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FRONTAL EEG ASYMMETRY IN RELATION TO WITHDRAWAL, APPROACH, AND ATTENTION BEHAVIORS

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ABSTRACT

Several studies have examined the relationship between frontal electroencephalograph (EEG) asymmetry and withdrawal/approach patterns in children. The observed variability in left and right frontal EEG asymmetry has identified right frontal asymmetry as a predictor of inhibitory behavior and negative affect, and, in contrast, a left frontal asymmetry association with approach behavior and positive affect. This current study replicates these frontal EEG asymmetry patterns in relation to withdrawal/approach behaviors, and extends the exploration of correlating frontal asymmetry with attentional networks.

EEG was recorded for 34 children, ages four to eight, during baseline tasks and stranger approaches. The videos were coded for distress and positive affect, as well as boldness and shyness behaviors, during the stranger approaches. Children then completed a child-friendly version of the Attention Network Test (ANT) to estimate alerting, orienting, and executive control functions. Additional behavioral data for the children was obtained from parent reports. For analysis, the children were divided into categories of "Left Frontal Asymmetry" and "Right Frontal Asymmetry" based on location of greater activation as recorded by EEG.

In accordance with the current literature, the children with right frontal asymmetry had greater scores for parent reported fear. Additionally, children with right asymmetry showed poor executive control function in ANT tasks involving conflict. In comparison, the children classified as left frontal exhibited greater orienting function and executive control during attention tasks. Parent reports of attentional focusing suggest that the children with left frontal asymmetry have greater attention control. The findings from the current study provide evidence for the use of frontal asymmetry as a biomarker for behaviors associated with later social anxiety.

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Acknowledgements

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Introduction

The implications of brain activity in the development of social anxiety disorders have been demonstrated in previous literature, though mostly through its association with behavior. Children with fearful temperament (early emerging individual differences) are predicted to be at greater risk for developing social anxiety, and children with certain patterns of brain activity are more likely to be inhibited. Additionally, it is known that there is an association between attention and anxiety; however, the link between attention and brain activity in children is not well researched. Understanding the interaction between brain activity, behavior, and attention during development may provide us with a more detailed profile of anxiety risk.

Temperament and Anxiety Risk

There is evidence that there is a psycho-biological predisposition for inhibited behaviors in children that persists throughout development and contributes to social anxiety. The literature defines the individual differences in a child's personality that surface from this biological predisposition as temperamental traits. Temperament can be used to describe behaviors of emotion and motor control that emerge early in a child's development, and have some stability over time. Both genes and environment contribute to a temperament profile, and it is therefore considered both a physiological and psychological construct. Temperamental inhibition, one well-studied profile of temperament, refers to a child's characteristically withdrawn, shy, or cautious response to unfamiliar people, objects, and situations.

The relationship between children's inhibition and later anxiety has been the focus of many temperament studies. Two longitudinal studies of two-year-old children from Kagan, Reznick and Snidman (1988) provided a basis for much of this research. They found that children who displayed extreme behavioral inhibition at age two in unfamiliar contexts were socially avoidant with unfamiliar children and adults at age seven. In contrast, children who were spontaneous in new contexts at age two were found to be largely talkative and interactive at age seven (Kagan et al. 1988). In another study, Joseph Biederman and colleagues, conducted a three year follow-up study of children who were defined as behaviorally inhibited at age four. They found that at age seven the initially inhibited children had significantly higher rates of anxiety disorders, including avoidant disorder, separation anxiety disorder, and agoraphobia compared to the non-inhibited children (Biederman et al., 1993). In a more recent longitudinal study, researchers found that inhibited behaviors were preserved over a twelve-year interval, first observed at age two (Schwartz et al., 1999). Both interviews and observer data indicated that the children with behavioral inhibition at age two displayed an increased vulnerability to general social anxiety compared to the uninhibited children (Schwartz et al., 1999). Following these studies, the importance of identifying early markers of behavioral inhibition becomes clear. Brain activity, introduced earlier, is one such early physiological marker which is considered a contributor to temperament and social anxiety, and will be the focus of this study.

EEG and Frontal Asymmetry

Physiological measures have often been used by psychologists to explain responsive behaviors, both physical and emotional. Asymmetrical brain activity measured through electroencephalograph (EEG) is one behavioral indicator on which researchers have focused. It is understood that greater relative activity in the right hemisphere of the frontal cortex of the brain is associated with negative affect and withdrawal behaviors in children, which make it particularly relevant to behavioral inhibition (Fox & Davidson, 1982). Conversely, greater relative activity in the left hemisphere of the frontal cortex of the brain is related to positive affect and behavioral approach (Fox & Davidson, 1982). Frontal brain asymmetry, for which test-retest EEG values have provided evidence of long term stability in school-aged children (ages 6-9), is often regarded as a trait marker for inhibited behavior in childhood (Vuga et al., 2008). These research findings support the use of frontal brain asymmetry in evaluating childhood risk for anxiety, and provide a foundation for this current study.

The frontal cortex is an area of the brain known to be involved in higher mental functioning, including the governance of social responses and regulation of emotion. The activity of this area of the brain, as well as others, is evaluated through the power of frequency bands. Alpha bands, with a frequency of 8-13 Hz in adults (or 5-9 Hz in children), are active when an individual is relaxed and uninvolved in specific cognitive activity, but awake and attentive. Several factors, including neural projections from sub-cortical structures, contribute to power in the alpha band. Lateral asymmetry of this alpha activity is common within individuals; however, the basis for uneven activity is unknown. Asymmetry values can be calculated by subtracting the left alpha power from the corresponding right alpha power, where positive values indicate greater relative right activity. These patterns of asymmetry can be detected through electroencephalograph recordings (EEG), and compared with the subject's behaviors to provide information regarding the associations between temperament and neural patterns.

Previous studies have provided support for the use of right frontal asymmetry as a predictor of behaviorally inhibited temperament in infants (Buss et al., 2003) and social behaviors and anxiety in middle childhood (McManis et al., 2002; Hannesdottir et al., 2009). These studies typically show that right frontal activation is associated with observed withdrawal behaviors and negative emotionality. Withdrawal related behaviors in laboratory settings include avoidance of novel stimuli, bodily freezing or fidgety behavior, and general shyness. In addition, negative reactivity, shown through displays of distress such as crying and sad or fearful facial expressions, has demonstrated a connection with frontal asymmetry. The presence of greater right frontal activity in extremely shy or fearful children during both baseline and stressful tasks (e.g., stranger approach situations), suggests the importance of distinct neural patterns of the frontal cortex in the temperament construct of behavioral inhibition.

