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Withdrawn and intrusive maternal interaction style and infant frontal EEG asymmetry shifts in infants of depressed and non-depressed mothers

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Abstract

The effects of maternal interaction style (intrusive/withdrawn) on the development of brain electrical activity were studied in infants of depressed and non-depressed mothers shortly after birth and again at 3–6 months of age. Infants of depressed mothers exhibited significantly greater relative right frontal EEG activation than infants of non-depressed mothers. Infants of depressed withdrawn mothers exhibited greater relative right frontal EEG activation than infants of depressed intrusive mothers. Furthermore, while infants of depressed mothers with intrusive interaction styles showed a shift towards greater relative left frontal EEG activation from birth to 3–6 months, infants of depressed mothers with withdrawn interaction styles showed a shift towards greater relative right frontal EEG activation.

Keywords

EEG asymmetry; Depression; Interaction style

Maternal depression has negative effects on infant behavior and physiology. For example, newborns of depressed mothers are more irritable, less consolable (Whiffen & Gotlib, 1989; Zuckerman, Als, Bauchner, Parker, & Cabral, 1990) and less responsive to stimulation (Abrams, Field, Scafidi, & Prodromidis, 1996). Infants of depressed mothers are also less responsive to facial expressions (Pickens & Field, 1996) and show more negative and less positive affect when interacting with both their mothers (Cohn, Campbell, Matias, & Hopkins, 1990; Field, 1984) and a non-distressed adult (Field et al., 1988). In addition, infants of depressed mothers exhibit a distinct physiological profile marked by greater relative right frontal EEG activation (Dawson, Klinger, Panagiotides, Hill, & Spieker, 1992; Dawson et al., 1999; Field, Pickens, Fox, & Gonzalez, 1996; Jones, Field, Fox, Lundy, & Davalos, 1997).

Asymmetries in brain electrical activity (EEG) over the frontal cortex are associated with the balance of the neural activity underlying two essential dimensions of affect regulation including behavioral approach and behavioral withdrawal (Davidson, 1996 and Fox, 1994). Greater relative right frontal EEG activation is thought to reflect greater behavioral withdrawal and has been associated with responses to negative stimuli, inhibited behavior, negative affect and poor emotion regulation (Davidson, 1996 and Fox, 1994). Infants also exhibit greater relative right frontal EEG activation during the expression, regulation and perception of negative/withdrawal emotions (Davidson & Fox, 1982; Dawson, Panagiotides, Klinger, & Hill, 1992; Field, Pickens, Fox, Gonzalez, & Nawrocki, 1998). Greater relative right frontal EEG

activation has been consistently noted in depressed adults (see Davidson, 1996 and Davidson, 2000 for reviews) and infants of depressed mothers as early as birth (Diego et al., 2004, Field et al., 2004 and Jones et al., 1998).

Frontal EEG asymmetry profiles in depressed individuals have been shown to remain stable across time (Tomarken, Keener, & Neubauer, 1994; Vuga et al., 2006) and are present even when these individuals show a remission in their behavioral symptoms (Henriques & Davidson, 1990). Frontal EEG asymmetry profiles have also been shown to remain stable from 1 month to 3 months (Jones, Field, Fox, et al., 1997) and from 3 months to 3 years (Jones, Field, Davalos, & Pickens, 1997) in infants of depressed and non-depressed mothers. As such, frontal EEG asymmetry is thought to reflect not only current affective state but also stable individual differences in affective style. However, at least one study has reported poor test retest stability for depressed adults (Debener et al., 2002) and several developmental studies have documented subgroups of infants who exhibit changes in their frontal EEG asymmetry patterns (e.g. Fox, Calkins, & Bell, 1994; Jones, Field, Davalos, et al., 1997; Jones, Field, Fox, et al., 1997). Furthermore, there is evidence to indicate that infants reared in deprived environments develop distinct brain electrical activity patterns including EEG asymmetries (Marshall, Fox, & BEIP, 2004) and decreased brain glucose metabolism across several of the cortical and limbic areas involved in affect regulation (Chugani et al., 2001).

