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Parenting and Children's Executive Function Stability Across the Transition to School

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Abstract

When children transition to school between the ages of 4 and 6 years, they must learn to control their attention and behavior to be successful. Concurrently, executive function (EF) is an important skill undergoing significant development in childhood. To understand changes occurring during this period, we examined the role of parenting in the development of children's EF from 4 to 6 years old. Participants were mother and child dyads (N = 151). Children completed cognitive tasks to assess overall EF at age 4 and age 6. At both time points, mothers and children completed interaction tasks which were videotaped and coded to assess various parenting dimensions. Results indicated that children with high EF at age 4 were more likely to have high EF at age 6. In addition, results suggested that higher levels of positive parenting across the transition to school promote stability of individual differences in EF.

Keywords

executive function; children; parenting; transition to school; individual differences

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Between the ages of 4 and 6 years, children transition into formal schooling and adapt to new demands of a classroom environment. To be successful in school, children must learn to control their attention and behavior. This conscious and deliberate control is commonly referred to as executive function (EF; Spiess, Meier, & Roebers, 2015), which contributes to both social and academic success. Although much is known about the age-typical improvements in EF from early to middle childhood, more research must be done to examine whether individual differences in EF stabilize.

In the current study, we address this gap in knowledge by investigating the stability of individual differences in EF from 4 to 6 years and test whether key aspects of the home environment modify this stability. In particular, we focus on the link between parenting and individual differences in stability of EF over this important developmental period when children are transitioning into school.

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EF and the Transition to School

EF is a multidimensional construct that is often divided into three distinct processes: inhibiting, shifting, and updating (Miyake, Friedman, Emerson, Witzki, & Howerter, 2000). Inhibiting (or inhibitory control) is the process of preventing oneself from responding with a predominant response. Shifting is the process of changing between mental sets of information by means of cognitive flexibility. Updating refers to the process of maintaining and manipulating information using working memory. These processes are critical for goal-directed behavior, and they are necessary for success in the school context.

As early as preschool age, individual differences in children's EF skills are detectable and are linked to later academic achievement (Brod, Bunge, & Shing, 2017). Neural systems undergo dramatic changes in this same developmental window, leading to substantial improvements in EF (Hala, Hug, & Henderson, 2003), especially between 3 and 4 years old (Clark et al., 2013; Willoughby, Wirth, & Blair, 2012). Individual differences in EF and delays in its development have been associated with educational resources in the home (Clark et al., 2013), gender, early language skills, and maternal education levels (Montroy, Bowles, Skibbe, McClelland, & Morrison, 2016).

Early individual differences in EF can play an important role in making a successful transition to school. For instance, children whose EF shows little improvement between the ages of 4 and 6 years old are more likely to display emotional symptoms, hyperactivity, and conduct problems (Hughes & Ensor, 2011). In contrast, when EF improves dramatically over the transition to school, children are more likely to report higher self-perceived academic competence.

Once they enter school, children are assessed on other skills to gauge their academic achievement, and EF is related to the development of these skills. Inhibitory control, cognitive flexibility, and working memory have been linked to achievement in various academic areas at different ages. For instance, EF has been shown to predict academic achievement from 6 to 9 years old (Clark & Woodward, 2014) and, specifically, math ability reliably from 4 to 6 years old (Schmitt, Geldhof, Purpura, Duncan, & McClelland, 2017). Among children 3 to 5 years old, there are associations between inhibitory control and the ability to understand most math components, cognitive flexibility and conceptual or abstract math, and working memory and advanced mathematical operations (Purpura, Schmitt, & Ganley, 2017).

Additionally, EF components are correlated with different areas of pre-literacy. In the same study by Purpura and colleagues (2017), inhibitory control and cognitive flexibility were linked with print knowledge, whereas working memory was related to phonological awareness. However, vocabulary was not associated with any aspect of EF in this study. In comparison, McClelland and colleagues (2014) described how inhibitory control as measured by Day-Night Stroop was shown to predict children's math ability during preschool and vocabulary during kindergarten, whereas inhibitory control measured by a Simon Says task was linked to math ability and vocabulary in kindergarten only. In contrast, children's cognitive flexibility was associated with math ability and vocabulary in preschool, but not in kindergarten. Finally, working memory was related to vocabulary in preschool years and then to math in kindergarten.

