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Infant EEG Asymmetry Differentiates Between Attractive and Unattractive Faces

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Infant EEG Asymmetry Differentiates Between Attractive and Unattractive Faces

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Dedication

This dissertation is dedicated to my husband, Loren, and my children, Jake and Kylie, for unyielding love, support, and encouragement.

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Infant EEG Asymmetry Differentiates Between Attractive and Unattractive Faces

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Infants prefer familiar adults (e.g. parents) to unfamiliar adults (e.g. strangers), but they also vary in which strangers they prefer. By 6-months, infants look longer at attractive than unattractive faces (e.g., Langlois et al., 1987); and by 12-months, infants show approach behaviors toward attractive strangers and withdrawal behaviors toward unattractive strangers (Langlois, Roggman, & Rieser-Danner, 1990). These preferences may be due to a mechanism referred to as cognitive averaging (e.g., Rubenstein, Kalakanis, & Langlois, 1999). Infants cognitively average face exemplars to form a face prototype. Infants likely perceive attractive faces as familiar because these faces are similar to the face prototype; and they likely perceive unattractive faces as especially novel because these face are dissimilar from the face prototype. Even young infants may be more motivated to approach attractive than unattractive faces but do not fully express this motivation due to limitations in locomotion and communication.

I applied EEG asymmetry to study neural correlates of approach and withdrawal motivation in response to attractive and unattractive faces with 6- and 10-month-olds. More specifically, I measured EEG alpha power at mid-frontal regions while 39 infants viewed a series of attractive and unattractive faces. Left EEG asymmetry relates to approach motivation whereas right EEG asymmetry relates to withdrawal motivation. I predicted infants would show greater left EEG asymmetry (i.e., approach motivation) when viewing attractive faces than when viewing unattractive faces, and that 6-month-olds would show even greater left asymmetry than 10-month-olds due to developmental differences in stranger wariness.

Results supported the main hypothesis but not hypotheses regarding age. Infant EEG asymmetry was greater in response to attractive faces than unattractive faces suggesting that infants are more motivated to approach attractive people than unattractive people as early as 6-months. These results link visual preferences evident at 6-months to overt behaviors evident by 12-months providing additional information regarding rudiments of attractiveness stereotypes. Furthermore, this investigation supports the use of EEG asymmetry methodology to measure infant approach/withdrawal motivation, providing infant researchers one more tool to better understand how infants evaluate novel individuals in their social environment as they decide whom to approach and whom to avoid.

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Introduction

To expand and learn about their social world, infants must balance the reward potential of exploration with the survival instinct for safety. They meet an increasingly larger number of people as they get older and must evaluate who is safe to approach and who is potentially dangerous. According to Fox (1991), immediate "affective computation" yields evaluative information for categorization of stimuli. This affective evaluation corresponds to motivation to approach or withdraw from stimuli and is measurable through brain activation. An infant may show approach motivation to their caregiver by signaling, smiling or moving toward him/her. In contrast, when a stranger is present, an infant may fuss, move away, or avert gaze indicating withdrawal motivation. These are examples of how approach/withdrawal motivation influences infant behavior toward familiar versus novel people. The infant is motivated to approach the familiar caregiver and avoid the novel stranger. But are infants motivated to approach some strangers more than others based on facial characteristics; and if so, at what age does this kind of differential motivation emerge?

Infants indeed respond differently to faces that vary in attractiveness. By 12-months, infants display overt social behaviors consistent with motivation to approach attractive strangers and withdraw from unattractive strangers (Langlois, Roggman, & Rieser-Danner, 1990). Approach/withdrawal motivation may emerge even earlier given that 6-month-old infants look longer at attractive than unattractive faces (Langlois, Ritter, Roggman, & Vaughn, 1991; Langlois et al., 1987; Taylor-Partridge & Langlois, 2009).

The interpretation of overt behaviors at 12-months is straightforward as direct manifestations of approach/withdrawal motivation. These older infants evaluate attractive strangers as more approachable than unattractive strangers. Although 6-month-olds look longer at attractive than unattractive faces, interpretation of the meaning underlying visual fixation is more complicated than the overt approach and withdrawal behaviors seen at 12-months. Infants may look longer at something they find positive and interesting or at something they find negative and threatening (Taylor-Partridge & Langlois, 2009; Vaish, Grossman, & Woodward, 2008). No research has directly linked motivation underlying visual preferences for attractive faces at 6-months to social preferences for attractive strangers at 12-months due to methodological constraints: Young infants do not have the mobility and communicative skills to display the same overt approach and withdrawal behaviors shown by older infants; older infants differ from younger infants in visual fixation.

Differences in early approach/withdrawal motivation in response to faces varying in attractiveness may be rudiments to the development of attractiveness stereotypes—individuals attribute positive characteristics and traits to attractive people and negative traits and characteristics to unattractive people. Attractiveness stereotypes are a social problem because unattractive people suffer many disadvantages while attractive people receive many advantages (Dion, Berscheid, & Walster, 1972; Eagly, Ashmore, Makhijani, & Longo, 1991; Langlois et al., 2000). Unattractive adults are more likely than attractive adults to be denied promotions and raises (e.g., Hamermesh, & Biddle, 1994; Hosoda, Stone-Romero, & Coats, 2003), to be sentenced of crime (e.g, Mazella &

Feingold, 1994), and to receive fewer dating opportunities (e.g., Walster, Aronson, Abrahams, & Rottman, 1966). Unattractive children are less likely than attractive children to be judged by their peers as smart, friendly, and popular (Dion & Berscheid, 1974; Styczynski & Langlois, 1977). Even mothers of unattractive infants treat their infants more negatively than mothers of attractive infants (Langlois, Ritter, Casey, & Sawin, 1995). Clearly, the consequences associated with stereotyping based on appearance are significant. Thus, understanding how and when preferences, attitudes and associations develop and interconnect is important to understanding stereotype development that results in differential treatment of attractive and unattractive individuals later in life (Fazio, Eiser, & Shook, 2004).

The current investigation serves two purposes: 1) to support the use of electroencephalogram (EEG) asymmetry as a physiological correlate of infant approach/withdrawal motivation, particularly in response to attractive and unattractive faces; 2) to link motivation driving visual preferences for attractive faces at 6-months to social preferences for attractive strangers at older ages. I begin by reviewing research on developmental changes in infant responses to social stimuli in the first year as it relates to approach/withdrawal motivation. I then discuss how changes in visual attention over the first year are consistent with development of approach/withdrawal motivation. I describe how mechanisms involved in perceptual familiarity may evoke greater motivation to approach attractive faces than unattractive faces in infancy. Finally, I describe how measurement of EEG asymmetry is linked to approach/withdrawal motivation and how I applied this method to study infant differential motivation toward attractive and unattractive faces.

APPROACH/WITHDRAWAL MOTIVATION AND SOCIAL PREFERENCES

Both approach and withdrawal are necessary motivational processes to navigate effectively through the environment. Approach motivation promotes appetitive behaviors to explore and learn about new things in the world or to acquire positive reward (Fox, 1991). When approach motivation is dominant, it is associated with positive affect and extraversion (Derryberry & Rothbart, 1997). Withdrawal motivation inhibits activity toward stimuli that are negative, fear evoking, or in which no reward is forthcoming (Derryberry & Rothbart, 1997; Rothbart & Bates, 1998; Putnam & Stifter, 2002). An important distinction is that approach and withdrawal are not mutually exclusive. One can be motivated to approach something while motivated to withdraw from it simultaneously (Fox, 1991). For example, an infant may be interested in approaching a clown for entertainment, but withdraw to his mother due to wariness. Thus, asymmetries in approach/withdrawal motivation represent the degree to which either approach or withdrawal is dominant. I discuss approach/withdrawal motivation in the context of related infant behaviors that contribute to keeping positive stimuli close in proximity and negative stimuli distant in proximity.

According to Rothbart (1988), infants have both an approach system that emerges early in infancy to promote exploration, and an inhibition to approach system (i.e., withdrawal) that emerges in the second half of the first year to inhibit exploration of stimuli that is either novel or high in intensity signaling potential danger. To study developmental differences, Rothbart tested this hypothesis in a study in which she presented infants with low intensity (e.g. rattle) and high intensity toys (e.g. moving bear with clanging symbols) at about 6-months and at the end of the first year. Rothbart found that infants in both age groups reached for low intensity toys similarly, but 12-month-olds were much slower to reach for high intensity toys. Latency to approach indicated that although 12-month-olds were likely interested in approaching the high intensity toys, withdrawal motivation was now moderating approach motivation inhibiting a quick approach. The emergence of inhibition to approach occurs around the same time in development as changes in visual attention and stranger wariness.

Visual Attention to Social Stimuli

Infants' earliest preferences relate to familiarity. Newborns turn their heads to the sound of their mothers' voice, her scent, or her image (Barrera & Maurer, 1981; DeCasper & Fifer, 1980; Macfarlane, 1972). Pascalis, deSchonen, Morton, and Deruelle (1995) used the visual paired comparison paradigm, in which two stimuli are presented side-by-side, to show that infants as young as 4 days looked longer at mother's face than a stranger's face. This preference is of evolutionary significance, contributing to the mother-infant bond that allows for protection and nurturance of the infant (Ainsworth et al., 1978; Bowlby, 1969). Infants younger than 5-months also look longer at same-race faces compared to other-race faces (Kelly et al., 2007; Kelly et al., 2005), female faces compared to male faces if their primary caregiver is female (Quinn, Yahr, Kuhn, Slater, & Pascalis, 2002), and positive facial expressions compared to negative facial expressions (Farroni, Menon, Rigato, & Johnson, 2007; LaBarbera., Izard, Vietze, & Parisi, 1976; see Vaish et al., 2008 for review). In each of these comparisons, one can argue that infants look longest at faces that are more perceptually familiar than other faces: In daily interactions, infants are more likely to see same-race faces than other-race faces, female faces than male faces (if their primary caregiver is female), and positive facial expressions than negative facial expressions. These findings suggest that infants prefer familiar social stimuli in early infancy and may even be more motivated to approach familiar social stimuli than novel social stimuli; however, motivation cannot be inferred from visual attention alone.

Unfortunately, the visual paired comparison is not a consistent measure of approach/withdrawal motivation because visual attention can be driven by either approach (i.e., interest in interaction) or withdrawal (i.e., vigilance) motivation. The assumption of the visual paired comparison is that infants look longest at stimuli they prefer (Fantz, 1961); however, infants older than 5- or 6-months often look longest at novel or negative stimuli (Vaish et al., 2008). For instance, Bartrip et al. (2001) found that 5-month-old infants looked longer at a stranger's face than a mother's face. Infants older than 6-months also look longer at negative facial expressions compared to positive facial expressions (Nelson & Dolgin, 1985; Wilcox & Clayton, 1968). It is unlikely that infants prefer a stranger compared to their mother or a negative facial expression compared to a positive expression, but are instead showing either interest in or wariness of novelty. Although their visual behavior in experimental settings changes, infants' appetitive behaviors toward their mothers throughout early childhood make it obvious that she is preferred, if not always the center of her child's attention. Changes in visual attention support the development of wariness in the last half of the first year and also demonstrate a limitation of the visual paired comparison paradigm. Visual attention is not a reliable indicator of approach or withdrawal motivation across the first year.