Even though infants of depressed mothers exhibit a profile of behavioral (Field et al., 2004) and physiological dysregulation as early as birth (Diego et al., 2004; Jones, Field, Davalos, et al., 1997; Jones, Field, Fox, et al., 1997; Lundy et al., 1999), infants of depressed mothers with distinct interaction styles develop distinct neurobehavioral profiles. Depressed mothers show two distinct maternal behavior patterns when interacting with their infants (Cohn, Matias, Tronick, Connell, & Lyons-Ruth, 1986; Tronick & Field, 1986). Mothers with an intrusive interaction style show rough physical contact and loud, fast verbal behavior, whereas mothers with a withdrawn interaction style show flat affect, disengaged behavior, and rare touching and vocalizing. The behavior manifested by the intrusive mothers may be the result of an overactive behavioral approach system (BAS), while the behavior of the withdrawn mothers may result from an overactive behavioral inhibition system (BIS). Greater behavioral approach and lower behavioral inhibition have been reported on the BIS/BAS scale in depressed mothers exhibiting an intrusive interaction style (Diego, Field, & Hernandez-Reif, 2001). In contrast, depressed mothers exhibiting a withdrawn interaction style report greater behavioral inhibition on the BIS/BAS scale and exhibit greater relative right frontal EEG activation (Diego et al., 2001).

Infants of depressed mothers with intrusive and withdrawn interaction styles also exhibit distinct neurobehavioral profiles. Three-, six- and seven-month-old infants of withdrawn depressed mothers tend to interact more poorly with their mothers (Cohn & Tronick, 1989; Field, Healy, Goldstein, & Guthertz, 1990; Jones, Field, Davalos, et al., 1997; Jones, Field, Fox, et al., 1997), and at 1-year they have lower Bayley mental development scale scores than infants of intrusive mothers (Jones, Field, Davalos, et al., 1997; Jones, Field, Fox, et al., 1997). Infants of withdrawn depressed mothers also exhibit greater relative right frontal EEG activation than infants of intrusive mothers as early as 3 months of age (Diego et al., 2002; Field, Diego, Hernandez-Reif, Schanberg, & Kuhn, 2003; Jones, Field, Davalos, et al., 1997; Jones, Field, Fox, et al., 1997).

Recent findings indicate that even though infants of withdrawn depressed mothers do not differ from infants of intrusive mothers at birth (Field et al., 2003), they begin to exhibit greater relative right frontal EEG activity as early as 3 months of age (Diego et al., 2002; Jones, Field, Davalos, et al., 1997; Jones, Field, Fox, et al., 1997). Further, infants of intrusive depressed mothers show a shift towards left frontal EEG activation whereas infants of withdrawn

depressed mothers show a shift towards right frontal EEG activation from three to 6 months of age (Jones, Field, Davalos, et al., 1997; Jones, Field, Fox, et al., 1997).

In the present study we assessed the development of frontal EEG asymmetry by assessing frontal EEG asymmetry at birth (before infants had a chance to extensively interact with their mothers) and at 3–6 months of age (after they had a chance to extensively interact with their mothers). Based on previous findings, we expected that infants of intrusive and withdrawn depressed mothers would not exhibit frontal EEG asymmetry differences at birth. Inasmuch as the central nervous system undergoes substantial structural changes across the first few months of life, the interaction style exhibited by depressed mothers was expected to significantly alter the development of their infants' frontal EEG asymmetry profile. Based on the findings from the Jones, Field, Davalos, et al. (1997) and Jones, Field, Fox, et al. (1997) studies, we expected that infants of withdrawn mothers would exhibit a shift towards right frontal EEG activation while infants of intrusive mothers would exhibit a shift towards left frontal EEG activation over the first 3–6 months of postnatal life.