Individual differences in other abilities have also been linked with EF development in childhood. Children with lower verbal mental ages at age 4 show greater increases in EF ability over the transition to school at age 6 (Hughes, Ensor, Wilson, & Graham, 2010). Further, when children show age-atypical EF before starting school, they may be able to catch up to their peers with age-typical EF. Poutanen and colleagues (2016) followed children for two years over the transition to school, and children who were categorized as having age-atypical EF prior to school entry performed similarly to their age-typical peers on measures of cognitive flexibility (but not inhibitory control) after school entry.

These different developmental trajectories provide insight into how children's EF can change over the transition to school. Our study adds to the current literature by examining whether several factors are linked to changes in EF across this important developmental window. However, we aimed to answer the question of what specific contextual factors are associated with the stability of individual differences in these skills as children enter school. Stability of individual differences in EF is rarely discussed in the literature, with the focus instead being mainly devoted to improvements in EF skills on average over time. Our study further contributes additional understanding of the numerous factors that are related to children's EF development by focusing on the association with parenting behaviors.

Parenting

When examining the development of children's EF, it is important to consider how parenting could play a role in shaping these abilities. Research has investigated several associations between a variety of parenting practices and the development of EF. There are four main dimensions of parenting which have been linked to individual differences in children's EF: scaffolding, positive versus negative control, stimulation, and sensitivity/responsiveness versus hostility/rejection (Fay-Stammbach, Hawes, & Meredith, 2014).

Parental scaffolding involves verbal and nonverbal actions that are used to motivate children to complete a difficult task (Lewis & Carpendale, 2009). Examples of this parenting behavior include autonomy support and encouragement of children's opinions, decisions, and actions (Matte-Gagné & Bernier, 2011). Consistent autonomy support by mothers over the first 3 years of life predicts stronger EF skills prior to the transition to school and later academic achievement in elementary school as well as high school (Bindman, Pomerantz, & Roisman, 2015). Hammond, Muller, Carpendale, Bibok, and Liebermann-Finestone (2012) examined the relation between early parental scaffolding and children's later EF ability, and scaffolding at age 3 directly predicted children's EF at age 4. Importantly, these associations hold even when controlling for children's prior EF and concurrent verbal ability, as it is a factor which can account for variance in EF (Hughes et al., 2010; McClelland et al., 2014).

Control can be viewed as a continuum of supportive positive control/discipline to negative control/discipline (Grolnick & Pomerantz, 2009). Maternal positive control has been strongly correlated with children's EF at age 4 (Hughes & Ensor, 2009). In addition, positive control measured at ages 6, 15, 24, and 36 months is positively correlated with children's EF abilities at 36, 48, and 60 months (Vernon-Feagans, Willoughby, & Garrett-Peters, 2016). However, there is also some evidence suggesting that positive control is not strongly linked with children's EF (Lee, Baker, & Whitebread, 2018; Weber, 2011).

Stimulation refers to offering opportunities for children to develop their cognitive skills during parent-child interactions, such as reading or completing puzzles together (Bradley, McKelvey, & Whiteside-Mansell, 2011). Specific gains in children's inhibitory control, cognitive flexibility, and working memory have been linked with parental use of stimulation in the home environment (Clark et al., 2013). However, there is contradictory evidence suggesting that stimulation may not be as strongly related with EF improvements as other dimensions of parenting such as sensitivity and responsiveness (Blair, Raver, & Berry, 2014).

Sensitive/responsive parenting includes warm behaviors and positive affect, whereas its counterpart hostile/rejecting parenting consists of negative affect and critical behaviors (Bernier, Carlson, Deschenes, & Matte-Gagné, 2012; O'Connor, 2002). The main theoretical explanation for the link between this dimension of parenting and EF stems from attachment theory, with research indicating that secure attachment in toddlerhood is related to better performance on EF tasks and fewer teacher-rated EF problems in kindergarten (Bernier et al., 2012). Negative early parenting behaviors, including negative affect, have also been shown to better predict children's EF at 3 years old in comparison to maternal education and child verbal ability (Cuevas et al., 2014). However, this association was not present at 2 years old, thus it may grow stronger as children age. There is also evidence indicating that parental warmth may buffer EF deficits in low birth weight children at age 5 (Camerota, Willoughby, Cox, & Greenberg, 2015).