Stranger Wariness

Studies of stranger wariness illustrate how infants differ developmentally in approach and withdrawal motivation in social situations. Based on a decline in positive affect and an increase in negative affect, the mean age of onset of distress to stranger approach is about 8-months (Gaensbauer, Emde, & Campos, 1976), with audible crying becoming evident at 10-months (Waters, Matas, & Sroufe, 1975) which corresponds with the development of inhibition to approach. Campos, Emde, Gaensbauer, & Henderson (1975) measured heart rate and affective response in 5- and 9-month-olds during stranger approach with and without their mothers in the room. Five-month-olds displayed heart rate deceleration, associated with interest and attention, and showed little distress behaviorally. Nine-month-olds manifested both negative affect and heart rate accelerations during stranger approach when their mother was not present. When their mother was present, older infants did not demonstrate obvious negative affect in response to stranger approach, but their heart rates accelerated—suggesting milder distress than when alone, but still a change in reaction to the stranger. In addition, Waters et al., (1975) and Mangelsdorf et al. (1995) both found that older infants were more distressed upon stranger approach than 6-month-olds.

Infants' responses to strangers also differ depending on characteristics of the stranger and of the situation. Feinman (1980) found that infants were most receptive to strangers who were small in size and the same-race as infants, who maintained a comfortable distance and made slow movements, and who approached when parents were nearby. Considering developmental and situational variables together, infants at 6-months may evaluate one stranger as more approachable than another if the strangers differ in a familiarity factor (e.g., race, gender), but not until later in the first year would infants necessarily evaluate one stranger as more threatening than another. Thus, young infants may differ from older infants in approach/withdrawal motivation in response to faces varying in perceptual familiarity. One facial characteristic that varies in perceptual familiarity is facial attractiveness.

ATTRACTIVENESS PREFERENCES AND MECHANISMS

Facial attractiveness of others is salient early in life. By 6-months, infants categorize attractive and unattractive faces into distinct groups (Ramsey, Langlois, Hoss, Rubenstein, & Griffin, 2004), prefer the same attractive faces that older children and adults find attractive (Langlois, Ritter, Roggman, & Vaughn, 1991; Langlois et al., 1987); match positive characteristics and behaviors with attractive faces and negative characteristics and behaviors with unattractive faces (Langlois et al., 2009); and most relevant to my dissertation, approach attractive people and withdraw from unattractive people (Langlois et al., 1990). Thus, attitudes toward attractive and unattractive people are forming and evolving into associations in the first year of life suggesting that mechanisms driving these developments are evident early in infancy. In this section, I will discuss mechanisms that may contribute to similarities between attractiveness and familiarity preferences, as well as further detail regarding studies of visual and behavioral preferences.

Mechanism in Attractiveness Preferences

Langlois and colleagues argue that attractiveness preferences are driven by an information processing mechanism referred to as cognitive averaging (Langlois & Roggman, 1990; Rubenstein, Kalakanis, & Langlois, 1999; Rubenstein, Langlois, & Roggman, 2002). According to this model, people process stimuli automatically by mathematically averaging exemplars within a category to form a prototype representing the category's central tendency. Because each prototype is an average of exemplars, people treat the prototype as the most representative example of that category and evaluate the prototype as attractive, likable, and *perceptually familiar* (Halberstadt, 2003; Langlois & Roggman, 1990; Rubenstein et al., 1999; Rubenstein et al., 2002; Winkielman, Halberstadt, Fazendeiro, & Catty, 2006). Faces that are similar to the prototype are also perceived as attractive, likable, and familiar. Attractive faces are more similar to the face prototype than unattractive faces (Bronstad & Langlois, 2008). Thus, perceptual familiarity resulting from cognitive averaging may be the key to why infants, children, and adults prefer attractive faces compared to unattractive faces (Langlois & Roggman, 1990; Rubenstein et al., 1999; Rubenstein et al., 2002).[1]

Research shows that adults and infants cognitively average visual stimuli, such as dot patterns (Bomba & Siqueland, 1983; Posner & Keele, 1968; Winkielman et al., 2006), schematic faces (Strauss, 1979), and real faces (Langlois & Roggman, 1990; Rubenstein et al., 1999), and treat exemplars closest to the central tendency as positive and familiar (See Rubenstein et al., 1999 and Rubenstein et al., 2002 for complete review). To show that infants prefer faces representing the internal prototype, Rubenstein et al. (1999) "averaged" female faces using a computer morphing program. They then conducted a study with 6-month-old infants using the visual paired comparison paradigm as in Langlois et al. (1987). Presented with averaged and unattractive faces, infants looked significantly longer at averaged faces than at unattractive faces suggesting that 6-month-olds prefer averaged faces more than unattractive faces. Rubenstein et al. (1999) also used the familiarization paradigm to test whether or not infants average across faces presented during the experiment. In the familiarization paradigm, infants viewed a set of attractive face exemplars presented individually until they became bored. Infants then

[1] An alternative explanation for attractiveness preferences is an exemplar model that suggests we store individual exemplars and prefer stimuli that are most similar to the central tendency of these exemplars (e.g. Nosofsky, 1988, 1991). Although prototype and exemplar theories disagree about what representation of faces is stored, both agree that attractive faces are favored because they are most similar to the central tendency (Rubenstein et al., 1999).

viewed an averaged face consisting of previously seen attractive face exemplars and a novel attractive face exemplar—one that had not been observed during familiarization. In the test phase, infants looked significantly longer at the novel face than the averaged face suggesting that infants perceived the averaged face as familiar even though they had not seen the averaged face previously—only the faces that contributed to the averaged face. Thus, infants average experienced faces and perceive attractive and averaged faces similarly but qualitatively distinct from unattractive faces.

To review, the mechanism of cognitive averaging results in a face prototype. New faces are automatically compared to this face prototype. If the face is similar to the face prototype, as are attractive faces, then infants perceive the face as familiar. If the face is dissimilar to the face prototype, as are unattractive faces, then infants perceive the face as especially novel. Infants are motivated to approach familiar people and withdraw from novel people, especially as stranger wariness emerges. Thus, cognitive averaging is the cognitive mechanism that results in perceived familiarity of attractive faces. Perceptual familiarity elicits different approach/withdrawal motivation for attractive (i.e., familiar) and unattractive (i.e., novel) faces. Together, these mechanisms provide a plausible explanation for why infants look longer at and are more likely to approach attractive faces compared to unattractive faces.

Visual Attention

Infants show the same developmental progression when attending to attractive versus unattractive faces as they do when attending to familiar (e.g., mother's face) versus novel (e.g., stranger's face) faces (e.g., Pascalis et al., 1995). Langlois and colleagues found that 6-month-old infants look longer at adult-rated attractive faces compared to adult-rated unattractive faces in the visual paired comparison paradigm (Langlois et al., 1991; Langlois et al., 1987; Taylor-Partridge & Langlois, 2009). Further study showed that infants look longer at attractive than unattractive faces regardless of whether the faces are Caucasian, African-American, male, female, adult, or infant (Langlois et al., 1991). However, 9- and 12-month-old infants divide their attention between attractive and unattractive faces suggesting that vigilance to perceptual novelty may now be moderating looking behavior (Taylor-Partridge & Langlois, 2009). These results are similar to results in visual paired comparison studies with older infants and mother's face versus stranger's face (Bartrip et al., 2001). Thus, although visual attention hints at underlying motivation to approach attractive faces and avoid unattractive faces, visual attention alone does not capture whether infants are motivated to socially interact with one kind of face (i.e., attractive) more than another (i.e., unattractive).

Social Preferences

By 12-months, infants' motivation is obvious as they perform differential social behaviors dependent on attractiveness of a stranger. Langlois et al. (1990) studied infants' behavioral responses toward a female "stranger". The stranger in each condition (varying between subjects) was the same woman wearing professionally constructed and applied masks that adults had rated as attractive or unattractive. Coding of infant behavior as the stranger approached and attempted to interact with the infants resulted in the following: Infants made more approaches, positive vocalizations, and play behaviors in response to the attractive stranger; infants made more withdrawal and distress behaviors in response to the unattractive stranger. Results suggest that facial appearance of strangers guides infant treatment of and interaction with strangers (Langlois et al., 1990). Thus, by 12-months, infants are motivated to approach attractive strangers and withdraw from unattractive strangers, possibly due to differences in perceptual familiarity between the two types of faces.

Valence Associations

As mentioned above, early attractiveness preferences are rudiments to stereotype development. If infants perceive attractive faces as familiar and evaluate familiar stimuli as positive, they may also associate attractive faces with other positive stimuli. If infants perceive unattractive faces as novel and evaluate novel stimuli as negative, they may also associate unattractive faces with other negative stimuli. Although infants categorize attractive and unattractive faces as distinct by 6-months (Ramsey et al., 2004), they do not display an ability to match attractive faces to other positive stimuli and unattractive faces to other negative stimuli until 12-months (Langlois et al., 2009).

In a series of studies, Langlois et al. (2009) found that 12-month-olds associate valence of vocalizations, schematic drawings, and animate behavior with attractive faces and unattractive faces in a matching paradigm; but did not find that 10-month-olds detect similar correlations between attractive faces and positive stimuli and unattractive faces and negative stimuli. In the studies with 12-month-olds, infants viewed attractive and unattractive faces simultaneously with either a positive or negative stimulus. In the first study, Langlois et al. (2009) presented schematic drawings of either a smiling face or a frowning face simultaneously with pairs of attractive and unattractive faces. Infants looked longer at attractive faces when presented with a smiling face and longer at unattractive faces when presented with a frowning face. In the second study, experimenters presented pleasant or unpleasant voices along with pairs of attractive and unattractive faces. Infants looked longer at attractive faces when presented with pleasant voices and longer at unattractive faces when presented with unpleasant voices. Lastly, infants saw attractive and unattractive faces paired with animated movies showing a square either helping a ball up a hill (positive valence) or hindering the ball from getting up the hill (negative valence). Infants in the positive condition looked significantly longer at attractive faces than infants in the negative condition; and infants in the negative condition looked longer at unattractive faces than infants in the positive condition. Thus, not only do infants perform affective computation and categorization of attractive and unattractive faces into valence categories, they also associate attractive and unattractive faces with other stimuli within those positive and negative categories by 12-months—the same age that they show approach behaviors to an attractive stranger and withdrawal behaviors to an unattractive stranger (Langlois et al, 2009; Langlois et al., 1990).

I presented these studies to show evidence of the progression from categorization and visual preferences for attractive faces by 6-months to differential treatment (i.e., approach and withdrawal behaviors) and valence associations based on attractiveness by 12-months. Valence associations are likely the earliest markers of attractiveness stereotypes. Ten-month-olds do not appear to have the ability to detect associations, much less perform a valence matching task (Langlois et al., 2009), thus valence associations likely develop very close to 12-months of age. However, infants may show approach/withdrawal motivation earlier than 12-months which would suggest that motivation to approach attractive faces and withdraw from unattractive faces may precede valence associations. Uncovering when infants develop greater motivation to approach attractive than unattractive faces would provide support for cognitive and affective mechanism resulting in perceived familiarity of attractive faces.

Both visual preference studies and overt behavioral studies have limitations that preclude their ability to assess approach/withdrawal motivation throughout the infant's first year. Visual attention appears to only suggest preferences until about 6-months of age, an age that also serves as the starting point for inhibition to approach. Thus, visual attention does not reliably represent approach/withdrawal motivation especially in the latter half of the first year (Vaish et al., 2008). The study of approach and withdrawal behaviors in response to an attractive and an unattractive stranger had two limitations (Langlois et al., 1990). The first is that it was a between subjects design, therefore infants either met the attractive stranger or the unattractive stranger and comparisons could not be made on how individual infants would respond to both types of faces. The second limitation is that this design cannot easily be extended to younger infants who are limited in communicative and locomotive skills. In the next section, I discuss EEG asymmetry as an alternative measure of infant approach/withdrawal motivation that may be applicable for 6- to 12-month-olds.

