Published in final edited form as:

Br J Dev Psychol. 2014 March ; 32(1): 50–64. doi:10.1111/bjdp.12021.

A Longitudinal Intergenerational Analysis of Executive Functions During Early Childhood

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Abstract

Despite the importance of executive function (EF) in both clinical and educational contexts, the etiology of individual differences in early childhood EF remains poorly understood. This study provides the first longitudinal intergenerational analysis of mother-child EF associations during early childhood. A group of children and their mothers ($n = 62$) completed age-appropriate EF tasks. Mother and child EF were modestly correlated by 24 months of age and this association was stable through 48 months. Importantly, maternal-child EF associations were still robust after controlling for verbal ability (potential indicator of verbal/crystallized intelligence) and maternal education (correlate of socioeconomic status and verbal intelligence). Potential implications of these findings as well as underlying mechanisms of the maternal-child EF association (gene-environment interplay) are discussed.

Keywords

executive function; early childhood; intergenerational transmission; individual differences

Well-regulated attention and memory processes are critical to healthy cognitive and social-emotional development (Bell & Deater-Deckard, 2007; Blair, 2002). Executive functions (EFs), for instance, are higher-order cognitive and self-regulatory processes (e.g., working memory, inhibitory control, cognitive flexibility) that are linked to the prefrontal cortex and

underlie goal-directed behaviors. The development of both the prefrontal cortex and EFs are protracted through childhood and early adulthood. During early childhood, EFs are linked to school readiness (e.g., Blair & Peters, 2003), academic performance (e.g., Bull, Espy, & Wiebe, 2008; St. Clair-Thompson & Gathercole, 2006), and early-onset disorders, including attention-deficit/hyperactivity disorder (ADHD), autism spectrum disorder, and phenylketonuria (e.g., Diamond, Prevor, Callender, & Druin, 1997; Semrud-Clikeman, Walkowiak, Wilkinson, & Butcher, 2010). Despite the significance of EF in both clinical and educational settings, the etiology of individual differences in EF during early childhood remains poorly understood.

In the present study, we use an intergenerational transmission analysis of mother and child EF to examine familial resemblance of EF. It has been hypothesized that bio-social mechanisms—both genetic as well as co-occurring socialization experience (environment)—support optimal regulatory development (Rueda, Posner, & Rothbart, 2004). Our primary interest is in determining if there is mother-child “familial” resemblance in EF by early childhood (and if so, when), which is essential in revealing a potentially critical area for future research. From one perspective, familial EF is an informative endophenotype for early-onset disorders and disorders with externalizing behaviors (e.g., ADHD; Doyle et al., 2005; Jester et al., 2009). Establishing mother-child EF resemblance during early childhood will also facilitate future research aimed at separating and specifying the particular bio-social mechanisms that underlie individual differences in early childhood EF.

Bio-Social Mechanisms of EF Transmission

Recent research has confirmed the role of parenting behaviors and socioeconomic status in the development of EF during early childhood (e.g., Bernier, Carlson, Deschenes, & Matte-Gagne, 2012; Hughes & Ensor, 2009). Less is known about the heritability of EF throughout early childhood. During adolescence and young adulthood, there is evidence that parent EF and child EF are strongly associated (Jester et al., 2009) and individual differences in EF are almost entirely heritable (Friedman et al., 2008) beyond contributions of intelligence. By 7 years of age, there is moderate heritability that overlaps between sub-constructs of EF such as working memory and inhibitory control (Wang, Deater-Deckard, Cutting, Thompson & Petrill, 2012). There are extensive changes in EF between early and middle childhood, and genes that are associated with many adult cognitive abilities, such as intelligence, are increasingly manifested during development (Alarcon, Plomin, Fulker, Corely, & DeFries 1998). Thus, there is likely a substantial increase in heritability, at least in attention-based aspects of EF, over the transition from early to middle childhood (Deater-Deckard & Wang, 2012) with moderate heritability already evident by 6 years of age (Polderman et al., 2006).

