Right frontal EEG asymmetry and behavioral inhibition in infants of depressed mothers

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A B S T R A C T

Recent studies have shown associations between maternal psychopathology and inhibited behaviors in infants. Moreover, physiological factors have been identified as affecting the continuity of behavioral inhibition across childhood. The purpose of the present study was to examine electroencephalogram (EEG) activity and inhibited behavior in 12-month-old infants of depressed versus non-depressed and mothers. Repeated measures MANOVAs indicated that the infants of mothers with stable psychopathology had greater relative right frontal EEG asymmetry, a pattern that typically accompanies greater negative affect and greater withdrawal behaviors. Infants of affectively ill mothers also showed more proximal behaviors toward a stranger and a novel toy than infants of well mothers, but fewer non-proximal behaviors toward their mothers. These results are discussed within a framework of behavioral inhibition for infants exposed to early psychopathologies in their mothers.

The literature has indicated that maternal psychopathology adversely affects infants (Cicchetti & Toth, 1998; Dawson, Ashman, & Carver, 2000; Diego et al., 2004; Diego, Field, Jones, & Hernandez-Reif, 2006; Downey & Coyne, 1990; Field, 1995; Jones, McFall, & Diego, 2004). When maternal mood disorders are stable during infancy, 1-year-old infants experience delayed growth and intellectual development (Fox, Henderson, Marshall, Nichols, & Ghera, 2005). Studies have also shown a relationship between maternal psychopathology and inhibited behaviors which have been identified as precursors to social reticence with peers and ultimately anxiety and depressive disorders (Feng et al., 2008; Hirshfeld-Becker et al., 2007). Recent theories suggest that in addition to disturbed social interactions with their mothers, infants of depressed mothers also have biological and physiological vulnerabilities that may predispose them to more stability in their disturbed social interactions (Field, 2000; Jones, Field, Fox, Lundy, & Davalos, 1997). The present study examined EEG activity, interactive behaviors, and socially inhibited behaviors in infants whose mothers are stable in their depression and anxiety during the first year of life.

Brain activity patterns (via an electroencephalogram, EEG) of the children of depressed mothers were examined because previous research has consistently shown that infants and children of depressed mothers have greater relative right frontal EEG asymmetry (Diego et al., 2004; Jones, Field, Davalos, & Pickens, 1997; Jones, Field, Fox et al., 1997). Theories have suggested that the right frontal region of the brain is specialized for emotions associated with negative emotions and behavioral withdrawal (Fox, Calkins, & Bell, 1994; Henderson, Fox, & Rubin, 2001). Based on this literature, the infants of depressed and anxious mothers were expected to show greater relative right frontal EEG asymmetry. EEG patterns in infants of depressed mothers have also been shown to be stable from the neonatal stage and across the first year of development (Diego et al., 2004).
2004; Field & Diego, 2008). Jones, Field, Davalos, et al. (1997) also demonstrated that right frontal EEG asymmetry, a marker of depressive symptoms in adults, was temporally stable from 3 months to 3 years.

Although studies have established a relationship between maternal anxiety and behavioral inhibition, few studies have shown that depressed mothers also influence their infants inhibited behaviors (Finman, Davidson, Colton, Straus, & Kagan, 1989; Fox, Henderson, Rubin, Calkins, & Schmidt, 2001; Fox, Schmidt, Calkins, Rubin, & Coplan, 1996). Moreover, depression and anxiety are very often comorbid (Durban, Klein, Hayden, Buckley, & Moerk, 2005; Kasch, Rottenberg, Arnow, & Gotlib, 2002).

Studies have frequently shown lower rates of behavior and affective expression of depressed mothers interacting with their infants (Cohn, Matias, Tronick, Connell, & Lyons-Ruth, 1986; Durban et al., 2005; Feng et al., 2008), and the infants of depressed mothers have also been less socially interactive or maladaptive in their social interaction patterns (Shamir-Essakow, Ungerer, Rapee, & Safier, 2004), suggesting that these infants may be learning or imitating their mothers’ depressive and anxious symptoms. Social experiences with a depressed parent (along with temperamental or genetic predispositions) could thereby make the infant vulnerable for the increased social withdrawal and internalizing behaviors noted in preschool children of depressed mothers (Feng et al., 2008; Field et al., 1996). Although many studies have examined social withdrawal and behavioral inhibition, these studies have been limited to children of mothers without psychopathologies (Kagan & Snidman, 1991). Studies have also shown that behavioral inhibition is associated with right frontal EEG asymmetry (Henderson et al., 2001) suggesting the need to further explore this relationship in infants of depressed and anxious mothers.