EEG Asymmetry

EEG measures electrical activity at the scalp emanating from the brain. Currents of electrical activity occur when chemicals released from axons of other neurons bind to post-synaptic receptors allowing positively and negatively-charged ions to differentially pass through the cell membrane. When these post-synaptic potentials occur with thousands of other such events across multiple neurons, the summation of these currents can be detected by EEG at the scalp. The cortex likely generates the electrical activity recorded at the scalp when interacting and responding to deeper brain networks such as the limbic system, but the exact origination of this electrical activity is still unknown (Pizzagalli, 2007).

Although brain electrical activity was noted in animals in the 19th century, Pizzagalli (2007) cites Berger (1929) as discovering rhythmic human brain activity by recording from an electrode placed on the forehead and on the back of the head. Berger also suggested that changes in these brain waves are related to changes in mental functioning. The alpha wave was the first brain wave described, later identified in adults as ranging in frequency between 8 and 13 hertz (Hz). Additional frequency bands and ranges for adults include delta (1-4 Hz), theta (4-8 Hz), beta (13-30 Hz), and gamma (36-44 Hz); however, the focus of the current study is on the alpha band. The frequency band for alpha varies with age. Marshall, Bar-Haim, and Fox (2002) measured EEG activity in infants multiple times from 5-months to 51-months of age. Oscillations similar to the adult alpha band were lowest in frequency for young infants and increased with age. Marshall et al. determined that EEG in the frequency range 6 to 9 Hz constitutes the alpha band for infants in the latter half of the first year until early childhood. Depending on the region, the 4 to 6 Hz range may be more appropriate for younger infants.

The amplitude of alpha rhythm is highest during relaxed states and decreases with mental activity or alertness (Pivik et al., 1993). Thus, an inverse relationship exists between alpha power and brain activation. When measuring EEG at homologous sites in opposite hemispheres, the log transform (Ln) of alpha power recorded from the left electrode is subtracted from that of the right electrode to calculate an asymmetry index for that region. For instance, the equation for the mid-frontal sites would be [Ln(F4) – Ln(F3)] according to standard EEG nomenclature with F4 representing the electrode placed at the right mid-frontal area and F3 representing the electrode placed at the left mid-frontal area according to the 10/20 system of electrode placement (Jasper, 1958). A positive score suggests more activation on the left (less left than right alpha power), while a negative score indicates more activation on the right (less right than left alpha power) (Pivik et al., 1993). An advantage of the EEG asymmetry index is that each participant serves as their own control because an issue such as skull thickness does not interfere with between subject comparisons (Pivik et al., 1993). Changes in EEG asymmetry can be either due to changes in activation in the left hemisphere, the right hemisphere, or both. Some studies only report EEG asymmetry index per condition, while others consider how each hemisphere contributes to the difference scores by running analyses on raw EEG power (see Coan & Allen, 2004). In the following review both the EEG asymmetry index and analysis of raw EEG power are presented when available.

The alpha band has been particularly well-studied with regard to emotion and motivation in the last three decades (Allen & Kline, 2004). Changes in EEG asymmetries represent changes in mental *state* when coinciding with responses to the environment. Patterns of EEG alpha asymmetries from frontal regions of the brain are associated with the experience of positive and negative affect (e.g. Cacioppo, 2004; Coan & Allen, 2004; Davidson, Ekman, Saron, Senulis & Friesen, 1990; Davidson & Fox, 1982; Fox & Davidson, 1988) and approach/withdrawal motivation (e.g. Davidson et al., 1990; Davidson, Jackson, & Kalen, 2000; Fox & Davidson, 1987; Jones & Fox, 1992). Greater relative left frontal EEG activation is associated with positive affect and approach motivation; greater relative right frontal EEG activation is associated with negative affect and withdrawal motivation. The exception is anger which is a negative affect associated with approach motivation and thus is related to greater left asymmetry (see Carver & Harmon-Jones, 2009; Coan & Allen, 2004; Davidson, 2004).

Many studies have examined differences in brain activation in positive versus negative states often coinciding with approach versus withdrawal motivation. Both infants and adults show differential hemispheric activation when performing or viewing various facial expressions and when experiencing events designed to elicit positive and negative affect or approach versus withdrawal motivation (Davidson et al., 1990; Davidson et al., 2000; Davidson & Fox, 1982; Fox & Davidson, 1987; Fox & Davidson, 1988; Jones & Fox, 1992). The following review focuses on differences in EEG asymmetry as a function of changes in affective motivational state.

Adults

Results of adult studies have shown differences in EEG asymmetry in response to video clips designed to elicit approach versus withdrawal motivational states. Adults show greater relative left activation in frontal and anterior temporal regions for happy compared to disgust and sad clips; alternatively, they show significantly greater right asymmetry in response to clips eliciting disgust and sadness than clips eliciting happiness (Davidson et al., 1990; Jones & Fox, 1992). Researchers confirmed that participants achieved the targeted affective state by evaluating participants' facial expressions (Davidson et al., 1990) and ratings of emotion, intensity, and approach vs. withdrawal motivation (Davidson et al., 1990; Jones & Fox, 1992). EEG asymmetries are most pronounced when co-occurring with facial expressions of genuine happiness or disgust, usually corresponding to the most intense video clips (Davidson et al., 1990). Intensity ratings for both disgust and sadness are positively correlated with right EEG asymmetry (Jones & Fox, 1992). Arousal as measured by facial expression and intensity ratings corresponds to the degree of EEG asymmetry in response to both positive and negative social stimuli.

In addition to issues of intensity, discrepancies in expected findings also revolve around genuineness of expression. In studies of adults, genuineness appears essential for positive affect but not for negative affect. Ekman (1989) differentiated between Duchenne (i.e. felt) smiles and unfelt smiles based on the facial muscles involved. Duchenne smiles involve action in both the zygomaticus (i.e. muscles that pull the corners of the lips upward) and orbicularus oculi (i.e. muscles surrounding eyes). Unfelt smiles only involve zygomaticus action without changes in the muscles around the eyes. Duchenne smiles are more authentic and natural than unfelt smiles. Ekman, Davidson, and Friesen (1990) and Ekman and Davidson (1993) found significantly greater left than right frontal/temporal activation during Duchenne smiles but no hemispheric asymmetry for unfelt smiles. A significant increase in right frontal activation during unfelt smiles compared to baseline accounted for the lack of asymmetry in this condition (Ekman et al., 1990). Consistent with results for unfelt smiles, Coan and colleagues (Coan, Allen, & Harmon-Jones, 2001) also did not find EEG asymmetry when they asked participants to voluntarily smile but did find right EEG asymmetry when participants displayed voluntary expressions associated with withdrawal (i.e. fear, sadness, and disgust). Thus, both emotion and arousal intensity are important in EEG asymmetry to assess motivation in response to valence stimuli.

Adult EEG asymmetries also emerge in response to affective music. For instance, Schmidt and Trainor (2001) found EEG asymmetries in adult responses to music varying in valence. Adults showed greater left frontal asymmetry in response to music considered joyful and happy, and greater right frontal asymmetry to music representing fear and sadness.

Although complex, EEG asymmetry appears to be a valid measure of certain approach and withdrawal motivational states in adults and usually these states correspond to positive and negative valence respectively. Genuine happiness and joy correlate strongest with left EEG asymmetry and approach motivation. Intense feelings of disgust, sadness, and fear relate to right EEG asymmetry consistent with withdrawal motivation.

Anger is a special case because when experiencing anger, adults show more left frontal activation emphasizing that frontal EEG asymmetry is driven more by approach/withdrawal motivation than by positive and negative valence (Carver & Harmon-Jones, 2009; Harmon-Jones, 2003). In sum, adult EEG asymmetry as a state measure is consistent with approach and withdrawal motivation and associated positive and negative affect varying with intensity.

Infants and Young Children

Early in life, infants show EEG asymmetries in response to stimuli and situations designed to elicit approach and withdrawal motivation, as well as positive and negative affect. Comparable to the adult studies described above, infants and young children participated in studies that used positive and negative video clips (Davidson & Fox, 1982; Pickens, Field, & Nawrocki, 2001) and affective music (Schmidt, Trainor, & Santesso, 2003) as stimuli. Researchers have also carried out more ecologically valid studies measuring infant affect and EEG asymmetry in response to approach of mothers versus strangers, mother separation (Fox & Davidson, 1987, 1988), infant-directed speech (Santesso, Schmidt, & Trainor, 2007), and taste (Fox & Davidson, 1986; Fernandez et al., 2003).

Infants are responsive to facial expressions of social partners and use facial expressions as cues for social interaction and interaction with the environment. Infants show more positive behaviors (i.e., smiling, cooing) when viewing happy expressions and more negative behaviors when viewing negative expressions (Serrano, Iglesias, &

Loeches, 1995). If EEG asymmetry is a feasible paradigm to measure infant states, then infant EEG asymmetry should differ in response to positive and negative facial expressions. Davidson and Fox (1982) studied differences in infant EEG hemispheric activation in response to videos of a woman with either happy or sad facial expressions. The EEG asymmetry index was significantly greater in the happy condition than in the sad condition. Comparisons of raw EEG data between hemispheres per condition resulted in significantly greater left activation (less power) than right activation during the happy condition, but no significant differences between hemispheres in the sad condition. Infants showed the expected left asymmetry signifying approach motivation for the happy condition, but did not show EEG asymmetry signifying either approach or withdrawal for the sad condition. One interpretation of the results is that when viewing sadness, infants experience both approach and withdrawal motivation so that activation is balanced in both hemispheres. Another interpretation is that the relationship between left asymmetry and approach motivation is stronger than the relationship between right asymmetry and withdrawal motivation. This study was the first of several reports (Fox & Davidson, 1986, 1987, 1988; Pickens et al., 2001; Buss et al., 2003) of infants showing asymmetries in response to stimuli varying in valence or designed to elicit approach or withdrawal motivation.

Research by Fox and Davidson (1987, 1988) included analyses of individual differences between EEG asymmetry and overt infant behavior. They designed the following conditions to elicit different affective responses: mother entering room; mother approach; mother reaching for infant; mother separation; and stranger approach. Infants made more Duchenne smiles toward mother than stranger and these smiles occurred with left EEG asymmetry in the frontal regions (Fox & Davidson, 1988). Even when infants smiled during stranger approach, the smiles differed from those during mother approach and occurred with right asymmetry unlike adult results of no hemispheric asymmetry with unfelt smiles (Ekman et al., 1990; Fox & Davidson, 1987, 1988). Infants showed even more positive affect, vocalizations, and EEG left frontal activation when mother reached for the infant compared to when mother entered the room (Fox & Davidson, 1987). EEG asymmetry in response to mother separation varied with some important individual differences related to overt infant behaviors. Infants who cried with sad expressions showed more right activation, but infants who did not cry during displays of sadness showed more left activation (Fox & Davidson, 1987, 1988). Similar results were evident for displays of anger, with angry criers showing more right frontal activation and angry non-criers showing more left activation (Fox & Davidson, 1988).

Fox and Davidson (1988) discussed the association between EEG asymmetry and approach and withdrawal and how these differences in the displays of joy, sadness and anger may differentiate between underlying motivation and the emotional meaning of facial expressions: “Certain discrete facial expressions of emotion such as anger or sadness may reflect either approach or withdrawal, depending on the stimulus context and the subject’s appraisal of that context” (p. 235). Sad expressions with vocalizations in response to separation could be interpreted as a desire to regulate negative affect by promoting the return of attachment figure, and thus be related to approach. Thus, differences in EEG asymmetries must be considered with regards to the context, individual differences in levels of arousal, and other structures in the brain that may contribute to electrical activity measured at the scalp.

