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:TITLE: Developmental neuropsychology.
:IMPRINT: Hillsdale, N.J. : Lawrence Erlbaum Associates, 1985-
:ARTICLE: Author: Fox NA and Davidson RJ Article Title: Electroencephalogram asymmetry in response to the approach of a stranger and maternal seperation in 10 month old infants

ARIEL

:VOL: 23 :NO: :DATE: 1988 :PAGES: 233-240
:VERIFIED: OCLC ISSN: 8756-5641 [Format: Serial]
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Developmental Psychology
1987, Vol. 23, No. 2, 233–240

Electroencephalogram Asymmetry in Response to the Approach of a Stranger and Maternal Separation in 10-Month-Old Infants

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We recently reported the presence of reliable asymmetries in frontal-brain electrical activity in infants that distinguished between certain positive- and negative-affect elicitors. In order to explore the degree to which these asymmetries in brain activity are associated with individual differences in affective response, 35 ten-month-old female infants were presented with a stranger-approach, mother-approach, and maternal-separation experience while an electroencephalogram (EEG) from the left- and right-frontal and left- and right-parietal scalp regions was recorded and facial and other behavioral responses were videotaped. Changes in frontal-EEG asymmetry reflected behavioral changes between conditions. In addition, individual differences in affective response to separation were related to differences in frontal-brain asymmetries. These findings indicate that lawful changes exist in asymmetries of frontal-brain activation during the expression of certain emotions in the first year of life and that individual differences in emotional responsivity are related to these measures of brain activity.

During the fourth quarter of the first year of life, infants display an increased frequency of negative affect in response to certain events. The two most widely investigated stimulus events that elicit this type of emotional response are the approach of an unfamiliar person and the abrupt departure of the mother from the infant's sight. Although the behavioral and autonomic responses to these events have been investigated previously, no data are available on the central-nervous-system manifestations of these emotional reactions. The principal goal of this study was to examine changes in electroencephalogram (EEG) activity and asymmetry associated with responses to these stimulus events. A secondary purpose was to relate changes in the pattern of brain electrical activity to individual differences in behavioral responses elicited by these situations.

In previous research, we established that differences in frontal-activation asymmetry associated with positive and negative affect that have been found in adults (e.g., Davidson, 1984a, 1984b) are also found in infants in the first year of life (Davidson & Fox, 1982; Fox & Davidson, 1986). Davidson & Fox (1982), for example, found greater relative left-frontal activation in 10-month-old infants in response to a videotape of an actress portraying happiness and laughter compared with sadness and crying. Fox and Davidson (1986) found frontal-asymmetry differences in the same direction in newborn infants in response to different tastes. In neither of these two previous studies were we able to relate individual differences in behavioral responsivity to EEG changes elicited by the stimulus conditions. The elicitors that were used in our previous studies did not produce a sufficient range of behavioral responsiveness to permit an analysis of individual differences.

This study was designed to investigate the frontal-asymmetry phenomenon in more complex and varied emotion-eliciting situations. The behavioral literature reports a wide range of responses by infants during the last quarter of the first year to the approach of an unfamiliar person (Scarr & Salapatek, 1970). Although most investigators agree that at least a portion of babies at this age will show signs of wariness (Sroufe, 1977), data on facial expression in response to stranger approach (Hiatt, Campos, & Emde, 1977; Lewis, Brooks, & Haviland, 1978) do not suggest the presence of a discrete fear expression in response to an unfamiliar person. Still other investigators (e.g., Solomon & Decarie, 1976) have observed considerable differences among individuals in other behavioral signs of negative emotion, including avoidance of the stranger and crying. Finally, cardiac acceleration has been found in certain infants in response to stranger approach (Campos, Emde, Gaensbauer, & Henderson, 1975), a pattern again indicative of negative affect.

A similar pattern of variability has been noted in the infant's response to maternal separation. Only a portion of infants at this age protest or cry in response to the departure of their mother (Weinraub & Lewis, 1977). Most infants display facial expressions of anger during separation, and these expressions are seen almost exclusively when the infant is crying (Shiller, Izard, & Hembree, 1986). Interestingly, infants displaying a greater number of expressions of sadness during separation were subsequently rated as more insecure in their attachment classification (Shiller et al., 1986). Thus, the emotional expression during separation may have some relation to the infant's overall emotional state. One of the goals of this study was to

This research was sponsored by grants from the Foundation for Child Development, the National Science Foundation (#BNS-8317229) and the National Institutes of Health (HD #17899).

We would like to thank Cynthia Stifter for her help in data analysis, Michael Gelles for his help in the coding of the facial-expression data, and Clifford Saron and Joseph Senulis for their technical assistance.