Method

Participants

Pregnant women were recruited during their third trimester (M gestational age = 26.9 weeks) from a prenatal clinic at our university hospital. Mothers were excluded if (a) they were carrying more than one fetus; (b) they smoked cigarettes, drank alcohol or used recreational drugs; (c) the fetus had demonstrated any abnormalities during an ultrasound exam; (d) the pregnancy was complicated; or (e) the mother had been prescribed medications other than vitamins. From an original pool of 120 pregnant women who met selection criteria, only the mothers and their infants ($N = 66$; $n = 38$ depressed, $n = 28$ non-depressed) who had valid EEG data on the newborn and infant examinations were included in this study. The demographic characteristics of these mothers did not differ from the larger pool of mothers originally recruited at the prenatal clinic. The mothers were low to middle SES ($M = 3.4$, $S.D. = 0.9$, on the Hollingshead Four-factor Index of Social Status), had a mean age of 28 ($S.D. = 6.8$) years and were distributed 44% Hispanic, 33% African-American, 18% Caucasian and 3% Asian. The mothers were right handed and 68% were married. The infants were distributed 32% male and on average were 1.7 weeks old ($S.D. = 0.79$, range 0–3 weeks) during the neonatal assessment and 17 ($S.D. = 3.3$, range 12–23 weeks) weeks old during the infant assessment (see Table 1 for distribution).

Procedures

Within the first few days after birth, mothers who had been recruited at a university hospital's prenatal clinic, visited our laboratory and were administered a demographic questionnaire, the CES-D and the BIS/BAS. During this visit their infant's EEG activity was recorded. The mothers were then invited to return to our laboratory when their infants were between 3 and 6 months of age at which time their infant's EEG activity was recorded again. During this visit, depressed mothers were also videotaped during a brief interaction with their infants.

Assessments

A Demographic Questionnaire was given to the mothers after signing an informed consent. The questionnaire included the mothers' age, ethnicity, marital status, handedness, occupation and education. Answers to the occupation and education questions were then used to compute SES based on the Hollingshead (1976) Four Factor Index of Social Status.

The Center for Epidemiological Studies-Depression scale (CES-D) (Radloff, 1977) is a 20-item scale, with scores ranging between 0 and 60. The frequency (within the last week) is rated on 20 symptoms including depressed mood, feelings of helplessness and hopelessness, feelings

of guilt and worthlessness, loss of energy, and sleep and appetite problems. A score of 16 or greater can differentiate clinically depressed and non-depressed individuals with only a 6% false positive and 36% false negative rate (Myers & Weissman, 1980). In addition, this scale has been shown to be reliable and valid for diverse demographic groups (Radloff, 1977). The CES-D has been successfully used as a self-report of depressive symptoms in a number of studies involving samples similar to the one of this study (see Field, 1996 and Field, 1998 for reviews).

The Behavioral Inhibition and Behavioral Approach System Questionnaire (BIS/BAS) (Carver & White, 1994) is a 24-item questionnaire consisting of personal statements followed by four severity options ranging from very true to very false. The BIS/BAS is designed to assess the tendency to behave in response to reward or in response to punishment. The behavioral inhibition system examines behavior in response to punishment and the behavioral approach system portion of the questionnaire examines behavior in response to reward. The BIS/BAS scales have adequate internal reliability (0.66–0.74) and adequate convergent and divergent validity with other measures including the PANAS, LOT, MAS, GTS, and Eysenck's Extraversion scale.

BAS/BIS difference scores were obtained by subtracting Z-transformed BIS scores from Z-transformed BAS scores. Positive scores denote greater BAS activity while negative scores denote greater BIS activity. This method has been used previously to analyse the relation between BIS/BAS scores and EEG activity (Sutton & Davidson, 1997) and has been found to relate to depressed mothers' maternal interaction style with their 3–6-month-old infants (Diego, Field, & Hernandez-Reif, 2001).

