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The role of frontal activation in the regulation and dysregulation of social behavior during the preschool years[*]

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Abstract:

We examined whether the interaction of resting frontal electroencephalogram (EEG) asymmetry and social behavior during peer play was related to the occurrence of maladaptive behavior in preschoolers. Two independent cohorts of children were observed interacting in same-age and -gender play quartets at 4 years of age. Each child was also seen individually for a psychophysiology session during which time measures of EEG activity were recorded. We found that highly sociable children who exhibited greater relative right frontal EEG asymmetry were more likely to exhibit externalizing problems than sociable children who exhibited greater relative left frontal EEG asymmetry. We also found that shy children who exhibited greater relative right frontal EEG asymmetry were more likely to exhibit internalizing problems than shy children who exhibited left frontal EEG asymmetry. These findings suggest that the pattern of frontal EEG asymmetry in combination with social behavioral style is a significant predictor of maladaptive behavior problems during the preschool period.

Article:

It has been suggested recently that the development of competent and incompetent social behavior in childhood is multiply determined. For example, in their pathways models, Rubin and colleagues have indicated that infant temperament, the quality of the parent-child relationship, and parental style "conspire" to provide an ecological niche within which develop normal or abnormal social and emotional behavioral styles (Rubin, Hymel, Mills, & RoseKrasnor, 1991; Rubin, LeMare, & Lollis, 1990). Although researchers have traced the predictive relations between early parent-child relationships and parenting styles and the development of children's adaptive and maladaptive behaviors (e.g., Booth, RoseKrasnor, & Rubin, 1991; LaFreniere & Dumas, 1992; Sroufe, 1983), the extent to which child temperament, and especially the process

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of emotion regulation, is a contributor remains relatively unknown. Nevertheless, recent evidence from our laboratory suggests that the origins of adaptive and maladaptive social behavioral styles may be found in the patterns of temperamental behavior that infants display in the first months of life.

The histories by which these infant temperaments are transformed involve many steps each linked to age or developmentally appropriate skills. Thus, for example, one of the first skills attained by infants is their control over the level of affective arousal. The establishment of appropriate sleep-wake rhythms and the increasing ability to utilize cognitive strategies for modulation of arousal are attained during the first year of life (Cicchetti, Ganiban, & Barnett, 1991). Later, the child must successfully deal with a wide range of novel and potentially threatening stimuli or conditions. The ability to modulate approach and withdrawal behaviors reflects an important social goal attained usually in the second year of life. The child must then be able to negotiate successfully with same-age peers in the social group. Learning how to share, cooperate, and interact with peers is a significant attainment during the preschool years.

The child's ability to negotiate successfully each of these steps is linked to successful continuation along a path of social competence (Howes, 1988). The child who is unsuccessful at early stages in negotiating his or her way in the social world may be embarking on a pathway to negative or maladaptive outcomes (see Parker, Rubin, Price, & DeRosier, 1995 for a recent review).

To understand the complex processes by which these varied and complex outcomes occur, it is necessary to first examine the temperamental origins or beginnings of these processes. A complete understanding of the effect of temperament on social behavior may inform us about the potential for maladaptive behavior in the young child.

Infants, at birth, vary in the manner in which they respond to stimuli. These individual differences in response thresholds and modes of response make up that which is generally referred to as the infant's personality or temperament. In general, most infants from the first weeks of life, are able to display a range of responses to stimuli presented to them. During these early months, they begin to regulate their pattern of internal arousal, establishing regular sleep-wake cycles and modulating their distress when soothed. These aspects of infant reactivity and regulation represent the origins of individual differences in behavioral response (Rothbart & Derryberry, 1982). Rothbart and Derryberry catalogued three aspects of infant reactivity including the latency with which the infant responds, the intensity of the response, and the frequency of that response. These aspects comprise the newborn's pattern of reactivity. Rothbart and Derryberry speculated that individual differences in reactivity had a biological origin and formed the basis of infant temperament.

Goldsmith and Campos (1982) elaborated on this notion of individual differences by referring to temperament as the manner in which individual infants expressed different discrete emotions. Thus, infant temperament was described as the degree to which certain emotions are expressed. The parameters of infant expression were similar to Rothbart and Derry-berry's (1981) parameters of reactivity; frequency, intensity, and latency of response of the expression of different emotions were posited to make up the characteristics of infant temperament. In this scheme, infants differ along these aspects in the manner in which they express anger, distress, joy, fear, sadness, and other discrete emotions.

Drawing upon the work of Rothbart and Derryberry (1981) and Goldsmith and Campos (1982), Kagan (Kagan & Snidman, 1991a) and Fox (Calkins, Fox, & Marshall, in press) have identified groups of infants who display a high degree of reactivity and are likely to express this reactivity via singular discrete emotions. Kagan and Snidman (1991a) identified infants who exhibited not only a high degree of motor reactivity, but also cried when presented with novel visual and auditory stimuli. Calkins et al. (in press) singled out infants who were both highly reactive to novelty and expressed this reactivity via a high frequency of negative affect and distress. In both instances, these infants displayed more fearfulness and behavioral inhibition as toddlers than other children (Calkins et al., in press; Kagan & Snidman, 1991b). Calkins and Fox (Calkins et al., in press) also identified a second unique group of infants. These were children who were highly reactive to novelty and expressed this reactivity via a high frequency of positive affect and vocalizations. These infants, they found, were sociable, exuberant, and at times, aggressive and impulsive as toddlers (Calkins et al., in press). Thus, it may be that the origins of inhibition and fearfulness or sociability and exuberance may be found in unique patterns of infant response to the environment. Reactivity and the disposition to express either positive or negative affect are innate attributes of two different but unique subgroups of infants. The intersection of reactivity and expression of negative affect reflects one temperamental type; the intersection of reactivity and positive affect reflects a second temperamental type.