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explore the relation between patterns of EEG asymmetry that distinguish between different responses to maternal separation. These data may bear on the interpretation of individual differences in response to separation, particularly because individual differences in patterns of EEG asymmetry have been related to depressive affective style in adults (Davidson, Schaffer, & Saron, 1985; Schaffer, Davidson, & Saron, 1983), with depressed subjects showing greater relative right-frontal activation during rest when compared with nondepressed subjects.

A final and central aim of this study was to continue the exploration of the functional significance of frontal cerebral asymmetries. A growing body of literature (see reviews by Davidson, 1984a; Fox, 1985; Tucker, 1981) supports the notion that left-frontal activation is observed during the experience and expression of positive affect and that right-frontal activation is observed during the experience and expression of negative affect. However, relatively little information is available that specifies the functional differences associated with activity in the left- and right-frontal regions. By examining the relation between individual differences in the behavioral response to stranger and mother approach and maternal separation, additional evidence would be obtained on the behavioral activities indexed by frontal-brain asymmetries.

Any attempt to examine differences in localization of EEG-asymmetry effects requires that left- and right-side recording be made from at least two scalp regions. If recordings were obtained only from the frontal region, we could not confidently state that the same asymmetries were not observable elsewhere on the scalp. In fact, in our recent study of taste-elicited asymmetries in newborn infants (Fox & Davidson, 1986) we found reliable asymmetries in the same direction in both frontal- and parietal-scalp regions. These findings raise the possibility that functional differentiation among different cortical regions increases developmentally, a suggestion consistent with recent data on developmental changes in regional brain metabolism in human infants (Chugani & Phelps, 1986). These considerations necessitate recordings from multiple scalp locations (see Davidson, 1984a, for an extensive discussion of this issue). The frontal region was chosen in light of extensive previous research indicating reliable asymmetries in brain electrical activity recorded from this area that are associated with affect (Davidson, Schwartz, Saron, Bennett, & Goleman, 1979). The frontal region was originally chosen for study in this context based on its prominent anatomical reciprocity with limbic structures directly involved in the control of emotional and motivational behavior (e.g., Nauta, 1971). The parietal region was chosen as a site to compare with frontal recording because it is also an association region, albeit one concerned with perceptual processing and cross-modal integration and therefore having little direct involvement in the generation of emotion.

Method

Subjects

The subjects for this study were 35 ten-month-old female infants. The rationale for using females in this study was based on reports of sex differences in EEG asymmetries (e.g., Davidson, Schwartz, Bromfield, & Pugash, 1976) and cerebral lateralization (e.g., McGlone, 1980). The mean age in months of the infants was 10.2 (SD = .14). All infants were born to two right-handed parents. Handedness of the parents was assessed using the Edinburgh Handedness Inventory (Oldfield, 1971). We were able to obtain usable behavioral and EEG data on 19 of the 35 subjects. The number of subjects varied for different comparisons depending on the number who showed artifact-free EEG for the particular set of conditions. The major reason for subject attrition was the presence of movement artifact in the EEG records. Only 3 infants were excluded because they would not tolerate the EEG recording procedure.

Table 1
Overview of the Experimental Design

Condition	Epoch	Duration (seconds)
Stranger approach (mother present)	Enter	15
	2 steps	15
	2 steps	15
	reach	15
Mother approach	At door	15
	2 steps	15
	2 steps	15
	reach	15
Maternal separation		60
Stranger approach (mother absent)	enter	15
	2 steps	15
	2 steps	15
	reach	15
Mother returns	experiment ends	

Note. The maternal-separation condition was curtailed if the infant became upset and cried.

Procedure

The experimental design of the study is outlined in Table 1. It consisted of three approach conditions, two by an unfamiliar female (the stranger) and one by the child's mother. Three different female strangers were used for the study with each stranger seeing a similar number of infant subjects.

The child was seated in an infant feeding table so that she was approximately 2 ft off the ground. The infant's mother was seated in a chair next to the infant. The mother was instructed to avoid eye contact and not interact with her infant during the stranger's approach. After a 30-s baseline condition, a female stranger entered the playroom and stood by the door for 15 s. At a prearranged signal the stranger approached the infant, taking two steps forward, and attempted to maintain eye contact with the infant. The stranger stood in this second position for 15 s. After a second signal, the stranger took another two steps forward, maintaining that position for 15 s. After the third signal, the stranger took another two steps forward and extended her arms as if to pick up the child. The stranger held this position for 15 s, after which she turned and left the room. During the entire stranger-approach sequence the stranger maintained a neutral facial expression. The mother had been instructed not to talk during the approach condition but to read a magazine that was left nearby. The stranger and mother were signaled by a small light that was hung on the wall behind and out of the infant's view.

