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EEG Asymmetry at 10 Months of Age: Are Temperament Trait Predictors Different for Boys and Girls?

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Abstract

Frontal EEG asymmetry patterns represent markers of individual differences in emotion reactivity and regulation, with right hemisphere activation linked with withdrawal behaviors/emotions (e.g., fear), and activation of the left hemisphere associated with approach (e.g., joy, anger). In the present study, gender was examined as a potential moderator of links between infant temperament at 5 months, and frontal EEG asymmetry patterns recorded during an Arm Restraint procedure at 10 months of age. Positive Affectivity/Surgency (PAS), Negative Emotionality (NE), and Orienting/Regulatory Capacity were considered as predictors, with PAS emerging as significant for males; higher levels translating into greater right frontal activation later in infancy. For females, ORC accounted for a significant portion of the frontal asymmetry scores, with higher ORC being associated with greater right frontal activation. The moderating influence of gender noted in this study is discussed in the context of implications for discrepancies in rates/symptoms of psychopathology later in childhood.

Keywords

Temperament; Infancy; EEG Asymmetry; Gender Differences; Moderator Effects

According to the Fox (1994) model of differential activation, frontal EEG asymmetry patterns are indices of individual differences in emotion reactivity and regulation. Specifically, activation of the right hemisphere during a resting baseline condition is linked with withdrawal behaviors and emotions (e.g., fear), whereas activation of the left hemisphere is associated with approach behaviors/emotions (e.g., joy, anger). Infants demonstrating resting right frontal EEG asymmetry (i.e., greater relative right frontal activation) cry more frequently upon separating from mothers relative to babies exhibiting left frontal EEG asymmetry (Bell & Fox, 1994; Davidson & Fox, 1989; Fox, Calkins, &

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Bell, 1994; Fox & Davidson, 1987), suggesting that patterns of resting frontal EEG asymmetry reflect individual differences in behavioral/emotional predisposition.

Frontal EEG asymmetry can also serve as a marker of the current emotional state. For example, Fox and Davidson (1987, 1988) reported left frontal asymmetry for infants during approach behaviors (e.g., positive vocalization, facial expressions of joy), along with greater relative right-frontal activation for the same children during withdrawal (e.g., distress, gaze aversion). More recently, Buss and colleagues (Buss, Malmstadt, Dolski, Kalin, Goldsmith, & Davidson, 2003) found greater right frontal EEG asymmetry during stranger approach for infants who exhibited higher levels of fear and sadness. Similar right frontal asymmetry findings have been reported by Diaz and Bell (2012) during stranger approach and during a jumping toy spider. Thus, concurrent trait and state behavioral correlates of frontal EEG asymmetry show a consistent pattern of findings during infancy, with greater relative right frontal asymmetry associated with withdrawal behaviors and greater relative left frontal asymmetry with approach behaviors.

There have also been longitudinal reports of early consistencies in frontal EEG asymmetry being associated with later approach and withdrawal behavior patterns (Smith & Bell, 2010). A more usual approach, however, is to use selected samples and examine how early temperament-related behaviors might indicate a potential risk for later problems, such as behavioral inhibition (i.e., withdrawal), and then focus on frontal EEG asymmetry (e.g., Fox, Henderson, Rubin, Calkins, & Schmidt, 2001). To our knowledge, prior studies have not addressed the potential of normal variations in early infant temperament to be associated with later relative frontal activation. The value in this latter approach is twofold. First, it allows examination of temperament-related behaviors and frontal asymmetries in non-selected samples. Second, it addresses questions concerning links between behavioral/emotional factors in the first six months of life with respect to later asymmetry indicators in typically developing samples. Thus, our study examined early temperament correlates of later frontal EEG asymmetry in a large non-selected sample of infants.

Development of Temperament

Temperament has been defined as constitutionally based individual differences in reactivity and self-regulation (Rothbart, 2011; Rothbart & Derryberry, 1981), influenced over time by heredity, maturation, and environment. Higher-order temperament constructs have been extracted from parent-report, including Negative Emotionality, Positive Affectivity/Surgency, and Regulatory Capacity/Orienting (Gartstein & Rothbart, 2003; Putnam, Ellis & Rothbart, 2001).

Negative emotionality has been linked conceptually and empirically to the personality trait of neuroticism in adulthood (Evans & Rothbart, 2007) and developmentally, negative emotionality is one of the first temperament attributes to emerge (e.g. Rothbart, 1989). Negative affectivity assessed in infancy predicts distress in the preschool period (Putnam et al., 2008), and stability in negative emotionality constructs by the toddler years has been reported (e.g., Lemery et al., 1999). Surgency in infancy is largely manifested through smiling, laughing, activity, appreciation of high intensity stimulation and approaching novel

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stimuli (Gartstein & Rothbart, 2003; Rothbart, 1989). The Surgency factor label is frequently used interchangeably with the terms positive emotionality and extraversion, including characteristics of enthusiasm, activity, approach tendencies and sociability (e.g. Rothbart & Ahadi, 1994). Individuals higher in positive affect have the tendency to be engaged, rather than disengaged, with their environment (Lonigan, Phillips, & Hooe, 2003), presumably because of stronger approach tendencies (Rothbart, Ahadi, & Hershey, 1994; Rothbart & Hwang, 2005; Windle, 1995).