Sibling studies, however, do not directly address intergenerational transmission of EF. In an investigation of the social influence on child EF, Hughes and Ensor (2009) examined the role of imitative learning by including a measure of planning. Using aggregate measures of the constructs of interests, they found that maternal planning was positively associated with 4-year-olds' EF. In some conceptualizations of EF, planning is considered a more “advanced” form of EF (Diamond, 2013; Miyake et al., 2000). Thus, although Hughes and

Ensor did not use a standardized EF measure for adults, their finding suggests that maternal and child EF are potentially associated by 4 years of age.

A recent adoption study, on the other hand, failed to find an association between biological mothers' EF and their children's EF at 27 months of age (Leve et al., in press). Although it is possible that the familial EF signal is not present by 27 months, the null findings are potentially related to measurement issues. Specifically, Leve et al. examined associations between individual EF tasks (i.e., mothers: color Stroop; children: shape Stroop and gift delay). However, given that EF task performance is also affected by non-EF demands (e.g., variance due to measurement error), when possible it is highly preferred to use latent variable analyses (often used with large sample sizes e.g., Bull, Espy, Wiebe, Sheffield, & Nelson, 2011) or to form a composite aggregate score (often used with smaller sample sizes) of a latent construct of correlated indicators because these analyses provide more reliable measures of EF (Carlson, Mandell, & Williams, 2004; Rushton, Brainerd, & Pressley, 1983).

Clearly, a challenge for researchers interested in early childhood EF is that adult tasks are inappropriate for children, and the appropriate child EF tasks change throughout this developmental period (e.g., Carlson, 2005). Thus, even if EF is familial during early childhood, the effect might be attenuated because of measurement problems and error variance.

The Present Study

The aim of the present study was to provide the first systematic longitudinal analysis of associations between mother and child EF during early childhood. We were interested in maternal EF because (1) mothers share half of their genes with their children; and (2) mothers are more likely to be the primary caregiver, and maternal EF has been associated with a host of caregiving behaviors that likely pertain to intergenerational transmission of a wider variety of individual difference attribute (Barrett & Fleming, 2011; Deater-Deckard, Wang, Chen, & Bell, 2012). Although there is evidence that maternal caregiving behavior is related to child EF at 18 to 26 months (Bernier et al., 2010), it is unknown whether maternal EF is related to child EF during this developmental period. Our findings will provide a critical step for future research investigating the additive or interactive contributions of maternal EF and maternal caregiving behaviors to child EF. By determining a time frame in early childhood when a familial EF "signal" is initially present, researchers can begin to examine the precise timing as well as the relative contributions of bio-social mechanisms involved in the intergenerational transmission of EF. Furthermore, regardless of the mechanisms, if it turns out that mother EF is a robust indicator of potential deficits in young children's EF, this would be critical for early screening and potential diagnosis of EF deficits and/or associated early-onset disorders as well as early intervention involving EF training.

To this end, a group of children and their mothers completed age-appropriate EF tasks (on separate occasions) that required a variety of EF skills (e.g., working memory, inhibitory control, cognitive flexibility), and children were tested at 24, 36, and 48 months of age. We

were interested in this age span because it captures the emergence (i.e., approaching the earliest age of reliable assessment of individual differences) and development EF. We hypothesized that maternal and child EF would be positively correlated and this association would be present by 4 years of age (Hughes & Ensor, 2009). Based on the behavioral genetics literature reviewed (Deater-Deckard & Wang, 2012; Friedman et al., 2008), we estimated an effect size for the mother-child correlation to be between .40 and .50, leaving some room for variance due to measurement error. There is evidence, however, that both verbal ability (a measure often used as an indicator of verbal or crystallized intelligence) and socioeconomic status (a broad indicator of family material and social resources) are associated with EF (e.g., Bernier et al., 2012; Kaler & Kopp, 1990). Thus, we used hierarchical regression analyses to determine whether the hypothesized mother-child EF association was robust when controlling for maternal education (a correlate of socioeconomic status and verbal intelligence), child verbal ability, and maternal verbal ability.