In addition to general reactivity patterns in children, lateral asymmetry found in the frontal cortex has been associated with the ability to regulate behavioral responses. Children with stable patterns of right frontal asymmetry have higher rates of internalizing behaviors, while children with stable left frontal asymmetry have higher rates of externalizing behaviors (Smith & Bell, 2009). Internalizing behaviors include fear and anxiety, while externalizing behaviors characterize problems such as aggression, hyperactivity and impulsivity. Based on these relationships, one would expect that children with heightened anxiety in stressful situations would also be hyper-vigilant in attention related tasks. Anxiety and attention processes have been linked in previous studies (Eysenck, 1997), and there is evidence that attention is associated with areas of frontal cortex activation. The association of frontal asymmetry with children's behavioral responses leads us to believe it also plays a role in attention. Greater right frontal activation may be linked to both internalizing regulating behaviors and increased attentional focusing; however, little research has been done to explore this relationship.

Attention

Assessing an individual's attention can be achieved through the study of three distinct but related attentional networks: orienting, alerting, and executive control (Fan, McCandliss, Sommer, Raz, & Posner, 2002). This concept of separate sources of attentional control provides a system for correlating different cognitive functions with specific anatomical regions of the brain. Alerting is described as attaining and sustaining an appropriate level of sensitivity to external stimuli, and has been linked to right hemisphere activation of both the frontal and parietal lobes. The orienting system is characterized by the selection of information from numerous sensory stimuli, and is related to the superior parietal lobe, frontal eye fields, and tempoparietal junction. The final system, executive control, is involved in conflict resolution and regulation of voluntary actions. Executive control is correlated with activation in the midline frontal areas, as well as the lateral prefrontal cortex, making this network relevant for questions regarding regulation and frontal asymmetry. The classification of these attentional networks provides useful information for understanding how anxiety and cognitive function are related.

The distinctly separate nature of these three attentional networks calls for a testing tool which can evaluate an individual's efficiency in each network. The Attention Network Test (ANT) is one such tool developed to measure attention functioning, which provides reliable results for adults and children (Fan et al., 2002). The ANT is comprised of a simple series of tasks that require subjects to determine the direction of a central arrow. To measure conflict, a flanker task is used where the central arrow is surrounded by distractor arrows (i.e., flankers) which may be pointing in the same or opposite directions from the target. Reaction times for these tasks produce an estimate of alerting, orienting, and executive control. For children, the ANT is modified to use a row of fish images, instead of arrows, to appear as a game.

The child-friendly version of the ANT was recently used in a study on the development of brain activations that are related to conflict processing and executive control in six to nine year old children. Comparing the ANT performance of children and adults, this study showed that the three attentional networks are independent of each other throughout development (Rueda et al., 2003). Children's attentional networks have been linked to several areas of temperament and self-regulation. A study from Gerardi-Caulton (2000) showed that 30 and 36 month-old children, with a high ability to resolve spatial conflict, had higher parent ratings of attention focusing than children with poor conflict resolution performance. This study shows that the attentional network of executive control may be related to a more general characteristic of self regulation. More recent studies have provided support for the association of attentional networks with trait anxiety (Pacheco-Unguetti et al., 2010), and this current study seeks to extend that understanding and provide information on its relationship with frontal asymmetry.

Current Study

This current study aims to extend the research on the involvement of right frontal asymmetry in both behavioral and emotional responses, as well as provide a novel report on the involvement of asymmetrical brain activity in the efficiency of attentional networks. EEG asymmetry was recorded across both baseline and stranger approach episodes for children ages four to eight; then, the episodes were coded globally to assess emotion and behavior. Attention networks were evaluated using the child-friendly version of the ANT to measure attentional network function. Children’s temperament was assessed through a parent survey, the Children’s Behavior Questionnaire short form (Putnam & Rothbart, 2006) and through independently coded affective behaviors during laboratory tasks.

Based on the previous literature, the following predictions were made: (a) Relative to the children who have greater left frontal asymmetry, children exhibiting greater right frontal asymmetry will display more temperamental inhibition (i.e., fear, shyness) during unfamiliar stimuli. Parent reports of “Fear” and “Shyness” will show a positive correlation with right frontal asymmetry. In contrast, children with greater left frontal asymmetry will express higher degrees of approach and boldness. (b) Children with greater right frontal asymmetry will perform better on the on the ANT than children with greater left frontal asymmetry. Parent reports of high

“Attentional Focusing” will show a positive correlation to the children with heightened right frontal activity.

Method

Participants

As part of a study designed to evaluate children’s attention and emotions, 34 children (11 female) were recruited to participate in a laboratory visit. Inclusion criteria were that children be right-handed, not taking any stimulant medications, and between four and eight years of age. The average age of participants enrolled in the study was 5.73 years (*SD*=1.27). The children participated in a laboratory visit that involved EEG recordings during a resting baseline and stranger approach episode, as well as completion of a computerized attention task. Independent observers rated children’s behavior and emotion during the stranger approach, EEG and ANT. Parents reported on children’s temperament characteristics. This study was approved by The Penn State Office of Research Protections (IRB # 27683).

Procedure

Laboratory Visit. Once at the laboratory, children were fitted with a neural net to be used for EEG data collection. The child then participated in several laboratory episodes, during which the mothers remained in an adjacent room, as they were not directly involved in the episodes. This study uses data from three episodes: a baseline task, a stranger approach conversation, and a computerized attention task. In appreciation of their participation, the families received $20 and the children were given a small gift.

Baseline Episode. The experimenter and child sat at a table together and looked through a picture book while baseline EEG was recorded. The child was instructed to keep their eyes open for 1 minute, and then closed for 1 minute. This eyes open, eyes closed, pattern was repeated twice at the beginning of the visit and twice at the end of the visit.

