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Infancy Predictors of Preschool and Post-kindergarten Executive Function

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Abstract

Little is known about factors that promote optimal development of executive function skills. The focus of this study was associations among early maternal behaviors, infant frontal brain electrical activity, and child executive functions at age four and following kindergarten. Infant frontal electroencephalogram was collected from 56 infants at 10 months of age and maternal positive affect was observed. Children completed executive function measures in the research laboratory at age four; parental-reported executive function was obtained following children's kindergarten year. Maternal positive affect and infant frontal brain electrical activity measured when the children were 10 months jointly and uniquely predicted both preschool and post-kindergarten executive function. Findings suggest parenting behavior and brain development in infancy are precursors of later self-regulatory executive function abilities.

Keywords

infancy; early childhood; executive function

Executive function (EF) is involved during deliberate, conscious cognitive processing. Although disagreement exists about a precise definition, EF is generally conceptualized to include the separate but related cognitive and regulatory constructs of working memory, inhibitory control, and cognitive flexibility (e.g., Carlson & Moses, 2001; Diamond, Barnett, Thomas, & Munro, 2007; Zelazo, 2004). Significant improvements in EF abilities from the toddler to kindergarten years may support the child's transition from external (i.e., parent-based) to more internal means of regulating behavior. With regulatory-related skills to resist inappropriate behaviors and instead respond more suitably to situational demands, to maintain attentional focus amid distraction, and to shift attention and perspective when required, EF allows children increasing control over their own actions (Diamond et al., 2007).

Rudimentary EF abilities emerge late in the first year of life; 12 month olds, unlike 7 month olds, can inhibit the impulse to reach to a previously rewarding but incorrect location on the A-not-B task (Diamond, 1990; Diamond, Prevor, Callender, & Druin, 1997). EF abilities continue to progress in early childhood but improve most dramatically between the ages of 3 and 5 (e.g., Carlson, 2005; Jacques & Zelazo, 2001), with particular gains seen in tasks requiring inhibitory control (Diamond, 2006). Data on the Stroop-like day-night task, a popular task assessing all three components of EF, illustrate this dramatic improvement.

Slightly less than half of 3-year-olds and slightly more than half of 4-year-olds can successfully complete this task, in contrast to 80% of 5-year-olds (Carlson, 2005; Gerstadt, Hong, & Diamond, 1994). Continuous but more gradual advances in EF ability occur in middle childhood (e.g., Romine & Reynolds, 2005), especially regarding working memory and cognitive flexibility performance.

Execution of EF relies heavily on the prefrontal cortex (PFC). Not surprisingly, significant maturational advances in PFC development coincide with significant gains in EF abilities (see Diamond, 2002, for review). Relative to other cortical areas, maturation of the PFC is delayed and protracted; development is first evident in the later half of the first year (Chugani & Phelps, 1986; Diamond, 2006) and continues well into adulthood (Luna et al., 2001). Because of the documented connections between cognitive and regulatory skills and the PFC (Diamond, 2002), one goal of the current study was to investigate early frontal development (measured via scalp-recorded brain electrical activity; e.g., Bell & Fox, 1992; Cuevas & Bell, 2011) and later EF abilities.

There is good evidence that early frontal development measured via the electroencephalogram (EEG) is related to concurrent EF abilities. (See Fox, Schmidt, Henderson, & Marshall, 2007, for a discussion of conceptual and methodological issues in developmental psychophysiology, including use of EEG.) EEG power, a measure of excitability of groups of neurons, measured at frontal scalp locations is associated with EF performance during infancy (e.g., Bell, 2012, 2001; Cuevas & Bell, 2011; Cuevas, Bell, Marcovitch, & Calkins, in press), toddlerhood (e.g., Morasch & Bell, 2011), and early childhood (Wolfe & Bell, 2004, 2007). EEG measured at age 4 is related to EF measured at age 6 (Cuevas, Hubble, & Bell, 2012), but to our knowledge, there is no research demonstrating that EEG measured during infancy is related to EF abilities during later childhood. Infant researchers have proposed that the maturation of the PFC and associated neural circuitry during the last half of the first year is the foundation for the emergence of higher order cognitive processes (Colombo & Cheatham, 2006). Thus, we expected that EEG measured during infancy would be correlated with EF skills many years later, in early childhood and early middle childhood.