Data from our laboratory (Fox, Calkins, & Schmidt, 1995) suggest that there are unique coherent patterns of physiology that underlie each of these temperamental types. These physiological patterns are reflected in EEG activity, heart rate, neuroendocrine activity and potentiated startle amplitude. Specifically, highly reactive infants who are disposed to express negative affect display right hemisphere EEG activity, elevated heart rate, elevated cortisol, and augmented startle amplitude. This physiological pattern of responses may reflect a hypersensitive amygdala, particularly areas of the amygdala involved in the maintenance of behaviors associated with conditioned fear (the central nucleus). The amygdala is involved in downward control of autonomic activity, and there are recent data indicating that central cortisol in the amygdala is elevated during the maintenance of fear states (see Schulkin, McEwen, & Gold, 1994 for a review).

Data from Kagan's laboratory have provided some of the evidence for these biological differences. For example, behaviorally inhibited toddlers display a pattern of elevated and stable heart rate over time and display consistent elevated levels of cortisol compared with noninhibited children (Kagan, Reznick, & Snidman, 1987, 1988). And, we have found that infants who are selected for characteristics of high motor reactivity and a disposition to express negative affect, are likely to exhibit greater relative right frontal EEG asymmetry (Calkins et al., in press).

In addition, Fox's laboratory utilized the potentiated startle paradigm with infants who differ in temperament (Schmidt & Fox, 1995). This paradigm, first described in the animal literature and used as a model system for studying fear conditioning, allows examination of the excitation of subcortical circuits including the amygdala and its central nucleus in the maintenance and response of the subject to fearful stimuli. In this study (Schmidt & Fox, 1995), auditory startle probes were presented to infants during a neutral condition and during approach of an unfamiliar adult. Data revealed that infants selected at 4 months as high motor reactive/high negative affect exhibited augmented potentiated startle responses compared with other infants, suggesting that differences in temperamental fear are indeed mediated by these amygdala circuits.

These high reactive/high negative infants are likely to display behavioral inhibition during the toddler years. Inhibited behavior is elicited by stimuli that are novel and by situations that may be interpreted as mildly stressful to the child. The behaviors seen include a high degree of vigilance, withdrawal behavior, anxious behaviors, negative affect, and a high degree of proximity seeking to a known caregiver.

Highly reactive infants who are disposed to express positive affect also provide us with a unique neural signature reflected in patterns of EEG activity, heart rate, and potentiated startle amplitude. These infants display left hemisphere EEG activity, low and variable heart rate, and attenuated startle responses in response to auditory startle stimuli. This pattern of response may reflect a dampening of amygdala action via specific limbic pathways. Highly reactive infants who were disposed to positive affect are likely to exhibit, as toddlers, extreme degrees of sociability, lack of fear, and in some instances impulsivity, and anger. But, in general, they are engaging and highly sociable children.

From among these two extreme groups, some children as they enter preschool appear to moderate their patterns of social response; while others continue to exhibit high degrees of fear and vigilance or high degrees of sociability, impulsivity, and anger. Thus, from among those children who may be observed to exhibit behavioral inhibition and vigilance in the second year of life, a subgroup of children emerges who, when interacting with peers or presented with novel social situations, exhibit shy, socially wary, and reticent behavior.

We have defined reticent behavior as a combination of onlooking and unoccupied responses that children make within a novel social peer setting (Coplan, Rubin, Fox, Calkins, & Stewart, 1994; Rubin, Coplan, Fox, & Calkins, 1995). This reticence is often accompanied by expressions of anxiety as well. Alternatively, behaviorally inhibited young children may find the means to regulate their arousal in the face of novelty; as such, they may not appear reticent or withdrawn as preschoolers (Rubin et al., 1995).

As with the behaviorally inhibited children, we suggest that there are multiple outcomes possible for extremely sociable children (e.g., Rubin et al., 1995; Rubin & Rose-Krasnor, 1992). For example, Rubin et al. (1995) reported that among highly sociable preschoolers, there are at least two distinct subgroups — those who are engaging and friendly in their behavior, and those who are angry, oppositional, and often impulsive. Thus, some highly sociable children may not have the means to moderate their arousal level and may appear oppositional and maladaptive.

A key element mediating the pathways to either adaptive or maladaptive behavior in either highly inhibited or highly sociable children involves emotion regulation. Children in either group who are able to manage their affective response appear to present with adaptive behavior, and children who are unable to manage or regulate their affect may present with maladaptive responses.

There are multiple means through which effective emotion regulation may occur. Among these means are the ability to switch attentional set, to have access to a range of different emotions, to verbally mediate affective response, and to plan and have flexibility when confronted with frustrating situations (Thompson, 1994). Underlying these skills is the development and effective use of certain areas of the frontal region.

A variety of data indicate that certain areas of the frontal lobes are involved in the management of emotion expression and the generation of strategies and skills necessary for the regulation of affect (see, e.g., Fox, 1994). These data are derived from a number of sources including work on the emotional consequences of localized brain lesions (see, e.g., Robinson, Kubos, Starr, Rao, & Price, 1984; Robinson & Szetela, 1981), the affective reactions of patients undergoing sodium amytal examination (WADA test; Perria, Rosadini, & Rossi, 1961; Serafetinides, Hoare, & Driver, 1965; Terrazian, 1964), and research on brain electrical activity patterns in clinical populations (Henriques & Davidson, 1991).

There are two major positions derived from these diverse data sets. One argues that specific areas of the right hemisphere control both the perception and expression of different emotions. The right frontal region in particular is intimately involved in the control of emotion expression (Borod, 1992). A second position, known as the valence model, postulates that the management or control of emotion expression is lateralized such that the control of negative emotions is localized to the right frontal region, while the control of positive emotions is localized to the left frontal region (Silberman & Weingartner, 1986).

A number of theorists have argued that the dimension along which emotional control is lateralized is one involving approach or withdrawal (Fox & Davidson, 1984; Kinsbourne & Bemporad, 1984). That is, emotions involving approach are controlled or managed by regions of the left frontal cortex, while emotions involving withdrawal are managed or controlled by regions of the right frontal cortex.