In infancy, a regulation temperament factor related to orienting attention has been identified (Gartstein & Rothbart, 2003). Measures of this early marker of regulation-related processes have been shown to predict later effortful control (Gartstein, Slobodskaya, Putnam, & Kinsht, 2009: Gartstein et al., 2013), consistent with the Rothbart, Sheese, Rueda & Posner (2011) developmental model in which regulation of reactivity is first afforded by the orienting system, and later chiefly by the executive attention system. The period of late infancy is of particular importance because it marks the beginning of rapid development, a time of major changes in the regulative aspects of temperament, including a shift from an orienting based regulatory system to systems of effortful control (Rothbart, et al., 2011). The emergence of more effortful regulation coincides with rapid development of the brain's executive attention system, influenced by lateral prefrontal cortex and anterior cingulate regions of the brain (Rothbart, Derryberry, & Posner, 1994; Rueda, 2012).

The study of temperament development is critical in its own right, and it's made even more important by the consistent links between temperament and the emergence/maintenance of behavior problems and symptoms of psychopathology in childhood. A large body of literature has related temperamental negative emotion to both externalizing- and internalizing-type behaviors (Rothbart, 2011; Rothbart & Bates, 2006; Thomas, Chess, & Birch, 1968). For example, higher levels of negative emotionality in infancy and early childhood predicted mothers' ratings of internalizing problems (i.e., anxiety/depression) at 7 years of age (Rende, 1993). Although components of Surgency have been most closely associated with externalizing behavior (Rothbart & Bates, 2006), Fowles (1994) proposed that internalizing problems, particularly those of a depressive nature, are due to low activity in behavioral approach systems, suggesting that low Surgency may be linked to internalizing problems. Regulatory aspects of temperament, especially Effortful Control, have also been found to play a role in shaping both externalizing and internalizing problems (Rothbart, 2011; Rothbart & Bates, 2006). It should be noted that Regulatory Capacity/Orienting measured in the first year of life moderated the impact of Negative Emotionality, so that behavior problems increased for children high in Negative Emotionality and low in Regulatory Capacity/Orienting (Gartstein, Putnam, & Rothbart, 2012).

Gender Differences in Temperament

Although a number of gender differences in temperament have been reported for older children and adults, fewer have been found for children younger than one year of age (Bates, 1987; Rothbart, 1989), and gender differences in infant behavior have been somewhat controversial (e.g., Ruble, Martin, & Berenbaum, 2006). Such differences in infancy have been largely limited to activity level and fear/behavioral inhibition. Higher activity level and

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approach have been reported for boys (Campbell & Eaton, 1999; Maziade, Boudreault, Thivierge, Caperaa, & Cote, 1984), with girls exhibiting greater hesitation in approaching novel objects (Martin, Wisenbaker, Baker, & Huttunen, 1997; Rothbart, 1988). Campbell and Eaton (1999) applied meta-analytic procedures to summarize 46 studies addressing activity level in infancy, estimating the size of the gender difference at .2 standard deviations. Gender differences in approach-withdrawal have been reported for cross-cultural samples (Carey & McDevitt, 1978; Hsu, Soong, Stigler, Hong, & Liang, 1981; Maziade et al., 1984), with parents rating males higher in their levels of approach. Martin et al. (1997) reported a large and significant gender difference for the Distress to Novelty dimension of temperament, with 6-month-old girls receiving higher scores than boys. Gartstein and Rothbart (2003) reported that male infants obtained high scores on Activity and High Intensity Pleasure, and female infants were rated higher on the Fear scale. Temperament differences between girls and boys are generally less pronounced in infancy (Prior, Smart, Sanson, & Oberklaid, 1993), and tend to increase with age, with a recent meta-analysis documenting moderate to large effects for gender differences in temperament among children 3 to 13 years of age (Else-Quest, Hyde, Goldsmith, & Van Hulle, 2006).

Gender differences in psychophysiological markers more generally, and frontal asymmetry in particular are not common. We were able to identify one published investigation addressing gender differences in asymmetry scores for preschool-age children (Theall-Honey & Schmidt, 2006). These authors reported that temperamentally shy 4-year-old children exhibited significantly greater relative right EEG activation during resting baseline and the presentation of the fear-eliciting video-clip relative to non-shy children. Importantly, shy girls displayed greater relative right EEG activation during the sad, happy, and fear-eliciting video-clips relative to shy boys, who displayed greater relative left EEG activation. Theall-Honey and Schmidt (2006) concluded that frontal EEG activation/emotion models might be gender-specific. It should be noted that the vast majority of existing studies focused on the main effects of gender, failing to consider interactions of gender with other salient factors. Although sex differences are interesting and important in their own right, the moderating role of gender with respect to factors implicated in social-emotional development is critical to address (Crick & Zahn-Waxler, 2003). Potential research questions involve the degree to which girls and boys differ in the factors that contribute to their social-emotional functioning and adjustment.