In particular, maternal sensitivity and maternal hostility have been shown to predict children's EF (Blair et al., 2011; Holochwost, 2013). However, there is mixed evidence about the predictive strength of each facet in comparison to the other. Some research indicates that only parental hostility is related to significant deficits in later EF development, whereas other studies indicate that both sensitivity and hostility are linked to children's EF (Hopkins et al., 2013; Hughes & Ensor, 2005). Additionally, ratings of parent-infant attachment security have been shown to predict EF better than ratings of these parenting behaviors (Bernier et al., 2012). In addition, some of these associations between parental sensitivity and children's EF are no longer significant when children's verbal ability is considered.

As compared to the current study, Blair, Raver, and Berry (2014) conducted similar research in which they followed children from 3 to 5 years of age and examined changes in EF as well as parenting dimensions (i.e., stimulation, sensitivity, and responsiveness). Higher ratings of parents' sensitivity and responsiveness over time predicted greater increases in children's EF, and these dimensions were stronger predictors of EF at 5 years old than children's EF at 3 years old. Our study aimed to provide additional knowledge about the connection between sensitive/responsive parenting and children's EF in early childhood. In addition, the current study was able to expand the focus of the research by examining the stability of individual differences in EF as well as including a reverse-score of hostile/rejecting parenting and older children who are transitioning to school.

Turning to methodological considerations, parenting practices can be examined in several ways, ranging from self-report questionnaires to interviews as well as observations of child-parent interactions. The current study used behavioral ratings of parenting practices during observations of parent-child interactions to eliminate parents' potential biases when answering questions on a questionnaire or in an interview. In addition, parenting and EF have been examined in some cross-sectional studies, providing mixed results instead of consistent findings (Fay-Stammbach et al., 2014). Our study attempted to clear up these inconsistencies by taking a strength-based approach and examining how positive parenting practices might affect the stability of individual differences in EF in a longitudinal study following children from age 4 to age 6.

Moreover, previous studies have mainly focused on how parenting is associated with EF improvements on average, rather than examining its potential role in the stability of individual differences in EF. Positive parenting may be connected with growth in EF skills over time *on average*, but it is not yet known whether supportive parenting is related to stability versus change over time in individual differences between children within a sample. Do children who make the transition to formal schooling, while also experiencing positive parenting, tend to "stabilize" in their EF skills relative to their peers? Or, do such sub-groups of children show lower stability of individual differences in EF?

Foundational theories regarding the development and stabilization of individual differences (e.g., Asendorpf, 1992; Scarr & McCartney, 1983) suggest on the one hand that individual differences between children will be most stable over time among those who are receiving consistent and adequate or better levels of positive, supportive caregiving. On the other hand, the absence of such experiences may produce strong ubiquitous environmental effects that interfere with or subsume the stabilization of individual differences. Thus, in addition to testing whether the parenting environment might have a predictive effect on changes in EF skills from 4 to 6 years on average, we also tested whether levels of positive parenting statistically moderated the stability of individual differences in EF skills over the school transition. To this end, the current longitudinal study followed the same families over two years across the transition to school in an effort to examine the statistical predictive effects of positive parenting on growth and stability of individual differences in children's EF.

Current Study

To understand stability and change between individuals during this important period in EF development, we examined the role of parenting in the stability of individual differences in children's EF from 4 to 6 years old. Previous research mainly investigates the ways in which EF improves on average over time, yet there is scant literature examining EF stability of individual differences. The limited literature suggests that individual differences in EF are moderately stable from 2 to 5 years of age when controlling for verbal ability (Carlson, Mandell, & Williams, 2004; Kloo & Sodian, 2017; Willoughby, Worth, & Blair, 2012). When parenting is examined as a potential moderator, higher self-reported responsiveness and stimulation as well as more observed parental sensitivity at ages 3 and 5 predicted modest increases in EF (Blair et al., 2014) between the two time points. To improve our understanding of stability and change in young children's EF development at this time, positive parenting must also be examined as a moderator.