A more recent re-statement of this valence model (Fox, 1994) argues that emotional control is derived from the dynamic balance or interaction between the two frontal regions. Areas in the right frontal region (and the competencies they subsume) are involved in the management of negative affect and distress. Right frontal activation is involved in the control of the expression of negative affect. Areas of the left frontal region (and the competencies they subsume) are involved in the management and control of positive affects. Left frontal activation is involved in the control of the expression of positive affects. This dynamic interplay between the left and right frontal cortices suggests a more complex and involved pattern of brain activity in the control and regulation of emotion.

As such, differences in frontal activation may be related to effective emotion management, and hence lead to the presence of either maladaptive or adaptive behavior. A frontal hypothesis has been presented by a number of different researchers with regard to conduct disorder and externalizing disorders (Kusche, Cook, & Greenberg, in press; Moffitt & Henry, 1989; Moffitt & Silva, 1988). Most of this research, however, has involved the study of children already identified with conduct or acting out problems. Few researchers have identified differences in frontal activation and have related them to specific temperamental patterns that may lead to maladaptive behavior (for an exception, see Moffitt, 1993).

Our working hypothesis then, has been that within extreme temperamentally defined groups of children, there will be those who will exhibit high degrees of either sociability or reticence. From among those exhibiting sociability or reticence, we should be able to differentiate between children who display adaptive versus maladaptive patterns of behavior as a function of the pattern of frontal activation.

In a series of studies with young adults, children, and infants, we have demonstrated that individuals exhibiting greater relative right frontal activation are more likely to display negative affect, while individuals exhibiting greater relative left frontal activation are more likely to display positive responses to novelty. For example, adult subjects displaying resting relative right frontal EEG activation were more likely to rate videotapes in a negative fashion (Jones & Fox, 1992) and more likely to be low on social approach (Schmidt & Fox, 1994) compared with individuals exhibiting resting left frontal activation. Fox et al. (in press) found that 4-year-old children with resting right frontal asymmetry were more likely to exhibit reticence and anxious behaviors during a peer play session compared with children exhibiting greater relative left frontal activation. Fox, Bell, and Jones (1992) reported that 10-month-old infants exhibiting greater relative right frontal activation during a neutral baseline situation were more likely to display separation distress compared to infants displaying left frontal activation.

Fox (1991, 1994) had earlier suggested that the pattern of resting frontal activation might reflect two salient aspects related to expression of emotion: a dispositional tendency to express either positive or negative affect and an ability or inability to modulate or regulate that affective response. Individuals with resting right frontal activation may be more likely to express negative affects and may be less able to modulate those affective responses. Individuals with resting left frontal activation, while more likely to express positive affect, would also be more likely able to regulate the expression of negative affect or distress.

In this study, we were interested in examining whether differences in the pattern of resting EEG frontal asymmetry would allow us to differentiate among children who exhibited reticent behavior in a standard play session or among children who exhibited sociable behavior in the play session. We predicted that the interaction of frontal EEG pattern and social behavior would produce the strongest effect with regard to the occurrence of maladaptive behavior. That is, reticent children exhibiting right frontal asymmetry should exhibit more internalizing symptoms than reticent children exhibiting left frontal asymmetry. Similarly, sociable children exhibiting right frontal asymmetry should exhibit increased symptoms of externalizing problems than sociable children exhibiting left frontal activation.

To test these hypotheses, we combined the data from two cohorts of children both seen at 4 years of age in identical testing situations. At age 4 years, children were observed in same-sex play quartets. In addition, each child was seen individually for a psychophysiology session during which measures of EEG activity were recorded. Mothers of the children were asked to fill out the Achenbach Child Behavior Checklist (CBCL; Achenbach & Edelbrock, 1981), and the internalizing and externalizing sub-scales were computed for each child. We then examined whether child behavior during the quartet session independently or in combination with frontal EEG activity best predicted internalizing and externalizing problems.

Method

Subjects

The subjects of this study were 96 preschool children (40 males and 56 females) from two independent cohorts. The children ranged in age from 46 to 62 months (M = 54.75 months, SD = 4.8 months). The children were primarily Caucasian (91.6%) (minority = 8.3%) and of middle-class background. All of the parents had completed high school and a majority of mothers (82%) and fathers (82%) were college graduates. The children were, for the most part, living with their families in or near College Park, Maryland.

Cohort 1. Cohort One consisted of 48 children who had been recruited when the children were 2 days of age in the newborn nursery. These children were randomly selected with the major exclusion criteria involving prenatal and postnatal health problems. Mothers of infants who had prenatal complications or infants who had perinatal health problems were excluded (see Stifter & Fox, 1990). These subjects were followed-up in the laboratory at 2 years of age, at which time they were observed in a series of conditions designed to assess their social responsiveness. These conditions included presentation of a robot, tunnel, and unfamiliar adult (see Kagan et al., 1987). The children's behaviors were coded and an index of behavioral inhibition was computed. High scores on this index reflected behaviors of long latency to approach and long duration proximity to mother; and low scores reflected the opposite pattern of behavior (see Calkins & Fox, 1992). Same gender quartets were organized using children's scores on this index: each quartet attempted to include one child who scored high on the index, one child who scored low on the index, and two children whose scores were near the mean.

Cohort 2. A second cohort of 48 children were recruited when they were 4 years of age. Again the major exclusion criteria were maternal prenatal health status and infant postnatal health status. Mothers of these children were given the Colorado Child Temperament Inventory (CCTI; Buss & Plomin, 1984; Rowe & Plomin, 1977). From the mother's answers on this questionnaire, the factors tapping sociability and shyness were computed. Children were rank-ordered on each of these two factors and same-sex play quartets were organized on the basis of these ranks. Each quartet attempted to have one child who was high on the shyness factor and low on the sociability factor, one child who was high on the sociability factor and low on the shyness factor, and two children whose scores on both these factors were near the mean.

Procedures

Play quartets. The four children and their mothers came to the laboratory. Children and mothers waited in an area of the lab until all four children had arrived and all parents had been briefed and consent granted. The four children were then led into a playroom containing a set of attractive toys. The children were told that they were to play in this room for a while and that afterward they would participate in a set of games. The children in each quartet had never met each other. Their main point in common was that all were participants in the larger longitudinal study. Children were given name tags, which were pinned onto their backs so that their names would be visible to the video camera. The sessions were video- and audiotaped for future coding and analysis.