Thus, along with the main effects of earlier indicators of temperament and gender, the latter can also be expected to moderate the extent to which temperament attributes, assessed in the first six months, are associated with EEG asymmetry recorded late in the first year of life. That is, the meaning of earlier temperament attributes may be altered with respect to later neurophysiological indicators of an infants' emotional state, depending on the gender of the child. In this framework, gender is viewed as a marker for a host of sex-linked distinctions in physiological processes that may be capable of influencing how earlier emotional/behavioral tendencies and motivational states translate into EEG activation during a task designed to elicit mild distress. For example, prenatal exposure to high levels of androgen has been linked to later behavior problems, primarily of the externalizing type (e.g., ADHD; Martel, Klump, Nigg, Breedlove, & Sisk, 2009), and utilized as an explanatory mechanism for early vulnerability observed in boys with respect to this set of problems (Crick & Zahn-

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Waxler, 2003). Although we were not able to locate research linking prenatal androgen exposure to infant frontal asymmetry indicators, it is possible that this connection exists, and in part explains the acting-out difficulties more common for boys later in childhood, that have been noted in the literature. In addition, different interactional histories over the critical early months could thus result in different patterns of associations between behavioral/emotional indicators collected in the first six months and EEG activation for boys and girls toward the end of the first year of life. Gender based discrepancies in these patterns of associations may be more apparent in the context of a distress-eliciting laboratory procedure administered by the mother, because of the demands placed on the infant (i.e., the need to lower one's own level of arousal, without maternal assistance).

The Current Study

The primary goal of the present study is to examine the potential role of gender as a moderator with respect to the links between infant temperament attributes, measured at 5 months of age, and frontal EEG asymmetry examined at 10 months of age. That is, we were interested in exploring how infant temperament traits are associated with later frontal brain activation patterns, and the extent to which the child's gender moderates these associations. These time points were selected because 5 months represents a developmental period when temperament attributes have been shown to cluster reliably into the three-factor structure, reflecting positive and negative affectivity respectively, along with regulation-related characteristics (Gartstein & Rothbart, 2003). At 5 months infants' frontal lobes are immature, and do not afford self-regulation; however, the early beginnings of regulation at evident later in the first year of life, around 10 months of age (Posner, Rothbart, Sheese, & Voelkner, 2012). Because executive attention skills, supported by maturing frontal lobes, play an organizing role with respect to the reactivity domains of temperament, the 10 month time point enables us to examine links with EEG activation in the context of this re-organization, resulting from advances in proposed attention related skills. Although low to moderate stability has been noted for temperament in infancy (e.g., Carranza et al. 2000; Rothbart, 1986), significant developmental changes take place during this time, especially between the first and second halves of in the first year of life. Examining earlier behavioral/emotional factors as correlates of later EEG asymmetry is especially important in light of this considerable change, likely related to maturational factors. Thus, three temperament factors: Positive Affectivity/Surgency, Negative Emotionality, and Regulatory Capacity/Orienting were examined as predictors of frontal EEG asymmetry scores derived during a stressful condition (i.e., associated with state), after controlling for resting baseline asymmetry (i.e., associated with trait). Parent-report was the source of temperament indicators, as it represents a widely utilized approach to temperament assessment, generally viewed as reliable and valid (Gartstein, Bridget, & Low, 2012). We expected all three temperament factors to make unique contributions to explaining frontal asymmetry occurring in the context of the stressor (i.e., arm restraint), with gender potentially changing the strength and/or direction of these associations. Whereas the existing literature suggests that positive affect, and possibly regulatory capacity, would be associated with greater left frontal activation, and negative affect would be associated with greater right frontal

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activation, specific a-priori hypotheses regarding the nature of moderation could not be proposed due to the lack of prior research.

Method

Participants

As part of a longitudinal study examining individual differences in cognition-emotion integration across early development, 410 healthy full-term infants (209 girls, 201 boys; 26 Hispanic, 383 Non-Hispanic, 1 Not reported; 315 Caucasian, 56 African American, 32 Multi-Racial, 2 Asian, 1 Other, 4 Not Reported) were recruited by two research locations (Blacksburg, VA; Greensboro, .NC), with each location recruiting approximately half of the total sample. For parents who reported educational information (404 mothers, 392 fathers), 99% of mothers and 97% of fathers graduated from high school (6 % and 7% technical degree; 42% and 31% bachelor's degree; 22% and 24% graduate degree; respectively). Mothers and fathers were approximately 29 and 32 years old (*SD* = 6 and 7), respectively, when the infants were born. Infants were recruited via commercial mailing lists, newspaper birth announcements, and word of mouth. All infants were born full term and were healthy at the time of testing. For the data associated with this report, infants' mean age (in days) was 162 (*SD* = 8) and 314 (*SD* = 11) at 5 and 10 months, respectively. For the 10-month visit, 365 infants returned to the laboratory. Of those not returning, 22 parents were too busy or declined to participate; 12 families could not be located; and nine families moved out of the local area. Additionally, two infants were 12 months old by the time of their visit and their data were not included because they were age outliers. Parents were paid for each laboratory visit.

