

Copyright  
by  
Jessica Michelle Jankowitsch  
2014

**The Thesis Committee for Jessica Michelle Jankowitsch  
Certifies that this is the approved version of the following thesis**

**Infants' Neural Processing of Facial Attractiveness**

**APPROVED BY  
SUPERVISING COMMITTEE:**

**Supervisor:**

---

Judith H. Langlois

---

Catharine H. Echols

---

David M. Schnyer

# **Infants' Neural Processing of Facial Attractiveness**

**by**

**Jessica Michelle Jankowitsch, B.S.**

**Thesis**

Presented to the Faculty of the Graduate School of

The University of Texas at Austin

in Partial Fulfillment

of the Requirements

for the Degree of

**Master of Arts**

**The University of Texas at Austin**

**December 2014**

## **Acknowledgements**

I would like to express my gratitude to my advisor, Dr. Judith Langlois, whose expertise, interest, and guidance have greatly shaped my graduate experience, in addition to this Thesis. I would also like to thank the other members of my committee, Dr. Catherine Echols and Dr. David Schnyer, for their patience, assistance, and helpful feedback. Additionally, I thank Dr. Rebecca Bigler and Dr. Jacqueline Woolley for their encouragement and support over the years.

Thank you to Dr. Logan Trujillo for his technical mentorship and kind counsel over the course of this research project. Thank you as well to my fellow Langlois Lab graduate students (past and present), Teresa Taylor Partridge, Connor Principe, Stevie Schein, and Frances Morales, for their support and providing me with feedback on the conception of the study and drafts of this Thesis. A huge thank you to Erin Anderson, who initially provided support as my very first research assistant and continued to do so until the end of this project as our Lab Manager. Many thanks also go out to the other undergraduate research assistants who assisted with stimuli creation, data collection, coding, and more: Angelica, Ashley, Christine, Hannah, Holly, Jill, Katie, Kellie Jo, Shana, Tarana, and Tiffany.

Lastly, thank you to my family, friends, and loved ones for their love and encouragement to see this project to completion.

## **Abstract**

### **Infants' Neural Processing of Facial Attractiveness**

Jessica Michelle Jankowitsch, M.A.

The University of Texas at Austin, 2014

Supervisor: Judith H. Langlois

The relationship between infants' neural processing of and visual preferences for attractive and unattractive faces was investigated through the integration of event-related-potential and preferential looking methods. Six-month-olds viewed color images of female faces previously rated by adults for attractiveness. The faces were presented in contrasting pairs of attractiveness (attractive/unattractive) for 1.5-second durations. The results showed that compared to attractive faces, unattractive faces elicited larger N290 amplitudes at left hemisphere electrode sites (PO9) and smaller P400 amplitudes at electrode sites across both hemispheres (PO9 and PO10). There were no significant differences between infants' overall looking times based on attractiveness, however, a significant relationship was found between amplitude and trial looking time; larger N290 amplitudes were associated with longer trial looking times. The results suggest that compared to attractive faces, unattractive faces require greater cognitive resources and longer initial attention for visual processing.

## Table of Contents

List of Figures .....	viii
Chapter 1: Introduction & Literature Review .....	1
Attractiveness Preferences .....	1
Averageness Theory .....	2
Neural Processing of Facial Attractiveness .....	3
Integration of Methods .....	8
Overview of Study .....	10
Chapter 2: Method.....	12
Participants .....	12
Stimuli .....	12
Procedure.....	13
Behavioral Data Collection .....	13
Neural Response Data Collection .....	14
Data Processing .....	15
Behavioral Data Processing .....	15
Neural Response Data Processing .....	16
Chapter 3: Results .....	18
Looking Behavior.....	18
Total Looking Time .....	18
First Looks.....	18
Average Trial Looking Time.....	19
ERP Responses.....	19
Amplitude .....	20
N290 Amplitude .....	20
P400 Amplitude.....	20
Latency .....	21
N290 Latency .....	21

P400 Latency .....	21
Relationship Between Looking Time and ERP Measures .....	22
Trial Looking Time and N290 Amplitude .....	23
Trial Looking Time and N290 Latency .....	23
Chapter 4: Discussion.....	24
Attractiveness Preferences .....	24
Neural Processing of Facial Attractiveness .....	25
Amplitude .....	25
Amplitude and Processing Fluency .....	26
Latency .....	26
Hemispheric Asymmetry.....	27
Averageness Theory .....	28
Integration of Methods .....	29
Future Research .....	30
Processing of Facial Attractiveness.....	30
Modified Behavioral-Neural Integration.....	32
Conclusions .....	33
References .....	40

## **List of Figures**

Figure 1: Examples of 32 Face Morphs .....	34
Figure 2: Electrode Sites Map .....	35
Figure 3: Attractive Face Stimuli .....	36
Figure 4: Unattractive Face Stimuli .....	37
Figure 5: PO9 and PO10 Grand Average ERP Waveforms .....	38
Figure 6: PO9 and PO10 Scalp Topographies .....	39



## **Chapter 1: Introduction & Literature Review**

Research has established that infants, like adults and children, prefer attractive to unattractive faces. When given the choice of looking at attractive or unattractive faces, infants look longer at faces judged by adults as attractive (Langlois et al., 1987; Langlois, Ritter, Roggman, & Vaughn, 1991; Samuels & Ewy, 1985; Slater et al., 1998). These visual preferences extend to faces that vary in race, age, sex, and species (Langlois, Ritter, Roggman, & Vaughn, 1991; Quinn, Kelly, Lee, Pascalis, & Slater, 2008).

### **ATTRACTIVENESS PREFERENCES**

To assess infants' preferences for attractiveness, researchers implement the preferential-looking technique (Fantz, 1958). Infants are presented with a pair of visual stimuli and looking behaviors are measured to evaluate whether infants can discriminate between and prefer one stimulus to the other. Researchers compare cumulative or average looking time to different stimuli (or categories of stimuli). Significantly greater looking to one stimulus (or stimulus category) compared to another, assuming the stimuli are equally novel, indicates that infants can discriminate between stimuli and may demonstrate that infants have a preference for some stimuli over others.

Langlois et al. (1987) investigated two- to three-month-old and six- to eight-month-old infants' looking time to color images of adult female faces, previously rated for attractiveness by adults. Each infant saw multiple trials of two faces, displayed simultaneously, from two conditions of paired faces (i.e., contrasting pairs: attractive/unattractive and similar pairs: attractive/attractive and unattractive/unattractive). Researchers recorded the length of visual fixation to each face presented in the pairs. The youngest infants looked longer to attractive faces than to unattractive faces in contrasting pairs. Older infants looked longer at attractive faces

compared to unattractive faces in both contrasting and similar pairs. These results demonstrated that infants differentiate between faces based on attractiveness and prefer to look at attractive faces.

In addition to visual preferences, social preferences for attractive faces emerge during infancy. By 12 months, infants show greater positive affect towards and interactions with attractive people and greater negative affect towards and avoidance of unattractive people (Langlois, Roggman, & Reiser-Danner, 1990). Although not yet capable of self-locomotion, infants as young as six months show differential hemispheric brain responses to attractive and unattractive faces that suggest motivation to approach attractive people and withdrawal from unattractive people (Partridge, 2010). Because infants are not exposed to the positive societal portrayals of attractiveness that adults and children experience, it is likely that preferences for attractiveness are learned through not socialization, but rather through another learning mechanism.

### **AVERAGENESS THEORY**

Attractiveness preferences have been attributed to cognitive information processing mechanisms (Rubenstein, Kalakanis, & Langlois, 1999). Averageness Theory is a proposed mechanism underlying facial attractiveness preference (Langlois & Roggman, 1990). Langlois and Roggman (1990) demonstrated that facial averages are perceived as more attractive than individual faces. They produced separate female and male averages of four, eight, sixteen, and thirty-two faces by mathematically averaging the pixel values of the face images. Adults rated the 32- and 16-face averages as more attractive than the individual faces used to create them. Composites made from increasingly more faces become more attractive and separate 32-face averages made from different and non-overlapping individual faces look extremely similar (see Figure 1).

Further support for Averageness Theory is found through infants' prototyping of faces; when familiarized with a sequence of faces, six-month-old infants responded to a previously unseen average of the faces as if it were "familiar," looking longer at novel and familiar individual faces compared to the averaged face during a paired-comparison novelty preference procedure<sup>1</sup> (Rubenstein, et al., 1999).

Prototypes are more representative of their category (more "face-like"), more familiar, and are processed more easily than non-prototypical exemplars (Potter & Corneille, 2008; Rubenstein, et al., 1999; Winkielman, Halberstadt, Fazendeiro, & Catty, 2006). Rubenstein, Kalakanis, and Langlois (1999) proposed that attractive faces are preferred because they are more prototypical; they are closer to the central tendency of the population of faces compared to unattractive faces. Although it is unknown whether individual faces are compared to an averaged internal prototype or averaged memory traces of exemplars, the disparity between individual faces and the prototype or exemplar traces may result in variations in processing effort and, in turn, preferences. We can predict that the less effortful the processing, the more a face is preferred.