The quartet session consisted of five parts. Part I was free play and lasted for 15 min. During this period of time the four children were in the room by themselves. Parents were in a waiting area and were asked, during this time, to fill out a series of questionnaires. Part II was a clean-up session that lasted up to 5 min. An experimenter entered the room and told the children that the free play session had ended and that they were going to play a series of games. The experimenter asked the children to clean up the toys, placing them in a large cardboard box that had been placed in the center of the playroom. Part III of the session consisted of speeches (10 min). The experimenter asked the four children to sit in a semicircle facing her (the children were facing the one-way mirror and their faces could be easily videotaped). The experimenter then told the children that they were going to play a brief game of show-and-tell during which each child would stand up and tell the rest something about their recent birthday party. The experimenter then asked for volunteers and allowed each child to stand and talk for up to 2 min. Following the speeches, the experimenter brought to the center of the room a small table and four chairs and asked the children to sit around the table. A basket with colored cards was on the table and the experimenter asked the children to take one card of each color and make up five sets of cards (Part IV). Following this, the final 15-min free play session began (Part V). The experimenter re-entered the room, brought the box with toys and allowed the children to play in the room by themselves for an additional 15 min.

During this visit to the laboratory, arrangements were made with each mother for an individual follow-up visit. These visits were usually within 2 weeks of the quartet session. Mothers were told that at the follow-up visit there would be a psychophysiological assessment and additional testing.

Individual visit. Children came in individually about 2 weeks later for a session in which EEG was recorded while they sat quietly attending to an interesting visual stimulus. Mothers of the children were asked to fill out the CBCL (Achenbach & Edelbrock, 1981) as well as the Colorado Child Temperament Inventory (Buss & Plomin, 1984; Rowe & Plomin, 1977).

EEG recording. When the child and mother returned to the lab, the child was shown the testing room, which had been decorated and designed to resemble a space shuttle. There were pictures of planets on the wall and ceiling, and a chair had been decorated as the command chair for the spaceship. In addition, a computer had been placed in the room and cardboard around the computer was set and painted to illustrate the controls of a spaceship.

A Lycra stretch cap was placed on the child's head for EEG recording. The cap contained the electrodes for EEG recording placed in an arrangement in accordance with the 10-20 system (Jasper, 1958). A small amount of Omni-Prep abrasive was put into each site and the scalp gently abraded with the blunt end of a Q-tip. A small amount of electrolyte was then placed in the site and impedances were checked. Impedances were accepted if they were 5K ohms or below.

EEG was recorded from six sites (F3, F4, P3, P4, 01, 02, referenced to vertex, Cz). In addition, separate channels for A 1 and A2 each referenced to Cz were recorded. Finally, Beckman mini-electrodes were placed on the outer canthus and supra orbit of one eye to record EOG.

All nine channels were amplified by individual 7p511 Grass AC amplifiers with the high pass setting at 1 Hz and the low pass at 100 Hz. The data from all nine channels were digitized at 512 Hz on an IBM AT using HEM acquisition software. The digitized data were stored for later artifact editing and analysis.

After the cap was in place and impedances were checked, a computer program was started. The program consisted of a colorful design creating a taurus and a star. The taurus and star were separate segments, and each lasted for 15 to 30 s. Each child was presented with a minimum of six taurus and star segments with the goal of collecting at least 3 min of EEG data during each condition. The child was instructed to hold still and attend to the screen when the star came on. The child was told that if he or she could attend to the star, he or she would win a prize at the end of the session.

EEG was recorded continuously during the computer session and a separate channel indicated the onset and offset of the star section. An unobtrusively placed camera recorded the child's behavior, including visual attention to the computer monitor, during the EEG recording. After the recording session, which lasted 10 min, the cap was removed, and any excess gel was removed from the child's hair. The child was taken to a second room for additional assessments.

Behavioral coding

The videotapes of the quartet sessions were sent to the second author (KHR) for coding. Coders were blind to the assignment of the individual children and to the hypotheses of the study.

<u>Free play sessions.</u> Behaviors in the first and second play sessions were coded with Rubin's (1989) Play Observation Scale. Tens intervals were coded for social participation (unoccupied, onlooking, solitary play, parallel play, conversation, group play) and the cognitive quality of play (functional, dramatic, and constructive play; exploration; games-with rules). This resulted in approximately 90 coding intervals per child in each of the two free play sessions.

Additional variables coded during the free play sessions included: (a) the proportion of observational intervals that included the display of anxious behaviors (e.g., automanipulatives, digit sucking, crying); (b) the latency to the child's first spontaneous utterance (first play session only); (c) the frequency of child-initiated social interactions; and (d) the frequency of social initiations from peers.

<u>Clean-up and ticket-sorting sessions.</u> During the clean-up and ticket-sorting sessions, the proportion of time each child spent off task-unoccupied was recorded. Behaviors were considered off-task during the cleanup if they did not involve such actions as picking up toys, or placing toys in the toy box. Off-task behaviors during the ticket-sorting session included not sorting tickets or not talking about the task at hand. Unoccupied behavior was defined similarly to the behavioral variable of the same name used during the free play sessions. Time spent off-task but engaged in any other type of alternative activity (e.g., goofing off, continuing to play with toys, disrupting others who were trying to clean up/sort tickets), was coded as off-task-goofing off.

Speeches. The speeches were coded for (a) the duration of the entire speech episode and (b) the percentage of time each child actually spent speaking. The duration of the episode was defined as the amount of time that each child "held the floor," from the moment he/she was asked to speak, until the researcher asked the next child to speak. The percentage of time spent talking was calculated by dividing the amount of "real-time" during which each child verbally described their birthday party, by the duration of their speech episode.