The primary purpose of the present study was to examine regional EEG activity and social behaviors in the form of behavioral inhibition in infants whose mothers exhibited stable depression across the first year of post-natal life. There appears to be, however, no studies to date that have examined the pattern of resting frontal brain electrical activity (EEG) and behavioral inhibition in children at risk during the first year of post-natal life. We predicted that infants of depressed mothers would exhibit greater relative right frontal EEG activity at rest and more behavioral inhibition compared with disinhibition than infants of non-depressed mothers. Based on previous studies that have shown delayed growth and intellectual development in infants of depressed mothers (Field, 1992), we also predicted that infants of depressed mothers would be delayed in their mental development compared with infants of non-depressed mothers.

1. Method

1.1. Participants

Forty, 1-year-old infants and their mothers participated in this study. Of those 40 dyads, 30 were stable in their group defined “stable depressed” (N = 16) or “stable non-depressed” (N = 14), \( \chi^2 = 8.28, p < 0.001 \). The children (14 girls) averaged 12 months of age (M = 12.5, SD = 0.9) and their mothers were low socioeconomic status (Hollingshead, 1975), M = 4.5, SD = 0.05, high school educated (M = 10.5, SD = 2.2), in their late teens (M = 19.5, SD = 2.6) and distributed 53% African American, and 47% White, Hispanic.

The depressed and the non-depressed groups did not differ on demographic factors (Table 1) except that, as expected, the mothers in the depressed group reported more symptoms of depression (M = 24.9 versus 9.3) on the Center for Epidemiological Studies-Depression Scale (CES-D; Radloff, 1977) and higher scores for anxiety (M = 15.6 versus 9.4), depression (M = 18.9 versus 8.0) and hostility (M = 20.3 versus 8.3) on the Profile of Mood States questionnaire (POMS; McNair, Lorr, & Droppleman, 1971).

1.2. Procedures

Mothers and their infants participated in a longitudinal study on maternal depression effects on infant development and were seen at the newborn period and again at 1-year of age. During the laboratory session, mothers were asked to complete the CES-D (Radloff, 1977), a demographic questionnaire (Hollingshead, 1975), and the POMS (McNair et al., 1971).

The children participated in an EEG session, an inhibition paradigm (modeled after Calkins, Fox, & Marshall, 1996; Kagan & Snidman, 1991), and a Bayley Scale for Infant Development (Bayley, 1969). Growth measures were also obtained (head circumference, length, and weight). All sessions lasted approximately 1 h and the order of procedures was randomly presented.

1.2.1. Maternal report measures

Mothers in the depressed group had been diagnosed as depressed on a clinical interview (the Diagnostic Interview Schedule, Robins, Helzer, Croughan, & Ratcliff, 1981) and had elevated CES-D scores at the newborn assessment and at any subsequent laboratory visits. During the 1-year laboratory session the mothers again completed the CES-D and the POMS.

1.2.2. Inhibition condition

The infants were observed in a playroom for three brief episodes: (1) novel room: 5 min of freeplay with mother in playroom; (2) novel person: stranger enters playroom and presents novel toy while keeping head down for 1 min, stranger plays with toy for 1 min, stranger invites child to play for 1 min and (3) novel objects: stranger presents electronic robot for 2 min and tunnel for 2 min.
Table 1

Demographic data.

<table>
<thead>
<tr>
<th></th>
<th>Depressed group (N = 16)</th>
<th>Non-depressed group (N = 14)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
</tr>
<tr>
<td><strong>Mother demographics</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age (in years)</td>
<td>19.3 (2.6)</td>
<td>19.6 (2.8)</td>
</tr>
<tr>
<td>Marital status (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single</td>
<td>87.5%</td>
<td>64.3%</td>
</tr>
<tr>
<td>SES: Hollingshead</td>
<td>4.5 (0.5)</td>
<td>4.4 (0.5)</td>
</tr>
<tr>
<td>Ethnicity (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>African American</td>
<td>50.0%</td>
<td>57.1%</td>
</tr>
<tr>
<td>White, Hispanic</td>
<td>50.0%</td>
<td>42.9%</td>
</tr>
<tr>
<td>Education (in years)</td>
<td>10.2 (2.6)</td>
<td>10.8 (1.7)</td>
</tr>
<tr>
<td>CES-D</td>
<td>24.8 (13.3)</td>
<td>9.3 (6.8) **</td>
</tr>
<tr>
<td><strong>POMS: Anxiety</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depression</td>
<td>18.9 (12.7)</td>
<td>8.0 (8.1)</td>
</tr>
<tr>
<td>Hostility</td>
<td>20.3 (11.4)</td>
<td>8.3 (6.4) **</td>
</tr>
<tr>
<td><strong>Infant demographics</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age (in months)</td>
<td>12.5 (0.8)</td>
<td>12.5 (1.1)</td>
</tr>
<tr>
<td>Gender of child (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>43.8%</td>
<td>42.9%</td>
</tr>
<tr>
<td>Female</td>
<td>56.2%</td>
<td>57.1%</td>
</tr>
<tr>
<td>Head circumference (cm)</td>
<td>46.8 (1.8)</td>
<td>47.2 (1.9)</td>
</tr>
<tr>
<td>Length (cm)</td>
<td>72.9 (2.5)</td>
<td>73.1 (2.0)</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>10.0 (9.1)</td>
<td>10.0 (9.2)</td>
</tr>
<tr>
<td>Ponderal index</td>
<td>2.5 (0.2)</td>
<td>2.5 (0.2)</td>
</tr>
</tbody>
</table>