After the stranger departed there was a 30-s intercondition interval. Following this interval the mother was signaled to stand and walk to the door, turn and face her infant, and smile. The mother then initiated her approach sequence, which was identical in form to the stranger's approach. After the last epoch of the mother's approach, in which she reached down as if to pick up her infant, she turned and left the room. The infant was then left alone in the playroom for 60 s. If the infant became upset and cried during the separation condition, the period of time was shortened. At the end of this 60-s maternal-separation condition the stranger reentered the playroom and initiated the identical approach sequence. After finishing this sequence the stranger left the room and the mother reentered, whereupon the experiment was terminated. Both mother and stranger remained silent throughout the entire experimental procedure.

The sequence of stranger approach with mother present, mother approach, maternal separation, and stranger approach with mother absent was invariant across all subjects. Previous research (e.g., Campos et al., 1975) demonstrated that infants were most upset during stranger approach with the mother absent. Because we wished to collect as many periods of facial expression and artifact-free EEG data as possible, it was decided to forgo counterbalancing the approach sequences across subjects.

A Sanyo Viewfinder Video camera was placed in front and to the right of the infant, and the infant's facial behavior was recorded on videotape with a Sony videotape recorder. The EEG was recorded from the left- and right-frontal and left- and right-parietal scalp regions referred to a common vertex using a lycra strechable cap (Electro-cap Corp). All electrode resistances were kept below 5000 Ω. The electrode cap contains all of the 10/20 electrode placements and comes in a range of different head sizes. Each infant wore a cotton vest that had a number of metal snaps sewn onto it. Elastic bands with snaps connected the sides of the cap to the vest. In addition, after the cap was placed on the infant's head, the infant's head was wrapped with an elastic bandage material (Coban). Both the Coban and the vest apparatus were used to ensure that the cap fit snugly on the infant's head and did not move during the experiment.

EEG was recorded from the left- and right-frontal and left- and right-parietal scalp regions (F3, F4, P3, P4) referred to a common vertex (Cz) to replicate procedures we have used in our previous research (Davidson & Fox, 1982; Fox & Davidson, 1986). In previous work with 10-month-old infants we found that frontal-EEG asymmetries discriminated between the affective valence of the stimulus conditions but that parietal asymmetry in most instances did not. These findings in infants are similar to those that have been obtained in adults (Davidson, 1984a) and suggest that asymmetries in the frontal region are particularly related to the expression of emotion.

Each of the four EEG leads was directed into its separate amplifier channels (Grass Model P7d). The output of each EEG amplifier was displayed on separate channels of a Grass Model 7 Polygraph and recorded on separate channels of a Vetter Model D FM instrumentation recorder for subsequent analysis. The entire recording system was calibrated before each testing session by inserting a 50-uV sine wave into the preamplifier of each channel. This signal was subsequently digitized and all values were scaled to the calibration signal, separately for each channel.

An observer stationed in the playroom timed each of the epochs. Behavioral and physiological data were synchronized by placing simultaneous event marks on the FM and video tapes.

Behavioral Data Coding

The videotaped data were coded in two ways: First, each of the videotapes was coded using Izard's Maximally Discriminative Facial Action Coding System (MAX; Izard, 1979). The MAX system describes 27 facial-movement units or appearance changes that in various specific combinations identify 10 affect expressions. An expression was coded if its duration was 1 s or longer. Each of the videotapes was scored by a rater trained in the MAX system who was blind to the experimental design and the particular epoch and condition events.

The videotapes were also coded by two coders who were trained on the behavioral system described by Waters, Matas, and Sroufe (1975). This system codes for the presence or absence of each of seven different behaviors including vocalization, gaze aversion, crying, motor movement, frowning, and avoidance. Previous data (Waters et al., 1975) have demonstrated a change in these behaviors in infants during a graduated stranger-approach sequence.

EEG analysis

EEG was low-pass filtered at 44 Hz (48 dB/octave) to prevent aliasing and then digitized with a PDP11/34 computer off-line at a sampling rate of 125 samples/s. All epochs confounded by either gross motor movement or eye movement artifact were eliminated prior to further analysis. The digitized data were then processed through a fast Fourier transform using a hamming window. Power density (in uV^2/Hz) was computed for all artifact-free EEG during each epoch in three frequency bands: 3–5, 6–8, and 9–11 Hz. We decided to examine power between 3 and 11 Hz on the basis of previous data that indicated that the majority of power in the EEG of 10-month-old infants is between these frequencies (Mizuno et al., 1970). In addition, because of direct current (DC) offset, we were concerned that power might be present in the 1- and 2-Hz bins that reflected these DC-like components rather than genuine changes in brain activity.