Another goal of the current study was to investigate the impact of a warm and nurturing environment during infancy on later EF. Although there is theoretical support for the idea that consistent exposure to an optimal environment may benefit neurocognitive development (Nelson & Bloom, 1997), the cognitive impact of positive experiential exposure is currently unknown (Thompson & Nelson, 2001). Examination of environmental factors that might positively impact EF development is, thus, an important research focus.

In contrast, a significant body of work has documented the relation between EF deficits and early child development. Children with low levels of EF are at risk for clinical-level ADHD symptomatology (e.g., Berlin, Bohlin, & Rydell, 2003; Campbell & von Stauffenberg, 2009; Gewirtz, Stanton-Chapman & Reeve, 2009), social difficulties (Fahie & Symons, 2003), academic difficulties (Liew, McTigue, Barrois, & Hughes, 2008; Zhou, Main, & Wang, 2010), particularly regarding mathematic performance (Ponitz, McClelland, Matthews, & Morrison, 2009; Welsh, Nix, Blair, Bierman, & Nelson, 2010), and difficulty regulating emotions (Lemery, Essex, & Snider, 2002; Kochanska, Murray, & Harlan, 2000). As previously noted, however, less is known about factors that promote optimal EF abilities. Identification of such factors is important for both theoretical and practical purposes. Individual differences in EF during early childhood have been linked with biologically-based variables such as age (e.g., Carlson, 2005), gender (e.g., O'Brien, Dowell, Mostofsky, Denckla, & Mahone, 2010), and brain electrical activity (e.g., Wolfe & Bell, 2004, 2007). Environmental variables, however, also impact emerging self-regulatory skills. A recent

study found that executive functioning skills are somewhat malleable, as comprehensive EF training substantially improves performance on novel EF tasks (Diamond et al., 2007).

Certainly one of the most salient environmental variables in infancy and early childhood is parenting. Although there is conceptual support for the influence of early caregiving behaviors on later child self-regulatory skills (Kopp, 1982), and indeed significant relations exist between parenting practices and the separate but related construct of effortful control (Kochanska, Murray, & Harlan, 2000), the impact of parenting on subsequent EF abilities is an under-explored area. However, there have been recent reports that the caregiving environment during infancy contributes to the development of later EF (e.g., Bernier, Carlson, Deschenes, & Matte-Gagne, 2011; Bernier, Carlson, & Whipple, 2010; Matte-Gagne & Bernier, 2011). Research by Hughes and Ensor (2009), for example, indicates that maternal behaviors such as scaffolding and planning (defined as parental demonstration of tasks), as well as family chaos were predicative of nearly a sixth of the variance in children's EF abilities at age 4. Likewise, Hammond et al. (2012) also report positive links between maternal scaffolding and children's EF abilities at age 4. Bernier and colleagues (2010) reported that maternal sensitivity, mind-mindedness, and autonomy support, measured when infants were 12 and 15 months of age, predicted toddler EF both six months and one year later, with autonomy support emerging as the strongest predictor. The authors proposed that responsive parenting may promote cognitive control through neurological development. It is generally accepted that early experiences play a role in brain development, as environmental experiences are believed to shape the neural synaptic pruning and cultivation that occur in infancy (e.g., Nelson & Bloom, 1997). Bernier and colleagues (2010) suggested that responsive parenting in infancy may promote high levels of EF in two ways: indirectly, by supporting optimal neural development, and directly, by providing an appropriate social environment to observe and practice positive regulatory strategies associated with EF. The work by Bernier and colleagues examined maternal behaviors during infancy and child EF up to age three (Bernier et al, 2011; Matte-Gagne & Bernier, 2011). We measured mother's positive affect during her interactions with her infant and expected that this maternal behavior measured during infancy would be correlated with EF skills many years later, in early childhood and early middle childhood.