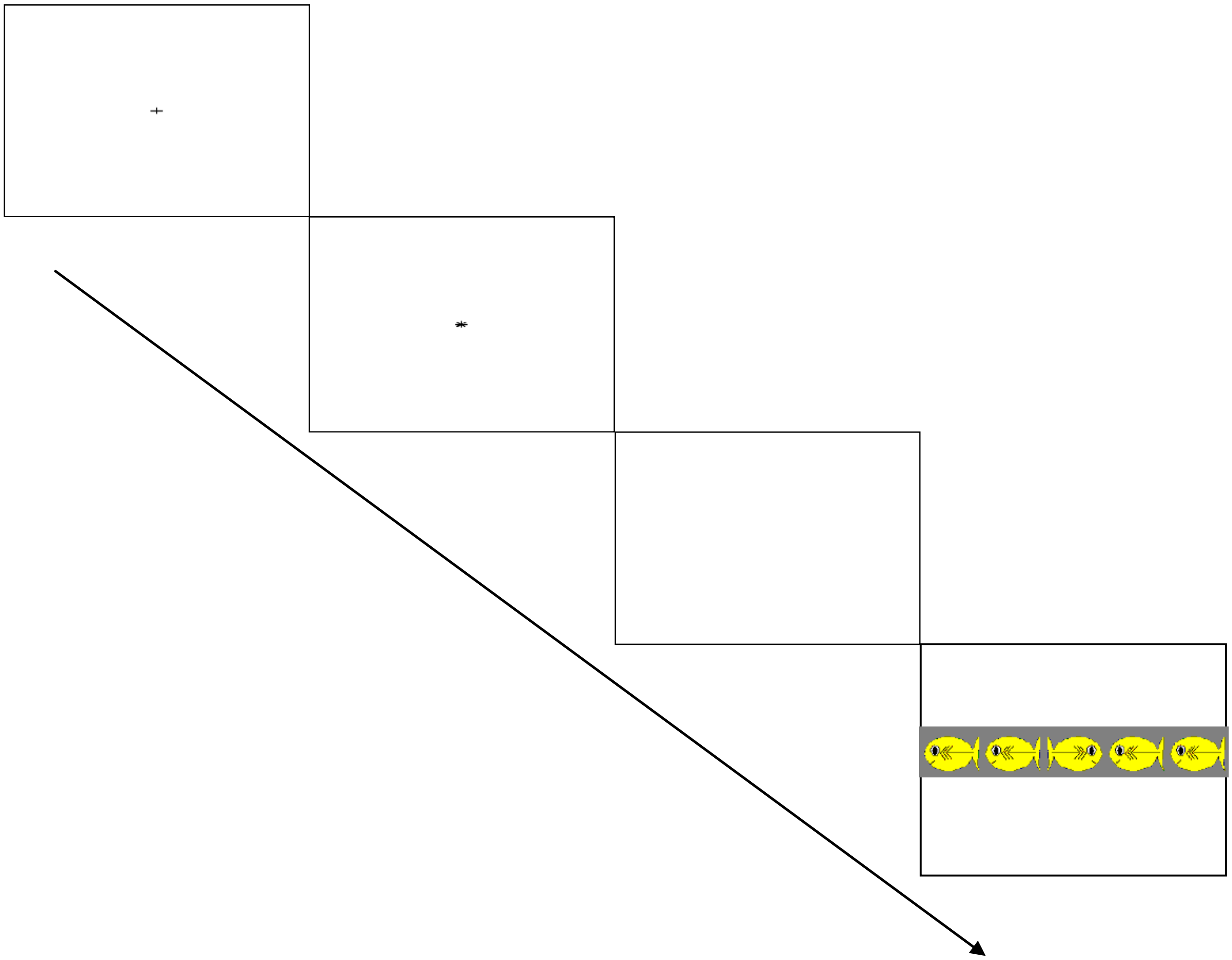
Stranger Approach Episode. The child was asked to wait in the laboratory room while the experimenter left to prepare the next activity. After the child had been sitting in the room alone for 10 seconds, an unfamiliar experimenter entered the room. In the first phase of the stranger approach (interactive), the experimenter stood near the child and asked several questions (i.e. “What kinds of games do you like to play”). The stranger paused for 30 seconds following each response from the child. This phase lasted for approximately three minutes. The second phase of the stranger approach was not conversational (non-interactive), and consisted of the experimenter explaining the purpose and function of the neural net for approximately one minute. The experimenter then stated that it was time to leave, and exited the laboratory room.

Attention Network Test. Following the stranger approach episode, the child completed the child-friendly version of the Attention Network Task (Fan et al., 2002) on a Dell PC using E-Prime 1.1 (Psychology Software Tools, Inc: Pittsburg, PA). The experimenter instructed the child to complete the task, and remained in the room throughout the test, however, did not provide feedback on the child’s performance. Children were seated approximately 10 inches from the computer screen and given a response box to either hold in their lap or place on a table in front of them, whichever was more comfortable.

Prior to beginning the task, the experimenter used a set of index cards depicting arrays of five fish to explain the “game” to the child. The child was instructed to focus their attention on the fish in the middle of the array of fish (i.e., the target) and to “feed that fish” using the response box in their lap. On the box, the rightmost button corresponded to fish depicted as facing rightward, and the leftmost button corresponded to fish depicted as facing leftward. To be sure the child understood, the experimenter asked the child to show which button on the response box corresponded to the correct response for the target arrays displayed on the index cards. Once the child clearly understood the instructions, they began a set of practice trials.

A session of the ANT consisted of a total of 16 practice trials and three experimental blocks of 32 trials. Each trial began with the presentation of a fixation cross for 400 ms. On some trials a warning cue was subsequently presented for 150 ms and represented one of four warning cue conditions: a center cue, a double cue, a spatial cue, or no cue. In the center cue condition, an asterisk was presented at the location of the fixation cross. In the double cue condition, an asterisk appeared at locations of the target both above and below the fixation cross. In the spatial cue condition, a single asterisk appeared in the position of the upcoming target. A fixation period (no fixation cross) of 450 ms followed the disappearance of the cue. Following this, the target array appeared and remained on the screen until a response was detected or a maximum of 1700 ms elapsed. During congruent trials, the target fish was surrounded by fish facing in the same direction; during incongruent trials, the target fish was surrounded by fish pointing in the opposite direction. Accuracy and reaction time were recorded for each trial. A schematic representation of the task is shown in Figure 1.