On the basis of the well documented association of activation with decreased power in the alpha band in adults (Lindsley and Wicke, 1974; Shagass, 1972) and the equally well-documented differences in dominant frequency of the infant EEG compared with adult EEG, we interpret decreases in power as indicative of activation. At this time, the specific frequency range of infant EEG that corresponds to adult alpha is not well specified. We therefore examined power in frequency bands of equal size from 3 to 11 Hz. Power in this range accounts for the majority of variance in infant EEG.

Results

Behavioral data

Two types of behavioral data were examined in this study: the presence of discrete facial expressions of emotions and the presence of behavioral signs of wariness or distress. Both sets of data revealed two important things: (a) differences were found across conditions in behaviors that reflect emotion and (b) considerable heterogeneity of response within condition was superimposed on these condition differences. For purposes of this research we were concerned with locating those condition–epoch combinations that demonstrated the most significant changes in either facial or other behavioral signs of emotion.

Table 2 presents the number of subjects who displayed different discrete facial expressions during each of the experimental conditions. During both the first stranger-approach sequence and the mother-approach sequence there was a high incidence of the emotion of joy. There was also a relative absence of anger, fear, or sadness during either of these conditions. A dramatic change in facial behavior was observed, as predicted, in response to maternal separation. This condition produced an increased incidence of anger and a decreased incidence of joy relative to the condition immediately preceeding it (mother reach). Thirty-seven percent of the infants displayed facial signs of joy during the mother-reach condition, and none of the infants displayed joy during maternal separation, $\chi^2(1, N = 19) = 8.58$, $p = .003$. In addition, only 11% of the infants displayed facial signs of anger during mother reach, but 58% displayed

Table 2
Number of Infants Displaying Discrete Facial Expressions During Experimental Conditions

Condition	Joy	Sadness	Anger	Fear
First stranger approach				
Enter	4	0	1	0
2 steps	7	0	0	0
2 steps	4	1	2	1
Reach	7	0	1	0
Mother approach				
Enter	9	2	2	0
2 steps	8	0	1	0
2 steps	7	1	1	0
Reach	7	1	2	0
Maternal separation	0	7	11	2
Second stranger approach				
Enter	2	6	4	2
2 steps	1	5	6	0
2 steps	2	5	5	2
Reach	1	5	5	1

Note. Data are based on the 19 subjects from whom artifact-free EEG was obtained. Note that more than one facial expression could have been contributed by an infant for a particular condition.

facial signs of this emotion during maternal separation, $\chi^2(1, N = 19) = 9.47, p = .002$.

Coding of nonfacial behavioral signs of emotion revealed a difference in the incidence of vocalization between the mother-enter and mother-reach conditions. During the mother-enter condition, 21% of the subjects showed vocalization, and during the mother-reach condition 58% of the subjects vocalized, $\chi^2(1, N = 19) = 5.40, p = .02$.

The measurement of behavioral signs of emotion indicated that reliable changes occurred between the mother-enter and mother-reach periods, and between the mother-reach and maternal-separation conditions. These behavioral data were used to guide our examination of condition-related EEG changes.

EEG Data

EEG data were examined by computing overall repeated measures analyses of variance (ANOVAS) for each of four condition comparisons for those epochs during which a sufficient amount of artifact-free data could be extracted: first stranger episode (enter/steps 1/steps 2/reach); mother enter versus mother reach; mother reach versus maternal separation; and maternal separation versus second stranger episode/enter epoch. These overall ANOVAS included condition, region, hemisphere, and band as factors. The Band factor was a three-level factor that consisted of power in the 3- to 5-Hz band, the 6- to 8-Hz band, and the 9- to 11-Hz band. When a significant main effect for band or interaction with band was obtained, separate ANOVAS with condition, region, and hemisphere as variables were computed for each of the three bands. Separate ANOVAS for each of the two regions were also computed in order to examine whether condition effects were specific to the frontal region, as we predicted they would be, based on previous research.

The overall ANOVA for the first stranger-approach condition ($N = 13$) revealed significant main effects for region, $F(1, 11) = 5.35, p = .04$, and band, $F(2, 10) = 40.46, p = .001$. The region effect was the result of greater activation in the frontal than in the parietal leads.[1] The band effect revealed greater power in the 3- to 5-Hz band than in the other two bands (Newman–Keuls, $p < .05$).

Separate ANOVAS on each of the three EEG bands were computed. There were no significant interactions with Condition for any of the three EEG bands.

During the mother-approach sequence sufficient artifact-free data for analysis was obtained only during the first and last epochs (mother enter and mother reach, $N = 9$). The overall ANOVA with condition, region, hemisphere, and band as variables revealed a significant main effect for region, $F(1, 8) = 9.08, p = .02$, and a significant main effect for band, $F(2, 7) = 15.68, p = .002$. The band main-effect was the result of greater power in the 3- to 5-Hz band than in the two other bands and greater power in the 6- to 8-Hz band than in the 9- to 11-Hz band ($p = .05$ for both, Newman–Keuls).