The purpose of our study was to examine associations between maternal behavior in infancy, specifically mother's positive affect during interactions with her child, infant frontal brain electrical activity, and subsequent child EF. Maternal warmth, a central factor in optimal caregiving that includes such behaviors as sensitivity and positive affect, has been found to predict adaptive parent-child interactions (Kochanska & Aksan, 1995; Mangelsdorf, Gunnar, Kestenbaum, Lang, & Andreas, 1990; Belsky, Crnic, & Woodworth, 1995). Similarly, warm maternal behavior promotes internalization of regulatory behavior in children (Kochanska & Aksan, 1995) as well as attachment security (De Wolff & van Ijzendoorn, 1997). Early attachment security, in turn, promotes later EF (Bernier et al., 2011), which lends further support for the idea that maternal behavior could predict child EF. Maternal positive affect during infancy and infant frontal brain electrical activity were thus examined as predictors of future child cognitive and self-regulatory EF skills. We hypothesized that both factors from infancy would predict child EF abilities during early childhood and following kindergarten.

Method

Participants and General Procedures

Fifty-six children (26 girls; 51 Caucasian, 4 Hispanic, 1 African American) and their mothers participated in the current study. Participants are part of a larger longitudinal study of cognition and emotion integration across infancy and early childhood and were recruited

using birth announcements and commercial mailing lists of new parent names. Children had no known neurological conditions or developmental delays. All parents who reported educational information had at least a high school diploma. Fifty one percent of mothers had college degrees, as did 34% of fathers. Mothers were approximately 31 years old (range 22–38) at the child's birth and fathers were approximately 34 years old (range 23–52).

Behavioral and physiological data collection took place in the laboratory when participants were 10 months of age ($M = 314.29$ days, $SD = 10.46$); additional behavioral data collection took place in the laboratory when the participants were 4 years of age ($M = 4$ years 6 weeks, $SD = 4$ weeks). After children had completed their kindergarten year ($M = 6$ years 16 weeks, $SD = 18$ weeks), parents were mailed the Behavior Rating Inventory of Executive Function – Preschool version (BRIEF-P, Gioia, Isquith, & Espy, 2003) and 54 families completed and returned the questionnaire.¹ Families were paid at each assessment for their participation.

Brain Electrical Activity at 10 Months

The 10-month assessment was conceptualized to coincide with the initial emergence of EF skills (Bell & Deater-Deckard, 2007). Upon arrival at the research laboratory for the infant visit, parents were shown the electrophysiological equipment and all research procedures were explained. After obtaining written parental consent, electrodes were applied to the infant's scalp for the electroencephalogram (EEG) recording.

Baseline EEG was recorded for a duration of 60 seconds ($M = 62.63$, $SD = 4.95$) while the infant sat on mother's lap. During the baseline recording, a research assistant manipulated a toy containing brightly colored balls on top of a table 1.1 m in front of the infant. This procedure quieted the infant and yielded minimal eye movements and gross motor movements. Mothers were instructed not talk to infants during the EEG recording. Immediately after baseline, a battery of cognitive and emotion regulation tasks not part of this report was administered.