Reliability. The Play Observation Scale (Rubin, 1989) and additional observational variables were coded by four independent observers. Interrater reliability on a randomly selected group of children totaling 30% of the sample (4 quartets; 16 children) was calculated between pairs of observers using Cohen's kappa. Kappas between pairs of raters ranged between K = 0.71 and K = 0.86. Intercoder disagreements were resolved by review and discussion.

EEG data reduction and measures

The digitized EEG data were transformed via software to an average reference configuration. The data were then scored manually for eye movement and gross motor movement artifact using software designed by James Long, Inc. The software allowed the display of all channels graphically on the computer screen. Using a cursor the operator could underline those sections of the EEG that were contaminated by motor movement or that contained eye movements as indicated by activity in the EOG.

Two coders, previously trained and tested to reliability, artifact scored the EEG data. One coder was responsible for scoring all subjects, and a second coder overlapped on 12 subjects. Cohen's kappa was computed to examine reliabilities among the coders. Kappa values ranged from 0.60 to 0.80.

The artifact-scored EEG was then analyzed using the same software system with a discrete Fourier transform, with a Hanning window of 1 s in length and 50% overlap. Power in single hertz bins from 1 through 20 Hz was computed for each segment of the taurus and star.

We computed a single composite measure of EEG power in the 6-8 Hz frequency band for the star condition by averaging across all star segments. EEG power for each site was then natural log (In) transformed. A laterality difference score was then computed for each homologous region as follows: (In power right hemisphere - In power left hemisphere). Positive scores on this metric are thought to represent greater relative left activation (Davidson & Tomarken, 1989).

Measures

On the basis of the play and interaction data, aggregate measures were formed reflecting' shyness (CCTI shyness scale, plus reticence) or sociability (CCTI sociability scale, plus group play, plus peer conversations). The individual measures that comprised each aggregate were z-scored before summing. Each of these aggregates was z-scored, and children in approximately the upper and lower 30% were selected.

Two additional aggregates were formed and served as the primary dependent measures. One aggregate reflected the incidence of externalizing behaviors (CBCL externalizing scale, plus acting out behavior during clean-up and ticket task, plus aggressive behavior); a second reflected the incidence of internalizing behavior (CBCL internalizing scale, plus off-task-unoccupied during clean-up and ticket task, plus anxious behavior). The individual measures that comprised each aggregate were z-scored before summing.

On the basis of the EEG assessment, each child was assigned a frontal laterality index reflecting relative left or right frontal EEG activation.

Data analyses

Initial analyses were computed to examine whether there were any differences in each of the dependent measures between cohorts one and two. The lack of any differences allowed us to combine the data from both cohorts for the subsequent extreme groups analysis.

To examine the interaction of the frontal asymmetry score and social behavior in predicting child maladaptive behavior, we computed a series of analyses of variance (ANOVAs) with frontal asymmetry score (left/right) and social behavior group (high/low) as between-subject factors. These analyses were computed separately on the aggregate outcome measures of internalizing and externalizing behaviors.

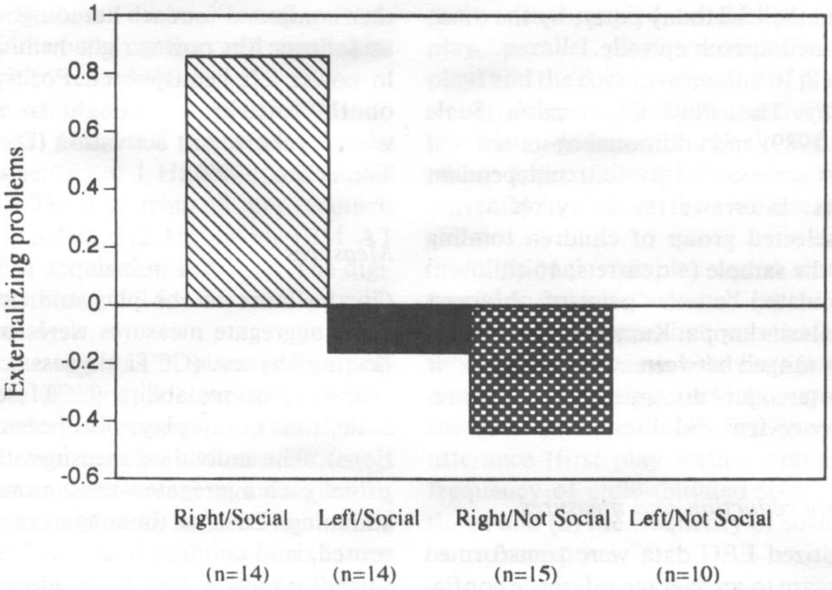

Figure 1. Frontal EEG activation and sociability in relation to preschoolers' externalizing problems.

Results

Frontal EEG asymmetry and social behavior in externalizing behaviors

Figure 1 presents the mean differences on the externalizing measure for the four extreme social groups. As shown in Figure 1, there was, as predicted, a significant interaction between frontal asymmetry score and social group (F(1, 49) = 5.74, p = .02).

Post hoc t tests revealed that highly sociable children who were right frontal (M = .86) were more likely to exhibit externalizing problems; and sociable children who were left frontal (M =

— .16) were not (t(26) = 2.39, p = .024). The main effect for social group was also significant (F(1, 49) =- 4.58, p = .037). Highly sociable children (M = .35) were more likely to exhibit externalizing problems compared with low sociable children (M = — .26). The main effect for frontal asymmetry group, however, was nonsignificant.

The interaction between frontal asymmetry score and shy group on the externalizing measure was nonsignificant, as was the main effect for frontal asymmetry group. There was, however, a significant main effect for shy group on the externalizing measure (F(1, 40) = 8.89, p = .005). Shy children (M = — .60) were less likely to exhibit externalizing problems than nonshy counterparts (M = .49).

Frontal EEG asymmetry and social behavior in internalizing behaviors

Figure 2 presents the mean differences on the internalizing measure for the four extreme shy groups. As shown in Figure 2, there was, as predicted, a significant interaction between frontal asymmetry score and shy group (F(1, 40), = 4.48, p = .04).