* \( p < 0.01 \)

** \( p < 0.001 \)

1.2.3. Coding of the inhibition condition

The primary measure of interest to us from these laboratory procedures was a measure of inhibited behavior. Inhibition was scored using procedures similar to those of Fox and colleagues (Calkins & Fox, 1992; Henderson et al., 2001; Fox & Calkins, 1993) and Kagan and colleagues (Kagan, Reznick, & Snidman, 1987; Reznick, Gibbons, Johnson, & McDonough, 1989). The summary measure of behavioral inhibition for each infant was computed by standardizing the sum of the following standardized variables: proximity (defined as within an arm’s distance) to mother during freeplay; latency to touch first toy during freeplay; proximity to mother during stranger approach, robot, and tunnel; latency to approach stranger, tunnel, robot.

Behavioral inhibition was defined as high frequencies of proximal behaviors to their mother and long latencies to approach the toy, stranger, robot, and tunnel. We also coded for crying and fretting as in Calkins and Fox (1992) but found no group variability, so this variable was dropped from the computation of behavioral inhibition. Finally, due to our interest in the infants’ behavior toward the toys versus toward their mother, summary scores were computed for proximity toward mother and latency to approach toys.

1.2.4. EEG assessment

EEG activity was recorded for 3 min prior to the administration of the behavioral assessments. During this recording, infants were shown their favorite toy in order to have them sit quietly with their eyes open. A stretch lycra cap (Electro-Cap, Inc.) with the international 10–20 system was positioned on the infant’s head. Omni-prep gel and electrode gel were inserted into the mid-frontal (F3, F4), temporal (T3, T4), parietal (P3, P4) and occipital (O1, O2) sites and referenced to the vertex site (Cz) on-line. The vertex site was the on-line reference location, however, after data collection the reference location was re-referenced to an average reference location. Although there has been controversy in the literature concerning the appropriate reference location and the number of sites needed for average referencing, we used an average reference because this has been recommended as the best reference site when working with infant participants (Pivik et al., 1993). Omni-prep gel was used to gently abrade the scalp and electrode gel was used to provide good conductance. EOG was also obtained using two Beckman mini-electrodes, one placed at the outer canthus, and the second placed at the supra orbit position of one eye. All electrode impedances were required to be less than 5 K ohms or the site was re-abraded with the blunt end of a Q-tip until optimal impedances were obtained.

The signal was passed through a Grass Model 12 Neurodata Acquisition System. The output from each amplifier was directed to a Dell 323D PC fitted with an Analog Devices RTI-815 A/D board. The sampling rate was 512 samples per second. The data were streamed across a computer screen and saved to a hard drive using data acquisition software (Snapstream, v. 3.21, HEM Data Corp., 1991).
1.2.5. EEG analysis
Artifact in the EEG was underscored by using the EOG channel as a cue for eye movement artifact and the eye and muscle artifact were eliminated from each channel. The data were submitted to a discrete Fourier Transform using a Hanning Window with 50% overlap. This analysis produced power for each single hertz frequency bin in picowatt ohms (equal to one microvolt squared) for each channel. Based on spectral plots, made on a subsample of the children, the 6–9 Hz band was used. Previous research (Bell, 2002; Fox et al., 1995) has shown that the 6–9 Hz frequency band in children of this age is similar to alpha band characteristics in adults. Frontal, temporal, parietal and occipital alpha EEG asymmetry scores were computed using the natural log power of the scores. The asymmetry score is a difference score, reflecting the power in one hemisphere relative to the power in the contra-lateral hemisphere (in right minus in left) with greater scores indicating greater relative left hemisphere EEG asymmetry. To remain consistent with previous literature on infants of depressed mothers (Field et al., 2004), our specific predictions about frontal activation asymmetries, the small sample size, and the fact that preliminary analyses showed distinct differences between anterior and posterior regions, only comparisons between the frontal and parietal sites were analyzed in subsequent ANOVAs.