## **NEURAL PROCESSING OF FACIAL ATTRACTIVENESS**

Fluent processing of attractive (more prototypical) faces has been documented through adult and child reaction time studies. Attractiveness affects the speed and accuracy of classifications. Adults and four to five-year-old children classify attractive faces more rapidly as male or female (Hoss, Ramsey, Griffin, & Langlois, 2005). When

---

<sup>1</sup> Paired-comparison novelty preference procedures rely on familiarization leading to novelty preference where as in standard preferential-looking techniques all presented stimuli are equally novel and infants are expected to look longer at preferred stimuli (Hunter & Ames, 1988). Because individual faces are introduced to infants before pairs of faces are presented, these faces are familiar to the infant and previously unseen faces should be preferred because they are novel. Although the infant never previously saw the composite of the familiarized faces, if cognitive averaging of the faces occurred it should be judged most familiar (See the paragraph that follows for explanation).

presented with chimpanzee faces and averaged, attractive, and unattractive human faces, adults more rapidly categorize averaged and attractive faces as human compared to unattractive faces (Trujillo, Jankowitsch, & Langlois, in press). Processing fluency measured through reaction time has been correlated with a more direct assessment of information processing: electrophysiological methods.

One valuable measure of brain activity utilized in studies of cognition is electroencephalography (EEG): scalp recordings of electrical activity produced by neurons firing in the brain. EEG signals time-locked to presentations of stimuli and averaged across multiple presentations of a stimulus produce event-related potentials (ERPs; Luck, 2005). An ERP waveform reflects the averaged electrical brain activation (measured from specific sites on the scalp) over time in response to a stimulus or stimulus category. The peaks and troughs of the ERP waveform, known as components, reflect different aspects of stimulus-related information processing (Luck, 2005). Researchers examine ERP component amplitude (the level of processing, in microvolts, at a component peak) and latency (the speed of processing, in milliseconds, measured as the time a peak amplitude occurs after stimulus onset). Comparisons of amplitude and latency of specific ERP components across different stimuli or categories of stimuli may indicate differences in the speed and timing of processing, how much effort the perceiver expends when processing information, and, indirectly, what is known, recognized, categorized, and liked (DeBoer, Scott, & Nelson, 2007; Kurtzberg, Vaughn, Courchesne, Friedman, Harter, & Putnam, 1984).

Research has connected individual ERP components to the processing of specific stimuli. In adults, the N170 component, a negative polarity peak<sup>2</sup> measured around 170

---

<sup>2</sup> ERP component peaks and troughs are positive or negative deflections of electrical voltage representing the sum of underlying neural activity. Deflections are calculated as differences between electrode site voltage readings and the average baseline neural activity.

ms post stimulus onset, has been related to the processing of faces and the encoding of physical information in faces (Bentin, Allison, Puce, & McCarthy, 1996; Trujillo, Jankowitsch, & Langlois, in press). Researchers found hemispheric response asymmetry; N170 amplitudes are larger in the right hemisphere over posterior parietal-occipital and occipital-temporal scalp regions (see Figure 2). The N170 shows consistent response to faces and lack of or negligible response to non-face stimuli, including cars, butterflies, hands, and visual noise, when compared to faces (Bentin et al., 1996; Halit, Csibra, Volein, & Johnson, 2004). In adults, the N170 has thus been recognized as a “face sensitive” component.

To further investigate the sensitivity of the N170 to facial stimuli, researchers have compared the N170 response of typical faces with those of atypical face stimuli, including inverted faces, discrete components of faces (eyes, nose, and lips), and animal faces. Temporal contrasts between normal and atypical face stimuli found delayed N170 responses to inverted faces and to isolated noses and lips. Compared to typical faces, inverted faces and isolated eyes produced greater N170 amplitudes which researchers interpreted as the result of additional required processing (Bentin et al., 1996). de Haan, Pascalis, and Johnson (2002) found that upright human faces produced smaller amplitudes than inverted human faces and monkey faces and shorter latencies than monkey faces, suggesting fewer cognitive resources are needed to process typical human faces.

The allocation of cognitive resources may vary across processing of faces based on attractiveness level. Researchers found that the N170 differentiates between levels of facial attractiveness. Unattractive faces produce larger N170 amplitudes compared to attractive and averaged faces (Halit, de Haan, & Johnson, 2000; Trujillo, Jankowitsch, & Langlois, in press). The differentiated response to attractiveness may result from more

fluent processing of attractive faces than of unattractive faces when processed in comparison to the face prototype (Halit, de Haan, & Johnson, 2000). N170 results in adults guide interpretations that more “facelike,” or prototypical, faces require less processing effort.

Investigations of equivalent face sensitive ERP components in infants have identified the N290 (negative peak around 290 ms) and the P400 (positive peak around 400 ms) as potential developmental antecedents of the adult N170 (de Haan, Johnson, & Halit, 2003; de Haan, Pascalis, & Johnson, 2002; Halit, Csibra, Volein, & Johnson, 2004). The N290 and P400 components are typically most prominent in ERPs from medial posterior and paramedial electrodes, with a right hemisphere bias similar to adults (de Haan, Johnson, & Halit, 2007). Studies with infants comparing typical faces to visual noise, non-human faces, and non-faces have produced results comparable with adult findings, split between the two components. Although the P400 is a positive polarity component while the N170 and N290 are negative polarity components, brain maturation may lead the N290 and P400 to converge into the N170. The developmental trajectory of these components is yet to be determined.

Unlike in adults, infants appear to process species categorization at an earlier time than face orientation. For example, N290 amplitude is smaller for monkey faces compared to human faces, suggesting that infants process monkey faces more like objects than faces at this stage of processing, whereas P400 amplitude is smaller (more negative) for inverted faces compared to upright faces (de Haan, Pascalis, & Johnson, 2002). These findings are consistent with adult N170 observations insofar as the neural processes reflected by the N290 and P400 contribute to the N170 later in development (see discussion for elaboration).

Another infant specific ERP component relevant to face processing and studies described below is the negative central (Nc) component. It is identified in six-month-olds through peak latency between 400 ms and 800 ms after stimulus onset and measured over the fronto-central electrodes (Courchesne, Ganz, & Norcia, 1981; de Haan, Johnson, & Halit, 2007; de Haan & Nelson, 1997; 1999). Nc response reflects greater attention to and recognition of familiar faces, demonstrated by showing infants their mother's face and strangers' faces (de Haan & Nelson, 1997). Greater amplitude has been found for mother's faces compared to stranger's faces. de Haan and Nelson (1997) propose that greater Nc amplitude indicates familiarity. Although the present study focuses on the N290 and P400 for direct comparison to adult N170 responses to attractiveness levels, Nc is of future interest because attractive faces are perceived as more familiar and may elicit neural familiarity response via the Nc.

ERP studies of face processing in 3-, 9-, and 12-month-old infants' exist—however, their findings are inconsistent or not relevant for the predictions of the present study because of the changes occurring in neural development during the first year of life (Cassia, Kuefner, Westerlund, & Nelson, 2006; Halit, de Haan, & Johnson, 2003; Key, Stone, & Williams, 2009; Scott, Shannon, & Nelson, 2006). Prior to the present study, no research has successfully investigated infants' neural processing of facial attractiveness and its potential relationship with visual preferences for attractive faces in infancy. The present study aimed to assess infants' neural responses to attractive and unattractive faces in the context of the visual preference paradigm through a new integrated methodology.

Experimenters have primarily conducted looking time procedures and electrophysiological research independently and sequentially to make similar assessments (see: de Haan & Nelson, 1997; Karrer & Monti, 1995; Nelson & Collins, 1991; Peltola, Leppänen, Mäki, & Hietanen, 2009; Quinn, Doran, Reiss, & Hoffman, 2010). Pairing the

two methods strengthens the ability to correlate behavior and neural processing. However, the two methods differ in how they present stimuli, making it difficult to integrate preferential-looking and event-related potential techniques for simultaneous data collection.

## **INTEGRATION OF METHODS**

Preferential-looking techniques require showing pairs of static stimuli for extended durations of time (10 seconds for instance), whereas ERP methods require numerous short presentations (<1 seconds) of a single stimulus. During a visual preference study, researchers expect infants to look back and forth between stimuli. This technique greatly contrasts with ERP studies where changes in fixation can lead to movement artifact in neural data. Combining these methods can lead to difficulty in time-locking stimulus presentation to neural response if infants are given freedom to saccade between stimuli during preferential looking trials. Although some researchers have attempted to integrate behavioral looking time measures with ERP, none have provided a robust solution to this methodological challenge.

Karrer and Monti (1995) attempted simultaneous collection of looking time and ERPs. They presented infants with a combination of a visual oddball task (stimuli are presented with different frequencies, the “oddball” stimulus occurs with limited frequency compared to the familiar stimulus) and a habituation paradigm (with infant controlled durations of stimulus presentation). Researchers recorded ERPs and looking time during the oddball trials, but were concerned primarily with the behavioral data from the habituation trials (when no ERPs were recorded). Although Karrer and Monti found differences in Nc amplitude when comparing familiar and oddball trials, there were no significant looking time differences between stimuli and comparisons were limited



because ERPs and visual preferences were not assessed simultaneously, preventing direct postulations of relations between behavior and neural measures.