Post hoc t tests revealed that shy children who were right frontal (M = 4.14) were more likely to exhibit internalizing problems; and shy children who were left frontal (M = .86) were not (t(21) = 2.07, p = .05). The main effect for shy group was also significant (F(1, 40) = 16.36, p = .001). Shy children (M = 2.43) were more likely than their nonshy counterparts (M = - .99) to exhibit internalizing problems. The main effect for frontal asymmetry group, however, was nonsignificant.

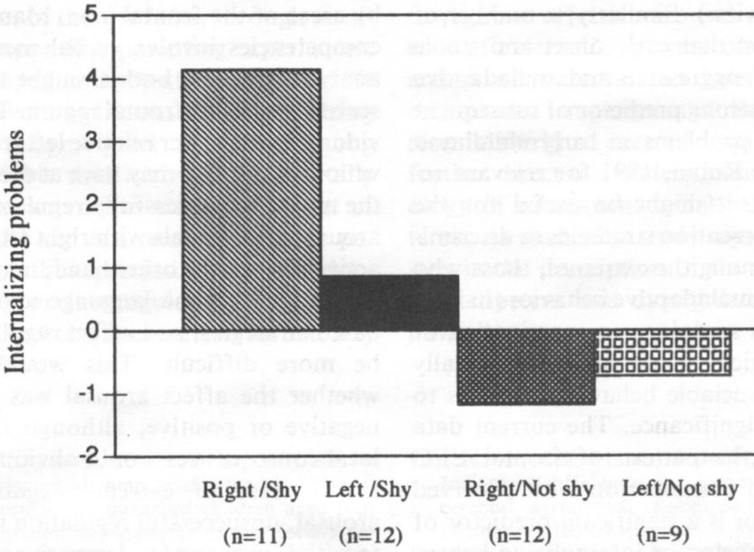

Figure 2. Frontal EEG activation and shyness in relation to preschoolers' internalizing problems.

The interaction between frontal asymmetry score and social group on the internalizing measure was nonsignificant, as was the main effect for frontal asymmetry group. There was, however, a significant main effect for social group on the internalizing measure (F(1, 49, = 8.39, p = .006).

Sociable children (M = - .85) were less likely to exhibit internalizing problems compared with their low sociable counterparts (M = 1.54).

Discussion

One of the issues confronting those studying the development of certain temperamental types of children is that even among extreme groups of children there are differences in the manner in which outcome is expressed. Kagan and his colleagues (Kagan et al., 1987), for example, reported that among children selected for extreme patterns of behavioral inhibition only a subgroup remain inhibited over time as the children enter into preschool and the school years. Children who were extremely inhibited as toddlers may no longer be inhibited as they enter preschool or elementary school.

The movement of children across these boundaries is, of course, multiply determined. Family and contextual factors have been proposed as important influences on the modification of temperamental styles to produce certain patterns of adaptive or maladaptive behavior (Rubin, Hymel, Mills, & Rose-Krasnor, 1991). Alternately, there may be particular physiological signatures that may help discriminate between extreme groups of children who, on the one hand, continue to display the temperamental disposition and those, on the other hand, who may exhibit discontinuity in behavioral style.

The identification of these physiological signatures may be of some importance, given the likelihood of significant maladaptive behavior from among those children who remain in the extreme groups over time. That is, there is evidence that children who remain reticent and socially withdrawn across age are more likely to be rated by their mothers as displaying internalizing problems (see Rubin, Stewart, & Coplan, 1995 for a review). Similarly, a number of studies suggest that early onset and stable exhibition of aggressive and maladaptive behavior is a strong predictor of subsequent externalizing problems in early childhood (see Pepler & Rubin, 1991 for relevant reviews). Thus, it might be useful for the design of intervention strategies to discriminate, from among the extremes, those who might exhibit maladaptive behaviors in later childhood. In so doing, an examination of the physiological concomitants of socially reticent and sociable behaviors appears to be of some significance. The current data suggest that the pattern of frontal EEG asymmetry in combination with observed social behavior is a significant predictor of either externalizing or internalizing behaviors during the preschool period.

Children who displayed extreme patterns of reticence during the quartet session and who also exhibited greater relative right frontal EEG activation had parents who were likely to report them as having more internalizing problems. Alternatively, children who, in the quartet session, displayed reticence but exhibited greater relative left frontal activation had parents who reported fewer internalizing symptoms. A similar pattern emerged for children displaying high degrees of sociability during the quartet session. Among these children, those exhibiting greater relative right frontal EEG activation had parents who reported more symptoms of externalizing problems compared to parents of equally sociable children who exhibited greater relative left frontal activation. Thus, among these two patterns of social behavior (extreme reticence or sociability) the pattern of frontal EEG activation was successful at discriminating those with or without maladaptive behavior problems.

Frontal EEG activation has been thought to reflect a temperamental marker for the disposition to display either negative or positive affect in response to mild stress or novelty (Fox, 1994). However, it may also reflect the individual's ability to regulate affective arousal. That is, many of the cognitive competencies that are involved in successful affect regulation may be mediated by areas of the frontal lobe. Many of these competencies involve verbal mediation or analytic abilities, both thought to be sub-served by the left frontal region. Thus, individuals with greater relative left frontal activation asymmetry may have at their disposal the means to successfully regulate affective arousal. Individuals with right frontal EEG activation, on the other hand, may not have access to the same language and analytic-based strategies; and affect regulation may be more difficult. This would be true whether the affect arousal was extremely negative or positive, although the behavioral consequences would obviously differ. In the case of extreme negative affect arousal, unsuccessful regulation might lead to withdrawal and/or depressive symptoms. In the instance of extreme positive affect arousal, unsuccessful regulation may lead to aggression and oppositional behaviors.

The role of frontal regulation or dysregulation in affect disorders has been postulated heretofore by several researchers. Moffitt (1993) and others have found that children with particular neuropsychological findings (often indicative of frontal pathology) were more likely to display conduct or oppositional disorders. And, there are numerous reports of the relation between frontal dysfunction and the presence of antisocial or delinquent behavior in adolescents (see Moffitt, 1993 for relevant review). These findings reinforce previous ones, but for a relatively young (preschool) sample.