Figure 1:



Electroencephalograph Recordings. EEG was continuously recorded during baseline, stranger approach, and ANT using a 128-channel dense array Geodesic Sensor Net (Tucker, 1993) and analyzed using Net Station software from Electrical Geodesics, Inc. (EGI, Eugene, OR) at a sampling rate of 500 Hz. Alpha (5-9 Hz) power values were computed for the frontopolar (Fp1/2), dorsolateral (F7/F8), dorsocentral (F3/F4), and parietal (P3/P4) sites. The power values calculated were based on the artifact-free, 1-s units of EEG data using an off-line whole-head average reference. This study only uses the data obtained from the baseline and stranger approach episodes.

Measures

Parent Report Measures. Following response to the advertisement, the child's eligibility was confirmed, and a packet containing consent forms and a child temperament questionnaire was mailed. The questionnaire included was the Child Behavior Questionnaire Short Form (CBQ; Putnam & Rothbart, 2006), and was to be returned upon arrival to laboratory. The CBQ short form consists of 94 items to assess temperament across three domains: surgency, negative affect, and effortful control. Each item relates to one of 14 subscales, including activity level, anger/frustration, approach/positive anticipation, attentional focusing, discomfort, falling reactivity/soothability, fear, high intensity pleasure, impulsivity, inhibitory control, low intensity pleasure, sadness, shyness, and smiling/laughter. Parents responded to the 94 statements on a six-point rating scale based on the extent to which the statement is true of their child (1 = extremely untrue of my child, 2= quite untrue of my child, 3 = slightly untrue of my child, 4 = neither true nor false of my child, 5 = slightly true of my child, 6 = extremely true of my child). Our study focuses on the CBQ domain of effortful control and the CBQ subscales of anger/frustration, approach/positive anticipation, attentional focusing, fear, and shyness.

Observer Ratings. Video recordings of the stranger approach episode were viewed to produce global coding ratings for negative affect, positive affect, boldness/approach, and shyness/withdrawal. The stranger approach episode was divided into two phases, and the children's behavior was coded in each phase separately. A five-point scale was used to assign the ratings for each dimension, which ranged from a score of 1, for little or none of the behavior observed, to 5, for extreme displays of the behavior observed. All episodes were double coded by two independent coders. Reliability, as determined by Chronbach's alpha, was very good for both phase 1 (negative affect: $\alpha = .93$; positive affect: $\alpha = .98$; boldness/approach: .94;

shyness/withdrawal: α = .89) and phase 2 (negative affect: α = .76; positive affect: α = .85; boldness/approach: .87; shyness/withdrawal: α = .88).

Data Reduction

Asymmetry Scores. The values for alpha power activity were analyzed at channels representing frontopolar (Fp1/Fp2), dorsolateral (F7/F8), dorsocentral (F3/F4), and parietal (P3/P4) sites in the brain. The asymmetry value for each site during a specific episode was calculated by subtracting the log left alpha power from the corresponding log right alpha power. Alpha power is inversely related to cortical activation, so negative values for this calculation indicated greater relative right activity at that particular site. To analyze differences in temperament and attention related to asymmetry at each site, participants were divided into two groups – children with left frontal asymmetry (positive asymmetry difference scores), and children with right frontal asymmetry (negative asymmetry difference scores). The EEG asymmetry groups were formed for each frontal asymmetry score (frontopolar, dorsolateral, dorsocentral, and parietal) for each of the three episodes (baseline, stranger approach phase 1, and stranger approach phase 2).

ANT Scores. The response time data recorded during the ANT task for each participant was used to calculate scores for the three attentional networks – alerting, orienting, and executive control. Alerting scores were calculated by subtracting the response times (ms) for trials in which the double cue was presented from trials with no cue presentation. Orienting scores were calculated by subtracting the response times for trials in which spatial cues were presented from trials in which a central cue was presented. Executive control scores were calculated by subtracting the response times for congruent trials from response times for incongruent trials.

Results

We used a series of t-tests to examine how right and left asymmetry groups differed on parent-reported temperament, observed behaviors (i.e., shyness, boldness, positive affect, negative affect) during stranger approach, and performance of networks of attention. Both age and gender were correlated with asymmetry (include the values for these correlations), but including these as covariates in the analyses did not change the pattern of results; therefore, we are only reporting t-tests to preserve power. A summary of means and standard deviations of study variables for the left and right asymmetry groups is provided in Table 1. As seen in the table, the correlations between asymmetry and the study variables were not restricted to solely the frontopolar sites. While the size of the left and right asymmetry groups vary across sites and episodes, as shown in Table 2, on average the number of children in the right asymmetry group (M = 10) was consistently lower than the number of children in the left asymmetry group (M =15).

Table 1: Means and Standard Deviations for Study Variables across Left and Right Asymmetry Groups