More recently, researchers have collected integrated behavioral and neural measures. Reynolds, Courage, and Richards (2010) examined simultaneous preferential-looking and ERP measures in response to paired comparison stimuli, providing evidence that the collection of ERPs during paired trials is possible. After familiarizing 4.5-, 6-, and 7.5-month-old infants with two visual stimuli, infants viewed alternating trials of a modified version of the oddball ERP paradigm and paired comparison trials of combinations of familiar and novel stimuli. The results showed correlations between visual preference and Nc amplitude measures, with greater Nc demonstrated for infants' preferred stimulus type regardless of the specific stimulus. The researchers suggest that Nc reflects the onset of sustained attention.

Traditionally, ERPs are time-locked to the onset of stimulus presentation. The defined origin for the ERP waveform provides accuracy of synchronizing brain processing across trials. Reynolds et al. (2010), however, segmented ERP trials via fixation onset, not at the onset of the stimulus presentation. This procedural deviation produces less precise ERPs. Because the researchers derived ERPs as time-locked with respect to saccade terminations, any experimenter error when measuring eye movement terminations would have produced artifactual trial-to-trial temporal jitter (i.e. differences in the latency of waveform components) of the single-trial EEG signal. This error in turn reduces the constructive summation of the time-locked EEG signals when averaging across trials to form an ERP. Additionally, as the stimuli are presented, they slide across the infant's retina immediately prior to the end of the infant's saccade, leading visual cortical regions involved in stimulus processing to activate before the time-locking event determined by researchers as the end of the saccade. Such pre-stimulus cortical activity

could confound baseline measures used in the quantification of ERP changes from pre- to post-stimulus presentation. These issues necessitate the design of more robust integration of visual preference and ERP methodologies.

## **OVERVIEW OF STUDY**

There were two goals of the present study. The first was to investigate infants' neural processing of facial attractiveness. No published studies have assessed infants' differential processing of facial attractiveness. Infants' ERPs should differentiate between levels of attractiveness in correspondence with the theory that attractive faces are more similar to face prototypes and thus processed more fluently. Based on previous adult and infant face processing findings, I predicted that attractive faces would be processed more fluently than unattractive faces, eliciting smaller N290 amplitudes, larger (less negative) P400 amplitudes, and shorter P400 latencies.

The second goal of this study was to integrate visual preference and ERP methods. Simultaneously collecting preferential-looking data and event-related potentials allowed for direct correlation between behavior and neural processing. I predicted that longer overall looking at attractive faces, indicating preference, would be correlated with smaller N290 amplitudes, indicating fluent processing. The procedure that follows could provide more reliable and accurate ERP data than previous attempts by capturing temporally-precise electrical responses to stimuli. Rather than define the ERP by fixation onset (see Reynolds, Richards, & Courage, 2010), establishing ERPs at stimulus onset is more consistent with standard ERP research.

This study modified the standard visual preference paradigm to ensure the time-locking of trials. The modifications also enabled the capturing of multiple ERPs for each face pair through segmenting the standard static presentation of visual preference stimuli

into consecutive repeated short presentations. If successful, behavioral and electrophysiological measures should reflect attractiveness preferences and face processing similar to that observed for these measures employed independently: Infants should show significantly greater looking times to attractive compared to unattractive faces and robust high signal-to-noise level ERPs that reflect face sensitive components found in previous facial processing ERP research (de Haan, Johnson, & Halit, 2007; de Haan, Pascalis, & Johnson, 2002; Halit, Csibra, Volein, & Johnson, 2004).

## **Chapter 2: Method**

### **PARTICIPANTS**

Participants included 80 six-month old full-term infants between the ages of five and six months ( $M = 191$  days, range of 175 to 208 days). The sample included Caucasian non-Hispanic (79%), Hispanic (14%), and mixed-race (7%) infants. The infants came from medium to high SES families recruited from the University of Texas at Austin's Children's Research Lab database of infants born in the Austin-metro area. The final analyses retained 43 (23 females, 20 males) of the original 80 infant participants. Based on a priori criteria, the analysis excluded all data from infants showing excessive fussiness, movement, or sleepiness (14) and affected by experimenter/equipment error (1). Data from infants were also excluded if the infant produced less than ten trials per stimulus type (22), which met the a priori criteria discussed below (de Haan & Nelson, 1997, 1999; Quinn, Westerlund, & Nelson, 2006).

### **STIMULI**

Stimuli consisted of approximately life-sized color images of adult female Caucasian faces with neutral expressions. The stimuli set included six faces: Three previously rated by adults as attractive (see Figure 3) and three previously rated by adults as unattractive (see Figure 4). I selected three faces rated highest in attractiveness ( $M = 4.53 \pm 0.12$ ) and three faces rated lowest in attractiveness ( $M = 1.88 \pm 0.08$ ) from a set of 60 female faces rated by adults ( $N = 43$ ) on a 7-point attractiveness scale (1 = unattractive or low attractiveness and 7 = attractive or high attractiveness). To eliminate possible distractions and confounds related to non-face preferences, a white oval cutout occluded the exterior of the face, including hairstyle, facial shape, ears, and jewelry). Using MATLAB (The Math Works, Inc., Natick, MA, USA) and Adobe Photoshop

(Adobe Systems Incorporated, San Jose, CA, USA), I assessed and corrected all images for the equivalence of luminance and contrast to control for potential differences in visual processing due to these characteristics.

To center the infants' attention, I created and showed two videos: one of an undulating green circle and ringing sound (intra-trial attention video), the other of sparkling stars and musical sounds (inter-trial attention video).

## **PROCEDURE**

Infants sat on their parent's lap or in a high chair centered in front of a 62-inch color monitor display. Facial images subtended  $\sim 84.59^\circ$  (w) x  $83.10^\circ$  (h) visual angle at a viewing distance of 180 cm. A camera focused on the infant recorded video to NetStation 4.4 (Electrical Geodesics, Inc., Eugene, OR, USA), a Macintosh based software package used for acquiring, viewing, and analyzing EEG/ERP data with synchronized video, which simultaneously recorded EEG and stimuli presentation events. I used E-Prime (Psychology Software Tools, Inc.), a PC based software package used for experiment presentation and data collection, on a separate computer to control stimuli presentation. Black room dividers hid the data collection equipment and additional contents of the room to prevent distraction.

## **Behavioral Data Collection**

During each presentation block, infants viewed ten instances of one pair of faces. Face pairs were selected randomly from each possible attractive/unattractive face combination and its left-right reversal. Infants participated until they saw a total of nine face pairs, or until they became tired or fussed, whichever came first. I determined in pilot testing that nine blocks of ten face pair exposures per block was the maximum number most infants would tolerate before fussing out. This number of presentations

ensured that the infants would produce a sufficient number of ERP segments (90 possible per infant, see description below) split between the two attractiveness face types.

Throughout each block, stimuli pairs flashed on and off the monitor, remaining on screen for 1.5 seconds (a longer duration than typical in ERP trials to provide time for visual preference assessment) and returning to a blank white screen for one second. We repeated the sequence within the block until the infant viewed ten instances of the face pair before moving on to the next block. From a control room adjacent to the experiment room, an experimenter watched the infant via video in NetStation. The experimenter conducted initial behavioral data coding online<sup>3</sup>, recording the direction of the infant's gaze and indicating when the infant turned its attention from the screen. E-Prime recorded both the left or right position of the attractive face and unattractive face and the coded direction of the infant's gaze. Upon assessment that the infant was not looking at the screen, the experimenter signaled for E-Prime to display the intra-trial attention video until the experimenter determined that the infant resumed fixation on the screen. After viewing ten instances of the face pair, the infant saw the inter-trial attention video to center their attention and provide a break before proceeding onto the next face pair.

### **Neural Response Data Collection**

We fitted infants with a HydroCel Geodesic Sensor Net (Electrical Geodesics, Inc.) with 32 channels (see Figure 2). Based on piloting, I omitted four optional electrodes (typically placed around the inferior orbits of each eye) because they distracted the infants. Electrode impedances (a measure of the obstruction of flow of electrons between the scalp and electrodes) were assessed and adjusted until they were below 100

---

<sup>3</sup> Although the experimenter had access to the stimulus presentation screen and thus potentially not blind to the placement of the attractive and unattractive faces, the experimenter was trained to focus on the video of the infant. Researchers were blind to face position during the offline coding of the behavioral data (see Data Processing – Behavioral Data Processing section, below).

k $\Omega$ , following Reynolds et al. (2010). NetStation recorded continuous EEG with an online reference<sup>4</sup> to Cz (the central midline electrode commonly used as a reference site) during the presentation of the face pairs. NetStation sampled activity at a rate of 250 Hz with a 0.1 to 30 HZ bandpass filter from the range of 28 scalp electrodes.