Method

Participants

The initial sample included 63 biological mother-child dyads. Children were part of an ongoing longitudinal investigation and mothers participated when children were either 3 ($n = 55$) or 4 ($n = 8$) years old. One dyad was excluded because the child was premature at birth. Of the 62 children (25 boys, 37 girls; 4 Hispanic, 58 Non-Hispanic; 57 Caucasian, 5 Multi-Racial) in our final sample, all participated at 2 years ($M = 2.09$ years; $SD = 22$ days), 61 returned at 3 years ($M = 3.10$ years; $SD = 28$ days), and 57 returned at 4 years ($M = 4.11$ years; $SD = 29$ days). Based on our hypothesized effect size of .40, and based on one-tailed alpha of .05 (because we were predicting a positive correlation), power ranged from .93 to .95 for our final sample sizes (57 to 62; G*Power: Faul, Erdfelder, Lang, & Buchner, 2007). All mothers (1 Hispanic, 61 Non-Hispanic; 1 African American, 1 Asian, 60 Caucasian) graduated from high school (1.6% technical degree; 40.3% bachelor's degree; 35.5% graduate degree). Mothers were between 21 and 43 years ($M = 34$ years, $SD = 5$) during the maternal assessment. Parents received an honorarium for each laboratory visit.

Procedure

Children participated in a battery of EF tasks with the duration of each task being 5 min or less. All tasks were video recorded and coded offline with interrater reliability (Cronbach's $\alpha = .90$) for at least 20% of our entire longitudinal sample. Mothers¹ visited the laboratory on a separate occasion for maternal assessment. Study procedures were approved by the institutional review board.

Child EF Measures

The child EF tasks were presented in the order that they are described below.

¹Most mothers are also included in manuscripts examining maternal EF, household chaos, and child conduct problems (Deater-Deckard, Chen, Wang, & Bell, 2012; Deater-Deckard, Wang, et al., 2012). These data are also included in an examination of the indirect and direct effects of maternal caregiving to child EF (Cuevas et al., in press).

A-not-B with invisible displacement (24 months)—The toddler A-not-B looking procedure is detailed in Morasch and Bell (2011). An attractive item (i.e., a red ball) was hidden under a cup (central location); the cup was shifted to one side (side A, counterbalanced left/right); and a barrier was placed in front of the cup. During the 5-s delay, the experimenter distracted the toddler (kept gaze at midline) and behind the barrier, placed a second cup (side B). The barrier was removed and toddlers were asked, ‘Where’s the ball?’ The first look toward either location was coded, and after two consecutive correct same-side searches, the hiding location was reversed (pattern AAB). Performance was the proportion of correct searches (Diamond et al., 1997).

Crayon delay (24 months)—The crayon delay procedure (Calkins, 1997) is detailed in Morasch and Bell (2011). Toddlers were presented with a box of crayons and a blank piece of paper. Before the child touched the crayons, the experimenter told him/her that she needed to leave the room. She instructed the toddler not to touch the crayons, box, or paper until she returned. The experimenter left the room for 60 s. Toddlers’ behavior during the delay was scored a 0 (*does not touch*), 1 (*touches paper*), 2 (*touches box*), 3 (*picks up box*), 4 (*takes crayons out of box*), or 5 (*colors with crayons*).

Tongue task (36 months)—The tongue task (Kochanska, Murray, & Harlan, 2000) required children to hold a goldfish cracker on their tongue without chewing it (three trials with delays of 10, 20, and 30 s). Performance was the proportion of successful trials.

Simon-says (36 and 48 months)—The Simon-says task followed the Bear/Dragon procedure (Carlson, Moses, & Breton, 2002) and is detailed in Wolfe and Bell (2007). Children were instructed to do what the nice horse (48 months: pig) “tells us” and to not do what the mean cow (48 months: bull) “tells us.” Children passed (36 months: $n = 29$; 48 months: $n = 51$) the practice trials if they followed the horse/pig’s command but ignored the cow/bull’s command. Ten test trials followed (half for each type, alternating order), and performance was the proportion of correct responses.

