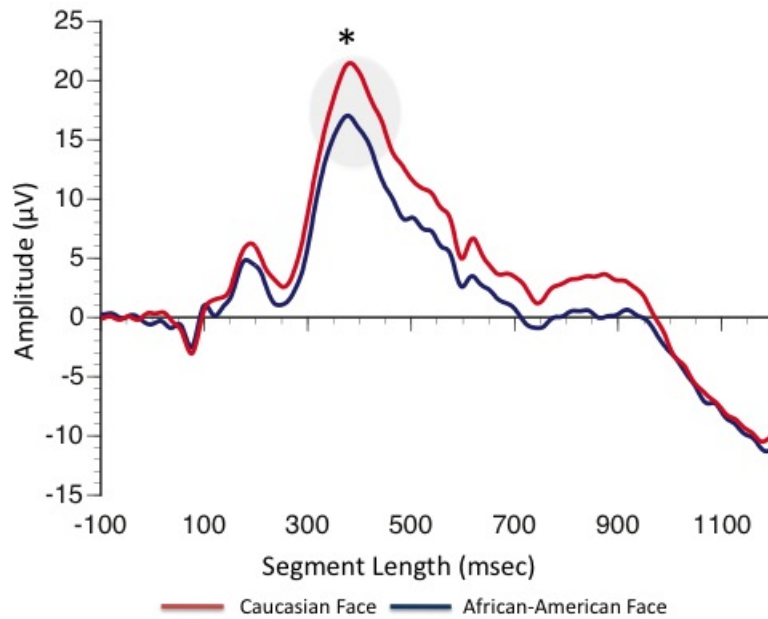


Figure 6: Nine-month-olds' P400 amplitude main effect of race. The P400 amplitude in response to Caucasian emotion faces was greater relative to African-American emotion faces.

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