Data were collected in both research locations using identical protocols. Research assistants from both locations were trained together by the second author on protocol administration, as well as on behavioral and psychophysiological coding. To ensure that identical protocol administration was maintained between the labs, the Blacksburg team periodically viewed DVD recordings and psychophysiology files collected by the Greensboro lab. To ensure that identical EEG analysis criteria were maintained between labs, the Blacksburg lab provided verification of artifact screening for psychophysiology data collected and coded by the Greensboro lab. This was done by visual inspection of the artifact markings for the EEG recordings throughout the artifact screening process, with feedback to the Greensboro lab. After artifact screen was completed, we calculated the proportion of artifact free EEG determined by each lab for individual infant EEG records by dividing the amount of artifact-free EEG (i.e., the number of DFT windows) by the length of the condition for both baseline and arm restraint. We examined proportion of artifact-free EEG rather than the raw amount because the Greensboro baseline condition was about 4 sec longer than the Blacksburg baseline and the length of the arm restraint condition was infant driven. There were no lab differences in the proportion of artifact-free EEG during baseline, $F(1, 370) = 2.80$, $p = .09$, or during arm restraint, $F(1, 237) = .71$, $p = .40$.

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Procedures

Infants and mothers visited the research lab on or within two weeks after their 5- and 10-month birthdays. This report focuses on the maternal report of temperament data at 5 months and the EEG data at 10 months.[1]

Baseline EEG was recorded for 1 minute while infants sat on their mothers' laps. During the baseline recording, a research assistant manipulated a toy containing brightly colored balls on top of the testing table, 1.1 m in front of the infants. This procedure quieted the infants and yielded minimal eye movements and gross motor movements, thus allowing infants to tolerate the EEG cap for the recording. Mothers were instructed not to talk to infants during the baseline EEG recording. EEG was also recorded during the arm restraint task.

EEG recording—EEG was recorded during baseline and during multiple cognitive and emotion tasks. The emotion-related EEG data used in this report were recorded during the arm restraint task. Recordings were made from 16 left and right scalp sites: frontal pole (Fp1, Fp2), medial frontal (F3, F4), lateral frontal (F7, F8), central (C3, C4), temporal (T7, T8), medial parietal (P3, P4), lateral parietal (P7, P8), and occipital (O1, O2). All electrode sites were referenced to Cz during recording. EEG was recorded using a stretch cap (Electro-Cap, Inc.) with electrodes in the 10/20 system pattern (Jasper, 1958; Pizzagalli, 2007). After the cap was placed on the infant's head, recommended procedures regarding EEG data collection with infants were followed (Fox, Schmidt, Henderson, & Marshall, 2007; Pivik et al., 1993). Specifically, a small amount of abrasive was placed into each recording site and the scalp gently rubbed. Following this, conductive gel was placed in each site. Electrode impedances were measured and accepted if they were below 10K ohms.

The electrical activity from each lead was amplified using separate SA Instrumentation Bioamps (San Diego, CA) and bandpassed from .1 to 100 Hz. Activity for each lead was displayed on the monitor of an acquisition computer. The EEG signal was digitized on-line at 512 samples per second for each channel so that the data were not affected by aliasing. The acquisition software was Snapshot-Snapstream (HEM Data Corp.; Southfield, MI) and the raw data were stored for later analyses.

EEG analysis—EEG data were examined and analyzed using EEG Analysis System software developed by James Long Company (Caroga Lake, NY). First, the data were re-referenced via software to an average reference configuration (Lehmann, 1987). The re-referenced EEG data were artifact scored for eye blinks using Fp1 and Fp2 (Myslobodsky et al., 1989) and for gross motor movements and these artifact-scored epochs were eliminated from all subsequent analyses. The data then were analyzed with a discrete Fourier transform (DFT) using a Hanning window of 1-s width and 50% overlap. Power was computed for the 6 to 9 Hz frequency band. Infants have a dominant frequency between 6 to 9 Hz (Bell & Fox, 1994; Marshall, Bar-Haim, & Fox, 2002). This band has been correlated with patterns of emotion reactivity and emotion regulation during infancy (Bell & Fox, 1994; Buss et al.,

[1]Stability in infant frontal asymmetry (utilizing frontal EEG asymmetries during resting baseline) was examined as a predictor of toddlerhood internalizing and externalizing behaviors with a subsample (n = 48) of 10-month-old participants, and reported elsewhere (Smith & Bell,2010).

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2003; Dawson, 1994; Diaz & Bell, 2012). The power was expressed as mean square microvolts and the data transformed using the natural log (ln) to normalize the distribution.

Frontal EEG asymmetry values were computed by subtracting ln power at left frontal (F3) from ln power at right frontal (F4). In infants, power in the 6–9 Hz band has been shown as inversely related to cortical activation during emotion reactivity and regulation (Fox, 1994). A negative frontal EEG asymmetry score reflects greater right frontal activation; a positive asymmetry score reflects greater left frontal activation.

Arm restraint task—EEG was also recorded during the arm restraint, which was used to induce negative reactivity (Laboratory Temperament Assessment Battery – LAB TAB, Goldsmith & Rothbart, 1999; Calkins, Dedmon, Gill, Lomax, & Johnson, 2002; Stifter & Braungart, 1995; Stifter & Spinrad, 2002). The arm restraint task reliably produces short-term distress in infants and is prominently used in the developmental literature for this purpose (Calkins et al., 2002). Mothers were asked to face their infants and instructed to gently hold their infant's arms down at the infant's sides so that their arm movements would be restricted. Mothers were also instructed to maintain a neutral facial expression and use no vocalizations with their infant for duration of 2 minutes, or after 10 seconds of hard crying.