Other events elicit affective responses signified by infant EEG asymmetry. Fox and Davidson (1986) showed that newborn infants showed relative right asymmetry in both the frontal and parietal regions when tasting plain water, and showed relative left asymmetry when tasting a sweet sucrose solution. These asymmetries were evident in both the 3 to 6 Hz and 6 to 12 Hz frequency bands but not the 1 to 3 Hz frequency band. In a similar study, newborn infants exposed to sucrose water before sticking the heel to elicit mild distress showed less right frontal activation in the 3 to 6 Hz band as opposed to infants who received plain water (Fernandez et al., 2003). The infants who received the sucrose water also showed less negative affect and a quicker return to baseline heart rate following the procedure than the control group. Something positive from the environment (i.e., sweet taste) appears to have attenuated the reaction to the negative event of the heel sticks. For newborns, a positive taste is associated with left EEG asymmetry in the absence of a negative event or less right EEG asymmetry when it is accompanied by a negative event. Even newborns show state changes in EEG asymmetry as a result of stimuli from their environment, but unlike many studies with adults and older infants, asymmetry was not isolated to anterior region but also included the parietal region.

While infant EEG asymmetries are evident in response to facial expressions, person approach, and even taste, infant EEG asymmetry in response to auditory stimuli is not consistent with results from adult EEG studies. Schmidt and Trainor (2001) found that adults respond with EEG asymmetries to music with emotional content, but Schmidt et al. (2003) did not find similar results for infants. Schmidt et al., (2003) measured physiological differences when infants at ages 3-, 6-, 9-, or 12-months heard orchestral music representing joy, fear, and sadness. Infants differed in EEG activation when presented with music compared to baseline and varied with age in whether the EEG activation occurred more in parietal vs. frontal regions and left vs. right hemispheres. However, infants did not show asymmetries in EEG dependent on valence of music. These results suggest that infants are not yet able to abstract valence from orchestral music as adults do, at least not as evidenced by EEG asymmetries. Santesso et al. (2007) tried the same type of study to determine if EEG asymmetries in 9-month-olds differentiated between valences of infant-directed speech, which they believed to better represent infants' real-world experience than orchestra music. Infant-directed speech describes the high pitch, slower, almost sing-song way children and adults speak to infants. Researchers included infant-directed speech representing love/comfort, surprise, and fear. Once again, auditory stimuli did not elicit changes in frontal EEG asymmetry. However, infants showed more overall frontal activation (i.e., F3 and F4 combined) during infant-directed speech compared to baseline, likely due to attention orienting. EEG frontal activation was highest for fear compared to the other three speech conditions. The surprise condition showed the next highest amount of activation, but comfort did not significantly differ from baseline. These studies show that perception of auditory valence may lag behind valence detection in other sensory modes when measured by EEG asymmetry.

By early childhood, EEG asymmetry differs between auditory stimuli of different intensity but not different valence. In the presentation of auditory vignettes representing low levels of happiness, sadness, anger, and fear to preschool aged children, Pickens et al. (2001) found significantly greater relative left activation for emotional vignettes compared to neutral vignettes, but found no significant asymmetries associated with types of emotion. More specifically, children showed relatively more left than right activation for happy, sad, and fear, but no asymmetry for anger. Experimenters confirmed through video coding that children were attentive and showed only mild changes in affective expression. The authors suggested that left activation signals more positive affect or low levels of negative affect and that right activation signals negative affect at high levels of arousal. If the emotional vignettes had elicited more arousal, then these researchers would have expected more right activation. Arousal (i.e., intensity of emotion) appears to be an important component in EEG asymmetries in childhood as in adulthood (Ekman et al., 1990; Ekman & Davidson, 1993, Fox & Davidson, 1988), but it is yet unclear the role that arousal plays in the direction of asymmetries that are thought to be guided by motivation to approach or withdraw.

The above studies support that brain activation in the frontal region differs between left and right hemispheres dependent on the kind and valence of stimuli. EEG frontal asymmetries were most compelling for social stimuli and situations presented directly to participants (e.g., Davidson & Fox, 1982; Fox & Davidson, 1986, 1987, 1988), rather than for auditory stimuli or stimuli not directly relevant to study participants (e.g., Pickens et al., 2001; Schmidt et al., 2003). The most compelling of these studies involved differences in EEG frontal asymmetries in 10-month-olds when presented with happy versus sad facial expressions and when approached by and separated from mother or approached by a stranger (Davidson & Fox, 1982; Fox & Davidson, 1987; 1988). These studies reflect the social significance of EEG asymmetry and also how infants who differ on measures of EEG asymmetry also differ in behaviors. Frontal asymmetries in infant brain activity may be especially apparent during evaluation of observable social stimuli given that they are not evident in response to music although differences are evident when adults listen to affective music (Schmidt & Trainor, 2001). These findings may reflect the immaturity of the frontal cortex in infancy and the specificity for the most important information at that time, namely socialization. The one caveat that is yet unexplainable is that infant directed speech is also social in nature and does not elicit hemispheric asymmetries (Santesso et al., 2007).

In summary, approach motivation, as suggested by relatively greater left than right frontal activation, to mother and sweet tastes encourages more interaction with these stimuli. Withdrawal motivation, as suggested by greater right than left frontal activation, may serve to keep the infant distant from strangers or harmful stimuli. Further studies of EEG asymmetry for different kinds of stimuli would be necessary at various ages to build a better understanding of the development of valence perception and motivation and the role of arousal and intensity.

CONCLUSIONS

Based on the reviewed literature, EEG asymmetry appears to be an appropriate and useful tool to study differential brain activation in response to attractive and unattractive people over the first year of life, because it captures the underlying neural responses associated with approach and withdrawal motivation. Young infants lack mobility necessary to approach or avoid someone physically. Emotional expressions are often fleeting in infancy, so also do not provide a consistent measure of motivation (Fox, 1991). Six-month-olds look longer at attractive than unattractive faces which may indicate approach/withdrawal motivation (Langlois et al., 1991; Langlois et al., 1987), but visual attention does not always represent preferences, especially from 6- to 12-months (Taylor-Partridge & Langlois, 2009; Vaish et al., 2008). Thus, the present investigation included a cross-sectional sample of infants at 6-months and 10-months to establish if EEG asymmetry is an appropriate measure of social motivation at these two ages.

My primary hypothesis was that infants would display significantly different EEG indexes for attractive and unattractive faces. The reasoning underlying this hypothesis based is that infants perceive attractive faces as familiar and unattractive faces as novel, because attractive faces are more similar to the face prototype and unattractive faces are dissimilar to the face prototype. Infants are motivated to approach familiar adults and withdraw from unfamiliar adults (Mangelsdorf et al., 1995; Waters et al., 1975) just as they are motivated to approach attractive strangers and withdraw from unattractive strangers by 12-months (Langlois et al., 1990). Furthermore, infants show left frontal

EEG asymmetries associated with approach motivation in response to happy expressions (Davidson & Fox, 1982) and the approach of a familiar adult (Fox & Davidson, 1988). Given this line of logic, infants should show greater left EEG asymmetry when viewing attractive faces than when viewing unattractive faces—supporting the claim that infants are more motivated to approach attractive than unattractive people.

Also concerning EEG asymmetry, I predicted a main effect for age. Six- and ten-month-olds differ in the degree they express stranger wariness. Stranger approach does not elicit acceleration of heart rate or negative affect in infants younger than 6-months, but does elicit these indications of distress by 9-months (Campos et al., 1975; Mangelsdorf et al., 2005; Waters et al., 1975). Thus, I expect infants at 6-months to experience approach motivation to a greater degree than 10-month-olds because withdrawal motivation is not yet moderating approach motivation. In fact, 6-month-olds are likely to show left EEG asymmetry for both types of faces, but more left asymmetry for attractive faces. Furthermore, 10-month-olds, but not 6-month-olds, may show right EEG asymmetry in response to unattractive faces because 10-month-olds experience more distress in response to strangers than 6-month-olds and may find unattractive faces especially alarming due to perceptual novelty. If however, 6- and 10-month-olds show equivalent levels of activation between the two hemispheres, this finding would suggest that even early on infants are motivated to approach attractive faces and withdraw from unattractive faces. EEG asymmetry would prove to be a consistent and powerful measure of motivation across development in the second half of the first year.

Significant differences in EEG asymmetry as a marker of change in motivational state (i.e., approach versus withdrawal) may be driven by changes in activation on the left, on the right, or on both sides. Therefore, I have additional predictions for EEG hemispheric activation with activation measured as the inverse of raw EEG power. Given Davidson and Fox's (1982) findings, I expect infants to show greater left than right hemispheric activation in the attractive condition similar to when infants viewed happy expressions. Expected results for hemispheric activation in the unattractive condition are not as clear cut. Infants have shown withdrawal behaviors in response to strangers (Mangelsdorf et al, 1995) and particularly in response to unattractive strangers (Langlois et al., 1990); however, infants have not shown consistent hemispheric differences with greater right than left frontal activation suggestive of withdrawal motivation either to sad faces (Davidson & Fox, 1982) or in some cases of stranger approach (Fox & Davidson, 1987, 1988). Thus, infant EEG response to unattractive faces may show symmetry rather than asymmetry between the two hemispheres consistent with Davidson and Fox's finding regarding the sad condition (Davidson & Fox, 1982). Alternatively, infants may show significantly greater right than left frontal activation in response to unattractive faces consistent with withdrawal behaviors shown toward an unattractive stranger at 12-months (Langlois et al., 1990).

Method

PARTICIPANTS

Thirty-nine healthy, full-term infants of right-handed parents provided usable EEG data. I excluded data from another 44 infants for the following *a priori* reasons: Less than 20 good epochs per condition (20; DeBoer, Scott, & Nelson, 2007); extreme fussiness (6); refusal to wear electrode cap (2); equipment problems (6); parent interaction (3); low impedances (3) and outliers greater than 2.5 standard deviations from the mean of the dependent variable (4). The sample consisted of two age groups: 19 six-month-olds (M = 185.21 days, SD = 7; 9 females); 20 ten-month-olds (M = 313.5 days, SD = 9.55; 10 females). According to parent report, the final sample consisted of Caucasian (82%), Hispanic (13%), Asian (2.5%), and multi-racial (2.5%) infants.

I recruited infants from the database of birth records provided to the University of Texas Children's Research Lab by the Texas Department of Health. Only Austin area infants for whom we had current addresses were contacted. I sent parents a letter describing the study and inviting their infants' participation. Research assistants phoned these families to answer questions, to determine who was willing to participate, and to schedule appointments for the parents and infants to visit the Children's Research Lab at the University of Texas.

STIMULI

Stimuli consisted of computer images of 10 Caucasian females that 40 or more undergraduate men and women rated for attractiveness on a 1- to 7-point Likert scale (1 = very unattractive; 7 = very attractive). Adjustments for contrast and brightness of images were made using Adobe Photoshop™ 7.0 to make the images as similar on these variables as possible (Langlois et al., 1987). Clothing cues were masked with a sheet placed over the shoulders of each face model. I selected faces that rated among the lowest and highest in attractiveness and compared the faces from the two attractiveness groups to find images that matched in eye color, hair color and general style, and brightness of photograph. Ratings for the selected low attractive faces ($M = 2.37$, $SD = .43$) differed significantly from rating of high attractive faces ($M = 4.52$, $SD = .75$), $F(1, 8) = 30.82$, $p < .01$.