Separate ANOVAS for each band with condition, region, and hemisphere as variables revealed a significant three-way interaction for the 6- to 8-Hz frequency band, $F(1, 8) = 6.28, p = .04$. There were no significant interaction effects in the two other frequency bands. The 6- to 8-Hz data are presented in Figure 1. As can be seen from this figure there were no differences in the asymmetry of parietal-brain activity between the mother-enter and mother-reach conditions. However, frontal asymmetry discriminated reliably between these conditions. In response to mother enter, infants showed significantly more left-frontal power (i.e., less activation) compared with EEG from the same lead during mother reach ($p = .05$, Newman–Keuls). In addition, a significant difference was found in frontal power between the right and left hemisphere during mother enter ($p = .05$). No difference between conditions was obtained in right-frontal power. These data indicate an increase in left-frontal activation (decrease in power) during the mother-reach (compared with the mother-enter) condition. Seven of 9 subjects display this change in left-frontal activation between these conditions.

In order to examine the relation between vocalization during mother enter and mother reach epochs and frontal-EEG asymmetry, we computed point–biserial correlations between frontal-laterality ratio scores ($R - L/R + L$ power in the 6- to 8-Hz band) and whether or not the infant vocalized. During the mother-enter epoch the correlation was .59 ($df = 15, p < .01$),[2] and during the mother-reach epoch the correlation was .73 ($df = 8, p < .01$). These data indicate that the relative left-sided

[1] In all subsequent analyses where a main effect for Region is reported the differences between the frontal and parietal data are in the same direction as reported above.

[2] There was a total of 9 infants who had usable EEG data during both mother-enter and mother-reach epochs. However, there were 17 infants who had usable EEG during mother enter and 10 infants who had usable EEG during mother reach. Since we had data on vocalization for all of these infants, the correlations reported are based on all available subjects.