The arm restraint task procedurally followed a toy removal task (Calkins et al., 2002; Stifter & Braungart, 1995; Stifter & Spinrad, 2002). Of the 365 infants who attended the 10-month research lab visit, 241 participated in the arm restraint task. The infants not participating in arm restraint were judged to have been sufficiently distressed by the toy removal task that the experimenter determined the infants would have been unable to complete the rest of the research lab visit protocol if arm restraint procedure had been administered.

The nature of the arm restraint task is such that by the virtue of eliciting distress, some EEG data may be compromised because of gross motor artifact. Thus, of the 241 infants participating in the arm restraint task, 201 (104 boys, 97 girls) contributed arm restraint EEG data to our analyses. Differences between children contributing EEG data obtained during the arm restraint task and those not providing data were examined. Specifically, t-tests were conducted for all of the other variables included in this study (i.e., Baseline Asymmetry, 3 IBQ-R factor scores), and no significant differences emerged at the .05 alpha level, although a trend-level effect was observed for Negative Emotionality. Infants who participated and provided EEG data in the context of the arm restraint procedure were rated marginally lower on Negatively Emotionality by their mothers relative to infants not participating in the task ($t = 2.00$, $df=1,385$, $p=.05$; participants' Mean = 2.94, SD=.64; non-participants' Mean = 3.08, SD=.69). The distribution of child sex across participant and non-participant groups did not differ, according to the results of a Chi Square test ($X^2=1.32$, $df=1$, $p = .25$). We also examined whether the three temperament factors (Positive Affectivity/Surgency, Negative Emotionality, Orienting/Regulatory Capacity, described below) were associated with the amount of artifact free usable EEG data. None of the three correlation coefficients reached statistical significance at the alpha level of .05 (r’s range -.03 to .02).

Infant Behavior Questionnaire-Revised (IBQ-R; Gartstein & Rothbart 2003)—The IBQ-R represents a 191 item parent-report instrument that yields 14 scales (See Table 1

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for definitions and example items), which in turn form three over-arching factors: Positive Affectivity/Surgency (PAS; Activity Level, Approach, High Intensity Pleasure, Perceptual Sensitivity, Smiling and Laughter, and Vocal Reactivity), Negative Emotionality (NE; Distress to Limitations, Fear, Sadness, and negatively loading Falling Reactivity), and Orienting/Regulatory Capacity (ORC; Cuddliness/Affiliation, Duration of Orienting, Low Intensity Pleasure, and Soothability). Reliability and validity of the IBQ-R has been supported for mothers and fathers, as well as samples from different countries, with Cronbach's α's ranging from .70 to .96 (Gartstein & Rothbart, 2003; Gartstein, Slobodskaya, & Kinsht, 2003). Importantly, satisfactory estimates of inter-rater agreement have also been obtained (Gartstein & Rothbart, 2003; Parades & Leerkes, 2008) and validity of this instrument has been supported by studies incorporating the IBQ-R and laboratory indicators of temperament (Gartstein et al., 2010; Gartstein & Marmion, 2008; Parade & Leerkes, 2008). In the present sample, internal consistency was satisfactory, with Cronbach's α's ranging from .86 to .96 (Mean = .91) for the three over-arching factors.

Results

Descriptive statistics were computed first, for the entire sample, and separately by gender (Table 2).

Simple Correlations

A number of significant simple correlations between the variables included in this study were observed, with somewhat different patterns of associations emerging for boys and girls (Table 3). Notably, for girls IBQ-R ORC was negatively associated with the arm restraint frontal asymmetry score, suggesting that as ORC scores increased, the left frontal activation decreased, and the right frontal activation increased. For boys, IBQ-R PAS was negatively correlated with the arm restraint frontal asymmetry scores, with higher levels of positive emotionality linked with decreased left frontal activation, and conversely increased right frontal activation. It should be noted that these correlation could also reflect increased activation in both hemispheres, with relatively greater activation in the right hemisphere compared to the left, being associated with higher ORC and PAS scores, for girls and boys respectively.

Multiple Regression Analyses: Gender as a Moderator of Links between Temperament and Frontal Asymmetry Scores

Hierarchical multiple regression analyses were performed to address child gender as a moderator of links between temperament and frontal EEG asymmetry scores. After the main effects and the baseline asymmetry scores were entered into the equation, interaction terms reflecting potential moderation were introduced. PAS and ORC were associated with significant moderation effects (Table 4), with the entire model accounting for 11% of the variance in frontal EEG asymmetry scores during the arm restraint task.[2]

[2]Hierarchical multiple regression models were also examined for the frontal baseline asymmetry scores as the dependent variable, as well as with asymmetry values computed by subtracting ln power at left parietal (P3) from ln power at right parietal (P4) region, failing to indicate significant interaction effects.