The presence of frontal EEG asymmetry differences among highly reticent or highly sociable children does not necessarily indicate that these asymmetry differences were present from early infancy or birth. Although there is evidence that certain temperamental types of children display stable left or right frontal EEG asymmetry from the infancy period (Fox, Calkins, & Bell, 1994), the current data sets do not provide the information to assess prior EEG status. It is possible that environmental influences produced differences among temperamentally reactive and negative affect disposed infants who exhibit greater relative right frontal EEG activation. One possibility is that a subset of these infants, through sensitive and responsible parenting experiences, have developed competent regulatory skills thereby preventing the onset of internalizing symptoms at age 4 years. Similarly, among highly sociable and active right frontally activated infants there may be a subset of children who did not receive adequate parental care, thus precluding the development of appropriate regulatory skills. Their 4-year EEG pattern thus reflects an inability to regulate affective arousal and the presence of externalizing symptoms. The interaction of parental/family/environmental context and temperamental disposition represents a critical area of inquiry that may further direct our understanding of the etiology of subsequent social behavioral patterns. As such, this study represents a first step in the description of the development of competent and dysregulated social behavior.

References

Achenbach, T. M., & Edelbrock, C. S. (1981). Behavioral problems and competencies reported by parents of normal and disturbed children aged four through sixteen. *Monographs of the Society for Research in Child Development* (pp. 1-82). 46(1, Serial No. 188).

Booth, C. L., Rose-Krasnor, L., & Rubin, K. H. (1991). Relating preschoolers, social competence and their mothers, parenting behaviors to early attachment security and high risk status. *Journal of Social and Personal Relationships, 8,* 363-382.

Borod, J. C. (1992). Interhemispheric and intrahemispheric control of emotion: A focus on unilateral brain damage. *Journal of Consulting and Clinical Psychology, 60,* 339-348.

Buss, A. H., & Plomin, R. (1984). *Temperament: Early developing personality traits.* Hillsdale, NJ: Erlbaum.

Calkins, S. D., & Fox, N. A. (1992). The relations between infant temperament, security of attachment and behavioral inhibition at 24 months. *Child Development, 63,* 1456-1472.

Calkins, S. D., Fox, N. A., & Marshall, T. R. (in press). Behavioral and physiological antecedents of inhibition in infancy. *Child Development.*

Cicchetti, D., Ganiban, J., & Barnett, D. (1991). Contributions from the study of high-risk populations to understanding the development of emotion regulation. In J. Garber & K. A. Dodge (Eds.), *The development of emotion regulation and dysregulation* (pp. 15-48). New York: Cambridge University Press.

Coplan, R. J., Rubin, K. H., Fox, N. A., Calkins, S. D., & Stewart, S. L. (1994). Being alone, playing alone, and acting alone: Distinguishing among reticence and passive and active solitude in young children. *Child Development, 65,* 129-138.

Davidson, R. J., & Tomarken (1989). Laterality and emotion: An electrophysiological approach. In F. Boller & J. Grafman (Eds.), *Handbook of neuropsychology* (pp. 419-441). Amsterdam: Elsevier.

Fox, N. A. (1991). If it's not left, it,s right: Electroencephalogram asymmetry and the development of emotion. *American Psychologist, 46,* 863-872.

Fox, N. A. (1994). Dynamic cerebral processes underlying emotion regulation. In N. A. Fox (Ed.), The development of emotion regulation: Behavioral and biological considerations. *Monographs of the Society for Research in Child Development* (pp. 152-166). 59(2-3, Serial No. 240).

Fox, N. A., Bell, M. A., & Jones, N. A. (1992). Individual differences in response to stress and cerebral asymmetry. *Developmental Neuropsychology, 8,* 165-184.

Fox, N. A., Calkins, S. D., & Bell, M. A. (1994). Neural plasticity and development in the first two years of life: Evidence from cognitive and socioemotional domains of research. *Development and Psychopathology, 6,* 677-696.

Fox, N. A., Calkins, S. D., & Schmidt, L. A. (1995, March). Putting humpty dumpty together: Or in search of a unified field theory to explain temperamental inhibition. In M. R. Gunnar (Chair), *Physiological stress reactivity and behavioral inhibition: Are we all talking about the same thing?* Symposium conducted at the Biennial Meeting of the Society for Research in Child Development, Indianapolis, IN.

Fox, N. A., & Davidson, R. J. (1984). Hemispheric substrates of affect: A developmental model. In N. A. Fox & R. J. Davidson (Eds.), *The psychobiology of affective development* (pp. 353-382). Hillsdale, NJ: Erlbaum.

Fox, N. A., Rubin, K. H., Calkins, S. D., Marshall, T. R., Coplan, R. J., Porges, S. W., Long, J. M., & Stewart, S. (in press). Frontal activation asymmetry and social competence at four years of age. *Child Development.*

Goldsmith, H. H., & Campos, *J.* (1982). Toward a theory of infant temperament. In R. N. Emde & R. F. Harmon (Eds.), *The development of attachment and affiliative systems* (pp. 161-193). New York: Plenum Press.

Henriques, J. B., & Davidson, R. J. (1991). Left frontal hypoactivation in depression. *Journal of Abnormal Psychology, 100,* 535-545.

Howes, C. (1988). Patterns of friendship. *Monographs of the Society for Research in Child Development,* 53 (Serial No. 217).

Jasper, H. H.(1958). The ten-twenty electrode system of the International Federation. *Electroencephalography and Clinical Neurophysiology, 10,* 371-375.

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

Kagan, J., Reznick, J. S., & Snidman, N. (1987). The physiology and psychology of behavioral inhibition in children. *Child Development, 58,* 1459-1473.

Kagan, J., Reznick, J. S., & Snidman, N. (1988). Biological basis of childhood shyness. *Science, 240,* 167-171.

Kagan, J., & Snidman, N. (1991a). Temperamental factors in human development. *American Psychologist, 46,* 856-862.