## **DATA PROCESSING**

### **Behavioral Data Processing**

We recorded each infant's looking behavior and corrected online coding mistakes via offline coding in NetStation. To prevent the possibility of experimenter bias based on the attractiveness of the face stimuli, the coders were blind to the faces presented to the infant and did not have access to information on the positions of the attractive and unattractive faces. While watching the video recording of the infant's looking behavior, coders indicated durations of fixations to stimuli and evaluated the direction (right or left) of the infants' looks if fixation lasted for at least 300 ms between stimulus onset and offset. I exported MATLAB computing software compatible files containing looking time durations, looking direction, and face type (attractive versus unattractive). Looking times to attractive and unattractive faces were separated and summed in MATLAB.

In a separate round of visual behavior coding, we rejected all trials where the infant was not looking at a stimulus at or before its onset or looked for less than 800 ms despite meeting the first requirement. The additional behavioral coding round indicated which trials were acceptable for ERP analysis.

---

<sup>4</sup> Reference refers to the calculation of EEG signals through difference between two electrodes – an electrode of interest and the “reference” electrode, thought to be isolated from the desired sites of interest (Luck, 2005).

At least one of three experimenters coded each infant. I determined the reliability of coding by calculating the intra-class correlations for 30% of the infants. The looking time coders achieved an intra-class correlation of .947, indicating high agreement.

### **Neural Response Data Processing**

After coding the data in NetStation as described above, I exported acceptable EEG data (trials where the infants fixated at or prior to stimulus onset with looking durations greater than or equal to 800 ms) into MATLAB compatible files. I artifact scored (rejected noise contaminated trials) with and analyzed the ERP data via the EEGLAB Toolbox (Delorme & Makeig, 2004) for MATLAB.

Two experimenters conducted manual artifact scoring via visual inspection for all participants in MATLAB. The artifact scoring coders achieved an intra-class correlation of .709, indicating acceptable agreement. I implemented Spherical Spline Interpolation to correct bad channels on all but nine participants. For three participants who showed excessive artifact, I implemented an automated artifact correction procedure (see Fujioka, Mourad, He, & Trainor, 2010). Electrode sites at the linked mastoids most frequently required correction. Experimenters visually inspected and removed trials contaminated by muscle, ocular, and signal artifacts.

During artifact scoring, we focused on the EEG signals at the two specific electrode sites of interest, PO9 and PO10. PO9 and PO10, parietal-occipital electrode sites, were of interest as these sites are proximal to the face sensitive region of the brain (the fusiform face gyrus) and thus enabled comparison with adult attractiveness N170 findings (Kanwisher, McDermott, & Chun, 1997; Trujillo, Jankowitsch, & Langlois, in press). We rejected all trials that showed obvious artifact or deviation from the signal cluster between -200 ms before stimulus onset (the baseline where no activity should be



present as stimulus processing should not yet have commenced) and 1000 ms after stimulus onset (the duration of time in which all face sensitive components of interest should occur). This rejection occurred via visual inspection. We rejected data from all infants who prior to or after artifact scoring retained less than 10 acceptable ERP trials each for attractive faces and for unattractive faces (a standard suggested by DeBoer, Scott, & Nelson, 2007). On average, we retained 26 trials per participant, evenly split between attractive ( $SE = 0.75$ ) and unattractive ( $SE = 0.70$ ) faces.

The collected EEG signals were segmented into periods starting -200 ms before stimulus onset and extending 1500 ms through the full duration of stimulus presentation. I extracted individual ERP segments from the EEG only for trials meeting the established fixation criteria. All ERPs were baseline-corrected by subtracting the average value of the -200 ms to 0 ms pre-stimulus interval, a time when the brain theoretically should not be processing stimuli and any shifts in activity can be considered noise. No ERPs were derived in instances where the infants did not maintain fixation for at least 800 ms after stimulus onset to prevent artifact contamination of the observed neural processing. I constructed grand average ERPs (the average of all ERPs for each face type across all retained participants) in MATLAB by averaging the segmented waveforms for all fixations to attractive faces and all fixations to unattractive faces.

After processing behavioral and ERP data, I related looking times to ERP amplitudes and latencies via least trimmed squares regression (see Results – Integrated Measures section, below).

## Chapter 3: Results

### LOOKING BEHAVIOR

For each face type (attractive and unattractive), I analyzed three behavioral dependent variables: total looking time in seconds, number of first looks, and average trial looking time in seconds. I conducted paired t-tests and repeated measures analysis of variance (RM ANOVA) to compare behavioral data for attractive and unattractive faces. I used Face type (attractive vs. unattractive) as the within-subjects factor and age (median split) and gender as between-subjects factors, which I analyzed to detect any unexpected influence of these participant attributes. I confirmed that there were no significant differences in looking time for males vs. females, younger vs. older infants, or the interaction between face type, gender, and age.

#### Total Looking Time

In the context of traditional preferential-looking techniques, total looking time is a standard measure of visual preference. All instances an infant looked at the attractive face or at the unattractive face were summed to produce each infant's total looking time to attractive faces and total looking time to unattractive faces. I did not find significant differences between infants' looking time to attractive ( $M = 50.11$  sec,  $SD = 12.54$ ) and unattractive ( $M = 48.22$ ,  $SD = 11.14$ ) faces;  $t(42) = .70$ ,  $p = .468$ ) although the mean looking times were in the expected direction.

#### First Looks

I investigated the number of first looks (defined as the face type infants fixated on during the first presentation of each of the nine face pairs) to attractive and unattractive faces to detect any attention patterns that may have resulted from the novel procedure, infant preferences, or another unknown factor. I summed each instance the infant looked

first to the attractive face or to the unattractive face to produce each first looks to attractive faces and first looks to unattractive faces totals. I found no significant difference between infants' first looks to attractive ( $M = 4.19$ ,  $SD = 1.22$ ) and unattractive ( $M = 4.81$ ,  $SD = 1.22$ ) faces;  $t(42) = 1.68$ ,  $p = .100$ ).

### **Average Trial Looking Time**

Average trial looking time provided a comparison of each infant's average attention to and preference for attractive and unattractive faces during individual trial presentations. The duration of looking for each instance the infant looked at an attractive face or an unattractive face were averaged to attain each infants' average trial looking time to attractive faces and unattractive faces. There were no significant differences between average individual trial looking times for attractive ( $M = 1.19$ ,  $SD = .13$ ) and unattractive ( $M = 1.20$ ,  $SD = .13$ ) faces;  $t(42) = .56$ ,  $p = .577$ ).

### **ERP RESPONSES**

I used repeated measure analysis of variance (RM ANOVA) for the factors of face type and electrode locations to analyze the differences in amplitude and latency of N290 and P400 components for the attractive and unattractive face grand average ERPs. I examined ERPs from electrode sites of interest over the posterior parietal-occipital scalp regions (specifically PO9, and PO10), sites typically linked to face processing and attractiveness processing in adults (see Figure 2).

Figures 5 and 6 show the grand average ERP waveforms at electrode sites of interest (PO9 and PO10) on the left and right hemispheres and scalp topographies at component latencies of interest. Consistent with past infant ERP work, the ERPs produced showed clear, discernable peaks typical of face processing in 6-month-old infants, including N290 and P400 components.

## **Amplitude**

I analyzed amplitude differences based on face type (attractive vs. unattractive) for N290 and P400 ERP components across PO9 and PO10 electrode sites.

### ***N290 Amplitude***

A 2-way RM ANOVA of N290 amplitudes yielded a significant main effect of face type,  $F(1, 42) = 10.00, p < .003, \eta^2 = .19$ . The main effect of electrode location was marginally significant,  $F(1, 42) = 3.19, p < .082, \eta^2 = .07$ . The interaction of face type and electrode location was significant,  $F(1, 42) = 5.64, p < .022, \eta^2 = .12$ . Post-hoc follow-up of the N290 component amplitude showed significantly smaller amplitude in the left-hemisphere (PO9) for attractive ( $M = -5.64, SD = 7.54$ ) compared to unattractive faces ( $M = -9.72, SD = 7.04$ ),  $p < .009$ , but not in the right-hemisphere (PO10) for attractive faces ( $M = -5.15, SD = 7.77$ ) compared to unattractive faces ( $M = -6.16, SD = 7.48$ ),  $p < .538$ .

### ***P400 Amplitude***

A 2-way RM ANOVA of P400 amplitude yielded significant main effects for face type  $F(1, 42) = 10.05, p < .003, \eta^2 = .19$ , and electrode location,  $F(1, 42) = 12.56, p < .001, \eta^2 = .23$ . However, the interaction of face type and electrode location was not significant,  $F(1, 42) = 1.65, p < .206, \eta^2 = .04$ . Post-hoc follow-up of P400 component amplitude showed significantly larger amplitude in the left-hemisphere (PO9) for attractive ( $M = 2.58, SD = 8.66$ ) compared to unattractive faces ( $M = -1.93, SD = 6.30$ );  $t(42) = 3.55, p = .001$ , and in the right-hemisphere (PO10) for attractive ( $M = 4.15, SD = 9.34$ ) compared to unattractive faces ( $M = 1.25, SD = 6.54$ );  $t(42) = 2.48, p = .017$ .