Mothers interaction style classification

Mothers were instructed to play with their infants for three minutes in a face-to-face position as they normally would at home, but without toys. The interaction was videotaped using a split-screen generator so that the mothers' and infants' faces and upper bodies were observable. The mothers' physical, affective and vocal behaviors were coded in 10 s time sampling units. The mothers were classified as intrusive if they demonstrated rough physical contacts such as: rough tickling, poking, pulling, shaking, and using brisk movements during at least 60% of the interaction. Mothers could also be classified as intrusive if they demonstrated rough behaviors during smaller proportions of time but demonstrated loud, non-contingent speech and exaggerated, fake, facial expressions. The mothers were classified as withdrawn if they had no physical contacts with their infants, or rarely touched them during at least 60% of the interaction time. Mothers could also be classified as withdrawn if they had somewhat greater physical contact with their infants but demonstrated flat affect and minimal speech throughout the interaction. The mothers whose interaction pattern could not be classified as intrusive or withdrawn were classified as undefined. Interobserver reliability was conducted using two independent observers for 30% of the videotaped interactions ($\kappa = 0.86$).

EEG

The infant's EEG was recorded using a size-appropriate, Lycra-stretchable cap (Electro-Cap International; Eaton, Ohio) from the mid-frontal (F3 and F4) and parietal (P3 and P4) regions and referenced to the vertex (Cz) while the infant was in a quiet alert state. Omni-prep gel was used to gently abrade the scalp, and electrode gel was inserted into each site to provide good conductance. Impedances were less than 10 k Ω . The vertex reference location was used because this reference site has been shown to produce comparable results to other reference sites, and it is the least invasive location for infants this age (Tomarken, Davidson, Wheeler, & Kinney, 1992). EOG was also obtained from the outer canthus and the supra orbit position of one eye using Beckman mini-electrodes.

The EEG signals were obtained using a Grass Model 12 Neurodata Acquisition System with filters set at 1 Hz high pass and 100 Hz low pass and a gain of 20,000. Prior to data collection, the signal for each channel was calibrated. The output was directed to a Dell 326 D PC fitted with an Analog Devices RTI-816 AbD board. The sampling rate was 612 samples per second, and the data were streamed across the computer screen and then saved to a hard disk using data acquisition software (Snapstream, v. 3.21, HEM Data Corp. 1991).

The EEG data were manually scored for eye and motor movement artifact using the EOG channels as cues, and the data containing artifact were underscored and eliminated from each channel. The amount of artifact did not differ between the groups. Data were then submitted to a discrete Fourier Transform using a Hanning Window with 60% overlap. The analyses produced power for single-Hertz (Hz) frequency bins from 1 to 20 Hz in picowatt ohms (one microvolt squared) for each channel using an EEG analysis program (James Long Company, Caroga Lake, NY). Spectral plots constructed for the newborn and infant data revealed that the majority of activity occurred within the 3–13 Hz frequency. This is consistent with previous research indicating that the majority of EEG power in infants resides in the 3–13 Hz frequency band (Fox & Davidson, 1984; Jones et al., 1998).

EEG power values were then log transformed to normalize the data, and frontal and parietal asymmetry scores were then computed. The asymmetry score is a difference score reflecting the power in one hemisphere relative to the power in the contralateral hemisphere ($\ln(\text{right}) - \ln(\text{left})$), with negative scores reflecting greater relative right EEG asymmetry and positive scores reflecting greater relative left EEG asymmetry. Infant EEG asymmetry has significant 1–3-month ($r = 0.46$) (Jones, Field, Fox, Lundy, & Davalos, 1996) as well as significant 3-month to 3-year stability ($r = 0.61$) (Jones, Field, Davalos, et al., 1997; Jones, Field, Fox, et al., 1997).

Results

Demographic variables

Analyses of variance (ANOVAs) and χ^2 analyses failed to reveal any significant group differences on demographic variables (Table 1).