Kagan, J., & Snidman, N. (1991b). Infant predictors of inhibited and uninhibited profiles. *Psychological Science, 2,* 40-44.

Kinsbourne, M., & Bemporad, B. (1984). Lateralization of emotion: A model and the evidence. In N. A. Fox & R. J. Davidson (Eds.), *The psychobiology of affective development* (pp. 259-291). Hillsdale, NJ: Erlbaum.

Kusche, C. A., Cook, E. T., & Greenberg, M. T. (in press). Neuropsychological and cognitive functioning in children with anxiety, externalizing, and comorbid psychopathology. *Journal of Clinical Child Psychology.*

Lafreniere, P., & Dumas, J. (1992). A transactional analysis of early childhood anxiety and social withdrawal. *Development and Psychopathology, 4,* 385-401.

Moffitt, T. E. (1993). The neuropsychology of conduct disorder. *Development and Psychopathology,* 5, 135-151.

Moffitt, T. E., & Henry, B. (1989). Neuropsychological assessment of executive functions in self-reported delinquents. *Development and Psychopathology, 1,* 105-118.

Moffitt, T. E., & Silva, P. A. (1988). Self-reported delinquency, neuropsychological deficit, and history of attention deficit disorder. *Journal of Abnormal Child Psychology, 16,* 553-569.

Parker, J., Rubin, K. H., Price, J., & DeRosier, M. (1995). Peer relationships, child development, and adjustment: A developmental psychopathology perspective. In D. Cicchetti & D. Cohen (Eds.), *Developmental Psychopathology, Vol. 2, Risk, Disorder, and Adaptation* (pp. 96-161). New York: Wiley.

Pepler, D. J., & Rubin, K. H. (1991). *The development and treatment of childhood aggression.* Hillsdale, NJ: Erlbaum.

Perria, L., Rosadini, G., & Rossi, G. F. (1961). Determination of side of cerebral dominance with amobarbital. *Archives of Neurology,* 4, 173-181.

Robinson, R. G., Kubos, K. L., Starr, L. B., Rao, K., & Price, T. R. (1984). Mood disorders in stroke patients. *Brain, 107,* 81-93.

Robinson, R. G., & Szetela, B. (1981). Mood change following left hemisphere brain injury. *Annals of Neurology, 9,* 447-453.

Rothbart, M. K., & Derryberry, D. (1981). Development of individual differences in temperament. In M. E. Lamb & A. L. Brown (Eds.), *Advances in developmental psychology* (Vol. I, pp. 38-85). Hillsdale, NJ: Erlbaum.

Rowe, D. C., & Plomin, R. (1977). Temperament in early childhood. *Journal of Personality Assessment, 41,* 150-156.

Rubin, K. H. (1989). *The Play Observation Scale (POS).* University of Waterloo. Available from author.

Rubin, K. H., Coplan, R. J., Fox, N. A., & Calkins, S. D. (1995). Emotionality, emotion regulation, and preschoolers, social adaptation. *Development and Psychopathology,* 7,49-62.

Rubin, K. H., Hymel, S., Mills, R. S. L., & RoseKrasnor, L. (1991). Conceptualizing different pathways to and from social isolation in childhood. In D. Cicchetti & S. Toth (Eds.), *The Rochester Symposium on Developmental Psychopathology Vol 2, Internalizing and externalizing expressions of dysfunction* (pp. 91-122). Hillsdale, NJ: Erlbaum.

Rubin, K. H., LeMare, L. J., & Lollis, S. (1990). Social withdrawal in childhood. Developmental pathways to rejection. In S. R. Asher & J. D. Coie (Eds.), *Peer rejection in childhood* (pp. 217-249). New York: Cambridge University Press.

Rubin, K. H., & Rose-Krasnor, L. (1992). Interpersonal problem solving and social competence in children. In V. B. van Hasselt and M. Hersen (Eds.), *Handbook of social development: A life-span perspective* (pp. 283-323). New York: Plenum Press.

Rubin, K. H., Stewart, S. L., & Coplan, R. J. (1995). Social withdrawal in childhood: Conceptual and empirical perspectives. In T. 011endick & R. Prinz (Eds.), *Advances in Clinical Child Psychology* (Vol. 17, pp. 157-196). New York: Plenum Press.

Schmidt, L. A., & Fox, N. A. (1994). Patterns of cortical electrophysiology and autonomic activity in adults' shyness and sociability. *Biological Psychology, 38,* 183-198.

Schmidt, L. A., & Fox, N. A. (1995). *Fear-potentiated startle responses in temperamentally different human infants.* Manuscript submitted for publication.

Schulkin, J., McEwen, B. S., & Gold, P. W. (1994). Allostasis, amygdala, and anticipatory angst. *Neuroscience and Biobehavioral Reviews, 18,* 385-396.

Serafetinides, E. A., Hoare, R. D., & Driver, M. V. (1965). Intracarotid sodium amylobarbitone and cerebral dominance for speech and consciousness. *Brain, 68,* 107-130.

Silberman, E. K., & Weingartner, H. (1986). Hemispheric lateralization of functions related to emotion. *Brain and Cognition,* 5, 322-353.

Sroufe, L. A., (1983). Infant-caregiver attachment and patterns of adaptation in preschool: The roots of maladaptation. In M. Perlmutter (Ed.), *Minnesota Symposium on Child Psychology* (Vol. 16, pp. 4183). Hillsdale, NJ: Erlbaum.

Stifter, C. A., & Fox, N. A. (1990). Infant reactivity: Physiological correlates of newborn and 5-month temperament. *Developmental Psychology, 26,* 582-588.

Terrazian, H. (1964). Behavioral and EEG effects of intracarotid sodium amytal injection. *Acta Neurochirica, 12,* 230-239.

Thompson, R. A. (1994). Emotion regulation: A theme in search of a definition. In N. A. Fox (Ed.), The development of emotion regulation: Behavioral and biological considerations. *Monographs of the Society for Research in Child Development* (pp. 25-52). 59(2-3, Serial No. 240).