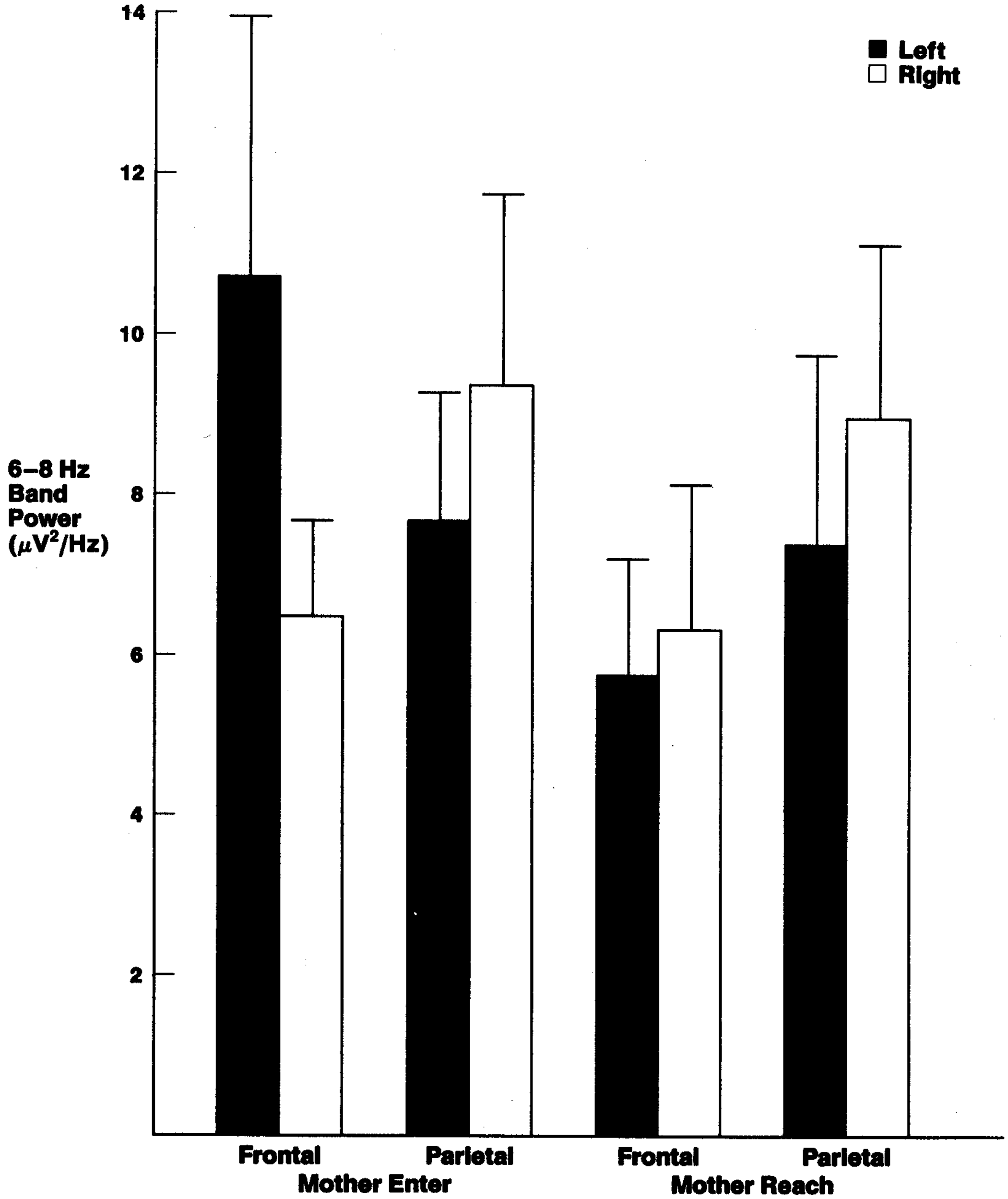

Figure 1. 6- to 8-Hz power density (in $\mu V^2/Hz$) for left- and right-frontal and left- and right-parietal (F3 and F4, P3 and P4, respectively) brain electrical activity during mother-enter and mother-reach epochs. $N = 9$ for this condition comparison.

frontal activation was associated with the presence of vocalization in the mother-approach condition.

From inspection of the videotapes of the infants behavior, it was clear that there were two behavioral patterns that occurred in response to maternal separation. Of the 14 infants for whom there was artifact-free EEG during this condition, 6 cried during maternal separation and the remainder did not cry or show overt distress.

The EEG data were examined as a function of the two different patterns of behavioral response during separation. Three different comparisons were examined. First, infant EEG for criers and noncriers in the condition just prior to the separation was compared with EEG during separation. Second, differences between criers and noncriers were examined during the separation episode itself. And, third, EEG of the criers and noncriers during separation was compared with EEG during the enter epoch for the second stranger approach (the epoch immediately following separation).

The overall repeated measures ANOVA comparing the mother-reach epoch to the maternal-separation epoch ($N = 4$ for criers and $N = 5$ for noncriers) revealed significant main effects for group, $F(1, 7) = 5.86$, $p = .05$, for region, $F(1, 7) = 12.82$, $p =$

.009, and for band, $F(2, 14) = 35.72$, $p = .001$ as well as a significant four-way interaction of Condition × Hemisphere × Band × Group, $F(2, 14) = 4.27$, $p = .04$. Separate ANOVAS on each frequency band were then computed. The ANOVA on the 3- to 5-Hz band revealed significant main effects for group, $F(1, 7) = 5.46$, $p = .05$, and for region, $F(1, 7) = 6.75$, $p = .04$. The group main effect was a function of less power for the criers ($M = 13.66$, $SD = 7.45$) than for the noncriers ($M = 26.63$, $SD = 20.70$). The three-way interaction of Condition × Hemisphere × Group was marginally significant, $F(1, 7) = 4.49$, $p = .07$. The ANOVAS on the 6- to 8-Hz band and 9- to 11-Hz band did not reveal any significant main or interaction effects.

Although no interaction with region was obtained for the 3- to 5-Hz analysis, separate ANOVAS for the frontal and parietal regions for this frequency band were computed. These analyses were performed to investigate a priori hypotheses on the basis of previous findings (Davidson & Fox, 1982; Fox & Davidson, 1986). The ANOVA on the frontal leads revealed, as predicted, a significant Condition × Hemisphere × Group interaction, $F(1, 7) = 6.10$, $p = .04$. The same interaction for the parietal leads was not significant. The frontal data are presented in Figure 2. As can be seen from this figure, during the mother-reach epoch, criers displayed less left-frontal power (increased left-frontal activation) than noncriers ($p < .01$, Newman–Keuls). Between the mother-reach and separation conditions, noncriers displayed a significant increase in right-frontal power (decrease in activation, $p < .05$). The pattern of asymmetry in the criers appears to reverse itself between the two conditions (mother reach and separation), although differences were not significant. However, during separation, criers displayed more right-frontal activation than noncriers ($p < .01$) (i.e., less power in the 3- to 5-Hz band). Seven of the 9 subjects (3 of 4 criers and 4 of 5 noncriers) displayed these changes in frontal asymmetry between the mother-reach and maternal-separation conditions.

An ANOVA ($N = 6$ for criers; $N = 8$ for noncriers), with group, region, hemisphere, and band as factors, was computed for the maternal-separation episode. Significant main effects were obtained for region, $F(1, 12) = 6.02$, $p = .03$, and band, $F(2, 11) = 12.14$, $p = .002$. The direction of these effects is the same as reported above. No other significant effects were obtained. In the separate ANOVAS for each band, no significant interactions with group were obtained.