EEG recordings were made from 16 left and right standard scalp sites: frontal pole (Fp1, Fp2), medial frontal (F3, F4), lateral frontal (F7, F8), central (C3, C4), anterior temporal, (T3, T4), posterior temporal (T7, T8), parietal (P3, P4), and occipital (O1, O2), referenced to Cz. EEG procedures followed recommended guidelines for working with developmental samples (Pivik et al., 1993). EEG was recorded using a stretch cap (Electro Cap, Inc.; Eaton, OH); NuPrep abrasive and EEG Gel conductor were inserted into each recording site and the scalp gently rubbed. Electrode impedances were measured and accepted if below 10 k Ω . The electrical activity from each lead was amplified using separate SA Instrumentation Bioamps (San Diego, CA) and bandpassed from .1 to 100 Hz. Activity for each lead was displayed on the monitor of an acquisition computer. The EEG signal was digitized online at 512 Hz for each channel so that the data were not affected by aliasing. The acquisition software was Snapshot-Snapstream (HEM Data Corp.; Southfield, MI) and the raw data were stored for later analyses.

EEG data were examined and analyzed using EEG Analysis System software developed by James Long Company (Caroga Lake, NY). The data were re-referenced via software to an average reference configuration and then artifact scored for eye movements and gross motor movements. These artifact scored epochs were eliminated from all subsequent analyses. The data were then analyzed with a discrete Fourier transform (DFT) using a Hanning window

¹We have previously reported with this sample that age four EEG, heart rate, EF behaviors (forward digit span, mommy-me Stroop-like task) and temperament-based inhibitory control predict post-kindergarten BRIEF-P general executive composite (Cuevas, Hubble, & Bell, 2012). Although this current manuscript also uses the BRIEF-P data, none of the age four data in the Cuevas et al publication are used in these current analyses, nor do we use the age four data to predict post-kindergarten BRIEF-P.

of 1-second width and 50% overlap. Power was computed using the 6–9 Hz frequency because infants have a dominant frequency in this range (Bell & Fox, 1992; Marshall, Bar-Haim, & Fox, 2002). The 6–9 Hz band during infancy and early childhood functions similarly to adult α Power was expressed as mean square microvolts and the data were transformed using the natural log (\ln) to normalize the distribution. In the infant EEG literature, higher baseline power values are indicative of greater brain maturation (e.g., Bell & Fox, 1992). Higher 6–9 Hz power values at frontal scalp locations have been associated with performance on tasks thought to require frontal lobes during infancy (e.g., Bell, 2001; Bell & Fox, 1992; Cuevas & Bell, 2011).

Medial and lateral baseline frontal EEG data (F3, F4, F7, F8) were the focus of these analyses because of the association with infant and preschool executive function performance (Bell, 2001; Wolfe & Bell, 2004, 2007). Because we had no hypotheses regarding hemispheric asymmetry, we averaged the EEG power values at F3, F4, F7, and F8 to obtain a composite frontal baseline EEG value.

Maternal Behavior Task at 10 Months

Following EEG collection and other tasks not associated with this report, maternal positive affect was assessed during a 2 minute task focusing on maternal behavior during a structured play activity. The infant was transferred to a high chair and the mother sat in front of and slightly to the left of her infant. A camera was focused on both mother and infant.

The experimenter presented the mother with two simple, age-appropriate infant toys and instructed her to play with her infant as she normally would at home. Maternal positive affect was coded in 30 second epochs on a 4-point scale adapted from Calkins, Hungerford, and Dedmon (2004) based on facial expressivity (i.e., smiling) and vocal affect. A score of 1 indicated no positive emotion, whereas a score of 4 indicated intense positive emotion, including laughing. Scores for each mother were averaged across epochs to create a composite maternal positive affect score. Maternal behavior was videotaped for off-line coding by trained research assistants. An independent observer coded 20% of the dyads to confirm reliability of coding; ICC = .85.

EF Assessments at Age 4

Children returned to the research lab at ages 2, 3 and 4 for continued participation in our longitudinal study. EF skills show great developmental changes across the toddler and preschool years. In this report, we focus on the age 4 data because EF skills begin to show stable individual differences at age 4 (Alloway, Gathercole, & Pickering, 2006; Jones, Rothbart, & Posner, 2003; Kochanska & Knaach, 2003). The three cognitive tasks that are the focus of this investigation involve a variety of EF skills and are similar to the EF battery used at age 3 by Bernier et al (2011).