2. Results

2.1. EEG analysis

A Group (depressed versus non-depressed) × Region (frontal versus parietal) repeated measures MANOVA was conducted on the infant’s EEG asymmetry scores. This analysis yielded a significant main effect for Group, $F(1,28) = 7.31, p < 0.01$, and a main effect for Region $F(1.28) = 6.26, p < 0.05$. Thus analyses were conducted separately for each region. ANOVAs yielded significant differences between the depressed and non-depressed groups in the frontal region, $F(1,28) = 7.60, p < 0.01$, but not in the parietal region, $F(1,28) = 2.19, p > 0.05$. The infants of depressed mothers showed greater relative right frontal EEG asymmetry than the infants of the non-depressed mothers ($M = −0.06$ versus $0.09$, respectively; Fig. 1).

To examine hemispheric differences between children of depressed and non-depressed mothers, a Group (depressed versus non-depressed) × Region (frontal versus parietal) × Hemispheres (right versus left) repeated measures MANOVA was conducted, using the EEG power scores as the dependent variable. Results showed significant main effects for Group, $F(1,28) = 10.97, p < 0.01$, and for Region, $F(1,28) = 3.40, p < 0.05$, and a significant Group × Hemisphere interaction effect, $F(1,28) = 5.26, p < 0.05$. Subsequent ANOVAs, conducted separately for each region, revealed a significant main effect for Group, $F(1,28) = 7.38, p < 0.01$, and a Group × Hemisphere interaction effect, $F(1,28) = 3.50, p < 0.05$, for the frontal region. Post hoc t tests revealed that infants of the depressed mothers had less left frontal EEG activation than the infants of the non-depressed mothers, $t(28) = 3.78, p < 0.01$ (Fig. 2). ANOVAs, using the parietal region data, revealed a significant main effect for Group, $F(1,28) = 8.64, p < 0.01$, but no significant interaction effects, $p > 0.05$.

2.1.1. Inhibition paradigm

ANOVA were conducted on the infant’s behavior during the inhibition paradigm. The results revealed that the infants in the depressed mother group showed less inhibited behavior than the infants in the non-depressed mother group, $F(1,29) = 9.80, p < 0.01$.

Examination of the behavioral data showed that the infants of the depressed mothers had a shorter latency to approach the stranger and novel toys, $F(1,28) = 5.80, p < 0.05$ but also demonstrated less proximity to their mothers during the stranger approach.

![Fig. 1. Frontal EEG asymmetry of 12-month-old infants of depressed and non-depressed mothers.](image-url)
Table 2
Behavioral inhibition and disinhibition in infants of depressed and non-depressed mothers.

<table>
<thead>
<tr>
<th></th>
<th>Depressed group ($N = 16$)</th>
<th>Non-depressed group ($N = 14$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
</tr>
<tr>
<td>Total inhibition(^a)</td>
<td>−0.47 (0.71)</td>
<td>0.53 (1.03)(^b)</td>
</tr>
<tr>
<td>Latency to approach</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stranger and toys (s)</td>
<td>48.98 (22.98)</td>
<td>80.09 (45.55)(^b)</td>
</tr>
<tr>
<td>Proximity to mother (1–4)</td>
<td>2.07 (0.68)</td>
<td>2.67 (0.59)(^b)</td>
</tr>
</tbody>
</table>

\(^a\) Note. Greater standardized score is equal to more inhibited behaviors.

\(^b\) \(p < 0.01\).

\(^c\) \(p < 0.001\).

and novel toy presentations, \(F(1,28) = 6.33, p < 0.01\), suggesting less inhibited behaviors toward the stranger and toys but more non-proximal (possibly inhibited) behaviors towards their mothers (Table 2).

### 2.1.2. Bayley developmental index scores and growth measures

ANOVA conducted on the Bayley mental and motor scores revealed that infants of depressed mothers had lower mental scores (\(M = 109.6\) verses 116.0), \(F(1,29) = 3.96, p < 0.05\), but did not differ on their motor scores (\(M = 116.9\) versus 120.6), \(F(1,29) = 0.57, p > 0.05\). The groups did not differ on the growth measures (head circumference, length, and weight).