Baseline Asymmetry								
	FP		DC		DL		P	
	Left	Right	Left	Right	Left	Right	Left	Right
CBQ Fear	3.51	3.19	3.21	3.76	**3.06***	**3.79***	3.40	3.44
Standard Deviation	1.15	0.85	1.11	0.90	1.07	0.94	1.13	0.89
SA Phase 1 Positive Affect	1.83	1.71	1.69	1.94	2.00	1.55	**2.00**	**1.10**
Standard Deviation	1.10	0.91	0.83	1.69	1.18	0.76	1.08	0.22
SA Phase 2 Positive Affect	**1.17***	**1.57***	1.31	1.28	1.21	1.40	1.26	1.40
Standard Deviation	0.36	0.61	0.52	0.44	0.40	0.57	0.47	0.55
ANT Conflict Score	**41.80**	**119.94**	54.71	94.11	74.51	59.97	82.89	22.71
Standard Deviation	99.77	57.00	104.38	68.58	117.88	60.50	69.39	145.93
Stranger Approach 1 Asymmetry								
	FP		DC		DL		P	
	Left	Right	Left	Right	Left	Right	Left	Right
CBQ Attentional Focusing	4.82	4.39	4.78	4.75	4.92	4.64	**5.10***	**4.22***
Standard Deviation	1.21	1.34	1.26	1.25	1.42	1.10	1.27	0.99
CBQ Effortful Control	5.19	4.86	5.12	5.12	5.29	4.99	**5.33**	**4.78**
Standard Deviation	0.54	0.90	0.59	0.68	0.69	0.57	0.62	0.50
ANT Orienting Score	26.40	-12.36	**55.02***	**-8.04***	29.01	13.97	1.51	53.11
Standard Deviation	93.36	82.18	89.88	85.13	100.70	85.95	82.47	100.77
Stranger Approach 2 Asymmetry								
	FP		DC		DL		P	
	Left	Right	Left	Right	Left	Right	Left	Right
CBQ Fear	**3.22***	**4.17***	**3.16***	**3.98***	3.16	3.72	3.85	2.87
Standard Deviation	1.18	0.93	1.13	1.05	1.15	1.13	1.11	0.99
CBQ Attentional Focusing	**5.02***	**4.06***	4.77	4.76	4.95	4.64	4.78	4.72
Standard Deviation	1.26	0.90	1.36	1.10	1.31	1.21	1.18	1.39
CBQ Anger/Frustration	5.14	5.75	4.18	4.36	**4.68***	**3.98***	4.27	4.22
Standard Deviation	0.68	0.50	1.08	1.12	0.74	1.18	1.24	0.74

*Note: Note. Values in boldface were significant, p<.05, and in the direction of the hypotheses (*denotes marginally significant, p<.10). FP = Frontopolar, DC = Dorsocentral, DL = Dorsolateral, P = Parietal*

Table 2: Number of Children in Left and Right Asymmetry Groups

	Asymmetry Groups							
	FP		DC		DL		P	
	Left	Right	Left	Right	Left	Right	Left	Right
Baseline	17	8	16	9	13	12	19	6
Stranger Approach 1	19	6	12	14	11	15	16	10
Stranger Approach 2	17	8	15	11	10	16	17	9

Note: Missing data accounts for the discrepancy in total N across sites. FP = Frontopolar, DC = Dorsocentral, DL = Dorsolateral, P = Parietal

Behavioral Results

Parent-Reported Temperament. The parent reports of behavior revealed several correlations with frontal asymmetry, most notably in parent reports of fear. The results of t-tests at three particular sites produced a marginally significant difference in the means of the left and right groups. Figure 2 illustrates the comparison of left and right asymmetry groups during the baseline episode and the non-interactive phase of stranger approach on means for children's parent-reported fear. In line with study hypotheses, greater right frontal asymmetry was associated with more parent-reported fear than was left asymmetry group. Children with right asymmetry at the dorsolateral (F7/8) sites during baseline had greater parent-reported fear than the children who showed left asymmetry ($t = 1.81$, $p < 0.10$). Children with right asymmetry at the frontopolar (Fp1/2) sites during the non-interactive phase of stranger approach, had greater parent-reported fear than the children showing left asymmetry ($t = 2.26$, $p < 0.10$). Children with right asymmetry at dorsocentral (F3/4) sites during non-interactive stranger approach had greater parent-reported fear than children who showed left asymmetry ($t = 1.89$, $p < 0.10$). Children with left asymmetry at dorsolateral (F7/8) sites during non-interactive stranger approach had greater parent-reported anger/frustration than children who showed right asymmetry ($t = -1.69$, $p < 0.10$).

Figure 2:

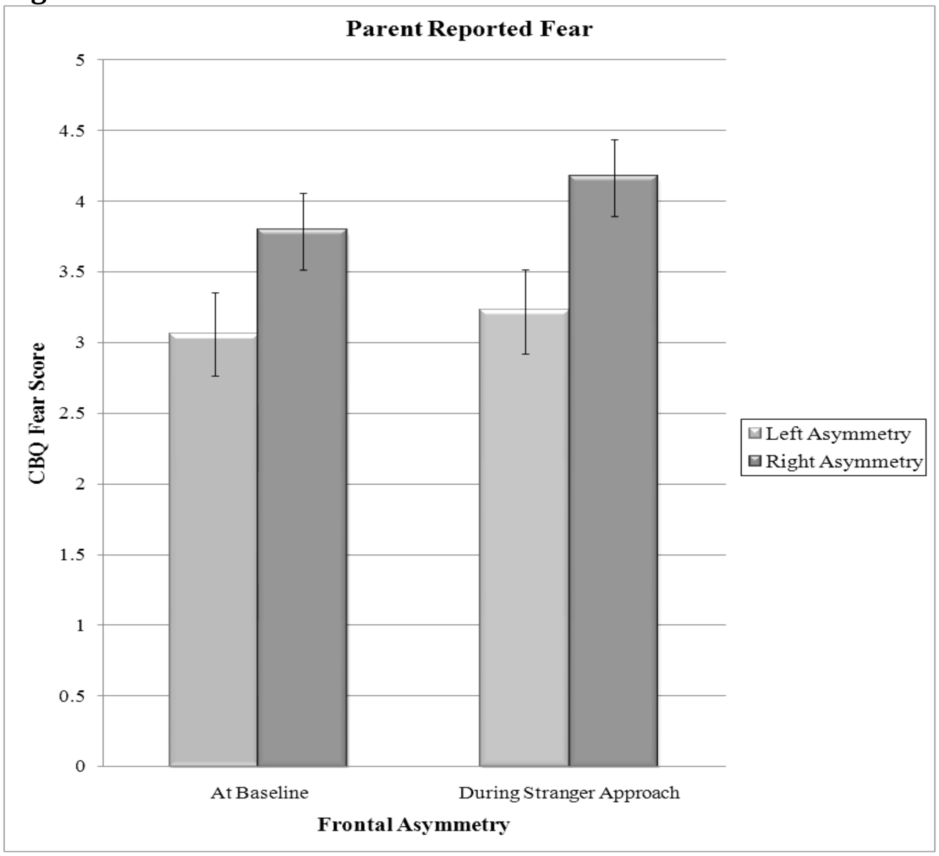


Figure 2: Bar graph depicting t-test results for CBQ Fear means. The baseline asymmetry difference illustrated here was recorded at the dorsolateral site, and the stranger approach score was recorded at the frontopolar site.