We predicted that parenting would predict growth in EF and statistically moderate the longitudinal stability of individual differences in EF. Specifically, we expected that children with the most positive and attentive parents would show the largest increases in EF on average, as well as the greatest stability of individual differences in EF skills from age 4 to age 6 years while controlling for parenting at age 4. Child sex, child verbal ability, and maternal education were used as control variables based on findings from previous research (Clark et al., 2013; Hughes & Ensor, 2005; Hughes et al., 2010; McClelland et al., 2014; Tillman & Granvald, 2014).

Method

Participants

Participants were recruited as part of a larger longitudinal study examining emotion regulation and cognitive integration, and they represent two cohorts, or approximately 75%, of the participants in the larger study. The remaining 25% are from a third cohort who did not have a research visit at age 6. The original sample at the age 4 visit included 242 participants, with 176 returning for a visit at age 6. The cohorts were recruited at two research locations, with the A location and the B location each recruiting half of the participants in the longitudinal study.

Of the 176 who returned, sixteen did not complete the age 4 parent-child interaction, two did not complete the age 6 parent-child interaction, six were missing data on two or more EF tasks at age 4, and one was missing data on two or more EF tasks at age 6. The final sample of participants, who had data at both time points for EF and parenting and could therefore be used in analysis, included 151 mother-child pairs. The final sample of 151 did not differ significantly from the remaining sample in terms of child sex ($t(174) = -0.953$, $p = .342$), maternal education level ($t(169) = -1.693$, $p = .092$), or maternal employment status ($t(174) = 0.087$, $p = .931$). Children and their mothers were recruited from a rural town in Virginia and a mid-size city in North Carolina. For the current study, approximately 53% of child participants were male, and were 48.87 months on average at the 4-year time point ($SD = 0.83$) and 78.49 months at the 6-year time point ($SD = 4.35$). The children were primarily White (78%), with 14% identifying as African American, 4% as multi-racial, and 1% as Asian. Regarding maternal education, 3.0% did not complete high school, 8.9% were high school graduates, 24.9% completed two years of college, and 63.3% completed beyond two years of college.

Procedure

Data were collected at both research locations using identical protocols. Research assistants from each location were trained together by the project's Principal Investigator (the last author) on protocol administration and behavioral coding. To ensure that identical protocol administration and EF coding criteria were maintained between the labs, the A site periodically watched DVD recordings collected by the B lab and the A lab provided reliability coding for the EF behavioral data coded by the B lab. The A site coded all mother-child interaction data collected by both labs.

As a part of their participation in the larger study, parents completed number of questionnaires on themselves, their child, and their home environment. On the day of the assessment session the study details were described again to the participants and informed consent was obtained from parents and verbal assent was obtained from the children.

Children completed a battery of age-appropriate executive function (EF) tasks at both the 4- and 6-year time point. Mother-child dyads also completed an interaction task together at both time points. Parents were thanked and provided with payment for participation. Parent-child dyads received $20 compensation for participation in the study. Child participants also received a small toy. Each site's Institutional Review Board approved the protocol for this study.

Measures

Child Executive Function: Age 4.—The Pig/Bull task followed the Bear/Dragon procedure (Carlson, Moses, & Breton, 2002) and was used to assess inhibitory control. Children were instructed to do what the nice pig "tells us" and to not do what the mean bull "tells us." Ten test trials (half for each type, alternating order) followed practice trials of each type, and children's response on each trial was coded as either correct or incorrect (Carlson, 2005). Intra-class correlations were used to assess inter-rater reliability (ICC = .99). Performance was the proportion of correct responses on inhibition (bull) trials.

The Dimensional Change Card Sort (DCCS; Zelazo, Frye, & Rapus, 1996) was used to assess cognitive flexibility. For this task, 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). Intra-class correlations were used to assess inter-rater reliability (ICC = .98). Performance was the proportion of correct post-switch responses.