APPARATUS

EEG data were acquired using a Neuroscan bioelectrical, signal acquisition system sampled at a rate of 500 Hz from mid-frontal 10/20 sites (F3, F4) referenced to CZ. Infants wore a Neuroscan Quik-Cap™ with pre-positioned (Jasper, 1958) Ag/AgCl electrodes. An electrode at the front of the cap served as the ground. Each electrode contained a QuickCell, a cellulose sponge-like insert. An electrolyte solution was inserted into each electrode with a blunt-tip syringe to expand the QuickCells and enhance conduction. The electrocap was connected to a NUAMPS amplifier. Signals from the electrode sites of interest were recorded using the *Acquire* module of the *Neuroscan Scan*

4.4 software (Neuroscan Inc., Charlotte, SC) and digitized online to a Dell computer. Before recording, I examined each electrode's impedance within the *Acquire* module to ensure sufficient conduction (x < 5k Ohms; Pivik et al., 1993).

Additional apparatus included a second computer and screen, a video camera recording to an Apple Macintosh computer, and a beeper. I controlled stimuli presentation from an adjoining room using the computer program *Stim2* (Neuroscan Inc., Charlotte, SC) to present faces on a 17" computer screen and simultaneously send triggers to the EEG recording to time lock each stimulus to EEG segments. The video camera was positioned in front of the infant directly under the computer monitor. The Macintosh computer recorded the video, while the Dell computer simultaneously captured key presses of a research assistant who recorded when the infant was looking at or away from the stimuli. A speaker was placed above the stimuli monitor so that by pushing a button in the control room a beep would sound encouraging the infant to return attention to the stimulus. This equipment (i.e., computer monitor, video camera, and speaker) in the study room was framed by a black ply board wall to mask potential distractions (e.g., computer, wires, and transducer).

PROCEDURE

When the family arrived for the study, I explained the procedure in detail while the infant acclimated to the study room. I reviewed the consent form for the study and an additional consent form to allow us to video and photograph the infant. Parents completed participant information forms and signed consent forms. Once prepared for

EEG, the infant sat on the parent's lap or in a high chair approximately 75 centimeters from the computer monitor.

Infants had the opportunity to view five attractive faces and 5 unattractive faces one at a time for a total of 20 seconds each. The presentation of 10 faces occurred twice in the same order per infant—*Stim2* did not allow for changes of presentation files quickly enough to load a new order. Each infant saw only one of the two orders. The first order for each pair of faces was chosen randomly and then the presentation of either the attractive or unattractive first within those pairs was chosen randomly. To ensure that infants did not simply respond to faces presented in a particular order (e.g., attractive faces always appearing first), I reversed the attractive face and its unattractive counterpart within their overall placement to create a second order presented to approximately half the infants.

Before viewing faces, infants viewed a black and white contrast pattern for several seconds to interest them in viewing the computer screen. The study began with a 500ms beep and a visual marker recorded to the EEG to later link video to EEG. Infants then saw a black dot the approximate size of a face, followed by the first face that appeared and remained on the screen for 10 seconds. As each trial ended, the black circle again appeared. Between-face interval was 1 second. Testing continued until all 10 trials were presented. I then restarted the presentation to increase the total number of seconds for each face presentation to 20.

EEG DATA REDUCTION

EEG data were processed using the *Edit* module of *Scan 4.4* software (Neuroscan Inc., Charlotte, SC). EEG was visually inspected and portions of the EEG record containing artifact were removed (Deboer et al., 2007). Periods during which infants were not attending to the faces were also removed. Data were band-pass filtered (high pass = 1; low pass = 100; 12 db/oct). Additional artifacts were removed via automatic threshold-based algorithm (rejection threshold = ±150 uV) implemented in Neuroscan. EEG data were low-pass filtered (low pass = 30; 12 db/oct) before separating EEG epochs into attractive and unattractive conditions.

EEG data within a given condition were divided into 1 second epochs with 50% overlap, spline fit to 512 Hz, and multiplied by a 10% hamming window before computation of spectral power density (mV^2/Hz) via fast Fourier transformation (FFT). Data were saved in a text format for each electrode in 1 Hz bins. I calculated alpha power density for the 6 to 9 Hz frequency band for F3 and F4 (Marshall et al., 2002) and computed the *EEG asymmetry index* as the difference between log-transformed alpha power density for the right and left sites [LN (F4) – LN (F3)] (Pivik et al., 1993). Power and activation are inversely related—negative scores indicate greater activation on the right while positive scores indicate greater activation on the left.

Results

Overview of Analyses

I ran three levels of analyses. First I ran preliminary analyses to ensure that the amount of usable data did not differ between conditions or age groups and that the number of useable epochs (i.e., 1 second segments) did not predict the EEG asymmetry index for either the attractive or unattractive condition. The second analysis assessed differences between the EEG asymmetry index for attractive and unattractive faces with age and gender as the between subject variables. I included gender as a between subjects factor because early studies only included female infants and less data are available for males. However, I did not make any specific predictions regarding gender. Finally, I ran analyses on raw EEG power to assess whether asymmetries were due to changes in the left hemisphere, right hemisphere, or both hemispheres.

Preliminary Analyses

Infants varied in the amount of usable data (i.e., number of epochs) that they provided; therefore I conducted analyses to test whether the number of epochs varied significantly by age or face type. The average number of epochs for the attractive condition was comparable to the average number of epochs for the unattractive condition, $t(38) = -1.18$, $p = .25$ (two-tailed). Although 10-month-olds tended to provide more usable epochs per condition than 6-month-olds, the differences were not significant (See Appendix A). I ran two regressions analyses with the following results: 1) number of epochs produced in response to attractive faces did not predict EEG asymmetry index; 2) number of epochs produced in response to the unattractive faces did not predict EEG asymmetry index (see Table 1). Thus, the amount of useable data did not differ significantly across conditions, nor did number of epochs predict asymmetry within the attractive or unattractive condition.

Infants viewed faces in one of two orders. To test whether infants responded differently depending on order,, I ran a 2 (face type) X 2 (order) ANOVA. Results indicated no significant differences for order, $F(1, 37) = .04$, $p = .84$., Thus, data were collapsed across order in subsequent analyses.

Table 1: Regression Models for Number of Epochs Predicting EEG Asymmetry Index

Predictor Variable	Model		
	b	*SE*	β
Attractive Condition			
Number of epochs	.00	.00	.01
R^2	.00		
Unattractive Condition			
Number of epochs	.00	.00	-.06
R^2	.00		

Note: *df* for both models = (1, 37)

EEG ASYMMETRY INDEX

I analyzed data using 2 (face type) X 2 (age) X 2 (gender) ANOVA with age and gender as the between subject variables and EEG asymmetry index as the within subjects variable. I expected a main effect for face condition and for age. Results indicated that only the main effect for face condition was significant (see Table 1). Infants showed significantly greater left EEG asymmetry when viewing attractive faces (*M* = .07; *SD* = .36) compared to unattractive faces (*M* = -.02; *SD* = .36), $F(1, 35) = 7.25$, $p < .01$ (see Figure 1). Most infants (72%) showed this pattern contributing the medium effect size (*Cohen's d* = .56, Cohen, 1977; Wolf, 1986).

Table 2: Repeated Measures Analysis of Variance for EEG Asymmetry

Source	*df*	*F*	Partial η^2	*p*
		Between subjects		
Age	1	.22	.01	.63
Gender	1	.09	.00	.77
Age X Gender	1	.03	.00	.87
Error	35	(.22)		
		Within subjects		
Attractiveness (Att)	1	7.26*	.17	.01
Att X Age	1	.03	.00	.87
Att X Gender	1	.23	.01	.63
Att X Age X Gender	1	.07	.00	.80
Error	35	(.02)		

Note. Values enclosed in parenthesis represent mean square errors.

* $p < .01$

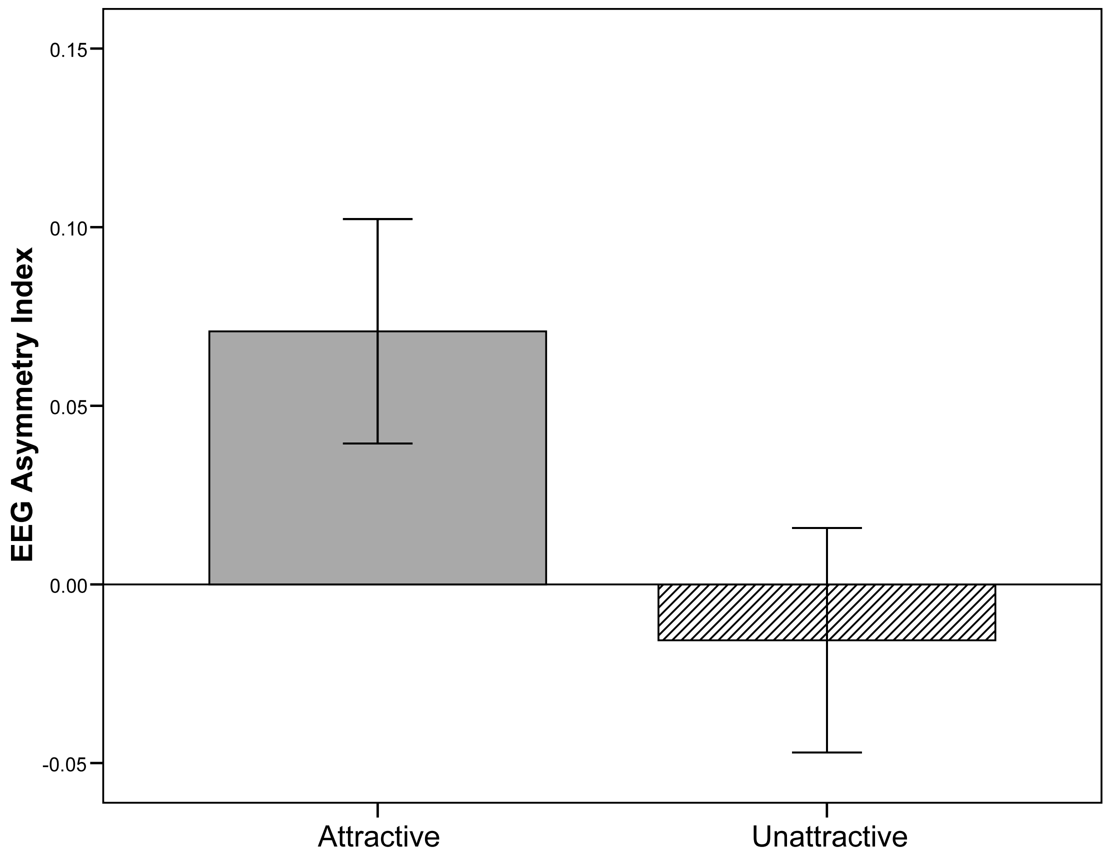

Figure 1: Mean frontal EEG asymmetry index (95% CI) for both 6- and 10-month-old infants when viewing attractive and unattractive faces. Positive scores indicate greater left than right activation.

EEG POWER

Because the previous analysis showed significant differences between EEG asymmetry across condition, I conducted follow-up analysis to test the *a priori* hypothesis that infants would show greater left activation (less alpha power) than right activation in the attractive condition and no significant difference between hemispheres for the unattractive condition—similar to results obtained by Davidson and Fox (1982). A 2 (face condition) X 2 (hemisphere) ANOVA with raw alpha power EEG data resulted in no main effect for either face type condition or hemisphere, but a significant face condition X hemisphere interaction, $F(1, 38) = 5.69$, $p = .02$ (see Figure 2). Results from paired-samples t-tests supported the hypothesis: Infants showed higher activation (less power) on the left ($M = 25.85$, $SD = 18.19$) compared to right ($M = 28.96$, $SD = 22.83$) in the attractive condition, $t(38) = -3.11$, p = .02 (*Cohen's d* = .34, Cohen, 1977; Wolf, 1986); but no difference between the two hemispheres in the unattractive condition, $t(38) = -.19$, p = .88. The differences in EEG asymmetry appear to be the result of less right activation in the attractive condition than the unattractive condition. Further *post hoc* t-tests showed that the left hemispheres did not differ significantly across condition $t(38) = -.58$, $p = .57$, nor did the right hemispheres differ significantly across condition, $t(38) = 1.748$, $p = .09$.