Parent-reported shyness was predicted to show a positive correlation with children's right frontal asymmetry; however, this result was not seen (t = -1.21, p > 0.10). Similarly, high parent-reported Approach/Positive Anticipation was expected to be related to greater left frontal asymmetry, but this difference was not significant, (t = -0.04, p > 0.10).

Behavior during Stranger Approach. Children with greater right than left frontal activity were expected to display greater shyness/withdrawal behaviors during the Stranger Approach episode than children with left frontal asymmetry; however, this difference was not observed, (t = -0.28, p > 0.10). Observations of boldness/approach were not significantly different between the two asymmetry groups, (t = -0.36, p > 0.10). In addition, observer ratings of distress (negative affect) was not significantly different between the left and right asymmetry groups ($t = 0.09$, $p > 0.10$).

Positive Affect. While not a part of our initial research objective, the results regarding frontal asymmetry and positive affect during the stranger approach episodes stood out as significant. During interactive stranger approach, children with baseline left frontal asymmetry displayed greater positive affect than those with baseline right frontal asymmetry, as measured through global coding by observers. Children with left asymmetry (at the parietal site – P3/4) displayed more positive affect than children with right asymmetry ($t = -3.22$, $p < 0.01$).

In contrast, during non-interactive stranger approach, children with baseline right frontal asymmetry displayed greater positive affect than those with baseline left frontal asymmetry. Children with right asymmetry (at the frontopolar (Fp1/2) site) showed more positive affect than left asymmetry group ($t = 1.97$, $p < 0.10$). These results are illustrated in Figure 3.

Figure 3:

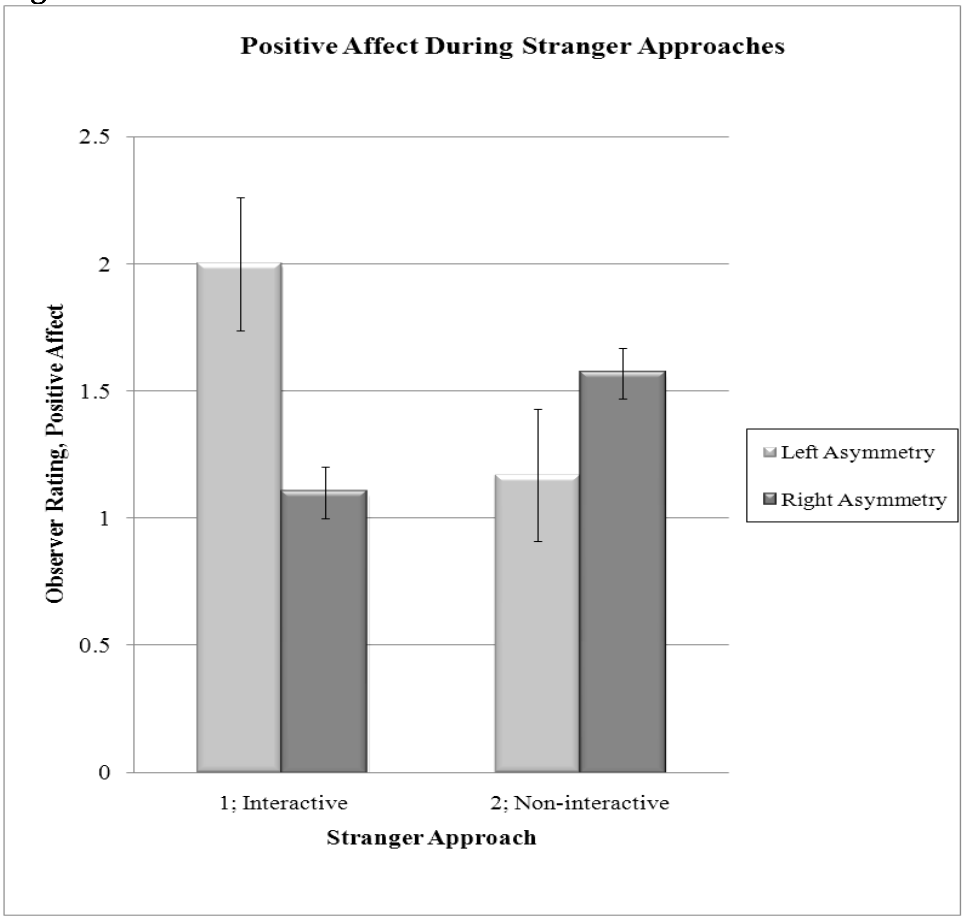


Figure 3 represents the positive affect means for left and right asymmetry groups during the two phases of stranger approach.

Attention Results

Parent Report of Attention. It was predicted that children with greater right frontal asymmetry would have higher parent-reported scores for Attentional Focusing on the CBQ. However, the results showed the opposite pattern – children with greater left frontal asymmetry had greater parent-reported Attentional Focusing. During Phase 1 Stranger Approach, children with left frontal asymmetry group at the parietal (F3/4) site, had better attention focusing than the right frontal asymmetry group, (t = -1.88, p < 0.10). Also, the non-interactive phase of stranger approach, children with left frontal asymmetry group at the frontopolar (Fp1/2) site had better attention focusing than children with right frontal asymmetry (t = -1.92, p < 0.10). These results are summarized graphically in Figure 4. In addition, there was a significant difference between the left and right asymmetry groups in parent-reported effortful control. Children with greater left asymmetry group during the interactive phase of stranger approach (at the parietal (F3/4) site) had higher parent-reported effortful control than the right asymmetry group, (t = -2.41, p < 0.05).