Neonatal/infant EEG asymmetry

A group (non-depressed/intrusive/withdrawn/undefined) by assessment period (neonatal/infant) repeated measures ANOVA conducted to assess for differences in frontal EEG asymmetry values revealed a main effect for group, $F(3, 62) = 32.34, p < 0.001$, and a significant group by assessment period interaction effect, $F(3, 62) = 4.90, p < 0.01$. Subsequent post-hoc Bonferroni corrected comparisons revealed the following (Fig. 1): (1) infants of intrusive, withdrawn and undefined depressed mothers exhibited significantly greater relative right frontal EEG asymmetry than infants of non-depressed mothers during the neonatal assessment ($p < 0.06$ for all comparisons); (2) infants of intrusive, withdrawn and undefined depressed mothers exhibited significantly greater relative right frontal EEG asymmetry than infants of non-depressed mothers during the infant assessment ($p < 0.06$ for all comparisons); (3) infants of withdrawn depressed mothers exhibited significantly greater relative right frontal EEG asymmetry than infants of intrusive depressed mothers during the infant ($p < 0.06$) but not the neonatal assessment ($p > 0.1$); and (4) while infants of withdrawn depressed showed a shift towards greater relative right frontal EEG asymmetry from the neonatal to the infant assessment ($p < 0.06$), infants of intrusive depressed mothers showed a shift towards left frontal EEG asymmetry ($p < 0.06$) from the neonatal to the infant assessment. A group by assessment period repeated measures ANOVA conducted to assess for differences in parietal EEG asymmetry values failed to reveal any significant main or interaction effects.

Pearson correlation analyses computed on maternal and infant variables revealed the following¹ (Table 2): (1) greater maternal depression scores were significantly related to lower maternal BAS/BIS difference scores (suggesting greater behavioral inhibition) and greater relative right frontal EEG asymmetry in infants during both the neonatal and 3–6-month assessments; (2) lower maternal BAS/BIS difference scores (suggesting greater behavioral inhibition) were also related to greater relative right frontal EEG asymmetry during both assessments; (3) neonatal frontal EEG asymmetry scores were related to infant frontal EEG asymmetry scores; and (4) the shift in frontal EEG asymmetry from the neonatal to the infant assessment was significantly related to the time that elapsed between these two assessments.

Separate multiple regression analyses were then conducted for the data from infants of depressed and infants of non-depressed mothers to assess whether maternal depression severity scores, maternal behavioral approach/inhibition scores and the time difference between the neonatal and infant assessments were related to the shift in frontal EEG asymmetry from the neonatal to the infant assessment (Table 3). The analysis conducted on the non-depressed group failed to reveal any significant effects. The analysis conducted on the depressed group revealed that maternal BAS/BIS difference scores and time elapsed between neonatal and infant assessments, out not maternal CES-D scores, significantly accounted for 31% of the variance in the shift in frontal EEG asymmetry from the neonatal to the infant assessment. These findings suggest that maternal behavioral approach was associated with a shift towards left frontal EEG asymmetry, while maternal behavioral withdrawal was associated with a shift towards right frontal EEG asymmetry in infants of depressed out not in infants of non-depressed mothers. Furthermore, these findings suggest that the magnitude in the shift towards either left or right frontal EEG asymmetry in infants of depressed mothers was related to how much time elapsed between the neonatal and the infant assessment (i.e. the older the infant was during the 3–6-month assessment, the greater the shift).

Pearson correlation analyses conducted on each of the four groups revealed that the absolute shift in frontal EEG asymmetry was significantly related to the time elapsed between the neonatal and the infant assessments for only infants of intrusive ($r(13) = 0.66, p < 0.06$) and withdrawn depressed mothers ($r(16) = 0.76, p < 0.001$) but not for infants of undefined depressed mothers ($r(9) = 0.10, N.S.$) or infants of non-depressed mothers ($r(28) = -0.16, N.S.$). Pearson correlation coefficients computed on neonatal and infant frontal EEG asymmetry values revealed significant test–retest stability for the entire sample ($r(66) = 0.79, p < 0.001$) and for the non-depressed ($r(28) = 0.66, p < 0.001$) and depressed undefined ($r(9) = 0.74, p < 0.06$) depressed groups only. Test–retest stability was marginally significant for the depressed intrusive groups ($r(13) = 0.64, p < 0.06$) and withdrawn groups ($r(16) = 0.46, p < 0.08$).