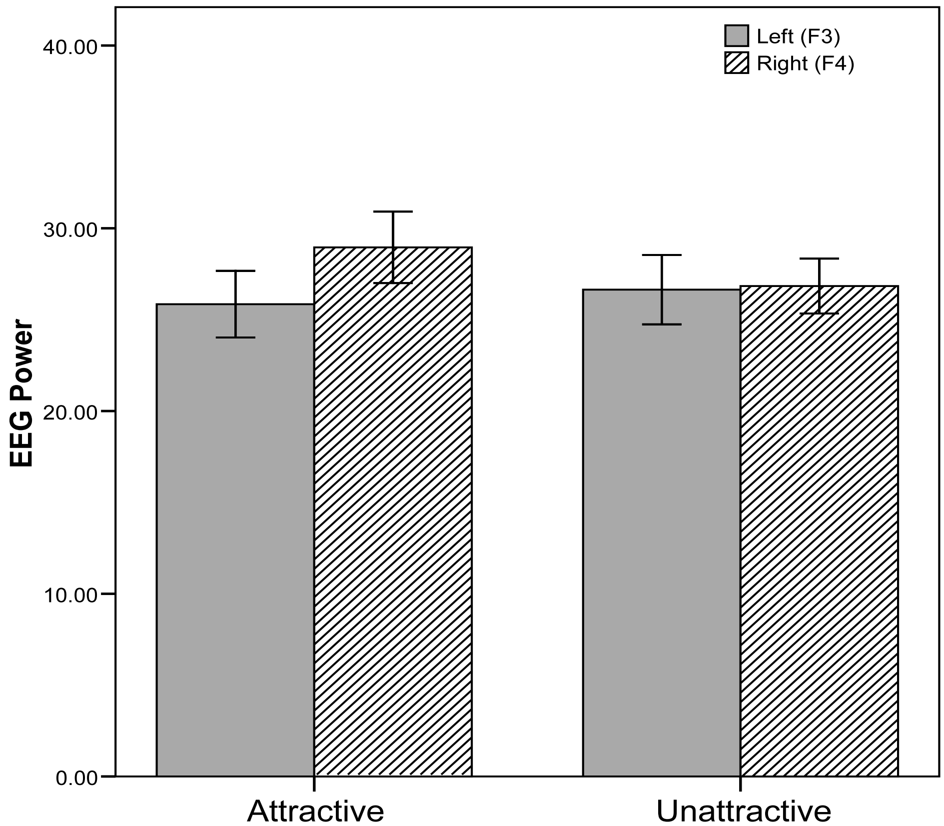

Figure 2: Mean frontal raw EEG power (95% CI) when infants view attractive and unattractive faces by hemisphere.

Discussion

I designed this study to support that infants have different levels of approach/withdrawal motivation in response to attractive and unattractive faces and to support the use of EEG frontal asymmetry as a marker of approach/withdrawal motivation in response to social stimuli. I expected attractive faces to elicit greater left EEG asymmetry than unattractive faces indicating that infants are motivated to approach attractive individuals than unattractive individuals. I also predicted that there would be hemispheric differences in the attractive condition with more activation on the left. If unattractive faces elicited withdrawal motivation, then I expected infants to show more right than left activation in the unattractive condition.

This investigation found significant differences in frontal brain activation dependent on attractiveness of face stimuli. Infants showed greater left frontal asymmetry when viewing attractive faces than when viewing unattractive faces. I also analyzed raw EEG power data, because differences in EEG asymmetry between conditions may be due to changes in the left hemisphere, right hemisphere, or both. Comparisons of hemispheric difference in raw EEG power uncovered significantly greater left than right activation in response to attractive faces but no significant difference between left and right hemispheres in the unattractive condition. These results are consistent with the Davidson and Fox (1982) study showing greater left EEG asymmetry when infants viewed happy faces compared to sad faces, and greater left than right hemispheric activation for the happy condition but not for the sad condition. Hemispheric power between conditions (e.g., left power for attractive vs. left power for unattractive) did not differ significantly. There is a trend for decreased right hemispheric activation for attractive faces compared to unattractive faces that would suggest decreased withdrawal motivation for attractive compared to unattractive. Thus, EEG asymmetry data suggest that infants are likely more motivated to approach attractive than unattractive faces; but whether these differences are due to increased approach or decreased withdrawal motivation in the attractive condition compared to the unattractive condition is unclear from these data.

Results do not support the alternative hypothesis that infants would show greater right than left hemispheric activation in response to unattractive faces consistent with Langlois et al. (1990) in which 12-month-olds demonstrated more withdrawal behaviors toward unattractive strangers than attractive strangers. Other studies found similar inconsistencies for withdrawal motivation and right asymmetry, but in some cases these inconsistencies were explainable by individual differences in expressions of distress (Davison & Fox, 1982; Fox & Davidson, 1987, 1988). The discrepancy in the current study could be due to several factors. For instance in Langlois et al. (1990), 12-month-olds viewed the approach of a live stranger who attempted to interact with the infants. Infants in the present study viewed static images of faces that did not interact with the infants. These static images may not have elicited enough arousal to register withdrawal motivation with EEG asymmetry (Ekman et al., 1990; Ekman & Davidson, 1993; Fox & Davidson, 1988; Pickens et al., 2001). *Dynamic* face stimuli may have elicited the expected right asymmetry. Another possibility is that 6- and 10-month-olds may not be as motivated to withdraw from unattractive faces as 12-month-olds. This interpretation is not as likely with 10-month-olds as 6-month-olds given that stranger wariness is fully developed by 10-months (Campos et al., 1975, Mangelsdorf et al., 1995; Waters et al., 1975). Further testing is necessary to tease apart the issues regarding withdrawal motivation and right EEG asymmetry in response to face stimuli.

This study included 6- and 10-month-olds of both genders to test for developmental and gender differences before (6-months) and after (10-months) stranger wariness is firmly established. There were no main effects or interaction effects for age or gender. Absence of significant age differences is interesting because stranger wariness literature suggest that 10-month-olds should have more withdrawal motivation toward strangers than 6-month-olds, in general, and therefore, should have more withdrawal motivation for unattractive faces than 6-month-olds. Although 6- and 10-month-olds do not differ significantly in asymmetry scores, the pattern of results is in the predicted direction. Ten-month-olds' asymmetry indexes are lower than 6-month-olds in both conditions suggesting that there is a trend for 10-month-olds to experience less approach motivation and possibly more withdrawal motivation. Analysis of gender differences is important because many of the early studies with 10-month-old infants included only females (Davidson & Fox, 1982; Fox & Davidson, 1987, 1988); however, gender does not appear to play a role in EEG asymmetries in response to face stimuli. Based on these results, approach motivation toward attractive faces emerges as early as 6-month, extends until 10-months, and does not differ for female and male infants.

A primary goal of this investigation was to support the use of EEG asymmetry as a measure of infant approach/withdrawal motivation in response to face stimuli that differ in salient characteristics, such as attractiveness. Infant brain activation showed a similar pattern for attractive faces versus unattractive faces as for mother's approach and reach versus stranger's approach (Fox & Davidson, 1987, 1988), and for happy faces versus sad faces (Davidson & Fox, 1982), strengthening the assertion that EEG asymmetry methodology is appropriate for studying state changes in infant approach/withdrawal motivation. Unlike visual fixation studies (Langlois et al., 1991; Langlois et al., 1987; Taylor-Partridge & Langlois, 2009), infants at 6- and 10-months did not differ significantly on the dependent measure, suggesting that EEG asymmetry consistently measures neural correlates of approach/withdrawal motivation across these two age groups.

The other primary goal of this investigation was to contribute to the understanding of early processes involved in the development of attractiveness attitudes and stereotypes. This study links attractiveness preferences apparent from visual attention at 6-months to preferences apparent from social behaviors at 12 months. It is well established that 6-month-olds look longer at attractive than unattractive faces in the visual paired comparison (Langlois et al., 1991; Langlois et al., 1987; Taylor-Partridge & Langlois, 2009), but visual attention only hints at underlying motivation. Compared to visual fixation, behaviors shown by 12-month-olds in Langlois et al. (1990) were much more obvious in suggesting approach motivation toward attractive people and withdrawal motivation toward unattractive people. The current study supports the claim that infants are more motivated to approach attractive than unattractive faces by 6-months, and fills the gap between 6- and 12-months by showing that 10-month-olds also are more motivated to approach attractive than unattractive faces.

EEG asymmetry indicating greater motivation to approach attractive than unattractive faces is consistent with proposed cognitive and affective mechanisms. Because of cognitive averaging, infants perceive attractive faces as perceptually familiar (Rubenstein et al., 1999). Infants prefer to interact with people they perceive as familiar (mother vs. stranger). Infant EEG asymmetry for attractive versus unattractive faces is similar to patterns shown in response to mother approach and reach versus stranger approach when infant appears distressed (Fox & Davidson, 1987, 1988). Furthermore, it has been shown that perceptual familiarity may generate positive affect (see Zajonc, 1980, 2004). Infants EEG asymmetry patterns are similar in response to attractive faces as to unattractive faces and in response to unattractive faces as to attractive faces. These similarities may be because infants view attractive, but not unattractive, faces as positive motivating interaction. As infants learn more about the world and parse other types of stimuli into those that are approachable and those that are not, infants make associations within each category that later turn into valence associations and further down the road stereotypes (Langlois et al., 2009).

Researchers who study approach/withdrawal motivation and evaluation assert that approach/withdrawal motivation results from automatic evaluation of stimuli as good or bad and is found in even the most basic species (Elliot, 2008; Ferguson & Bargh, 2008). I believe that infant EEG asymmetry serves as a marker of motivation evoked by social evaluation. Although face perception research alludes to evaluation in discussing preferences, few researchers focus on the development of infant social evaluation in the formation of attitudes. One exception is a study of evaluation of social behaviors: Hamlin, Wynn, and Bloom (2007) found that 6- and 10-month-old infants prefer a character that helps a target rather than one that hinders a target from reaching its goal. That study (Hamlin et al., 2007) and the current EEG study suggest that approach/withdrawal motivation is a construct that can and should be studied in infancy to perhaps enhance the understanding of developing social evaluation.

LIMITATIONS

Two important limitations of this study include sampling bias and large attrition rates. Some parents declined to allow their infants to participate in this study because the parents were not comfortable with the procedure or because they did not believe their infant would wear the cap. Thus, the sample was limited by parents' concern and perceptions of their infants' temperament.

Additionally, about 50% of infants who participated in the study did not provide usable data. Attrition rates are higher for infant EEG/ERP studies than for infant behavioral studies. I removed EEG data from further analysis when the infant was not attending to stimuli or when there was artifact—usually due to infant movement or fussiness. If infants did not provide the minimum number of usable epochs per condition, their data was removed from further analysis. Published EEG/ERP studies report attrition rates averaging around 50% (see de Haan, 2007 for a table of attrition rates in electrophysiological studies). I ran exploratory analysis to ensure that the number of usable epochs did not predict EEG asymmetry for either attractive or unattractive conditions; lack of significant results suggests the method is appropriate even for infants who provide substantially less data than other infants. Other researchers have commented on differences between infants who complete studies and those who do not. For instance, Slaughter and Suddendorff (2007) reviewed infant research that used visual paradigms from the last 20 years and found that attrition rates due to fussiness for infant visual paradigms ranged from 0% to 62% with a mean around 14%, but did not appear to systematically relate to outcomes. Infants who did not complete the study may differ from infants who completed the study in temperamental factors. Because temperament is also linked to EEG asymmetries, there may be significant differences in EEG activation between infants who did and did not provide usable date. However, it is unlikely that the direction of EEG asymmetry for attractive compared to unattractive stimuli would differ substantially. In fact differences between hemispheric power suggestive of withdrawal motivation may have approached significance with the inclusion of infants especially high in social wariness, because those infants are more likely to show withdrawal behaviors (e.g., Rothbart, 1988).