A forward digit span task was administered to assess working memory. Though some view forward digit span as a measure of verbal short-term memory (Alloway, Gathercole, & Pickering, 2006), the backward version of the digit span often proves to be too difficult for young children (Bull, Espy, & Wiebe, 2008; Houwen, Kamphorst, van der Veer, & Cantell, 2019). For this task, based on previous work (Wechsler, 1986), children were presented with sequences of digits and instructed to repeat the sequences. Two practice trials of sequences two digits in length were given to ensure understanding and then the task began. Two trials of the same length sequence were presented, and children were allowed one recall attempt for each sequence. If the child recalled at least one of the two trials correctly, the length of the sequence increased by one digit. The sequences were lengthened until errors were produced on two consecutive trials of the same length (Blankenship et al., 2019). Intra-class correlations were used to assess inter-rater reliability (ICC = 1.00). The variable of interest was the highest correct trial achieved.

When possible, it is preferred to create a composite score of correlated indicators to form a latent construct (Carlson, Mandell, & Williams, 2004; Rushton, Brainderd, & Pressley, 1983). To estimate the overall EF construct, we computed and analyzed a single composite score representing inhibitory control, cognitive flexibility, and working memory, which is consistent with previous literature in this age group (Hughes et al., 2010, Wiebe, Espy, & Charak, 2008). For all EF tasks, intra-class correlations were used to assess inter-rater reliability (ICC ≥ .90) and it was established for at least 20% of our longitudinal sample. The first principal component among the three task scores explained 44.72% of the variance (λ = .60 - .75). We further conducted a confirmatory factor analysis (CFA), to test for a general EF construct. The model fit was perfect because it was saturated. Standardized loadings ranged from .37 [95% CI’s from .16 to .58] to .63 [95% CI’s from .34 to .91]. All three scores were standardized and averaged for every child who had at least two task scores (17 of the total 151 children included were missing one of the tasks included in the composite). The average score was standardized again to yield a composite z-score that was widely and normally distributed.

Child Executive Function: Age 6.—A number-based computerized Stroop task was used to assess inhibitory control (Ruffman, Rustin, Garnham, & Parkin, 2001). The task had three conditions: letters, numbers, and mixed (both letter and numbers). Emphasis was placed on the mixed condition, which is considered to involve the most conflict. Children were instructed to count either letters (“AAA”=3) or number digits (“555” = 3) and to indicate their responses on the keyboard. Practice trials were provided. There was a total of 75 task trials (25 per condition). The variable of interest was mean reaction time for correct trials only in the mixed condition. Accuracy was high overall (M = 90.47% trials correct, SD = 12.85%), and no participants were excluded for low accuracy.

The Dimensional Change Card Sort (DCCS; Zelazo et al., 1996) was used to assess cognitive flexibility. For this task, 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). Children who passed the post-switch condition also participated in the borders condition. During this phase, children sorted according to one dimension for cards with borders (e.g., shape) and sorted according to the other dimension for cards without borders (e.g., color; counterbalanced). Intra-class correlations were used to assess inter-rater reliability (ICC = .99). Performance was the proportion of correct borders responses.

A backwards digit span task was administered to assess working memory. For this task, based on previous work (Wechsler, 1986), children were presented with sequences of digits and instructed to repeat the sequences backwards. Two practice trials of sequences two digits in length were given to ensure understanding and then the task began. Two trials of the same length sequence were presented, and children were allowed one recall attempt for each sequence. If the child recalled at least one of the two trials correctly, the length of the sequence increased by one digit. The sequences were lengthened until errors were produced on two consecutive trials of the same length (Blankenship et al., 2019). Inter-rater reliability was not computed here, as the administration of the task stops once the child is unable to complete any more of the task, and there is no need to assess reliability. The variable of interest was the highest correct trial achieved.