Day-night (36 months) and yes-no (48 months)—For the day-night task (Gerstadt, Hong, & Diamond, 1994), children were instructed to say “day” when shown a moon card and to say “night” when shown a sun card. The yes-no task was created in our research lab (e.g., Wolfe & Bell, 2007) and is conceptually and procedurally similar to the day-night task. Children were instructed to say “yes” when the experimenter shook her head no and to say “no” when the experimenter nodded her head yes. For each task, once children passed two learning trials, they received 16 test trials (half for each type) in a pseudorandom order. Correct responses received 1 point and incorrect responses followed by self-correction received .5 point. Performance was the proportion of points earned.

Dimensional Change Card Sort (DCCS: 48 months)—For this task (Zelazo, Frye, & Rapus, 1996), children were instructed to sort cards based on two dimensions (i.e., color, shape). Children first sorted six cards by one dimension (pre-switch; counterbalanced across participants) and then were instructed to switch and to sort the remaining six cards by the other dimension (post-switch). Performance was the proportion of correct post-switch responses (e.g., Bernier et al., 2012).

EF composite measures (24, 36, 48 months)—Because EF task performance is also affected by non-EF demands (e.g., variance due to measurement error) it is essential to obtain multiple measures of latent constructs, such as EF (Carlson et al., 2004; Rushton et al., 1983). Thus, we used principal component analysis to verify that EF measures at a particular age were associated, and then calculated EF composite scores. The 24-month composite included crayon delay performance (reverse scored so that higher scores represented better performance) and A-not-B performance, $r(59) = .46, p(1\text{-tailed}) = .001$. At 36 months, the first principal component among the three tasks (tongue task, Simon-says, day-night) explained 53% of the variance ($\lambda = .68 - .77$). Likewise, the first principal component among the 48-month tasks (Simon-says, yes-no, DCCS) explained 58% of the variance ($\lambda = .74 - .79$). At each age, individual indicator scores were standardized, averaged, and standardized again to yield an EF composite² z-score. Finally, a child EF composite was formed by averaging the annual composite z-scores, and the final overall composite standardized again to yield a z-score. The first principal component explained 54% of the variance ($\lambda = .69 - .79$). This is our most reliable measure of child EF because it includes multiple measures assessed at different time points.

Mother EF Tasks

All EF tasks except backward digit span were computer administered.

Stroop color-word task—Mothers were instructed to press the color-labeled key that matched the color word. They received congruent (i.e., color words in the same color ink) and incongruent (i.e., color words in a different color ink) trials (Stroop, 1935). Performance was the percent accuracy for a set of 20 words during a block of mixed congruent and incongruent trials.

Wisconsin Card Sorting Test (WCST)—Mothers were instructed to match a card (64 total) to one of four key cards (Heaton & PAR Staff, 2003). The images on the cards varied in color, quantity, and shape, and participants must sort the cards according to an undisclosed rule (e.g., by shape) that they had to ascertain via feedback. The sorting rules changed several times. The age-standardized percentile score associated with conceptual level (i.e., consecutive correct responses occurring in runs of three or more) was the measure of interest.

Attention Network Test (ANT)—Mothers responded to a central target (an arrow) by pressing one of two keys to indicate if the arrow points left or right (Fan, McCandliss, Sommer, Raz, & Posner, 2002). Targets varied in the presence/absence of flankers as well as whether the flankers were congruent or incongruent. Performance was defined as the conflict score (i.e., executive attention measure)—the difference in reaction time between incongruent and congruent trials.

Backward digit span—An experimenter read a seemingly random series of single-digit numbers to participants. Mothers were instructed to repeat the sequence aloud in the reverse

²In the case of missing data, composites consisted of the remaining performance measures.

order, and they received 2-digit practice trials. Test trials began with two different 4-digit sequences, and digit span increased by a single digit until the participant failed to provide a correct response to both trials at a given span. Performance was defined as the highest digit span with a correct response.

EF composite measure—The first principal component among the four tasks (with ANT reverse scored so that higher scores indicated better performance) explained 44% of the variance ($\lambda = .57 - .81$). Scores were standardized, averaged, and standardized again to form a composite z-score.