As an additional note, the discrepancy between lack of right EEG asymmetry associated with withdrawal at 6- and 10-months but overt withdrawal behaviors at 12-months may be due to study characteristics. Although I tried to make the study procedure as infant friendly as possible (e.g., pleasant distractions while preparing infant), EEG studies are more demanding of infants than behavioral studies. Infants who are willing to wear the cap, sit calmly, and attend to the presented faces may not experience as much withdrawal motivation in general as infants who do not provide good EEG data. Characteristics may differ between those infants who complete an EEG study and those infants who complete a behavioral study. Infants who did not complete the study may have shown more right activation in response to unattractive faces, which would have been more consistent with withdrawal behaviors shown by 12-month-olds (Langlois et al., 1990). Thus, sampling bias limits the extent that these results generalize to infants high in anxiety. Although not all infants tolerate the EEG procedure, it is the best available method to measure brain activation in response to experimental conditions in infancy (Fox, Schmidt, Henderson, & Marshall, 2007).

FUTURE DIRECTIONS

To my knowledge this is the first study of EEG asymmetry in response to attractiveness. There are several directions to explore in the future. Although the current results suggest that approach/withdrawal motivation is likely present in response to attractive and unattractive faces by 6-months, it does not show when this index first emerges in response to faces. Further research of younger infants may provide important information about the developing structures of the brain that contribute to these asymmetries recorded at the scalp while also providing more information about early social development (Fox et al., 2007). Also, given that EEG asymmetry is present in adults in response to stimuli eliciting approach and withdrawal motivation, children and adults may also show EEG asymmetry in response to attractive and unattractive faces. Thus, future studies should include individuals younger than 6-months and older than 10-

months to further discover whether EEG asymmetry is consistent from infancy through adulthood in response to social stimuli and specifically attractive and unattractive faces. It is possible that as infants get older, static images may not be arousing enough to elicit asymmetries. Several studies have shown that asymmetries in frontal EEG are greatest for high intensity images and video clips (Davidson et al., 1990; Ekman et al., 1990; Ekman & Davidson, 1993; Jones & Fox, 1992; Fox & Davidson, 1988). Thus, modifications to stimuli and procedure may be necessary for older age groups.

In addition to developmental differences, I am interested in testing whether individual differences explain variability in EEG asymmetries in response to attractive and unattractive faces. Of the 39 participants in the current study, eleven infants did not show the predicted pattern of EEG asymmetry. Adding additional variables as covariates in future studies of EEG asymmetry may account for additional variance and provide further understanding of approach/withdrawal motivation. For instance, other studies of motivational states using EEG asymmetry showed that the presence or absence of vocalizations and certain facial expressions accounted for variability in EEG asymmetry (e.g., Fox & Davidson, 1988), thus these variables may be interesting to analyze in future studies. Furthermore, we recently found that individual differences in temperament related to patterns of visual attention toward attractive and unattractive faces in the visual paired comparison with 9- and 12-months suggesting that temperament factors may also influence EEG asymmetries in response to social stimuli. Thus, studying individual differences may detect underlying results not readily evident otherwise providing a better understanding of cognitive and emotional processes (Canli, 2004; Kosslyn et al., 2002).

Conclusions

Although the emphasis here is on motivation resulting from social evaluation of faces differing in attractiveness, EEG asymmetry methodology may be a promising way to study developing evaluation mechanisms in other social categories, such as gender or race. I used EEG asymmetry to measure changes in motivational state. Resting EEG asymmetry is associated with individual differences in trait tendencies to approach or withdraw to the environment in general. In fact, most of the developmental research involving EEG asymmetry focuses on resting EEG and how it predicts behavior (see Coan & Allen, 2004 for review). Much less is known about how EEG asymmetry represents changes in infant motivational state in response to potential social partners. Given that stereotypes regarding attractiveness, race and gender appear to develop by 3-years of age (see Aboud, 1988; Ruble, Martin, & Berenbaum, 2006; Styczynski & Langlois, 1977), understanding the neural components of evaluation and approach/withdrawal motivation may illuminate important, early processes in stereotype development as well as brain/behavior relationships and mechanisms guiding social development.

Appendix

Table 3: Mean Number of Epochs by Age and Condition

	Attractive		Unattractive		Overall	
Age	*M*	*SD*	*M*	*SD*	*M*	*SD*
6-months[a]	37.11	18.24	28.37	21.74	37.74	4.37
10-months[b]	47.35	20.15	50.90	20.29	49.13	4.26
Overall	42.36	19.68	44.79	21.68	43.43	3.05

Note. Positive means represent left asymmetry and negative means represent right asymmetry.

[a]n = 19. [b]n = 20.

Table 4: Descriptive Statistics for EEG Asymmetry Index by Age and Condition

	Attractive		Unattractive		Overall	
Age	*M*	*SD*	*M*	*SD*	*M*	*SD*
6-months[a]	.10	.39	.01	.35	.06	.08
10-months[b]	.04	.33	-.04	.37	.00	.08
Overall	.07	.36	-.02	.36	.03	.06

Note. Positive means represent left asymmetry and negative means represent right asymmetry. [a]n = 19.

[b]n = 20.

References

Ainsworth, M. D., Blehar, M., Waters, E., & Wall, S. (1978). *Patterns of attachment.* Hillsdale, NJ: Erlbaum.

Allen, J.J.B., & Kline, J.P. (2004) Frontal EEG asymmetry, emotion and psychopathology: The first, and the next, twenty-five years. *Biological Psychology, 67*, 1–5.

Barrera, M., & Maurer, D. (1981). Discrimination of strangers by the three-month-old. *Child Development*, *52*, 558-563.

Bartrip, J., Morton, J., & de Schonen, S. (2001). Responses to mother's face in 3-week to 5-month-old infants. *British Journal of Developmental Psychology, 19,* 219-232.

Bomba, P. C. & Siqueland, E. R. (1983). The nature and structure of infant form categories. *Journal of Experimental Child Psychology, 35*, 294-328.

Bowlby, J. (1969) *Attachment and loss: Volume 1. Attachment*, New York: Basic Books.

Bronstad, P. M., Langlois, J. H., & Russell, R. (2008). Computational models of facial attractiveness judgments. *Perception, 37*, 126-142.

Buss, K. A., Malmastadt Schumacher, J. R., Dolski, I., Kalin, N. H., Goldsmith, H. H., & Davidson, R. J. (2003). Right frontal brain activity, cortisol, and withdrawal behavior in 6-month-old infants. *Behavioral Neuroscience, 117*, 11-20.

Cacioppo, J. (2004). Feelings and emotions: Roles for electrophysiological markers. *Biological Psychology*, *67*, 235-243.

Campos, J. J., Emde, R. N., Gaensbauer, T., & Henderson, C. (1975). Cardiac and behavioral interrelationships in the reactions of infants to strangers. *Developmental Psychology, 11*, 589-601.

Carver, C., & Harmon-Jones, E. (2009). Anger is an approach-related affect: Evidence and implications. *Psychological Bulletin*, *135*, 183-204.

Coan, J. A. & Allen, J. B. (2004). Frontal EEG asymmetry as a moderator and mediator of emotion. *Biological Psychology, 67,* 7-49.

Coan, J. A., Allen, J. J. B., & Harmon-Jones, E. (2001). Voluntary facial expression and hemispheric asymmetry over the frontal cortex. *Psychophysiology, 38*, 912-925.

Cohen, J. (1977). *Statistical power analysis for behavioral sciences* (revised ed.). New York: Academic Press.

Davidson, R. (1992). Prolegomenon to the structure of emotion: Gleanings from neuropsychology. *Cognition and Emotion, 6*, 245-268.

Davidson, R. (2004). What does the prefrontal cortex 'do' in affect: Perspectives on frontal EEG asymmetry research. *Biological Psychology*, *67*, 219-233.

Davidson, R., Ekman, P., Saron, C., Senulis, J., & Friesen, W. V. (1990). Approach/withdrawal and cerebral asymmetry: Emotional expression and brain physiology: I. *Journal of Personality and Social Psychology,58,* 330-341.

Davidson, R. J. & Fox, N. A. (1982). Asymmetrical brain activity discriminates between positive and negative affective stimuli in human infants. *Science, 218*, 1235-1237.

Davidson, R. J., Jackson, D. C., & Kalin, N. H. (2000). Emotion, plasticity, context, and regulation: Perspectives from affective neuroscience. *Psychological Bulletin, 126,* 890-909.

DeBoer, T., Scott, L. S., & Nelson, C. A. (2007). Visual attention and recognition memory in infancy. In Michelle de Haan (Ed.), *Infant EEG and event-related potentials* (pp. 101-143). New York: Psychology Press.

DeCasper, A. J., & Fifer, W. P. (1980). Of human bonding: Newborns prefer their mothers' voices. *Science, 208*, 1174.

de Haan, M. (2007). Visual attention and recognition memory in infancy. In Michelle de Haan (Ed.), *Infant EEG and event-related potentials* (pp. 101-143). New York: Psychology Press.

Derryberry, D., & Rothbart, M. (1997). Reactive and effortful processes in the organization of temperament. *Development and Psychopathology*, *9*(4), 633-652.

Dion, K. K. & Berscheid, E. (1974). Physical attractiveness and peer perception among children. *Sociometry, 37*, 1-12.

Dion, K. K., Berscheid, E., & Walster, E. (1972). What is beautiful is good. *Journal of Personality & Social Psychology, 24*, 285-290.

Eagly, A., Ashmore, R., Makhijani, M., & Longo, L. (1991). What is beautiful is good, but . . .: A meta-analytic review of research on the physical attractiveness stereotype. *Psychological Bulletin*, *110*, 109-128.

Ekman, P. (1989). The argument and evidence about universals in facial expressions of emotion. *Handbook of social psychophysiology* (pp. 143-164). Oxford England:

John Wiley & Sons.

Ekman, P., & Davidson, R. (1993). Voluntary smiling changes regional brain activity. *Psychological Science*, *4*, 342-345.

Ekman, P., Davidson, R., & Friesen, W. (1990). The Duchenne smile: Emotional expression and brain physiology: II. *Journal of Personality and Social Psychology*, *58*, 342-353.

Elliot, A. J. (2008). Approach and avoidance motivation. In A. J. Elliot (Ed.) *Handbook of approach and avoidance motivation* (pp. 3-14). New York: Psychology Press

Fantz, R. L. (1961). The Origin of form perception. *Scientific American, 204*, 66-72.

Farroni, T., Menon, E., Rigato, S., & Johnson, M. H. (2007). The perception of facial expressions in newborns. *European Journal of Developmental Psychology, 4,* 2–13.

Fazio, R. H., Eiser, J. R., & Shook, N. J. (2004). Attitude formation through exploration: Valence asymmetries. *Journal of Personality and Social Psychology, 87*, 293-311.

Feinman, S. (1980). Infant response to race, size, proximity, and movement of strangers. *Infant Behavior & Development*, *3*, 187-204.

Ferguson, M. & Bargh, J. A. (2008) Evaluative readiness: The motivational nature of automatic evaluation. In A. J. Elliot (Ed.) *Handbook of approach and avoidance motivation* (pp. 289-306). New York: Psychology Press

Fernandez, M., Blass, E. M., Hernandez-Reif, M., Field, T., Diego, M., & Sanders, C. (2003). Sucrose attenuates a negative electroencephalographic response to an aversive stimulus newborns. *Developmental and Behavioral Pediatrics, 24,* 261-266.