When possible, it is preferred to create a composite score of correlated indicators to form a latent construct (Carlson et al., 2004; Rushton et al., 1983). To estimate the overall EF construct, we computed and analyzed a single composite score representing set shifting, inhibition, and working memory, which is consistent with previous literature in this age group (Hughes et al., 2010; Wiebe et al., 2008). The first principal component among the three task scores explained 43.31% of the variance (λ = .57 - .72). We further conducted a confirmatory factor analysis (CFA), to test for a general EF construct. Six outliers on the Stroop reaction time measure were removed prior to testing. The model fit was perfect because it was saturated. Standardized loadings ranged from .35 [95% CI's from .08 to .61] to .47 [95% CI's from .13 to .81]. All three scores were standardized and averaged for every child who had at least two task scores (12 of the total 151 children included were missing one of the tasks included in the composite. The average score was standardized again to yield a composite z-score that was widely and normally distributed.

Positive Parenting Age 4.—We computed a parenting construct that is represented by observer-rated dimensions of parenting during a series of parent-child interactions during which dyads played games. For all parenting dimensions, interrater reliability (ICC ≥ .70) was established for at least 20% of our longitudinal sample. Intra-class correlations for the three parenting dimensions used in the current study are provided in Table 6. At the 4-year time point, mothers and children participated in a puzzle and etch-a-sketch interaction task. Mothers were instructed to assist children in completing a puzzle or replicating a picture on the etch-a-sketch (Deater-Deckard & Petrill, 2004). Mothers were instructed to work with children on the puzzles task as they would at home. The etch-a-sketch task involved the mother and child each controlling one knob of the etch-a-sketch and working together to complete two separate pictures that increased in difficulty. This process resulted in three total interaction tasks. Interactions were video-taped and later coded using a global rating system adapted from previous work (Calkins, Hungerford, & Dedmon, 2004; Smith, Calkins, Keane, Anastopoulos, & Shelton, 2004), and it measures maternal positivity, attention facilitating, intrusiveness, directiveness, permissiveness, and negativity. Three of these dimensions are used in the current study. The puzzles task was administered for five minutes and each etch-a-sketch task was administered for up to one minute each. Coding epochs were 30 seconds. Mean scores were computed across epochs for each task using a 4-point scale (1 = low incidence of behavior; 4 = high incidence).

To estimate a parenting construct, we computed and analyzed a composite score that includes three codes of *positivity*, *attention facilitating*, and *negativity* (reverse scored) across the three interaction tasks for a total of nine codes. We focused on these three codes, based on previous theory and empirical work highlighting the importance of warm, sensitive, responsive and low-hostility parenting in the etiology of child EF development (e.g., Blair et al., 2011; Cuevas et al., 2014; Holochwost, 2013; Hughes & Ensor, 2005). Mother's *positivity* refers to her actions and displays of warmth, including closeness, friendliness, and encouragement. *Attention facilitating* refers to sensitivity towards the child, demonstrated through behavior that responds to the child's interests and abilities. *Negativity* (reverse scored) reflects hostility or negative affect, including harsh control, towards the child. These three dimensions showed acceptable convergence based on exploratory and confirmatory factor analysis, as described below. The first principal component among the three codes explained 40.18% of the variance (λ = .35 - .77). In a confirmatory factor analysis (CFA), model fit was perfect because it was saturated. Standardized factor loadings ranged from .24 [95% CI's from .07 to .40] to .75 [95% CI's from .66 to .84]. All parenting codes were averaged for all mothers who had at least eight of the nine codes. The composite score was widely and normally distributed.

Positive Parenting Age 6.—We again computed a single composite score representing positive parenting at age 6 years. For all parenting dimensions, interrater reliability (ICC ≥ .80) was established for at least 20% of our longitudinal sample. Intra-class correlations for the three parenting dimensions used in the current study are provided in Table 7. Mothers and children participated in an etch-a-sketch and marble maze interaction task. Mothers were instructed to assist children in replicating a picture on the etch-a-sketch and navigating a marble through a maze (Deater-Deckard & Petrill, 2004). The etch-a-sketch task involved the mother and child each controlling one knob of the etch-a-sketch and working together to complete two separate pictures that increased in difficulty. Similarly, the marble maze involved the mother and child each controlling one knob that moved the maze either horizontally or vertically. This process resulted in three total interaction tasks. Mothers were instructed to work with children on the task as they would at home. Interactions were video-taped and later coded using a global rating system adapted from previous work (Calkins et al., 2004; Smith et al., 2004), and it measures maternal positivity, attention facilitating, intrusiveness, directiveness, permissiveness, and negativity. Three of these dimensions are used in the current study. Each task was administered for about five minutes and coding epochs were 20 seconds. Mean scores were computed across epochs for each task using a 4-point scale (1 = low incidence of behavior; 4 = high incidence).