The Pig/Bull task closely followed the Bear-Dragon procedure described by Carlson and Moses (2001; adapted from Reed, Pien, & Rothbart, 1984), and requires children to follow the instructions given by one puppet and ignore the instructions given by another puppet. The experimenter showed the child the pig puppet, told him or her that this was a nice puppet, and instructed the child to do as the pig said. The experimenter then showed the child the bull puppet, told him or her that this was a mean and grumpy puppet, and instructed the child to *not* do as the bull said. The bull trials, which require both inhibitory control and working memory EF skills, were the trials of particular interest in this study. Children received two practice trials with feedback and then eight test trials with no feedback. Test trials consisted of four pig and four bull trials in alternating order. The final score was a percentage based on the number of successful bull (inhibition) trials (i.e., 4

successes = 100, 3 successes = 75, 2 successes = 50, 1 success = 25, 0 successes = 0). Interrater reliability was calculated for 25% of the sample and was high; ICC = .99.

The Dimensional Change Card Sort (DCCS; Zelazo, Frye, & Rapus, 1996) requires children to sort cards first by one rule, and then by a second rule such that the two criteria used are incompatible with each other. Thus, this task is typically considered to require the EF skill of cognitive flexibility, although it may also involve inhibitory control and working memory. The experimenter used a set of 14 laminated cards (11 cm×7 cm); each card had either a red or blue car on it, or a red or blue flower on it. Children were first told to sort 7 test cards by color (or shape; pre-switch condition), and then to sort the remaining 7 cards by shape (or color; post-switch condition). In the post-switch condition, children were given no feedback on their performance but were reminded of the new sorting criterion after each trial. Final scores were a percentage of correct post-switch trials. Twenty five percent of the post-switch trials were double-coded; ICC between coders' scores suggested good reliability; ICC = .98.

The yes-no task (Wolfe & Bell, 2004, 2007), conceptually similar to the day-night task (Diamond et al, 1997), requires children to inhibit and override their natural reaction to head nods and shakes. Children are instructed to say “no” when the experimenter nods her head and to say “yes” when the experimenter shakes her head, thus taxing both inhibitory control and working memory. Children received 2 practice trials, during which they were praised or corrected, and 10 test trials, with 5 head nods and 5 head shakes arranged in a pseudorandom order. The series of stimulus gestures was presented as follows: Y, N, N, Y, N, Y, Y, N, N, and Y. No feedback was given during testing. The percentage of correct trials was calculated. Twenty five percent of the post-switch trials were double-coded; ICC between coders' scores suggested good reliability; ICC = .94.

Post-kindergarten EF Assessment

Following participants' kindergarten year, parents were mailed the Behavior Rating Inventory of Executive Function, Preschool Version (BRIEF-P), which assesses everyday executive functioning and is appropriate for children up to age 6. The BRIEF-P is composed of 63 items that load onto the following scales: Inhibit, Shift, Emotional Control, Working Memory, and Plan/Organize. These 5 scales can be combined for a Global Executive Composite (GEC) score, or an index of global EF. Items assess children's daily executive functioning in their natural environment (e.g., “is impulsive,” “needs help from adults to stay on task,” “talks or plays too loudly”) and are rated on a 3-point scale (1 = never, 2 = sometimes, 3 = often). On the BRIEF-P, a lower score on all scales indicates more optimal EF abilities and a high score indicates risk of executive dysfunction. For consistency, we reverse scored the items so that the BRIEF-P was scored in the same direction as our age 4 EF tasks (i.e., high on the BRIEF-P is optimal). Internal consistency and test-retest stability on the BRIEF-P scales is high and ranges from .80 to .97 and .78 to .90, respectively (Gioia et al., 2003). For our sample, internal consistency on the BRIEF-P scales ranged from .89 to .91.