Child and Mother Verbal Ability

MacArthur-Bates Communicative Development Inventory (MCDI: 24 months)

—The MCDI “Words and Sentences” form (Fenson et al., 1992) was completed by toddlers’ mothers to provide a measure of toddler verbal ability. The MCDI is an inventory of common words and phrases. We used the percentile score associated with vocabulary production.

Peabody Picture Vocabulary Test (PPVT: 36 and 48 months, mothers)

—The PPVT-III (Dunn & Dunn, 1997) or PPVT-IV (Dunn & Dunn, 2007) was administered to children and mothers individually to determine receptive vocabulary and verbal comprehension. The PPVT-III and -IV are nationally standardized instruments, and the measure of interest was participants’ standardized scores.

Results

Descriptive statistics for all measures can be found in Table 1 and correlations among our individual EF measures and control variables are in Table 2. To investigate maternal-child EF associations, we computed bivariate correlations for our EF composite measures. We hypothesized that maternal and child EF would be correlated from .40 to .50. Next, we used hierarchical regression analyses to determine whether the maternal-child EF association was present after controlling for potential confounds: child verbal ability, maternal verbal ability, and maternal education. Consistent with classical applications of probability theory and our directional hypotheses, we report one-tailed *p*-values for our correlations as well as the *t*-tests for our regression weights. Two-tailed *p*-values are reported for regression *F*-tests. Although it has become common for researchers to use two-tailed *p*-values when testing directional hypotheses, this practice nevertheless can inflate type-II error by reducing statistical power (e.g., Hays, 1988, pp.276–277).

Maternal and Child EF Composites

Bivariate correlations confirmed that our child EF composites were correlated over time across the three ages, with *r*s = .23 - .36, *p*s = .04. As can be seen in the left portion of Table 3, maternal and child EF are associated by 24 months of age. The child EF composite, our most reliable measure, reveals the strongest maternal-child EF association—the only correlation that reached our hypothesized .40–.50 level. The 24-, 36-, and 48-month child-

mother EF correlations were modest, with r 's = .22 – .35, and the same effect sizes were found using intraclass correlations.

The results of hierarchical regression analyses controlling for maternal education, child verbal ability, and maternal verbal ability are in Tables 4–7. Child verbal ability was a significant predictor of corresponding EF only at 48 months of age, accounting of 15% of the variance (Table 6). Although maternal education and verbal ability did not account of unique variance in child EF when initially added to any of the models, maternal education accounted for unique variance in the final 36-month EF and child EF composite models (Tables 5 and 7). Importantly, the final step in each model revealed that once controlling for other factors, maternal EF was significantly related to child EF in all analyses, accounting for 6–15% of the unique variance in child EF (Tables 4–7). The corresponding effect sizes (i.e., standardized betas) are presented in Table 3 (right portion) for comparison with initial correlation analyses (left portion). As can be seen, child and maternal EF are associated, even when controlling for verbal ability and maternal education. In fact, the pattern of findings is nearly identical for both sets of analyses in Table 3.

Discussion

These data provide the first longitudinal intergenerational analysis of mother-child EF associations during early childhood. We found that mother and child EF were modestly (but significantly) associated by 24 months of age, and this association was relatively stable through 48 months of age. The early childhood EF composite—our most reliable measure—exhibited the strongest association with maternal EF and the only effect size within the hypothesized range of $r = .40$ to $.50$. Importantly, these associations were still robust after controlling for verbal ability (a potential indicator of verbal or crystallized intelligence) and maternal education (a correlate of socioeconomic status and verbal intelligence).

In contrast to examination of the familial EF effect in adolescence as estimated by Jester et al. (2009), we were not able to use the same battery of EF tasks for both mothers and their very young children. Consequently, the current effect sizes might have been attenuated because of challenges in measuring the same executive abilities in both children and adults. Despite these challenges, the mother-child EF “signal” was present by 24 months of age. In contrast, Leve et al. (in press) failed to find an association between maternal EF and child EF at 27 months when using individual EF tasks. These divergent findings are potentially related to measurement issues, and highlight the informative value of using multiple measures of a latent construct, such as EF (Carlson et al., 2004; Rushton et al., 1983).