## **Latency**

I analyzed latency differences based on face type (attractive vs. unattractive) for N290 and P400 ERP components across PO9 and PO10 electrode sites.

### ***N290 Latency***

A 2-way RM ANOVA of N290 latencies showed a significant main effect of electrode location,  $F(1, 42) = 4.35, p < .043, \eta^2 = .53$ . Neither the main effect of face type,  $F(1, 42) = 1.81, p < .186, \eta^2 = .04$ , nor the interaction between electrode location and face type were significant,  $F(1, 42) = 1.12, p < .295, \eta^2 = .03$ . Follow-up analysis showed that the N290 latency on the right-hemisphere electrode site (PO10) was significantly shorter for attractive faces ( $M = 301.40, SD = 58.25$ ) compared to unattractive faces ( $M = 325.21, SD = 50.06$ ),  $p = .024$ , while there was no difference at PO9 for attractive faces ( $M = 313.86, SD = 52.86$ ) compared to unattractive faces ( $M = 326.05, SD = 49.41$ ),  $p < .242$ .

### ***P400 Latency***

A 2-way RM ANOVA of P400 latencies showed no significant main effects for face type,  $F(1, 42) = .20, p < .656, \eta^2 = .01$ , or electrode location,  $F(1, 42) = .34, p < .561, \eta^2 = .01$ . The interaction between face type and electrode location was significant,  $F(1, 42) = 4.33, p < .044, \eta^2 = .09$ . Follow-up analysis of the interaction showed no coherent trends; PO9 latencies were not significantly shorter for attractive ( $M = 491.72, SD = 79.11$ ) compared to unattractive faces ( $M = 514.79, SD = 81.07$ ) and PO10 latencies were not significantly longer for attractive ( $M = 502.14, SD = 75.98$ ) compared to unattractive faces ( $M = 495.54, SD = 86.35$ ),  $ps > .11$ .

## **RELATIONSHIP BETWEEN LOOKING TIME AND ERP MEASURES**

I analyzed the relation between ERP component amplitude and latency and individual trial looking times. Analyzing individual trial looking time with N290 and P400 amplitudes and latencies provided direct comparison of simultaneous behavioral and neural reactions. I used least-trimmed-squares regression to analyze the relationship between individual trial looking times and ERP amplitudes and latencies. Least-trimmed-squares regression is a robust statistical technique not influenced by outliers and model assumption violations (Atkinson & Cheng, 1999; Rousseeuw & Leroy, 2003). Least-trimmed-squares regression finds the subset  $k$  of  $n$  data points with the minimal squared residuals sum. Here,  $k$  was determined a priori according to a 95%-confidence-interval global exclusion threshold for outliers.

I examined the predictive relationship between amplitudes and latencies and trial looking time by first arranging the data for attractive faces and for unattractive faces by increasing amplitude, increasing latency, and decreasing trial looking time. This was done to for comparison to our predicted model that that both amplitude and latency should increase and looking time should decrease for unattractive faces compared to attractive faces. I also collapsed attractive and unattractive face data to detect an overall relationship between ERP component measures and trial looking time. I calculated separate slope changes in response for each participant and used linear regression to predict the slopes of the ERP component changes for the corresponding slopes for the trial looking times.

On average, I excluded 14% of data points for amplitude analyses and 12% of data points for latency analyses from the final tests relating trial looking times and ERP amplitudes and latencies. The relationship between trial looking time and ERP component amplitudes and latencies were assessed only for previously attained

significant ERP findings. I found significant results for N290, but no significant results for P400 ( $ps > .240$ ). All results were corrected for multiple comparisons.

### **Trial Looking Time and N290 Amplitude**

I found that greater N290 amplitude responses (from low high attractive to low attractive faces) from electrode site PO9 corresponded with greater trial looking times ( $\beta_{PO9} = -.43 \pm .16$ ,  $t(37) = -2.72$ ,  $p < .021$ ). In general, unattractive faces elicited larger (more negative) N290 amplitudes and longer trial looking times and attractive faces elicited smaller (less negative) N290 amplitudes and shorter trial looking times. I also found that larger N290 amplitude responses from electrode site PO9 corresponded with longer trial looking times within the collapsed dataset ( $\beta_{PO9} = -.47 \pm .16$ ,  $t(37) = -2.91$ ,  $p < .013$ ).

### **Trial Looking Time and N290 Latency**

I found that increasing N290 latency responses from electrode site PO10 corresponded to increasing trial looking times within the collapsed data ( $\beta_{PO10} = .45 \pm .14$ ,  $t(38) = 3.20$ ,  $p < .006$ ). In general, shorter latencies were associated with shorter trial looking times and longer latencies were associated with longer trial looking times. I found no significant relationship between trial looking time and N290 latency when comparing attractive and unattractive face data ( $ps > .194$ ).

## **Chapter 4: Discussion**

The present study examined the relationship between infants' behavioral responses to and neural processing of facial attractiveness through the integration of event-related potential (ERP) and visual preference methods. To my knowledge, this is the first study to demonstrate infants' differential neural processing of attractive and unattractive faces and to examine the relationship of differential processing and looking behavior towards attractive and unattractive faces.

### **ATTRACTIVENESS PREFERENCES**

The study did not yield expected visual preference results. While developmental researchers have found robust preferences for attractive compared to unattractive faces in infants (Langlois et al, 1987; 1991) and my data showed that mean looking times were in the expected direction for attractive and unattractive faces, there were no significant differences in looking time in this study. I posit that the absence of visual attractiveness preference is due to the short duration that the stimuli remained on the screen during each presentation (1.5 seconds) within the interrupted format (1 second white screen between repetitions) of the face pair presentations. Traditional preferential-looking studies show static stimuli pairs for 10 seconds or greater. Decreasing the presentation duration to 1.5 seconds, although repeating the stimuli pairs for an overall 15 seconds when summed, may have prevented the infants from engaging in preferential looking. I predict that I would find preference for attractive faces over unattractive faces if I presented the stimuli pairs for a greater, yet to be determined, length of time.



## NEURAL PROCESSING OF FACIAL ATTRACTIVENESS

This study found that infants' neural processing differentiates between attractive and unattractive faces. The results are comparable to that of past research of adults' neural processing and differentiation of facial attractiveness.

### **Amplitude**

Amplitude differences were found between attractive and unattractive faces at both N290 (left hemisphere at PO9 electrode site) and P400 (left hemisphere at PO9 and right hemisphere at PO10). These ERP amplitude difference patterns are similar to those observed between attractive and unattractive faces in studies of the adult N170. In adult face processing research, smaller amplitudes for attractive faces compared to unattractive faces have been argued to reflect more fluent processing of attractive versus unattractive faces (Halit, de Haan, & Johnson, 2000; Trujillo, Jankowitsch, & Langlois, in press). Like adult N170 responses, infant N290 amplitude was smaller for attractive faces compared to unattractive faces.

Comparing infant P400 neural responses to adult N170 responses is more challenging due to differences in component polarity; P400 is a positive component and N170 is a negative component. The N170 in adults and P400 in infants have both been shown to reflect similar patterns of configural and featural face processing (Scott & Nelson, 2005). N170 is believed to arise from the merging of P400 and N290 during childhood due to growth and tissue folding throughout development that changes the neuroanatomical brain structure (see Andersen, 2003). This brain maturation may lead to a shift in the N290 and P400 dipole sources. These two signals merge into a single response and thus may summate in a manner consistent with their between-condition differences for the separate responses in infants and the single response in adults. For example, a larger (more negative) N290 for unattractive versus attractive faces combined

with a smaller (more negative) P400 for unattractive versus attractive faces would yield the pattern observed for faces in adult N170 responses to facial attractiveness. Based on this speculation, we can evaluate the P400's amplitude as negative polarity shifts related to processing of facial attractiveness. Similar to the adult N170, the infant P400 is more negative in polarity for unattractive faces compared to attractive faces. These findings suggest that infants engage in processing of attractiveness in a manner comparable to adults despite differences in neurological maturity and experience.

### ***Amplitude and Processing Fluency***

Reaction time data support my argument that amplitude differences based on attractiveness level found in the present study reflect differences in processing fluency. Adult N170 amplitude responses to attractive, averaged, and unattractive faces predict the reaction time with which participants categorize faces as either human or chimpanzee (Trujillo, Jankowitsch, & Langlois, in press). Attractive and averaged faces produce shorter reaction times than unattractive faces. Here, I found similar amplitude differences corresponding with level of attractiveness, but were not able to access processing fluency in infants through reaction time. As we cannot instruct infants to perform reaction time tasks, other measures must be considered to evaluate the speed of processing and support our argument that differences in preference for and processing of attractive and unattractive faces are indicative of processing fluency. Directing attention to latency results in infancy research may also provide additional support for processing fluency based on attractiveness.