Figure 4:

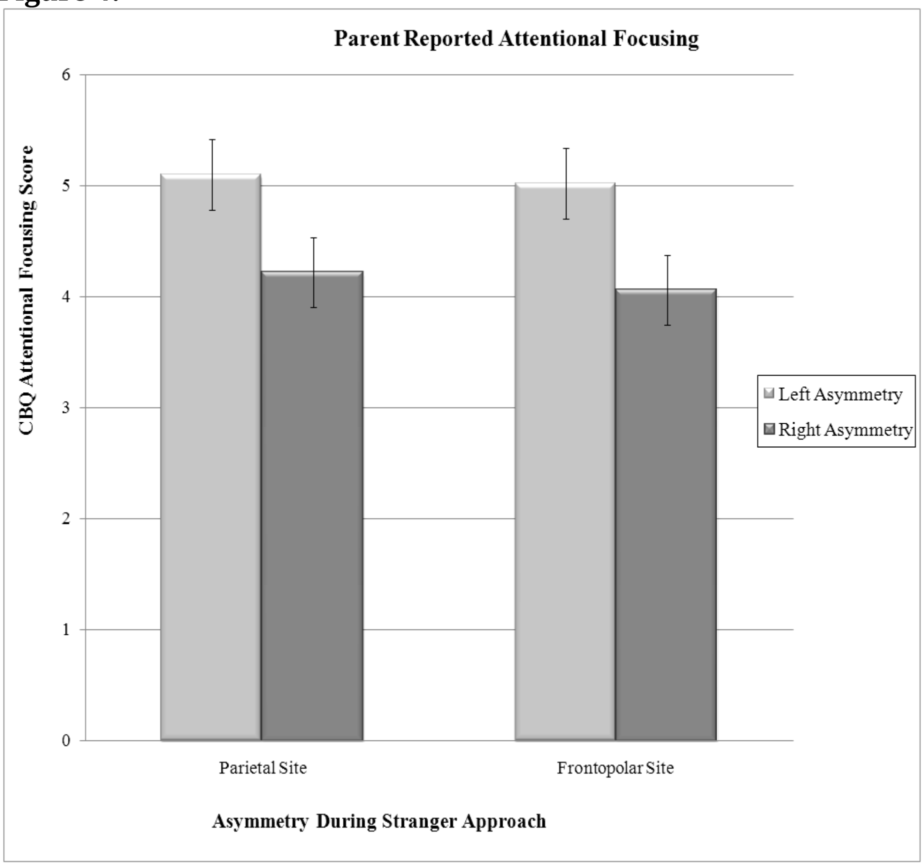


Figure 4 represents the mean CBQ attentional focusing scores for the left and right asymmetry groups.

Laboratory Attention. Corresponding with the results for CBQ Attentional Focusing, we found that children with greater left frontal asymmetry performed better on the Attention Network Test than children who showed right frontal asymmetry during baseline and stranger approach phase 1. There was a significant difference in ANT Conflict scores between the baseline frontopolar (Fp1/2) left and right asymmetry groups, (t = 2.04, p < 0.05). The conflict score mean for right frontal asymmetry group reflected greater interference in identifying the target in congruent and incongruent trials.

In addition, a marginally significant difference was observed for the ANT Orienting score during interactive stranger approach. Children with greater left activation at the dorsocentral (F3/4) site, showed better orienting than the right frontal asymmetry group, (t = -1.76, p < 0.10). These results are reflected in Figure 5.

Figure 5:

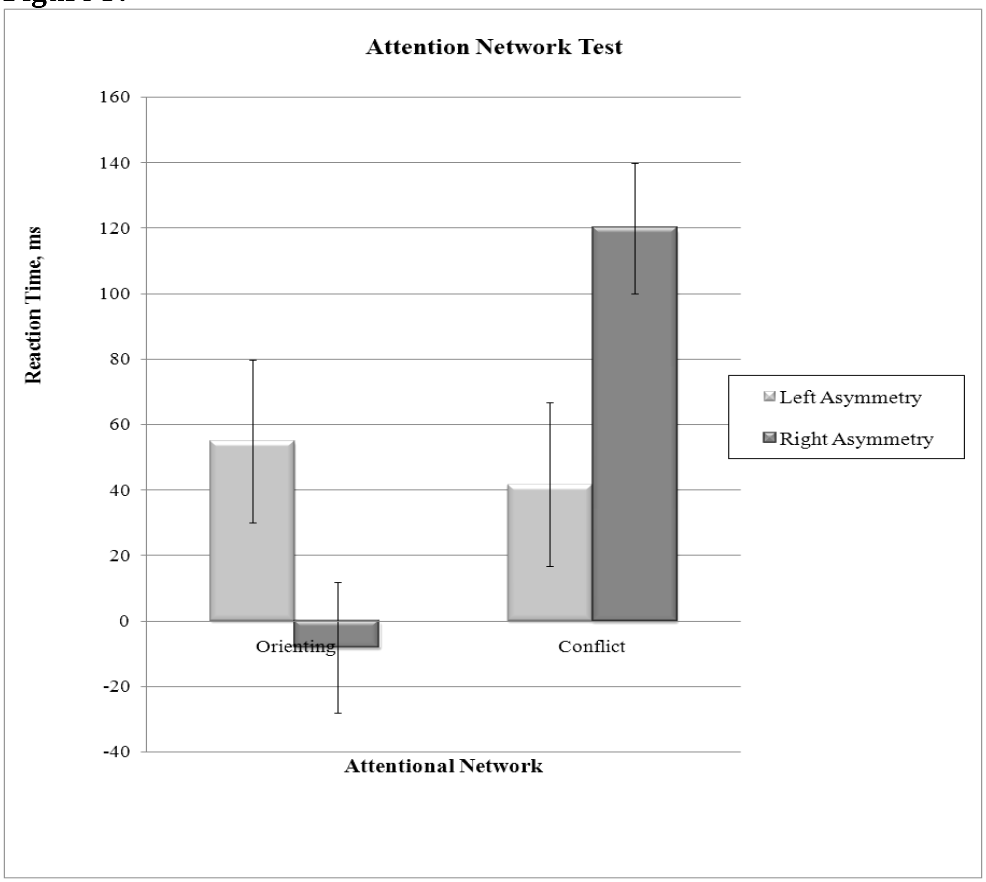


Figure 5 illustrates the mean ANT scores for the left and right asymmetry groups. The orienting score reflects asymmetry recorded during phase 1 stranger approach at the dorsocentral site. The conflict score reflects asymmetry recorded during baseline at the frontopolar site.

Discussion

The goal of the current study was to examine how frontal EEG asymmetry is related to temperament and attention behaviors during childhood. Parent reports of child temperament, laboratory observations, and performance on the ANT provided measures for better understanding the links between brain activity and behavior. Our findings largely support our hypotheses based on Davidson and Fox's (1982) model of right frontal brain asymmetry. Fearful behaviors were associated with greater right activation, while bold behaviors were related to greater left frontal asymmetry. Furthermore, our findings, though in contradiction with our attention hypothesis, demonstrated that right frontal asymmetry is associated with poor performance in attention tasks.