Our findings suggest that the foundational bio-social mechanisms that underlie the mother-child EF signal occur during infancy and emerged over the toddler and preschool periods. This is consistent with evidence that parenting behaviors during infancy are related to variability in EF during early childhood (Bernier et al., 2012; Hughes & Ensor, 2009; Kraybill & Bell, 2012), and the developmental emergence of heritability in executive attention and memory skills in childhood (Deater-Deckard & Wang, 2012). Whether the mother-child EF signal is present prior to 24 months is a topic that warrants future investigation. However, the measurement issues faced during early childhood are even more

complex during infancy (e.g., receptive language, productive language, few age-appropriate EF tasks).

Although maternal and child EF are associated—even when controlling for other influences (i.e., maternal education, verbal ability)—we were not able to statistically distinguish the variance components representing additive and interactive heritable and non-genetic sources. One potential mechanism underlying maternal-child EF associations would involve polymorphisms in multiple genes associated with the production and utilization of the neurotransmitter dopamine (for reviews see Barnes, Dean, Nandem, O’Connell, & Bellgrove, 2011; Bell & Deater-Deckard, 2007; and Deater-Deckard & Wang, 2012). For instance, variations in COMT and DRD4 (genes involved in dopamine metabolism) are associated with EF as well as activation of frontal regions (e.g., Bishop et al., 2006). Our understanding of the genetic contributions to intelligence has been greatly enhanced by studies that examined different parent-offspring types (e.g., adoptive, step-parents, fathers; Alarcon et al., 1998). The inclusion of EF in parent-offspring as well as twin studies during early childhood will be informative regarding genetic contributions to individual variation in EF.

One potential limitation of our findings is that we did not have a composite measure of intelligence. Our EF measure assessed multiple aspects of EF (e.g., inhibitory control, working memory, cognitive flexibility), as compared to verbal ability (an indicator of verbal or crystallized intelligence) and maternal education (associated with verbal intelligence), and our EF measure could have been more reliable. Undoubtedly, future research is necessary to further parse out the unique contributions of EF and intelligence to this association during early childhood. Previous work, however, has established that during adolescence familial association in EF are present above and beyond contributions of intelligence (Jester et al., 2009). To achieve a more comprehensive understanding of the mother-child EF association, future research using a latent growth curve approach is necessary to differentiate children's mean level in EF and their rate of change over time, and how the two relate to mothers' EF. However, a larger sample size and a consistent battery of EF tasks across the developmental span are requisites for this type of analysis. The latter is a particular challenge for EF assessment during this span of development as highlighted by Carlson (2005), but this obstacle can be potentially overcome with more frequent assessments over a shorter developmental span.

Although our sample varied in verbal ability and maternal education, our sample was predominately Caucasian and all mothers graduated from high school. A test of whether this effect is consistent across ethnic groups and across the full socio-economic spectrum is essential in determining the generalization of our findings. Finally, like any study of EF during early childhood, there were challenges in EF measurement. As with other studies (e.g., Carlson, 2005), our children showed high performance on the Simon-says task at 48 months. We included this measure because it was informative of individual differences in EF, and it was also part of our 36-month EF composite. However, this would only potentially attenuate the present effect sizes.

There has been substantial interest in the development and effectiveness of EF training programs designed to improve EF during early childhood (e.g., Diamond, Barnett, Thomas, & Munro, 2007). Our data provide evidence that maternal and child EF are associated during early childhood. Thus, maternal EF could be used as an early indicator of children at risk for EF deficits or potentially at risk for early-onset disorders. This indicator would be useful regardless of the specific underlying mechanism (environment, genetic, environment by gene interaction) of mother-child EF association.