### **Latency**

I found differences in processing latency between attractive and unattractive faces. At PO10, N290 responses to attractive faces had shorter latencies than responses to

unattractive faces. This finding may represent more fluent, rapid processing of attractive faces compared to unattractive faces. I also found a significant P400 latency interaction between face type and electrode site hemisphere. The interaction at P400 is more difficult to support as a legitimate finding with no apparent patterns arising from the data. The P400 component ERPs had two distinct peaks instead of just one. The presence of multiple peaks within a component makes the analysis and interpretation of the latency difference more problematic. Here, in combination with no significant main effects, the complicated interaction may be spurious.

### **Hemispheric Asymmetry**

The hemispheric asymmetry of neural processing of facial attractiveness in infants for both amplitude and latency has interesting implications. Previous infant behavioral studies described hemispheric asymmetry and right-hemisphere advantage in face discrimination, conflicting with some of my results (de Schonen, Gil de Diaz, & Mathivet, 1986; de Schonen & Mathivet, 1990). In conflict with past research, I found amplitude differences for N290 in the left hemisphere at PO9, but not in the right hemisphere at PO10. However, I found latency differences for N290 in the right hemisphere at PO10, but not in the left hemisphere at PO9. de Haan, Pascalis, and Johnson (2002) provide support for my findings, with 6-month-olds showing strong left-hemisphere sensitivity and less right-hemisphere sensitivity. This hemispheric asymmetry was found in response to upright and inverted human and monkey faces (see de Haan, Pascalis, & Johnson, 2002, Figure 3, page 204). It is unclear how my facial attractiveness processing findings relate to these face inversion and species processing findings. Further investigation is needed to interpret these left-hemisphere sensitivity findings that diverge the body of ERP face processing research.

Recent adult face processing research also provides possible clarification for both these and my findings of hemispheric asymmetry. Functional magnetic resonance imaging (fMRI) results in adults suggest that the left hemisphere initially processes low-level face appearance, or the degree of how “face-like” is an image (Meng, Cherian, Singal, & Sinha, 2012). Images that are more “face-like” initially produced greater neural activation in the left hemisphere. The left hemisphere amplitude difference between attractive and unattractive faces in the present study might reflect processing of general face semblance. Meng and colleagues (2012) also found that, slightly later in processing, the right hemisphere then engages in perceptual judgment and response differentiation, which indicates active categorization of the stimulus as a face or non-face. The right hemisphere latency difference between attractive and unattractive faces in the present study may reflect face categorization, although infants did not compare faces to non-faces, thus limiting the context for categorization. Because Meng and colleagues (2012) compared faces to non-face “face-like” images instead of comparing within face groups, further investigation is needed to distinguish activation differences within the category of faces while considering hemisphere asymmetry to verify the assessment of my findings.

#### **AVERAGENESS THEORY**

Although averaged faces were not among the stimuli presented to participants, the present study provides support for the application of averageness theory to infants’ processing of attractive faces. Infants’ neural response patterns match averageness theory predictions of face processing. Infants appear to process attractive faces, argued to be closer to the prototype and more average and facelike, more fluently than unattractive faces. I predict that infants would process averaged faces most fluently compared to individual faces of all face categories.

## **INTEGRATION OF METHODS**

The study did not yield typical visual preference results of overall longer looking at attractive faces compared to unattractive faces, preventing intended analysis of the relationship between visual preferences for and neural processing of attractive faces compared to unattractive faces. However, I did find a relationship between trial looking times and neural responses. Although, as predicted, unattractive faces elicited larger N290 amplitudes and longer N290 latencies and attractive faces elicited smaller N290 amplitudes and shorter N290 latencies, these neural responses correlated to trial looking times in the direction opposite of that expected. Neural responses to unattractive faces correlated with longer looking times whereas neural responses to attractive faces correlated with shorter looking times. These correlations do not match expectations of attractiveness preferences leading to longer looking to attractive faces than unattractive faces.

I propose that the limited time the faces were presented (1.5 seconds) prevented the engagement of preference based looking and processing. However, my finding of infants focusing less initial visual attention, measured here as trial looking time, on attractive faces than unattractive faces during early processing suggests that infants require less exposure to process attractive faces than unattractive faces. I speculate that when comparing the stimuli to their internal face prototype, the infants more rapidly evaluated the attractive faces in comparison to the prototype because attractive faces are more similar to the prototype than unattractive faces. The attractive faces thus required less visual attention than the unattractive faces. I predict that if infants were permitted to look longer at the faces, the initial processing attention would shift to preferential looking, with longer overall looking to attractive faces than unattractive faces. I further speculate that if I experimented with presenting more than 10 repetitions per face pair, I

might find a trial presentation count where a transition from attention to preference would occur. While infants would initially show longer trial looking to unattractive faces, they would shift to longer trial looking to attractive faces.

Conceptually, this study's integration of visual preference and ERP methods for simultaneous collection of behavioral and neural data make it an important advancement for developmental research despite its failure to replicate past visual preference findings. Because a large proportion of research on infant cognition employs some variation of the looking-time paradigm, it is necessary to adjust the present method to attain results consistent with the body of infancy research. Although visual preference paradigms on their own provide valuable information about infant cognition, these methods infer rather than directly measure the underlying information processing behind behavior. In contrast, ERPs measure neural response directly, though inference is still required in interpretation of ERP responses. Combining these distinct methods helps to define the relationship between behavior and neural processing.

## **FUTURE RESEARCH**

The findings guide two distinct lines of future research. One study should incorporate averaged and midrange attractive faces in standard ERP research with infants. A second study should modify and improve upon the integration of visual preference and ERP methods.

### **Processing of Facial Attractiveness**

The first suggested future study would present infants with unattractive, medium attractive, high attractive, and averaged female faces utilizing a traditional (non-integrated) ERP method. The present study found differential processing of attractive and unattractive faces by infants, but did not evaluate differences in neural processing of

averaged faces or faces of midrange attractiveness. A more rigorous test of averageness theory would assess infants' processing of averaged and medium attractive faces. Including medium attractive faces would test whether the relation between attractiveness and processing fluency is linear versus nonlinear. On the one hand, averaged faces, like attractive individual faces, may be processed most fluently, as averaged faces should be most similar to face prototypes. Likewise, medium attractive faces should be processed more fluently than unattractive faces, if the relationship is linear. On the other hand, nonlinear threshold relations between attractiveness and fluency are also possible. Averaged and attractive faces could be privileged and processed substantially more fluently than either medium or unattractive faces. Conversely, unattractive faces, as poor exemplars, could be processed markedly less fluently than medium or averaged and attractive faces.

This line of research could also confirm that my findings of differential processing of attractiveness by infants are consistent when examined within a standard ERP collection framework. Because the present differential processing findings were acquired through an altered method, there remains the possibility that this differentiated processing occurs only in the context of paired comparison of stimuli. By collecting ERPs elicited by faces presented individually rather than in pairs, I can verify whether the integrated method results are comparable to standard ERP research results.

Additionally, this future studies should examine another infant ERP component linked to face processing: The Nc component found between 400 ms and 800 ms after stimulus onset. The Nc has been studied in the context of presentation of the infant's mother's and strangers' faces and is thought to indicate familiarity. Although all faces I presented to the infants are strangers, I would expect attractive and averaged faces to produce neural responses more similar to mother's faces, (larger NC amplitude) and

unattractive faces to produce neural responses similar to strangers' faces (smaller NC amplitude). This prediction comes from attractive and averaged faces being closer to the prototype and thus proposed to be more familiar.

### **Modified Behavioral-Neural Integration**

The second suggested study should improve upon the integrated method established in the present study in order to capture expected visual preferences for attractive faces compared to unattractive faces. The new study would follow a procedure similar to the present study, but would feature a series of modifications to the paired stimuli presentation length and number of repetitions of paired stimuli presentation to determine the ideal framework for attaining ERPs and visual preference simultaneously. In the first two parts of the new study, the length of time the stimuli appear on the screen would be increased from 1.5 to 2.5 and 5 seconds. The still to be determined number of instances each stimuli pair is presented would be decreased in order to maintain a short overall experiment duration for the infant participants. The third part of the new study would retain the 1.5 second presentation while increasing the number of instances each face pair is presented to 20 presentations to provide additional overall face presentation time in hopes of capturing visual preferences. The still to be determined number of face pairs presented would be decreased in order to maintain a short overall experiment duration for the infant participants. These three separate modifications would be assessed for looking time patterns.

If further attempts of integrating visual preference and ERP methods are successful, I should find typical infant visual preference and ERP responses. Doing so would allow us to test the relationship between neural processing and preferences for attractive faces compared to unattractive faces. If I find that ERP responses correlate with



looking time, it would help validate looking time as an acceptable measure of infant information processing. Conversely, if neural response and looking time are unrelated, I might call into question the use of behavioral looking time assessments of information processing.