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The interaction effects were further explored by examining the contribution of IBQ-R factors to arm restraint frontal asymmetry scores for boys and girls separately (Table 5), and by graphing the interaction effects. For boys, higher PAS at 5 months of age was linked with greater relative right frontal activation during the arm restraint procedure conducted at 10 months. The regression model accounted for 12% variance in boys' frontal EEG asymmetry during arm restraint. For girls, higher ORC scores were associated with greater relative right frontal activation during arm restraint. The regression model accounted for 11% variance in girls' frontal EEG asymmetry scores during arm restraint. Scatter plots of the three temperament factors and frontal EEG asymmetry indicators examined separately for boys and girls (available from the corresponding author upon request) suggested overall greater variability for boys, relative to girls.

Discussion

Results of this study are consistent with our hypotheses, as gender moderated the links between manifestations of reactive and regulatory aspects of temperament at 5 months of age and frontal EEG asymmetry measured at 10 months of age during a mildly stressful procedure. For boys, PAS emerged as a key predictor of frontal asymmetry, with higher levels translating into greater right frontal activation later in infancy. For girls, ORC accounted for a significant amount of variance in the frontal asymmetry scores, with higher maternal ratings of ORC being linked with greater right frontal activation. NE was not associated with the EEG asymmetry indicators obtained later in infancy, regardless of gender, and main effects of PAS and ORC did not account for significant amounts of variance.

The moderating influence of gender noted in this study suggests that the origins of frequently observed discrepancies in rates and symptoms of psychopathology may be identifiable in the first year of life. For boys, being perceived by the mother as high in positive affect and approach tendencies at 5 months of age was associated with greater right frontal activation during a mildly stressful task at 10 months. Given the previously demonstrated links between the EEG pattern of relatively greater frontal activation and withdrawal/distress (Buss et al., 2003; Fox & Davidson, 1987, 1988), the present results suggest that male infants who had been more outgoing and active previously, are more adversely affected by the mildly stressful procedure wherein their movement is restricted. That is, their EEG pattern is consistent with neurophysiological functioning observed under conditions of distress/withdrawal. For girls, this effect was observed for regulation/orienting, with those exhibiting better early regulatory capacity more likely to present with greater right frontal activation during arm restraint. Whereas prior research has indicated that children who present with greater fearfulness, shyness, and/or negative affect demonstrate relatively higher levels of right frontal EEG activity at baseline (Calkins, Fox, & Marshall, 1996; Davidson & Rickman, 1999; Fox et al., 1995) and during stressful tasks (Schmidt, Fox, Schulkin, & Gold, 1999), the present study suggests that Positive Affectivity/Surgency and Orienting / Regulatory Capacity (measured earlier in infancy) differentially contribute to right frontal EEG activation during arm restraint for boys and girls. It is notable that mothers were asked to hold their infants' arms down while facing them in the context of the arm restraint procedure conducted in this study. Thus, infants who demonstrated greater positive

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emotionality in the case of boys, and higher levels of regulatory capacity for girls, may have found this episode particularly aversive, given that they may have had limited exposure to similarly restricting interactions with their mothers in the 5 months prior to our follow-up evaluation. That is, higher levels of Positive Affectivity/Surgency for boys, and Orienting / Regulatory Capacity for girls, at 5 months of age could have translated into more positive interactional histories with mothers, resulting in a tendency to present with EEG-based indicators of withdrawal/distress in response to mothers administering the arm restraint procedure. This pattern of results also suggests that although the arm restraint procedure is generally thought of as "mildly" stressful, for infants with certain temperament profiles (which differ based on gender) this episode may entail higher levels of discomfort.

Our results suggest that the framework discussed earlier, wherein gender serves a marker for differences in physiological process, such as those involved in endocrine functioning, may be viable, and should be investigated in future research. It may also be that the moderation effect of gender observed in this study is related the differences in brain structures and functions previously reported for males and females (See Hines, 2011 for a Review). For example, Goldstein et al. (2001) reported that the amygdala tends to be larger in males, with females' hippocampus observed to be larger in size. According to results obtained by Gron et al. (2000), navigation through a virtual maze resulted in overall superior performance for males, with some gender differences in the patterns of activation (e.g., women showed more activity in the right prefrontal cortex, with significantly more activity in the left hippocampal region noted for males). An alternative interpretation relies on the mechanism of the infants' interactional history, and is consistent with the literature that indicates mothers respond differently to their sons and daughters (Golombok & Fivush, 1994; Lewis, 1972; Lovas, 2005), who in turn vary with respect to their early temperament profiles (Campbell & Eaton, 1999; Maziade, et al., 1984; Ruble & Martin, 2006), presenting with different affordances as a social interaction partner (e.g., Biringen, Robinson, & Emde, 1994). As such, results of this study likely carry implications for the goodness-of-fit framework (Thomas & Chess, 1977), suggesting that what constitutes an appropriate match with respect to parental demands and expectations on one hand, and child attributes on the other hand, may depend on the gender of the child. Over time, such differences could result in divergent trajectories with respect to behavior problems/symptoms of psychopathology due to inconsistent socialization goals for boys and girls. Specifically, it has been suggested that parents prioritize relationship orientation for female, and competence/autonomy for male offspring (Chodorow 1978; Miller, 1986). This potential explanatory mechanism should be addressed directly in future research, as the present study did not include measures relevant to socialization and/or differential interactional histories.