Discussion

Consistent with previous research (Dawson et al., 1992a and Dawson et al., 1999; Field, Fox, Pickens, & Nawrocki, 1996; Jones, Field, Davalos, et al., 1997; Jones, Field, Fox, et al., 1997), infants of depressed mothers exhibited significantly greater right frontal EEG activation than infants of non-depressed mothers during both the neonatal and the 3–6-month infant assessment periods. The presence of neonatal frontal EEG asymmetry differences is supported by findings relating maternal depression and biochemistry during mid pregnancy to neonatal frontal EEG asymmetry (Field et al., 2004). This finding is also consistent with newborns of

¹In order to explore whether EEG power across the left or right hemispheres independently contributed to the changes in infant EEG asymmetry scores, a series of exploratory correlation analyses were conducted on F3 and F4 EEG power values during the neonatal and infant visits and the shift in F3 and F4 power from the neonatal to the infant assessment. These analyses (conducted on both the complete dataset and for the data for the depressed and non-depressed groups separately) failed to reveal any significant relationships between F3 and F4 power and shift -power scores and maternal CES-D and BIS/BAS scores or infant frontal EEG asymmetry changes.

prenatally depressed mothers exhibiting greater relative right frontal EEG activation than infants of postnatally depressed mothers (Diego et al., 2004).

Infants of depressed mothers who show intrusive and withdrawn interaction styles exhibited distinct EEG asymmetry patterns at the 3–6-month infant visit but not at the neonatal assessment. Similarly, the findings from the multiple regression analyses revealed that depressed mothers behavioral approach/inhibition scores accounted for a significant portion of the variance in the shift in frontal EEG asymmetry from the neonatal to the infant assessment. These findings are consistent with previous research showing that infants of depressed mothers with a withdrawn interaction style show greater right frontal EEG activation at 3–6 months of age (Jones, Field, Davalos, et al., 1997; Jones, Field, Fox, et al., 1997) but not at birth (Field et al., 2003). That the EEG asymmetry of infants in the intrusive and withdrawn groups shifted in opposite directions across the first few months of life is also consistent with previous findings indicating that frontal EEG asymmetry differences between infants of intrusive and withdrawn mothers are exhibited at 6 months of age but not at 3 months (Jones, Field, Davalos, et al., 1997; Jones, Field, Fox, et al., 1997).

The neonatal data of this study are inconsistent with the frontal EEG asymmetry differences reported for neonates of depressed mothers reporting high behavioral inhibition and high behavioral approach reported by Field et al. (2001). This discrepancy could be attributed to a lack of sufficient statistical power in the current and the Field et al. (2003) studies. Even though infants of intrusive and withdrawn mothers had similar absolute frontal EEG asymmetry scores in the current study (-0.06 intrusive versus -0.10 withdrawn), Field et al. (2003) study (-0.06 intrusive versus -0.09 withdrawn), and the Field et al. (2001) study (-0.03 intrusive versus -0.10 withdrawn), the sample size of the current and the Field et al. (2003) study may not have been sufficient to show the statistical difference between scores that was noted in the Field et al. (2001) study ($n = 13$ intrusive and $n = 16$ withdrawn for the current sample, $n = 32$ intrusive and $n = 28$ withdrawn for the Field et al. (2003) sample, versus $n = 40$ intrusive and $n = 40$ withdrawn for the Field et al., 2001 sample). Alternatively this discrepancy in findings could be attributed to differences in the group classification between these studies. While the current study and the Field et al. (2003) study classified mothers based on their interaction ratings at 3–6 months, the Field et al. (2001) study utilized a self report measure of behavioral inhibition and behavioral approach during pregnancy to classify depressed mothers as intrusive or withdrawn. This difference in classification strategy may have yielded groups of mothers with distinct biochemical profiles during pregnancy that may differently affected fetal development. This is supported by the elevated cortisol and norepinephrine levels exhibited by depressed mothers reporting high behavioral inhibition during pregnancy (Field et al., 2001) but not by depressed mothers with withdrawn interaction styles (Field et al., 2003).