## **CONCLUSIONS**

Although the novel integration of preferential looking and ERP techniques did not yield expected behavioral results, I have found support for averageness theory with evidence that infants may process attractive faces more fluently than unattractive faces. These results match past findings of differentiated processing by adults based on attractiveness with the exception that ERP amplitude responses were strongest at the left-hemisphere electrode site instead of right hemisphere electrode site (Halit, de Haan, & Johnson, 2000; Trujillo, Jankowitsch, & Langlois, in press). Further research is necessary to verify and expand upon my findings of infants' differentiated face processing based on attractiveness and to refine, clarify, and improve upon the integrated ERP and visual preference method and results.



Figure 1: Examples of 32 Face Morphs

These faces were created in MorphAge using 32 individual young adult Caucasian female faces. Each morph was made from a random set of 32 distinct faces of varying levels of attractiveness. None of these faces were presented to participants in the present study.

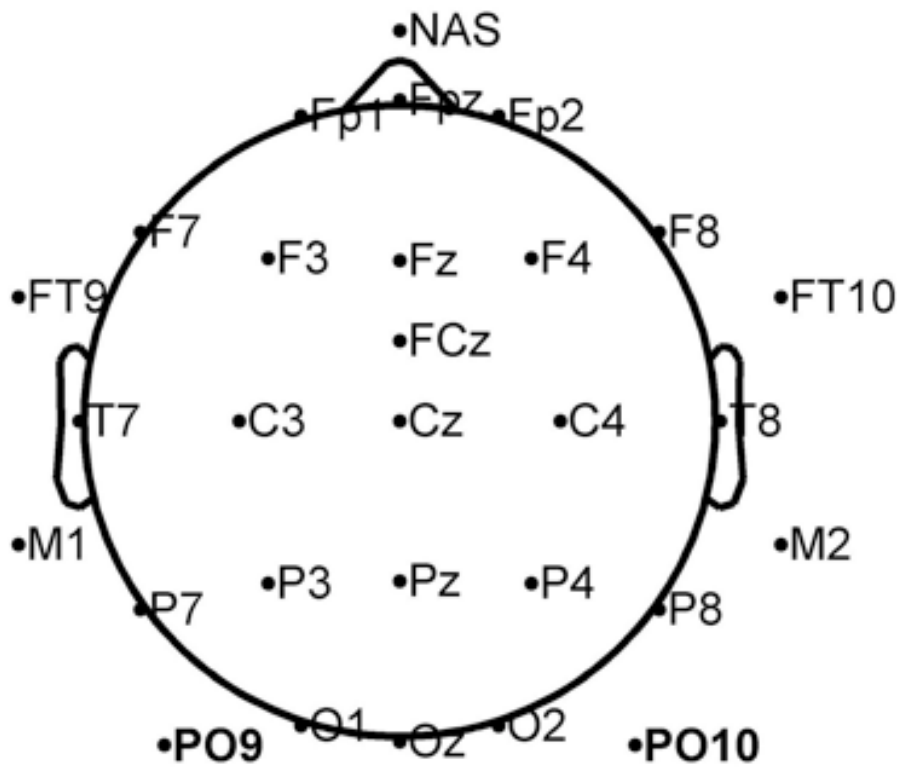


Figure 2: Electrode Sites Map

Scalp map of a HydroCel Geodesic Sensor Net (Electrical Geodesics, Inc.) with 32 channels. The electrodes relevant to this study have are in bold font: PO9 and PO10.



Figure 3: Attractive Face Stimuli

Pictures of attractive face stimuli presented to participants. Each of these faces was presented in pairs with the unattractive face stimuli.



Figure 4: Unattractive Face Stimuli

Pictures of unattractive face stimuli presented to participants. Each of these faces was presented in pairs with the attractive face stimuli.

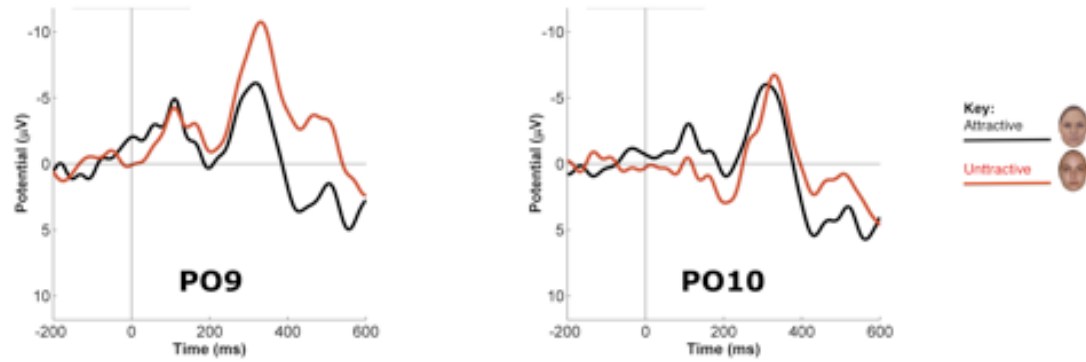


Figure 5: PO9 and PO10 Grand Average ERP Waveforms

These grand average event-related potential waveforms show the responses elicited by attractive and unattractive faces. The figures represent ERPs from the left-hemisphere (PO9) and right-hemisphere (PO10) electrode sites of interest.

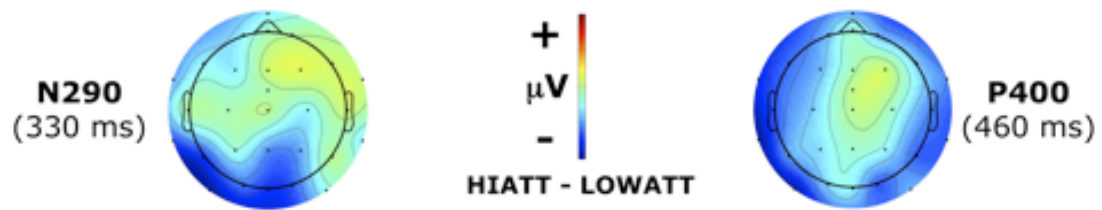


Figure 6: PO9 and PO10 Scalp Topographies

These scalp topographies show differences between attractive and unattractive face for N290 and P400 component voltage. The N290 is mapped at a latency of 330 ms and the P400 is mapped at a latency of 460 ms.

## References

- Andersen, S. L. (2003). Trajectories of brain development: Point of vulnerability or window of opportunity?. *Neuroscience and Biobehavioral Reviews*, 27(1-2), 3-18. doi:10.1016/S0149-7634(03)00005-8
- Atkinson, A. C. & Cheng, T. C. (1999) Computing least trimmed squares regression with the forward search. *Statistics and computing*, 9 (4). 251-263. doi:10.1023/A:1008942604045
- Bentin, S., Allison, T., Puce, A., Perez, E., & McCarthy, G. (1996). Electrophysiological studies of face perception in humans. *Journal Of Cognitive Neuroscience*, 8(6), 551-565. doi:10.1162/jocn.1996.8.6.551
- Cassia, V., Kuefner, D., Westerlund, A., & Nelson, C. A. (2006). A behavioural and ERP investigation of 3-month-olds' face preferences. *Neuropsychologia*, 44(11), 2113-2125. doi:10.1016/j.neuropsychologia.2005.11.014
- Courchesne, E., Ganz, L., & Norcia, A. M. (1981). Event-related brain potentials to human faces in infants. *Child Development*, 52(3), 804-811. doi:10.2307/1129080
- de Haan, M., Johnson, M. H., & Halit, H. (2003). Development of face-sensitive event-related potentials during infancy: A review. *International Journal of Psychophysiology*, 51(1), 45-58. doi:10.1016/S0167-8760(03)00152-1
- de Haan, M., Johnson, M. H., & Halit, H. (2007). Development of face-sensitive event-related potentials during infancy. In M. de Haan (Ed.), *Infant EEG and event-related potentials* (pp. 78-99). New York, NY US: Psychology Press.
- de Haan, M., & Nelson, C. A. (1997). Recognition of the mother's face by six-month-old infants: A neurobehavioral study. *Child Development*, 68(2), 187-210. doi:10.2307/1131845
- de Haan, M., & Nelson, C. A. (1999). Brain activity differentiates face and object processing in 6-month-old infants. *Developmental Psychology*, 35(4), 1113-1121. doi:10.1037/0012-1649.35.4.1113
- de Haan, M., Pascalis, O., & Johnson, M. H. (2002). Specialization of neural mechanisms underlying face recognition in human infants. *Journal of Cognitive Neuroscience*, 14(2), 199-209. doi:10.1162/089892902317236849
- de Schonen, S., Gil-de-Diaz, M., & Mathivet, E. (1986). Hemispheric asymmetry in face processing in Infancy. In H.D. Ellis, M.A. Jeeves, F. Newcombe & A. Young (Eds). *Aspects of face processing*. (pp. 199-209). Hingham, MA: Martinus Nijhoff.
- de Schonen, S., & Mathivet, E. (1990). Hemispheric asymmetry in a face discrimination task in infants. *Child Development*, 61(4), 1192-1205. doi:10.2307/1130887