Results

Mean values for maternal and physiological variables at 10 months and EF abilities at age four and following kindergarten are presented in Table 1. A composite score for EF abilities at age four was created by averaging the performance across the three tasks; all had been scored as percentage correct and all were intercorrelated (see Table 2). Children's scores on the BRIEF-P were in keeping with reported standardized scores from typically-developing populations (Gioia et al., 2003).

Table 3 displays the bivariate correlations between maternal and physiological variables at 10 months and EF abilities at age four and following kindergarten. Both four year and post-kindergarten EF abilities were significantly correlated with both infancy variables. Although there was no correlation between the 10-month variables of infant frontal EEG and maternal positive affect ($r = -.06$), the 4-year behavioral EF and post-kindergarten BRIEF-P composites were positively correlated ($r = .37, p < .05$). In previous research sociodemographic variables such as child gender and parental education level have been shown to impact EF performance. No associations were found, and thus no sociodemographic variables are included in further analyses.

Predicting Childhood EF from Infancy EEG and Maternal Behavior

To test our hypothesis that both maternal positive affect and frontal EEG activity in infancy would contribute to EF performance in early childhood and post kindergarten, two separate regression analyses were conducted with maternal positive affect and frontal baseline EEG as predictors. Table 4 presents the results of these two analyses. In the first analysis, ten month variables jointly accounted for 15% of the variance in four year EF composite variable. Both maternal positive affect and baseline frontal EEG activity emerged as significant and unique predictors, accounting for 8% and 7% of the variance, respectively.

In the second analysis, ten month variables also jointly accounted for 15% of the variance in post-kindergarten EF. As with the age four analysis, both maternal positive affect and frontal EEG activity emerged as significant and unique predictors. Each explained a unique 8% of the variance.

Although we did not hypothesize a moderation effect (e.g., maternal positive affect during infancy interacts with infant frontal baseline EEG) in predicting age 4 or post-kindergarten EF, we included a second step in each regression analysis in which we explored potential moderation. For both age 4 EF and post-kindergarten EF, the change in R^2 was .00 when testing a potential moderation effect.

Discussion

Our study provides further evidence that experience during infancy has a lasting influence on child regulatory EF abilities and is consistent with finding from other researchers that early parenting behavior is a precursor of later EF (e.g., Bernier et al., 2010; Bernier et al., 2011; Matte-Gagne & Bernier, 2011). Our data offer the first evidence that both maternal behavior and infant brain electrical activity at 10 months predict EF three years and five years later. Notably, infancy predictors together accounted for 15% of the variance in EF abilities at both later time points. This percentage is quite modest, however. It may be that our snapshot of these infancy variables was too simplistic and that a more complex examination of infant neurocognition and parenting behaviors (perhaps involving several measures of maternal positive affect, warmth, and scaffolding, for example) is required.

One attempt we made at considering a more complex association between parenting behaviors and infant neurocognition and later EF abilities was to examine a potential interaction effect between maternal positive affect and infant frontal baseline EEG in predicting age 4 and age 6 EF. The suggestion by Bernier and colleagues (2010) that nurturing parenting behaviors influence neurocognitive development and other early cognitive neuroscience research literature did not lead us to hypothesize an interaction, or a moderating effect of maternal positive affect on infant frontal EEG or vice versa. Indeed, including an interaction variable in the second step of the regression analyses proved fruitless. Thus, maternal positive affect during infancy and infant frontal EEG are unique predictors of later EF.

Given the lengthy development of cognitive and regulatory EF skills, it is possible that relative contributions from biology and the environment may shift across different age groups. Examining the relative contributions of early brain development and maternal behavior across different developmental periods would allow us to identify whether contributions remain the same across time or whether they differ as a function of age. Data from Wiebe et al. (2009) indicate that the effects of the environment and biological expression on children's self-regulatory behavior differed from infancy to preschool. Potential relations between early frontal functioning and parenting behavior in infancy warrant further investigation, and given the complex nature of the interaction between environmental and biological factors (e.g., Wiebe et al., 2009), it is possible and indeed likely that infant frontal EEG and maternal positive affect work together, as well as individually, to influence emerging self-regulatory EF capacities.