Fox (1991). If it's not left, it's right. *American Psychologist, 46*, 863-872.

Fox, N., & Davidson, R. (1986). Taste-elicited changes in facial signs of emotion and the asymmetry of brain electrical activity in human newborns. *Neuropsychologica, 24,* 417-422.

Fox, N., & Davidson, R. (1987). Electroencephalogram asymmetry in response to the approach of a stranger and maternal separation in 10-month-old infants. *Developmental Psychology*, *23*(2), 233-240.

Fox, N., & Davidson, R. (1988). Patterns of brain electrical activity during facial signs of emotion in 10-month-old infants. *Developmental Psychology*, *24*(2), 230-236.

Fox, N. A., Schmidt, L. A., Henderson, H. A., & Marshall, P. J. (2007). Developmental psychophysiology: Conceptual and methodological issues. In J. Caccioppo (Ed.) *Handbook of psychophysiology (3rd ed.)* (pp. 453-481). New York, NY: Cambridge University Press.

Gaensbauer, T. J., Emde, R. N., & Campos, J. J. (1976). Stranger distress: Confirmation of a developmental shift in longitudinal sample. *Perceptual and Motor Skills, 43*, 99-106.

Halberstadt, J. (2003). It's not just average faces that are attractive: Computer-manipulated averageness makes birds, fish, and automobiles attractive. *Psychonomic Bulletin & Review, 10*, 149-156.

Hamermesh, D. S., & Biddle, J. E. (1994). Beauty and the labor market. *The American Economic Review*, *84*, 1174-1194.

Hamlin, J., Wynn, K., & Bloom, P. (2007). Social evaluation in preverbal infants. *Nature*, *450*, 557-559.

Harmon-Jones, E. (2003). Clarifying the emotive functions of asymmetrical frontal cortical activity. *Psychophysiology, 40*, 838-848.

Hosoda, M., Stone-Romero, E. F., & Coats, G. (2003). The effects of physical attractiveness on job-related outcomes: A meta-analysis of experimental studies. *Personnel Psychology, 56,* 431-462.

Jasper, H.A. (1958). The ten–twenty system of the International Federation. *Electroencepholography and Clinical Neurophysiology*, **10**, 371–375.

Jones, N. A., & Fox, N. (1992). Electroencephalogram asymmetry during emotionally evocative films and its relation to positive and negative affectivity. *Brain and Cognition*, *20*, 280-299.

Kelly, D., Liu, S., Ge, L., Slater, A., Lui, Q, Pascalis, O., Lee, K., & Quinn, P. C. (2007). Cross-Race Preferences for Same-Race Faces Extend Beyond the African Versus Caucasian Contrast in 3-Month-Old Infants. *Infancy*, *11*, 87-95.

Kelly, D., Quinn, P., Slater, A., Gibson, A., Ge, L., Pascalis, O., Smith, M., & Lee, K (2005). Three-month-olds, but not newborns, prefer own-race faces. *Developmental Science*, *8*, 31-36.

LaBarbera, J. D., Izard, C. E., Vietze, P., & Parisi, S. A. (1976). Four- and six-month-old infants' visual responses to joy, anger, and neutral expressions. *Child Development, 47,* 535–538.

Langlois, J. H., Griffin, A. M, Rubenstein, A. J., Rosen, L., Taylor-Partridge, T., Ramsey, J., Hoss, R., & Principe, C. (2009). Infants link valence with facial attractiveness: Rudiments of a stereotype? Manuscript submitted for publication (Received "revise and resubmit" 14 May 2009, Journal of Personality and Social Psychology).

Langlois, J. H., Kalakanis, L., Rubenstein, A. J., Larson, A., Hallam, M., & Smoot, M. (2000). Maxims or myths of beauty? A meta-analytic and theoretical review. *Psychological Bulletin, 126,* 390-423.

Langlois, J. H., Ritter, J. M., Casey, R. J., & Sawin, D. B. (1995). Infant attractiveness predicts maternal behaviors and attitudes. *Developmental Psychology, 31*, 464-472.

Langlois, J. H., Ritter, J. M., Roggman, L. A., & Vaughn, L. S., (1991). Facial diversity and infant preferences for attractive faces. *Developmental Psychology, 27*, 79-84.

Langlois, J. H. & Roggman, L. A. (1990). Attractive faces are only average. *Psychological Science, 1*, 115-121.

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,* 363-369.

Langlois, J. H., Roggman, L. A., & Rieser-Danner, L. A. (1990). Infants' differential social responses to attractive and unattractive faces. *Developmental Psychology, 26,* 153-159.

Macfarlane, AJ. Olfaction in the development of social preferences in the human neonate. *Ciba Found Symp*. 1975;33:103–117.

Mangelsdorf, S., Shapiro, J., & Marzolf, D. (1995). Developmental and temperamental differences in emotional regulation in infancy. *Child Development*, *66*(6), 1817-1828.

Marshall, P., Bar-Haim, Y., & Fox, N. (2002). Development of the EEG from 5 months to 4 years of age. *Clinical Neurophysiology*, *113*, 1199-1208.

Mazzella, R. & Feingold, A. (1994). The effects of physical attractiveness, race, socioeconomic status, and gender of defendants and victims on judgements of mock jurors: A meta-analysis. *Journal of Applied Social Psychology, 24*, 1315-1344.

Nelson, C. A. & Dodgin, K. G. (1985). The generalized discrimination of facial expressions by seven-month-old infants. *Child Development, 56*, 58-61.

Nosofsky, R. M. (1988). Exemplar-based accounts of relations between classification, recognition, and typicality. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 14,* 700-708.

Nosofsky, R. M. (1991). Tests of an exemplar model for relating perceptual classifications and recognition memory. *Journal of Experimental Psychology: Human Perception and Performance, 17,* 3-27.

Pascalis, O., de Schonen, S., Morton, J., & Deruelle, C. (1995). Mother's face recognition by neonates: A replication and an extension. *Infant Behavior & Development*, *18*, 79-85.

Pickens, J., Field, T., & Nawrocki, T. (2001). Frontal EEG asymmetry in response to emotional vignettes in preschool age children. *International Journal of Behavioral Development, 25*, 105-112.

Pivik, R.T., Broughton, R.T., Coppola, R., Davidson, R.J., Fox, N., & Nuwer, M.R. (1993). Guidelines for the recording and quantitative analysis of electroencephalographic activity in research contexts. *Psychophysiology, 30*, 547–558.

Pizzagalli, D.A. (2007). Electroencephalography and High-Density Electrophysiological Source Localization. In: J.T. Cacioppo, L.G. Tassinaru, G.G. Berntson (Eds.), *Handbook of psychophysiology (3rd ed., pp. 56-84))*. Cambridge, U.K.: Cambridge University Press.

Posner, M. I., & Keele, S. W. (1968). On the genesis of abstract ideas. *Journal of Experimental Psychology, 77*, 353-363.

Putnam, S., & Stifter, C. (2002). Development of approach and inhibition in the first year: Parallel findings from motor behavior, temperament ratings and directional cardiac response. *Developmental Science*, *5*, 441-451.

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

Ramsey, J. L., Langlois, J. H., Hoss, R. A., Rubenstein, A. J., & Griffin, A. M. (2004). Origins of a stereotype: Categorization of facial attractiveness by 6-month-old infants. *Developmental Science, 7*, 201-211.

Rothbart, M. (1988). Temperament and the development of inhibited approach. *Child Development*, *59*(5), 1241-1250.

Rothbart, M. K. & Bates, J. E. (1998). Temperament. In W. Damon (Series Ed.) & N. Eisenberg (Vol. Ed.), *Handbook of child psychology: Vol 3. Social, emotional, and personality development* (5th ed., pp. 105-176). New York: Wiley.

Ruble, D. N., Martin, C. L., & Berenbaum, S. A. (2006). Gender development. In W. Damon & R. M. Lerner (Series Eds.) & N. Eisenberg (Vol. Ed.), Handbook of child psychology: Vol. 3. Social, emotional, and personality development (6th ed., pp. 858-932). Hoboken, NJ: Wiley.

Rubenstein, A. J., Kalakanis, L., & Langlois, J. H. (1999). Infant preferences for attractive faces: A cognitive explanation. *Developmental Psychology, 35,* 848-855.

Rubenstein, A. J., Langlois, J. H., & Roggman, L. (2002). What makes a face attractive and why: The role of averageness in defining facial beauty. In G. Rhodes & L.

A. Zebrowitz (Eds.), *Facial attractiveness: Evolutionary, cognitive, and social perspectives* (pp. 1-33). Westport, CT: Ablex.

Santesso, D. L., Schmidt, L. A., & Trainor, L. J. (2007). Frontal brain electrical activity (EEG) and heart rate in response to affective infant-directed (ID) speech in 9-month-old infants. *Brain and Cognition, 65*, 14-21.

Schmidt, L. A. & Trainor, L. J. (2001). Frontal brain electrical activity (EEG) distinguishes valence and intensity of musical emotions. *Cognition and Emotion, 15,* 487-500.

Schmidt, L. A., Trainor, L. J., & Santesso, D. L. (2003). Development of frontal electroencephalogram (EEG) and heart rate (ECG) responses to affective musical stimuli during the first 12 months of post-natal life. *Brain and Cognition, 52,* 27-32.

Serrano, J., Iglesias, J., & Loeches, A. (1995). Infants' responses to adult static facial expressions. *Infant Behavior & Development*, *18*, 477-482.

Slaughter, V., & Suddendorf, T. (2007). Participant loss due to 'fussiness' in infant visual paradigms: A review of the last 20 years. *Infant Behavior & Development*, *30*, 505-514.

Strauss, M. S. (1979). Abstraction of prototypical information by adults and 10-month-old infants. *Journal of Experimental Psychology: Human Learning & Memory, 5*, 618-632.

Styczynski, L.E., & Langlois, J.H. (1977). The effects of familiarity on behavioral stereotypes associated with physical attractiveness in young children. *Child Development, 48,* 1137-1141.

Taylor-Partridge, T., & Langlois, J. H. (2009). Individual differences in infant visual attention to attractive and unattractive faces. Manuscript in preparation.

Vaish, A., Grossman, T., & Woodward, A. (2008). Not all emotions are created equal: The negativity bias in social-emotional development. Psychological Bulletin, 134, 383-403.

Walster, E., Aronson, V., Abrahams, D., & Rottman, L. (1966). Importance of attractiveness in dating behavior. *Journal of Personality and Social Psychology, 4*, 508-516.

Waters, E., Matas, L., & Sroufe, L. A. (1975). Infants' reactions to an approaching stranger: Description, validation, and functional significance of wariness. *Child Development, 46*, 348-356.

Wilcox, B., & Clayton, F. (1968). Infant visual fixation on motion pictures of the human face. *Journal of Experimental Child Psychology*, *6*, 22-32.

Winkielman, P., Halberstadt, J., Fazendeiro, T., & Catty, S. (2006). Prototypes are attractive because they are easy on the mind. *Psychological Science, 17*, 799-806.

Wolf, F.M. (1986). *Meta-analysis: Quantitative Methods for Research Synthesis*. Beverly Hills, CA: Sage.

Zajonc, R. B. (1980). Feeling and thinking: Preferences need no inferences. *American Psychologist, 35*, 151-175.

Zajonc, R. A. (2004). Exposure effects: An unmediated phenomenon. In: A. S. R. Manstead, N. Frijda, & A. Fischer, (Eds.), Feelings and emotions: The Amsterdam symposium (pp. 194-203). New York: Cambridge University

Vita

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