Previous research has yielded significant gender effects with respect to temperament as early as infancy (Campbell & Eaton, 1999; Gagne, Miller, & Goldsmith, 2013; Gartstein & Rothbart, 2003; Martin, Wisenbaker, Baker, & Huttunen, 1997; Maziade, Boudreault, Thivierge, Caperaa, & Cote, 1984; Rothbart, 1988), with males commonly described as more active and females as more hesitant to approach new or unfamiliar stimuli. Gender differences in EEG asymmetry have also been reported, with Fox, Bell and Jones (1992), noting that female infants demonstrated greater relative left frontal activation compared to male infants. However, to our knowledge the present study is the first to demonstrate that

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gender moderates links between early manifestations of temperament attributes and EEG asymmetry scores obtained in the context of a mildly stressful situation. Whereas prior research has indicated that infants selected based on high levels of activity and negative emotionality at 4 months of age demonstrated right frontal asymmetry (i.e., greater relative right frontal activation) later in infancy, results of this investigation suggest that in an unselected community sample of infants greater positive affectivity and regulatory capacity, for boys and girls respectively, contribute to greater relative right frontal activation in a mildly stressful task. While the lack of significant main effects for the three temperament predictors (i.e., PAS, NE, and ORC) is somewhat surprising given prior research, this may be a function of the sample involved in the present study, and further points to the importance of the observed moderation effects.

Some limitations are relevant to forming conclusions from this study. First, a good number of infants did not participant in the arm restraint task because the prior task (i.e., toy removal) was sufficiently distressing that the experimenter determined to not administer arm restraint. That is, infants who participated in arm restraint were not overly distressed by a different frustration task. Thus, the effects observed in this study may represent an underestimate of the identified associations, which could have been stronger if the infants who reacted with greater distress to being frustrated in the previous episode had been included. This inadvertent attrition likely contributed to the lack of significant findings for NE in particular, as it presumably resulted in a more restricted distribution of negative affectivity scores, relative to PAS and ORC, limiting our ability to detect associations. Second, the nature of the arm restraint procedure is such that not all infants contributed EEG data for our analyses due to significant gross motor artifact during the task. One marginally significant difference emerged between infants who provided EEG data in the context of the arm restraint procedure and those who did not. Infants who provided sufficient EEG data were rated marginally lower on NE by their mothers 5 earlier, relative to infants who did not provide EEG data during the arm restraint task. Thus, somewhat less distress prone infants were more likely to tolerate this procedure successfully, contributing EEG data for analysis.

In sum, gender moderated the effect of temperament on frontal EEG asymmetry scores during a moderate stressor, after controlling for baseline asymmetry. Consistent with the theoretical model articulated by Crick and Zahn-Waxler (2003), gender influenced the nature of the relationship between earlier manifestations of reactivity/regulation and frontal asymmetry indicators obtained later in infancy. Although interaction effects observed in this study await replication and extension, this early gender-related difference in the associations between temperament and physiological markers of emotional state could cascade into gender differences in symptoms/behavior problems, frequently observed later in childhood (Baillargeon et al., 2012; Zahn–Waxler, Klimes–Dougan, & Slattery, 2000).

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Table 1

Scale Definitions: Infant Behavior Questionnaire - Revised (IBQ-R)

Positive Affectivity/Surgency	
Activity Level	Gross motor activity, including movement of arms and legs, squirming and locomotor activity. ("When put into the bath water, how often did the baby splash or kick?"; similar in length/content to the original IBQ scale)
Approach	Rapid approach, excitement, and positive anticipation of pleasurable activities. ("When given a new toy, how often did the baby get very excited about getting it?")
High Intensity Pleasure	Pleasure or enjoyment related to high stimulus intensity, rate, complexity, novelty, and incongruity. ("During a peek-a-boo game, how often did the baby smile?")
Perceptual	Detection of slight, low intensity stimuli from the external environment.
Sensitivity	("How often did the baby notice fabrics with scratchy texture (e.g., wool)?")
Smile and Laughter	Smiling or laughter during general caretaking and play. ("How often during the last week did the baby smile or laugh when given a toy?"; shorter and different in content from the original IBQ scale)
Vocal Reactivity	Amount of vocalization exhibited by the baby in daily activities. ("When being dressed undressed during the last week, how often did the baby coo or vocalize?")
Negative Emotionality	
Distress to Limitations	Fussing, crying or showing distress while a) in a confining place or position; b) in caretaking activities; c) unable to perform a desired action. ("When placed on his/her back, how often did the baby fuss or protest?"; shorter, but similar in content to the original IBQ scale)
Fear	Startle or distress to sudden changes in stimulation, novel physical objects or social stimuli; inhibited approach to novelty. ("How often during the last weed did the baby startle to a sudden or loud noise?"; different in content from the original IBQ)
Sadness	Lowered mood and activity related to personal suffering, physical state, object loss, or inability to perform a desired action; general low mood. ("Did the baby seem sad when the caregiver was gone for an unusually long period of time?")
Falling Reactivity/ Rate of Recovery from Distress	Rate of recovery from peak distress, excitement, or general arousal; ease of falling asleep. ("When frustrated with something, how often did the baby calm down within 5 minutes?")
Orienting/Regulatory Capacity	
Cuddliness	Expression of enjoyment and molding of the body to being held by a caregiver. (When rocked or hugged, during the last week, how often did the baby seem to enjoy him/herself?")
Duration of Orienting	Attention to and/or interaction with a single object for extended periods of time. ("How often during the last week did the baby stare at a mobile, crib bumper or picture for 5 minutes or longer?"; similar in length/content to the original IBQ scale)
Low Intensity Pleasure	Amount of pleasure or enjoyment related to low stimulus intensity, rate, complexity, novelty and incongruity. ("When playing quietly with one of is/her favorite toys, how often did the baby show pleasure?")
Soothability	Reduction of fussing, crying, or distress when soothing techniques are used by the caregiver. ("When patting or gently rubbing some part of the baby's body, how often did s/he soothe immediately?"; similar in length/content to the original IBQ scale)