The pattern of EEG findings reported here is different from typical reports in the literature of concurrent EEG and behavior. Higher baseline EEG power values are typically considered to be indicative of greater maturation in the infancy (Bell & Fox, 1992) and early childhood (Wolfe & Bell, 2004) literatures. Similarly, higher power values are typically correlated with better EF performance (Bell, 2001; Cuevas et al, in press; Orekhova, Stroganova, & Posikera, 2001; Wolfe & Bell, 2004). However, in these data, there was a negative correlation between infant frontal EEG power values during baseline and EF abilities at ages 4 and 6. Lower frontal EEG power values during infancy were associated with higher levels of EF performance during early and middle childhood.

In previous work with a different sample we reported a negative correlation between EEG power values at 8 months and EEG power values at 4.5 years (Wolfe & Bell, 2007). We suggested that the developmental pattern of EEG maturation likely was the reason for the negative correlation. Infant EEG has its greatest power in the lower end of the 6–9 Hz frequency band and child EEG has its greatest power in the upper end of this band (Marshall et al, 2002). Although we are focused on 4-year EF behaviors in this manuscript and not 4-year EEG, the same principle may apply. The changing nature of early EEG patterns may mean that the specific frequency correlated with behavior concurrently may not be the same correlated with later behaviors.

In conclusion, knowledge of the antecedents of EF can provide greater insight into the nature of this vital regulatory ability. Our findings indicate that differences in parenting behaviors as well as neurocognitive development are two contributing factors to individual differences in child EF, providing further evidence that experience during infancy has a lasting influence on child regulatory EF abilities. Many questions, however, still remain. Do early neurocognitive development and parenting behaviors still remain predictive of EF abilities in populations with known deficits in EF, such as children with attention deficit disorder? Given that EF continues to develop into adolescence and adulthood, does the predictive value of these variables change over the course of childhood and beyond? Further longitudinal work may help to address these and other important questions.

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Table 1

Mean, Standard Deviation, and Range for Parenting, EEG, and Executive Function (EF) Measures

Variable	Mean	S.D	Range	n
10 mo maternal positive affect	2.68	.48	2.00–4.00	56
10 mo frontal baseline EEG	2.65	.35	1.81–3.96	56
4 yr EF composite	.78	.24	0.13–1.00	55
Post-kindergarten BRIEF-P	51.13	9.87	34.00–79.00	54

Table 2

Intercorrelations Among Executive Function Measures at Age 4

	Yes/No	Pig/Bull	DCCS
Yes/No	—		
Pig/Bull	.33*	—	
DCCS	.25 ^a	.35**	—

^a $p = .06$.* $p < .05$.** $p < .01$.

Table 3

Bivariate Correlations between Maternal Positive Affect and Baseline Frontal EEG at 10 months, Four Year EF, and Post-kindergarten EF

	10 month maternal positive affect	10 month baseline frontal EEG
Four year EF	.29 *	-.27 *
Post kindergarten EF	.27 *	-.27 *

* $p < .05$.

Table 4

Summary of Regression Analysis Predicting Age 4 and Post-kindergarten Global Executive Function Performance from 10 Month Data

	B	SE(B)	β	<i>t</i>	<i>p</i>	<i>sR</i>²
<i>Predicted: 4 year EF</i>						
10 month maternal positive affect	.14	.06	.28	2.18	.03	.08
10 month frontal baseline EEG	-.17	.09	-.25	-2.00	.05	.07
$R^2 = .15, F(2, 55) = 4.65, p = .01$						
<i>Predicted: Post kindergarten EF</i>						
10 month maternal positive affect	5.40	2.54	.28	2.13	.04	.08
10 month frontal baseline EEG	-7.58	3.55	-.28	-2.13	.04	.08
$R^2 = .15, F(2, 53) = 4.53, p = .02$						