Acknowledgments

This research was supported by grants HD049878 and HD057319 from the *Eunice Kennedy Shriver* National Institute of Child Health and Human Development (NICHD) awarded to Martha Ann Bell. The content of this manuscript is solely the responsibility of the authors and does not necessarily represent the official views of the NICHD or the National Institutes of Health. We are grateful to the families for their participation in our research and to our research teams for their assistance with data collection and coding. Katherine Morasch is now at Walter Reed Army Institute of Research.

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Table 1
Descriptive Statistics for Child and Maternal Measures of Executive Function (EF) and Verbal Ability.

Measure	Mean	Min	Max	SD	N
24 months					
A-not-B	0.69	0.29	1.00	0.21	62
Crayon delay	2.87	0.00	5.00	2.19	61
MCDI percentile	47.95	5.00	99.00	29.30	57
EF composite	0.00	-1.68	1.64	1.00	62
36 months					
Tongue task	0.65	0.00	1.00	0.39	58
Simon-says	0.78	0.50	1.00	0.22	29
Day-night	0.44	0.00	1.00	0.31	53
PPVT standardized	113.90	78.00	147.00	13.64	61
EF composite	0.00	-2.11	1.70	1.00	59
48 months					
DCCS	0.74	0.00	1.00	0.42	57
Simon-says	0.97	0.50	1.00	0.09	51
Yes-no	0.76	0.00	1.00	0.25	53
PPVT standardized	116.37	83.00	150.00	14.22	57
EF composite	0.00	-3.55	0.83	1.00	57
Child					
EF composite	0.00	-2.76	2.05	1.00	62
Mother					
WCST	54.66	1.00	99.00	26.64	61
Stroop color-word task	95.39	64.00	100.00	8.45	59
Attention Network Test	148.92	68.00	291.00	55.33	62
Backward digit span	5.40	2.00	9.00	1.57	47 ^a
PPVT standardized	109.03	89.00	139.00	10.48	62
EF composite	0.00	-2.60	2.04	1.00	62

Note.

^aTask was not initially in experimental protocol.

Zero-order Correlations Among Individual Measures of Executive Function, Verbal Ability, and Education for Child (24, 36, 48 months) and Mother.

Table 2

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1. A-not-B_24	-.46***	-.09	.25*	-.02	.21	.26*	.23*	-.06	.08	.22*	.11	.05	.01	.18	.16	.23*
2. Crayon delay_24	-	.00	-.25*	-.32*	-.21	-.23*	-.18	-.14	-.19	-.11	-.23*	-.03	.15	-.25*	-.05	-.16
3. MCDI_24		-	-.03	.63***	.33***	.12	.29*	.08	.18	.21	.24*	.08	.00	.17	-.03	.04
4. Tongue task_36			-	.36*	.25*	.00	.15	.32*	.35***	.17	.22*	-.03	-.11	.26*	.34***	.26*
5. Simon-says_36				-	.29	.16	.31	.37*	.38*	.02	.30	.16	-.51**	.02	.23	.29
6. Day-night_36					-	-.07	-.08	.13	.13	.04	.42***	-.07	-.03	.25	-.10	.09
7. PPVT_36						-	.41***	.25*	.19	.67***	-.09	-.02	-.06	-.08	.26*	.41***
8. DCCS_48							-	.38**	.32**	.43***	.06	.14	-.19	.25	.27*	.31***
9. Simon-says_48								-	.39**	.18	.06	-.06	.08	.42**	.09	.11
10. Yes-no_48									-	.24*	.16	.33**	-.14	.28*	.33**	.27*
11. PPVT48										-	.05	.01	-.06	.10	.32**	.38**
12. WCST_m											-	.24*	.32**	.43***	.17	.01
13. Stroop_m												-	-.21	.18	.24*	-.08
14. ANT_m													-	-.09	-.19	-.11
15. Backward digit_m														-	.21	-.13
16. PPVT_m															-	.44***
17. Education m																-

Note. One-tailed *p* -values:

p .001,

**
p .01,

*
p .05.

ANT = Attention Network Test; DCCS = Dimensional Change Card Sort; MCDI = Mac Arthur-Bates Communicative Development Inventory; PPVT = Peabody Picture Vocabulary Test; WCST = Wisconsin Card Sorting Test

Table 3

Effect Sizes for the Association Between Maternal and Child Executive Function (EF) Composite Measures.