Frontal Asymmetry and Temperament

The findings of the present study largely replicated past research (e.g. Davidson & Fox 1982; 1988), which identified right frontal asymmetry as a predictor of behaviors related to later anxiety. Despite our prediction that shyness would be associated with right frontal asymmetry, only parent-reported fear was related to asymmetry. This association of right asymmetry and fear was consistent between baseline and during both phases of stranger approach, as well as across several different frontal sites. Similar to past research (Davidson & Fox, 1982; 1988) using 10 month old infants, this study did not find any relation between inhibition and the parietal site. We failed to find a significant association between right frontal asymmetry and shyness/withdrawal/distress behaviors in the laboratory.

The EEG recordings and parent reports also revealed an association between left frontal asymmetry and anger/frustration. Studies have shown that children with left frontal asymmetry are more likely to exhibit approach behaviors (Fox et al. 2001), including anger. A 2006 study conducted by Forbes et al., showed that left asymmetry in boys between the ages of three and nine was related to aggressive behaviors. More generally, researchers have demonstrated that children with left frontal asymmetry are more likely to exhibit externalizing behaviors. Smith and Bell (2010) found that toddlers with stable left frontal asymmetry were rated higher by mothers in scales of externalizing emotions such as attention problems and aggressive behavior. The findings regarding anger/frustration in the current study were consistent with the literature.

Affective Behaviors

The current literature on frontal asymmetry consistently associates left frontal asymmetry with positive affect, and right frontal asymmetry with negative affect. However, a recent study from Light et al. (2009) found that children, ages six to 10, showed changes in frontal activation during emotion tasks. They found that contentment was related to greater left asymmetry, while concern and positive empathy were related to changes toward increasing right asymmetry. The findings of the current study extend the literature on this association between frontal asymmetry and low levels of positive affect under different conditions. During the first phase of stranger approach, which required interaction between stranger and participant, children with left frontal asymmetry experienced greater positive affect. However, during the second phase of stranger approach, which was non-interactive, children with right frontal asymmetry displayed greater positive affect.

As Light and colleagues (2009) found right asymmetry was associated with low levels of positive affect, the current study found that children with right asymmetry displayed positive affect when no interactive participation was required for the episode. These studies imply that we cannot simply assign right frontal activity as a predictor of withdrawal and negative emotion. Instead, right frontal asymmetry could be a predictor of positive emotions, such as content, that do not have strong approach motivations. This link between positive affect during passive activities and right frontal asymmetry has also been demonstrated in adults. Douglas Teti presented findings at the International Conference of Infant Studies (2010) which demonstrated that mothers displaying positive affect during a passive viewing task of their infants' pictures showed a shift to right frontal asymmetry from baseline. These findings, in addition to those from the current study, provide support for role of prefrontal cortex in regulating emotions.

Frontal Asymmetry and Attention Networks

The findings from the parent reports indicated that children with greater left activity had higher mean scores for attentional focusing. This association was reported for asymmetry at both the frontopolar site and the parietal site. While asymmetry studies have focused on the frontal cortex for its role in emotion, the parietal brain areas are related to attention networks. As an indicator of the ability to maintain focus on specific tasks, this CBQ score provides some insight on the relationship between asymmetry and attention. In a study of females, ages 19 years and older, higher ratios of resting EEG slow waves to fast waves (a greater theta/beta ratio) was related to attentional control (Putman et al. 2010). Adult studies have shown that brain waves can be a useful correlate in studying attention behaviors; however, the current findings provide support for the efficacy of brain asymmetry in development.

The prediction for this study was that children with right frontal asymmetry would score higher in attention categories, and perform better on the ANT. Right frontal activation, and behavioral inhibition, is linked to hypervigilance in unfamiliar situations, which indicates a child's increased sensitivity to their environment. Children with right frontal asymmetry, if hypervigilant, were predicted to be more aware of the task, and produce better response times for the ANT. However, similar the parent reports, the ANT showed that children exhibiting left frontal asymmetry produced faster reaction times to the ANT tasks. This suggests that, contrary to my hypothesis, children with right frontal asymmetry are unable to channel their sensitivity to their surroundings to a specific attention task.

More specifically, the children with right frontal asymmetry had more difficulty in recognizing spatial cues than central cues, producing a higher orienting score than the children with left frontal asymmetry. Additionally, the mean response time for the conflict score – incongruent versus congruent trials – was greater for children with right frontal asymmetry. The decreased ability to process conflict reflects poor executive control functioning in the right frontal asymmetry group.

Research has provided information on the association between behaviors and anxiety, as well as how anxiety modulates attention. In a study of adults ages 17-32, deficiencies in the executive control network were associated with trait anxiety, while overfunctioning alerting and orienting networks were related to state anxiety (Pacheco-Unguetti et al., 2009). However, the relationship of these anxious behaviors and attention has not yet been related to frontal asymmetry. The current study adds to the anxiety/attention literature by providing a direct link between frontal asymmetry and attention in middle childhood.

Limitations

The conclusions drawn from this study are limited by several factors. The size of this sample was relatively small, and this factor could influence the strength of the results. By increasing the sample of children observed, the associations that emerged between study variables could become more obvious. In addition, a longitudinal study of the links between asymmetry and attention would provide a stronger basis for its link to the development of anxiety. Finally, the conclusions on emotion regulation could be clarified if this study observed the individual changes elicited in left and right asymmetry in the transition from baseline activity to stranger approach tasks.

Conclusion

The findings of the current study support the literature on frontal asymmetry and its relationship with child temperament, in addition to extending the research on attention and anxiety. The associations between frontal asymmetry and attention demonstrated in this sample provide evidence for a psychophysiological correlate for which to predict anxiety behaviors. Better defining early identifiers, such as frontal asymmetry, for temperamental traits and attention behaviors that lead to social anxiety can direct future research in understanding the basis of anxiety disorders and developing preventive interventions. While frontal asymmetry is already considered a predictor of risk for social anxiety, this study provides support for the use of brain asymmetry as a biomarker for attention behaviors in children.

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