The overall ANOVA, which included band, comparing the maternal-separation condition and the enter epoch of the second stranger-approach condition revealed a significant main effect for band, $F(2, 16) = 20.67$, $p = .001$. However, none of the separate band analyses comparing the maternal-separation condition and the second stranger-approach/enter epoch revealed interactions of condition with hemisphere or any group (crier or noncrier) differences.

Discussion

The data from this study indicate that reliable changes in frontal-EEG asymmetry occur during both the mother-approach sequence and between the mother-reach and maternal-separation conditions. During mother reach, infants showed greater left-sided frontal activation compared with EEG during the mother-enter condition. Importantly, no differences in parietal asymmetry were observed between these conditions. The presence of vocalization during these periods was highly correlated with frontal-activation asymmetry. Those infants who vocalized showed more left-sided frontal activation than those who did not vocalize.

The second major finding to emerge from this study was the difference in the pattern of frontal asymmetry associated with individual differences in behavioral response. Those infants who cried in response to maternal separation showed a large increase in relative right-frontal activation during this condition compared with the condition immediately preceeding this epoch (mother reach). The noncriers displayed a change in right-frontal power between these conditions, with a decrease in activation observed during the maternal-separation (compared with the mother-reach) conditions. Again, no differences between these groups were found in parietal asymmetry.

The finding that subjects showed increased left-frontal activation in response to the mother-reach (compared with the mother-enter) condition is consistent with the behavioral data. Specifically, infants displayed increased vocalization during the reach (compared with the enter) epoch. Kinsbourne (1978) has suggested that vocalization and approach behavior are closely linked, particularly in infancy. The pattern of left-frontal activation during the reach versus enter epochs of the mother-approach condition may index this increase in behavioral signs of approach. The fact that no differences between these conditions were observed in the parietal leads again underscores the special involvement of the frontal lobes in affective behavior. It is not possible to disentangle from these data whether the left-sided frontal activation reflects the mere presence of vocalization or the positive affective state that presumably was reflected in the vocalization during the mother-approach sequence. At the very least, this finding suggests that vocalization should be carefully monitored in studies concerned with EEG asymmetries during the generation of affect.

Our finding of differences in frontal-EEG asymmetry that distinguish between infants who differ in their response to maternal separation is also consistent with adult findings on differences in frontal-EEG asymmetry between subjects who differ in affective style (see reviews by Davidson, 1984a; Tucker & Williamson, 1984). The infants who cried in response to maternal separation showed an increase in relative right-frontal activation in this condition compared with the preceeding condition, and those infants who did not cry in response to this stressor showed a decrease in activation of the right-frontal region. This decreased activation may reflect an active inhibition of the right-frontal region. The degree to which infants exhibited this inhibition may be associated with individual differences in affective style (see Fox & Davidson, 1984, for a discussion of this issue).

An important methodological issue is illustrated by the data from this study. Some of the significant effects were obtained for the 6- to 8-Hz frequency band and others were obtained for the 3- to 5-Hz frequency band. These band windows were arbitrarily chosen within the frequency range accounting for most of the variance in EEG from 10-month-old infants (3–11 Hz). It is possible that if we chose a 4- to 6-Hz band, all of the significant effects would have been obtained for just this single