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Table 2

Descriptive Statistics: Demographics; Independent and Dependent Variables

Variable	Mean	Range	Standard Deviation
Entire Sample			
Baseline Asymmetry Scores	0.03	−1.14 – 1.95	0.26
Arm Restraint Asymmetry Scores	0.05	−1.35 – 3.19	0.45
IBQ-R PAS	4.73	2.77 – 6.68	0.70
IBQ-R NE	3.01	1.54 – 5.30	0.67
IBQ-R ORC	5.05	3.57 – 6.60	0.55
Boys			
Baseline Asymmetry Scores	0.04	−0.84 – 0.88	0.22
Arm Restraint Asymmetry Scores	0.05	−1.35 – 1.70	0.41
IBQ-R PAS	4.76	3.10 – 6.68	0.69
IBQ-R NE	3.03	1.66 – 5.30	0.66
IBQ-R ORC	5.05	3.57 – 6.60	0.53
Girls			
Baseline Asymmetry Scores	0.02	−1.14 – 1.95	0.30
Arm Restraint Asymmetry Scores	0.06	−1.12 – 3.19	0.50
IBQ-R PAS	4.70	2.77 – 6.22	0.71
IBQ-R NE	2.99	1.54 – 4.92	0.67
IBQ-R ORC	5.05	3.69 – 6.29	0.57

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Table 3

Correlations: 5-month IBQ-R Factors, Baseline/Arm Restraint Asymmetry scores, computed separately for boys and girls

	NE	PAS	ORC	Arm Restraint Frontal Asymmetry	Baseline Frontal Asymmetry
IBQ-R NE	-------	.18*	−.18*	−.05	−.07
IBQ-R PAS	.09	-------	.51**	−.31**	−.14^
IBQ-R ORC	−.16*	.49**	-------	.01	.08
Arm restraint Frontal Asymmetry	−.12	−.05	−.21*	-------	.15*
Baseline Frontal Asymmetry	−.03	−.01	−.01	.23*	-------

* p<.05 level;

** p< .01 level;

^ p<.10. Boys' correlations are presented above the diagonal and girls' correlations are below.

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Table 4

Multiple Regression Analyses: IBQ-R Factors and Interactions with Infant Sex as Predictors of Arm Restraint Frontal EEG Asymmetry

Variable	R	R^2	R^2change	F change	Beta
Dependent Variable: Arm Restraint Frontal EEG Asymmetry					
Model 1	.01	.00	.00	.01	
Child's Sex					.01
Model 2	.19	.03	.03	6.84*	
Child's Sex					.01
Baseline Frontal Asymmetry					.18*
Model 3	.26	.07	.04	2.08	
Child's Sex					−.01
Baseline Frontal Asymmetry					.17*
IBQ-R NE					−.07
IBQ-R PAS					−.10
IBQ-R ORC					−.09
Model 3	.33	.11	.04	3.31*	
Child's Sex					.24^
Baseline Frontal Asymmetry					.14*
IBQ-R NE					.03
IBQ-R PAS					−.33**
IBQ-R ORC					.11
IBQ-R NE*Sex					−.17
IBQ-R PAS*Sex					.38**
IBQ-R ORC*Sex					−.33*

* $p<.05$ level;

** $p< .01$ level;

^ $p<.10$.

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Table 5

Multiple Regression Analyses: IBQ-R Factors as Predictors Arm Restraint Frontal EEG Asymmetry separately for Boys and Girls

Variable	R	R^2	R^2change	F change	Beta
Boys					
Model 1	.13	.02	.02	1.80	
Baseline Frontal Asymmetry					.13
Model 2	.35	.12	.11	3.82*	
Baseline Frontal Asymmetry					.08
IBQ-R NE					.03
IBQ-R PAS					−.36**
IBQ-R ORC					.13
Girls					
Model 1	.23	.05	.05	5.22*	
Baseline Frontal Asymmetry					.23*
Model 2	.33	.11	.06	2.00	
Baseline Frontal Asymmetry					.19^
IBQ-R NE					−.15
IBQ-R PAS					.12
IBQ-R ORC					−.27*

* p<.05 level;

** p< .01 level;

^ p<.10.