- DeBoer, T., Scott, L. S., & Nelson, C. A. (2007). Methods for acquiring and analyzing infant event-related potentials. In M. de Haan (Ed.) , *Infant EEG and event-related potentials* (pp. 5-37). New York, NY US: Psychology Press.
- Delorme, A., & Makeig, S. D. (2004). EEGLAB: an open source toolbox for analysis of single-trial EEG dynamics including independent component analysis. *Journal of Neuroscience Methods*, 134(1), 9-21. <http://dx.doi.org.ezproxy.lib.utexas.edu/10.1016/j.jneumeth.2003.10.009>
- Fantz, R. L. (1958). Pattern vision in young infants. *The Psychological Record*, 843-47.
- Fujioka, T., Mourad, N., He, C., & Trainor, L. J. (2011). Comparison of artifact correction methods for infant EEG applied to extraction of event-related potential signals. *Clinical Neurophysiology*, 122(1), 43-51. <http://dx.doi.org.ezproxy.lib.utexas.edu/10.1016/j.clinph.2010.04.036>
- Halit, H., Csibra, G., Volein, Á., & Johnson, M. H. (2004). Face-sensitive cortical processing in early infancy. *Journal of Child Psychology And Psychiatry*, 45(7), 1128-1234. doi:10.1111/j.1469-7610.2004.00321.x
- Halit, H., de Haan, M., & Johnson, M. H. (2000). Modulation of event-related potentials by prototypical and atypical faces. *Neuroreport: For Rapid Communication of Neuroscience Research*, 11(9), 1871-1875. doi:10.1097/00001756-200006260-00014
- Halit, H., de Haan, M., & Johnson, M. H. (2003). Cortical specialisation for face processing: Face-sensitive event-related potential components in 3- and 12-month-old infants. *Neuroimage*, 19, 1180-1193. doi:10.1016/S1053-8119(03)00076-4
- Hoss, R. A., Ramsey, J. L., Griffin, A. M., & Langlois, J. H. (2005). The role of facial attractiveness and facial masculinity/femininity in sex classification of faces. *Perception*, 34(12), 1459-1474. doi:10.1068/p5154
- Karrer, R., & Monti, L. A. (1995). Event-related potentials of 4–7 week-old infants in a visual recognition memory task. *Electroencephalography & Clinical Neurophysiology*, 94(6), 414-424. doi:10.1016/0013-4694(94)00313-A
- Kanwisher, N., McDermott, J., & Chun, M. M. (1997). The fusiform face area: A module in human extrastriate cortex specialized for face perception. *The Journal of Neuroscience*, 17(11), 4302-4311.
- Key, A. F., Stone, W., & Williams, S. M. (2009). What do infants see in faces? ERP evidence of different roles of eyes and mouth for face perception in 9-month-old infants. *Infant and Child Development*, 18(2), 149-162. doi:10.1002/icd.600
- Kurtzberg, D., Vaughan, H. G., Courchesne, E., Friedman, D., Harter, M., & Putnam, L. E. (1984). Developmental aspects of event-related potentials. *Annals Of The New*

- York Academy Of Sciences, 425300-318. doi:10.1111/j.1749-6632.1984.tb23551.x
- Langlois, J. H., Ritter, J. M., Roggman, L. A., & Vaughn, L. S. (1991). Facial diversity and infant preferences for attractive faces. *Developmental Psychology*, 27(1), 79-84. doi:10.1037/0012-1649.27.1.79
- Langlois, J. H., & Roggman, L. A. (1990). Attractive faces are only average. *Psychological Science*, 1(2), 115-121. doi:10.1111/j.1467-9280.1990.tb00079.x
- Langlois, J. H., Roggman, L. A., Casey, R. J., Ritter, J. M., Rieser-Danner, L. A., & Jenkins, V. Y. (1987). Infant preferences for attractive faces: Rudiments of a stereotype?. *Developmental Psychology*, 23(3), 363-369. doi:10.1037/0012-1649.23.3.363
- Langlois, J. H., Roggman, L. A., & Rieser-Danner, L. A. (1990). Infants' differential social responses to attractive and unattractive faces. *Developmental Psychology*, 26(1), 153-159. doi:10.1037/0012-1649.26.1.153
- Luciana, M., & Nelson, C. A. (1998). The functional emergence of prefrontally-guided working memory systems in four- to eight-year-old children. *Neuropsychologia*, 36(3), 273-293. doi:10.1016/S0028-3932(97)00109-7
- Luck, S. J. (2005). *An introduction to the event-related potential technique*. Cambridge, MA: MIT Press.
- Luck, S. J. (2007). *What is an ERP?* Retrieved from: <http://www.erpinfo.org/what-is-an-erp>
- Meng, M., Cherian, T., Singal, G., & Sinha, P. (2012). Lateralization of face processing in the human brain. *Proceedings of the Royal Society B, Biological Sciences*. doi:10.1098/rspb.2011.1784
- Nelson, C. A., & Collins, P. F. (1991). Event-related potential and looking-time analysis of infants' responses to familiar and novel events: Implications for visual recognition memory. *Developmental Psychology*, 27(1), 50-58. doi:10.1037/0012-1649.27.1.50
- Partridge, T. (2010). Infant EEG asymmetry differentiates between attractive and unattractive faces. *Dissertation Abstracts International*, 70, (9-B), 5870.
- Peltola, M. J., Leppänen, J. M., Mäki, S., & Hietanen, J. K. (2009). Emergence of enhanced attention to fearful faces between 5 and 7 months of age. *Social Cognitive And Affective Neuroscience*, 4(2), 134-142. doi:10.1093/scan/nsn046
- Potter, T., & Corneille, O. (2008). Locating attractiveness in the face space: Faces are more attractive when closer to their group prototype. *Psychonomic Bulletin & Review*, 15(3), 615-622. doi:10.3758/PBR.15.3.615

- Quinn, P. C., Doran, M. M., Reiss, J. E., & Hoffman, J. E. (2010). Neural markers of subordinate-level categorization in 6- to 7-month-old infants. *Developmental Science*, 13(3), 499-507. doi:10.1111/j.1467-7687.2009.00903.x
- Quinn, P. C., Kelly, D. J., Lee, K., Pascalis, O., & Slater, A. M. (2008). Preference for attractive faces in human infants extends beyond conspecifics. *Developmental Science*, 11(1), 76-83. doi:10.1111/j.1467-7687.2007.00647.x
- Quinn, P. C., Westerlund, A., & Nelson, C. A. (2006). Neural Markers of Categorization in 6-Month-Old Infants. *Psychological Science*, 17(1), 59-66. doi:10.1111/j.1467-9280.2005.01665.x
- Reynolds, G. D., Courage, M. L., & Richards, J. E. (2010). Infant attention and visual preferences: Converging evidence from behavior, event-related potentials, and cortical source localization. *Developmental Psychology*, 46(4), 886-904. doi:10.1037/a0019670
- Rousseeuw, P. J., & Leroy, A. M. (2003). *Robust regression and outlier detection*. Honoken, NJ: John Wiley & Sons, Inc.
- Rubenstein, A. J., Kalakanis, L., & Langlois, J. H. (1999). Infant preferences for attractive faces: A cognitive explanation. *Developmental Psychology*, 35(3), 848-855. doi:10.1037/0012-1649.35.3.848
- Samuels, C. A., & Ewy, R. (1985). Aesthetic perception of faces during infancy. *British Journal Of Developmental Psychology*, 3(3), 221-228. doi:10.1111/j.2044-835X.1985.tb00975.x
- Scott, L. S., & Nelson, C. A. (2006). Featural and configural processing in adults and infants: A behavioral and electrophysiological investigation. *Perception*, 35(8), 1107-1128. Doi:10.1068/p5493
- Scott, L. S., Shannon, R. W., & Nelson, C. A. (2006). Neural correlates of human and monkey face processing in 9-month-old infants. *Infancy*, 10(2), 171-186. doi:10.1207/s15327078in1002\_4
- Slater, A., Von der Schulenburg, C., Brown, E., Badenoch, M., Butterworth, G., Parsons, S., & Samuels, C. (1998). Newborn infants prefer attractive faces. *Infant Behavior & Development*, 21(2), 345-354. doi:10.1016/S0163-6383(98)90011-X
- Trujillo, L.T., Jankowitsch, J.M., & Langlois, J.H. (in press). Beauty is in the ease of the beholding: A neurophysiological test of averageness theory of facial attractiveness. *Cognitive, Affective, & Behavioral Neuroscience*. doi:10.3758/s13415-013-0230-2
- Trujillo, L. T., Kornguth, S., & Schnyer, D. M. (2009). An ERP examination of the differential effects of sleep deprivation on exogenously cued and endogenously cued attention. *Sleep*, 32, 1285-1297.

Winkielman, P., Halberstadt, J., Fazendeiro, T., & Catty, S. (2006). Prototypes Are Attractive Because They Are Easy on the Mind. *Psychological Science*, 17(9), 799-806. doi:10.1111/j.1467-9280.2006.01785.x