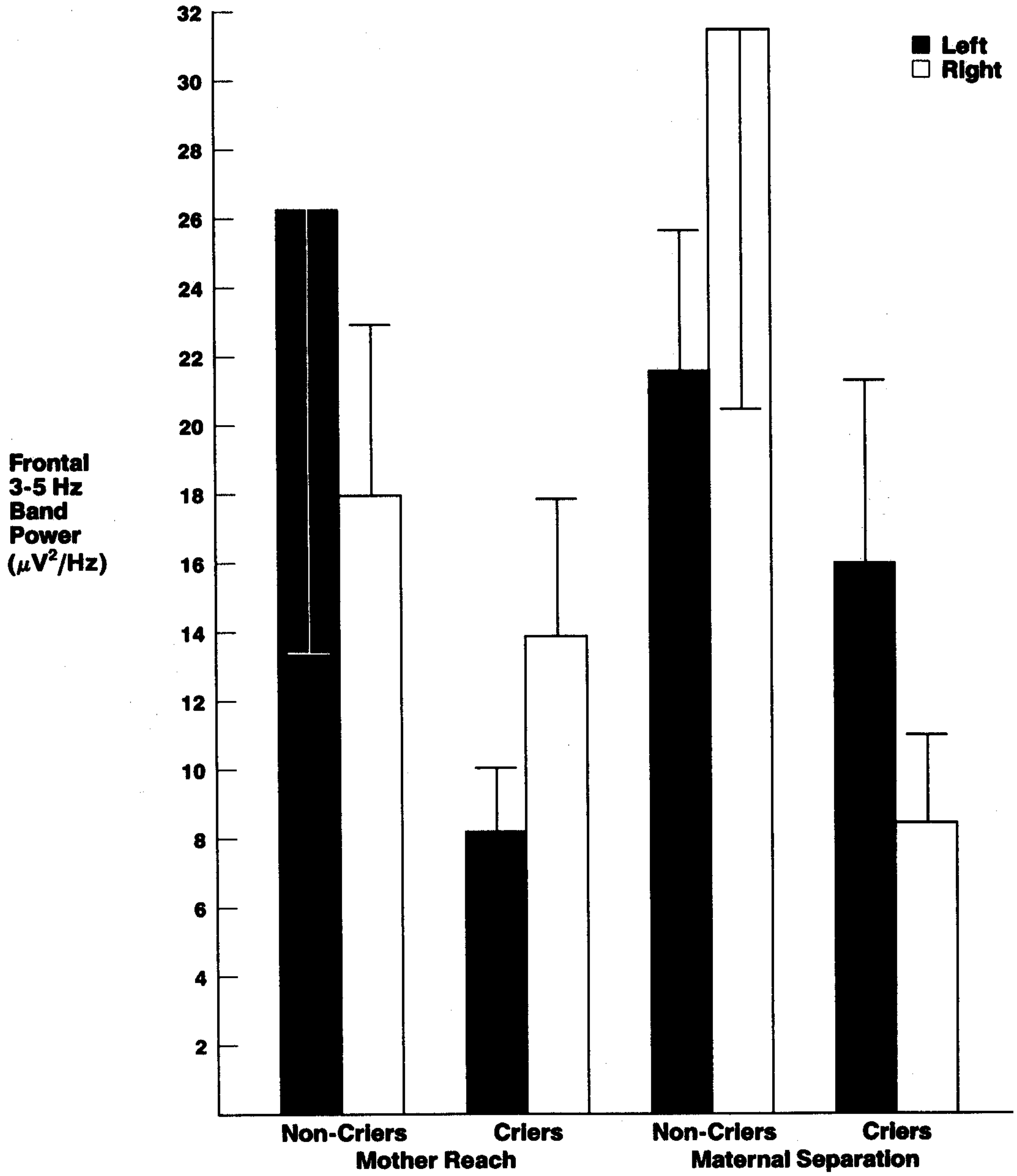

Figure 2. 3- to 5-Hz power density for left- and right-frontal brain electrical activity during mother-reach and maternal-separation epochs for criers ($N = 4$) and noncriers ($N = 5$).

band window. An examination of the factor structure of infant EEG is required to empirically determine band boundaries. The functional significance of these empirically derived bands could then be systematically explored. This type of analysis requires a very large sample size for the factor analysis. We are in the process of collecting a sufficiently large number of subjects across several different experiments in order to address this issue.

A relatively high proportion of subjects displayed facial signs of joy in response to the initial stranger-approach sequence and the mother-approach condition. In response to maternal separation, a dramatic change in facial behavior was observed with the majority of infants showing facial signs of sadness and anger. The large percentage of subjects displaying these emotions was continued in the final stranger-approach epoch (when the mother was absent).

It is noteworthy that there were few instances of facial expressions of fear that could be coded during the first or second stranger approach. Although infants displayed other signs of wariness (e.g., gaze aversion and crying, especially during the second stranger approach), they did not exhibit facial behaviors that indicated the presence of fear. Few studies have used a microanalytic system to code facial behavior during stranger approach and those that have used such a system (e.g., Hiatt et al.,

1977) found stranger approach to elicit few of the components of facial signs of fear.

An important methodological issue associated with the attempt to compare physiological changes among conditions assumed to produce different emotions should be addressed. In most studies of the physiological manifestations of emotion in both infants and adults (including this study) the assumption is made that well-defined stimulus situations will produce consistent changes in affective behavior. According to this logic, comparisons among conditions in physiology are therefore straightforward because the conditions are assumed to differ in the characteristic affective behavior that they produce. The data obtained in this study clearly underscore the complexity and heterogeneity of affective response and therefore call into question the validity of this assumption. Indeed, several emotion theorists have highlighted the lack of precise stimulus response relations as the sine qua non of emotion (e.g., Ekman, 1984). Two conclusions emerge from these considerations. The first concerns the desire in future research to select elicitors that maximize the likelihood of obtaining a greater number of instances of "pure" emotion. The second concerns the utility of relating EEG changes to individual differences in behavioral responsiveness to the elicitor. The importance of this effort is underscored by the findings from this study.

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Received July 28, 1985
Revision received September 28, 1986 ■