Child Age	Maternal-Child EF Association	Maternal-Child EF Association ^a
24 months	.22 [*]	.27 [*]
36 months	.35 ^{**}	.35 ^{**}
48 months	.32 ^{**}	.27 [*]
24–48 months	.41 ^{***}	.41 ^{***}

Note: One-tailed *p*-values:***
p .001,**
p .01,*
p .05.^aControlling for maternal education, child verbal ability, and maternal verbal ability. See regression analyses (Tables 4–7).

A Hierarchical Regression Analysis of Maternal-Child Executive Function (EF) Association at 24 Months Controlling for 24-Month Verbal Ability, Maternal Education, and Maternal Verbal Ability.

Table 4

Step	<i>R</i> ²	<i>R</i> ²	<i>F</i>	<i>F</i>	<i>β</i> when first entered	<i>t</i> when first entered	<i>β</i> in Final model	<i>t</i> in Final model
<i>Dependent variable: 24-month EF</i>								
1. Verbal ability (24 months)	.00		0.18		-.06	-.042	-.13	-.094
2. Maternal education	.06	.06	1.58	1.11	.17	1.12	.22	1.48
Maternal verbal ability					.11	0.76	.05	0.17
3. Maternal EF	.12	.06	3.77 ⁺	1.82			.27	1.94 [*]

Note: One-tailed *p*-values for *t*-tests and two-tailed *p* -values for *F*-tests.

^{*} *p* .05;

⁺ *p* .06. *n* =57.

A Hierarchical Regression Analysis of Maternal-Child Executive Function (EF) Association at 36 Months Controlling for 36-Month Verbal Ability, Maternal Education, and Maternal Verbal Ability.

Table 5

Step	R ²	R ²	F	F	β when first entered	t when first entered	β in Final model	t in Final model
<i>Dependent variable: 36-month EF</i>								
1. Verbal ability (36 months)	.00			0.25	.07	0.50	-.03	-0.19
2. Maternal education	.09	.09	2.59	1.81	.27	1.76*	.30	2.02*
Maternal verbal ability					.10	0.67	-.03	-0.20
3. Maternal EF	.20	.11	7.31**	3.34*			.35	2.70**

Note: One-tailed p-values for t-tests and two-tailed p-values for F-tests.

** p .01;
* p .05, n = 59.

A Hierarchical Regression Analysis of Maternal-Child Executive Function (EF) Association at 48 Months Controlling for 48-Month Verbal Ability, Maternal Education, and Maternal Verbal Ability.

Table 6

Step	R ²	R ²	F	F	β when first entered	t when first entered	β in final model	t in final model
<i>Dependent variable: 48-month EF</i>								
1. Verbal ability (48 months)	.15			9.37**	.35	3.06**	.27	2.06*
2. Maternal education	.21	.0(5	2.16	4.70**	.13	.094	.17	1.23
Maternal verbal ability					.19	1.37	.10	0.68
3. Maternal EF	.23	.07	4.89*	5.00**			.27	2.21*

Note: One-tailed *p*-values for *t*-tests and two-tailed *p*-values for *F*-tests.

**
p .01;

*
p .05. *n* =57.

A Hierarchical Regression Analysis of Maternal-Child (Composite of 24-, 36-, and 48-Month Assessments) Executive Function (EF) Association Controlling for Maternal Education and Verbal Ability.

Table 7

Step	R ²	F	β when first entered	t when first entered	β in Final model	t in final model
<i>Dependent variable: Child EF Composite (24, 36, 48 months; controlling for verbal ability at each age)</i>						
1. Maternal education	.09	2.51	.17	1.20	.22	1.69*
Maternal verbal ability			.18	1.31	.04	0.33
2. Maternal EF	.24	11.37****			.41	3.37****

Note: One-tailed *p*-values for *t*-tests and two-tailed *p*-values for *F*-tests.

p .001;

*
p .05. *n* = 62.