The number of weeks that elapsed between the neonatal and infant, 3–6-month, assessment accounted for a significant portion of the variance in the shift in frontal EEG asymmetry exhibited by infants of depressed mothers. Correlation analyses further revealed that the absolute shift in frontal EEG asymmetry was significantly related to the time elapsed between the neonatal and the infant assessments for only infants of intrusive and withdrawn depressed mothers, suggesting that older infants of intrusive and withdrawn depressed mothers exhibited a greater frontal EEG asymmetry shift. Caution must be taken when interpreting these findings, however, as infants were not longitudinally assessed from 3 to 6 months of age.

It has been argued that frontal EEG asymmetry is a stable physiological marker that reflects an individual's affective style (Davidson, 1996 and Davidson, 1998). This is supported by several studies adult and developmental studies, which have documented the stability and developmental continuity of frontal EEG asymmetries (e.g. Jones, Field, Davalos, et al., 1997; Jones, Field, Fox, et al., 1997; Vuga et al., 2006). However, poor stability and

developmental shifts in frontal EEG asymmetry have also been documented (e.g. Debener et al., 2002; Jones, Field, Davalos, et al., 1997; Jones, Field, Fox, et al., 1997). The present study supports both sets of findings. As a whole, infants exhibited stable frontal EEG asymmetry profiles from birth to 3–6 months of age. However, while infants of non-depressed and depressed mothers exhibited moderate stability, infants of depressed mothers with intrusive and withdrawn interaction styles exhibited variable frontal EEG asymmetry profiles. The lower stability exhibited by infants of depressed mothers with intrusive and withdrawn interaction styles are consistent with the shift in frontal EEG asymmetry exhibited by these groups of infants.

It is possible that the shift in frontal EEG asymmetry profiles exhibited by infants of depressed mothers with distinct interaction styles result from complex epigenetic interactions occurring at sensitive periods throughout prenatal and postnatal development. As such, infants of depressed mothers may inherit a genetic vulnerability towards negative affect. This genetic vulnerability could interact with the exposure to elevated maternal corticosteroid levels during pregnancy and result in the expression of a neurobehavioral dysregulation profile at birth that is characterized by negative affect and is reflected by greater relative right frontal EEG activation. Interactions involving differences in maternal care (resulting from different interaction styles) could further lead to variations in the development of frontal EEG asymmetries. This is supported by recent findings indicating that maternal care during the first week of life can alter neural development and gene expression across several of the structures involved in affect regulation, including the HPA axis (Fish et al., 2004). These effects appear to be mediated by alterations of DNA methylation and chromatin structure that persist throughout the lifespan (Weaver et al., 2004).

Future research should longitudinally assess the relationship between maternal interaction styles of depressed mothers across infancy, childhood and beyond to help clarify the impact of these early interactions across development. Finally, these data highlight the need for more prenatal and postnatal interventions. For example, prenatal interventions, such as massage therapy aimed at reducing depressed mothers' elevated cortisol and norepinephrine levels during pregnancy have reduced the effects of an imbalanced prenatal environment on fetal development (Field, Diego, Hernandez-Reif, Schanberg, & Kuhn, 2006). Interaction coaching specifically tailored to a depressed mothers' interaction style has also helped reduce the effects of poor arousal regulation and negative interactions on infant postnatal development (Malphurs, Field, & Larrain, 1996).

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Figure 1. Frontal EEG asymmetry (Ln(f4)-Ln(f3) 3-13Hz power) for neonates and 3-6 month-old infants of non-depressed mothers and depressed mothers with intrusive, withdrawn and undefined interaction styles.