### 3. Discussion

That the infants of depressed mothers showed greater relative right frontal EEG asymmetry is consistent with previous studies on infants of depressed mothers (Diego et al., 2006; Field, 1995; Jones, Field, Davalos et al., 1997; Jones, Field, Fox et al., 1997). The reduced EEG activation in the left hemisphere is also consistent with factor-analytic studies of mood in depressed patients, suggesting that such individuals primarily have decreased positive affect (not increased negative affect, Tellegen, 1985; Watson, Clark, & Carey, 1988) and the theoretical view that approach-related deficits and inhibition correspond to less left frontal EEG activation (Biederman et al., 2001; Fox, 1991, 1994; Henderson et al., 2001; Hirshfeld-Becker et al., 2007).

Contrary to our hypothesis, the infants of depressed mothers were less inhibited toward the stranger and the novel toys compared to the infants of non-depressed mothers. The infants of depressed mothers were more likely to approach a novel situation, suggesting fewer inhibited behaviors (and more disinhibition) towards the stranger and the novel toys. Yet these same children were less likely to remain in proximity to their mothers. Infants of depressed mothers may spend less time in proximity to their mothers for a number of reasons. First, infants of depressed mothers may just be more interested in novel toys and situations. Second, infants of depressed mothers may have a secure attachment relationship with their mothers and feel comfortable exhibiting enhanced exploratory behaviors during the inhibition tasks. Third, infants of depressed mothers may have a more approach-type temperamental disposition and may be driven to explore novel people and situations rather than remain in proximity to their mother. These explanations, although possible, seem unlikely for several reasons. First, the infants did not seem to be gaining knowledge from their enhanced interest in novel toys and situations as indicated by their lower scores on the Bayley Mental Developmental Index. Second, studies with infants of depressed mothers have
demonstrated that these infants are less likely to be securely attached to their mothers rather studies have shown that infants of depressed mothers are more often demonstrate insecure, avoidance or insecure, disorganized attachment (Lyons-Ruth, Lyubchik, Wolfe, & Bronfman, 2002; Martins & Gaffan, 2000; McMahon, Barnett, Kowalenko, & Tennant, 2006). Finally, infants of depressed mothers have been shown to exhibit greater right frontal asymmetry (as was also demonstrated in the present study) and those infants with patterns of right frontal EEG activation are less inclined to demonstrate enhanced approach motivation (Calkins & Fox, 1992; Fox et al., 2001; Hane, Fox, Henderson, & Marshall, 2008).

A more likely explanation is that infants of depressed mothers may have appeared less inhibited simply because they were less inclined to seek emotional support from their mothers, i.e., they do not stay in proximity to their mothers which has traditionally been used as an indication of inhibition (Henderson et al., 2001). Their faster approach toward the objects could reflect an absence of seeking emotional support from their mother because they have come to expect less emotional availability from their typically unresponsive mothers (Field, 1992). As if lacking viable options, the infants of depressed mothers often appeared disorganized when presented with a novel situation and insufficient maternal cues. The data, in fact, showed a smaller range of behaviors for the infants of the depressed mothers and the videotape records showed that these infants were more often “off on their own wandering” and not in proximity to their mothers or the toy/stranger. Further studies are needed to investigate these behaviors within the context of inhibition and social withdrawal.

As noted previously, the infants of the depressed mothers also showed lower scores on the Bayley Mental Scale, consistent with the data reported by Field (1992). Other studies (Radke-Yarrow, Cummings, Kuczynski, & Chapman, 1985; Zahn-Waxler, Cummings, McNew, & Radke-Yarrow, 1984) have noted less exploratory behavior, less speaking, and greater sadness in toddlers of depressed mothers which may relate to their reduced cognitive abilities on the Bayley.

A number of limitations were present, with the most notable being the small sample size. Mothers with depressive disorders are especially difficulty to assess in longitudinal studies. Yet following these families from the neonatal period up to a year and possibly further into childhood may help to garner a better understanding of the consequences of maternal depression on their child’s social and emotional functioning.

Overall, these data suggest that the infants of depressed mothers exhibited altered physiological and cognitive development compared to infants of non-depressed mothers. The infants of depressed mothers had greater right frontal EEG asymmetry and lower scores on the Bayley Mental Scale for Infant Development. These results seemed inconsistent with the lesser inhibition of these infants (greater approach behavior toward the stranger and the toys) although, as noted, that behavior may have derived from greater avoidance of their mothers. Further research is needed to explore these relationships and the antecedents of these developmental differences as well as to examine their behaviors longitudinally as risk factors for the development of behavioral disorders.

Acknowledgments

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