Table 1

Means and distributions of the demographic variables for non-depressed mothers and depressed mothers with intrusive, withdrawn and undefined interaction styles and their infants (standard deviations under means in parentheses).

	Intrusive N=13	Withdrawn N=16	Non-depressed N=28	Undefined N=9	F/Chi
<u>Neonatal Age</u>	1.69 (.75)	1.50 (.82)	1.86 (.80)	1.78 (.83)	F(3,61) = 0.68, N.S.
<u>Infant Age</u>	17.08 (3.34)	16.88 (3.42)	17.14 (3.25)	17.00 (3.87)	F(3,61) = 0.02, N.S.
3-mo-old N	1	1	3	1	$\chi^2(9) = 0.76$, N.S.
4-mo-old N	6	7	11	4	
5-mo-old N	3	5	8	2	
6-mo-old N	3	3	6	2	
<u>Mother's Age</u>	26.67 (5.53)	27.50 (6.24)	30.57 (5.72)	26.89 (4.43)	F(3,61) = 2.06, N.S.
<u>SES</u>	3.62 (0.96)	3.56 (0.89)	3.14 (1.08)	3.67 (0.71)	F(3,62) = 1.24, N.S.
<u>Ethnicity</u>					
Caucasian	7.7%	18.8%	21.4%	22.2%	$\chi^2(9) = 3.15$, N.S.
Hispanic	46.2%	43.8%	46.4%	44.4%	
Black	46.2%	31.3%	28.6%	33.3%	
Asian	0%	6.3%	3.6%	0%	
<u>Marital Status</u>					
Single	46.2%	31.3%	25.0%	33.3%	$\chi^2(3) = 5.27$, N.S.
Married	53.8%	68.8%	75.0%	66.7%	
<u>Gender</u>					
Male	30.8%	25.0%	35.7%	33.3%	$\chi^2(3) = 0.56$, N.S.
Female	69.2%	75.0%	64.3%	66.7%	

Table 2

Pearson correlation analyses conducted to explore the relationship between maternal depression severity (CES-D) and behavioral approach/behavioral inhibition scores (BAS-BIS), infant frontal EEG asymmetry scores during the neonatal (N.EEG) and 3–6 weeks (I.EEG) assessments, change in infant frontal EEG asymmetry (Δ EEG), and the time elapsed between the neonatal and the infant assessments.

	CES-D	BAS-BIS	N.EEG	I. EEG	Δ EEG
BAS-BIS	–0.22				
Neonatal Frontal EEG Asymmetry	–0.48**	0.35**			
Infant Frontal EEG Asymmetry	–0.49**	0.46**	0.79**		
Frontal EEG Asymmetry Change	–0.11	0.25*	–0.16	0.47**	
Time Between Assessments	–0.06	0.07	0.12	–0.05	–0.28*

* $p < 0.05$;

** $p < 0.01$;

* Positive scores denote greater BAS activity while negative scores denote greater BIS activity.

Table 3

Multiple regression analyses conducted to explore the effects of depression severity (CES-D), behavioral approach/behavioral inhibition (BAS-BIS^{*}) and weeks elapsed between the neonatal and the infant assessment on the change in infant frontal EEG asymmetry values.

F (3, 34) = 5.02, p < .01, R² = 0.31		Beta	t	p
Depressed	BAS-BIS [*]	0.46	3.25	< 0.01
	CES-D	0.06	0.45	N.S.
	Time between assessments	-0.32	2.21	< 0.05
Non-depressed	F (3, 24) = 0.91, N.S., R ² = 0.10	Beta	t	P
	BAS-BIS [*]	-0.10	-0.48	N.S.
	CES-D	-0.15	-0.67	N.S.
	Time between assessments	-0.27	-1.29	N.S.

* Positive scores denote greater BAS activity while negative scores denote greater BIS activity.