To estimate a parenting construct, we again computed and analyzed a composite score that includes three codes of *positivity*, *attention facilitating*, and *negativity* (reverse scored) across the three interaction tasks for a total of nine codes. Mother's *positivity* refers to her actions and displays of warmth, including closeness, friendliness, and encouragement. *Attention facilitating* refers to sensitivity towards the child, demonstrated through behavior that responds to the child's interests and abilities. *Negativity* (reverse scored) reflects hostility or negative affect, including harsh control, towards the child. These three codes were included based on previous work (Cuevas et al., 2014) and a principal components analysis. The first principal component among the three codes explained 34.3% of the variance (λ = .37 - .74). We further conducted a confirmatory factor analysis (CFA), and model fit was perfect because it was saturated. Standardized loadings ranged from .22 [95% CI's from .05 to .40] to .71 [95% CI's from .60 to .83]. All parenting codes were averaged for all mothers who had at least eight of the nine codes. The composite score was widely and normally distributed.

There is no consensus on how best to include time-varying moderators in data analysis. For our analyses, we used a standard residual change approach (see Blair et al., 2014; i.e., using 6-years parenting, controlling for 4-years parenting). For this residuals analysis, we used standardized composite z-scores for both waves.

Verbal Ability.—The Peabody Picture Vocabulary Test (PPVT-IV; Dunn & Dunn, 2007) was administered to children to determine receptive vocabulary and verbal comprehension. The PPVT–IV is a nationally standardized instrument and children's percentile scores were used in the current study as a control variable.

Results

Descriptive statistics and bivariate correlations were computed to understand patterns of variance in and covariance between the covariates, EF composite scores and parenting composite score at both time points (Table 1). All variables were normally distributed. Descriptive statistics and bivariate correlations of the individual variables that were used in the composites are provided in Tables 2, 3, and 4.

As shown in Table 1, the moderator of interest—positive parenting—showed a stability correlation of .30. Thus, parenting was a time-varying moderator. There is no standard approach for examining a time varying moderator in a longitudinal analysis. We decided to use a residual parenting score approach (i.e., using parenting at age 6 years and controlling for parenting at age 4 years).

To test the hypothesized moderating effect of change in parenting between the two time-points on the stability of EF between ages 4 and 6, we use the standardized parenting composite score at age 6 but included age 4 standardized parenting composite as a covariate. We estimated a hierarchical multiple regression equation (standardized variables provided mean-centered predictors) to explain variance in child EF at age 6; Step 1: child sex (Male = 1, Female = 2), PPVT age 6 (z), maternal education (z), age 4 EF (z), parenting age 4 (z), and parenting age 6 (z); Step 2: parenting age 6 X age 4 EF (z) (Table 5).

The full equation explained 22.2% of the variance in child EF at age 6, ($F(7, 150) = 5.81$, $p < .001$). There was a significant main effect of EF at age 4, such that higher executive function at age 4 predicted higher EF at age 6, controlling for scores on the PPVT, maternal education, parenting, and child sex ($\beta = .27$, $p = .001$). There was a significant moderating effect of the parenting at age 6 on the stability of child EF ($\beta = 0.18$ $p = .018$), controlling for PPVT scores, child sex, maternal education, and parenting at age 4.

To interpret the two-way interaction term, we conducted post-hoc probing using estimation of simple slopes at the mean and 1 and 2 *SD* above and below the sample mean of the parenting score at age 6 as the moderator (Figure 1). The stability of EF between age 4 and age 6 was significant for slopes at the mean and levels above the mean of parenting at age 6, controlling for parenting at age 4 (mean: $\beta = .34$, $p < .001$; +1 *SD*: $\beta = .54$, $p < .001$; +2 *SD*: $\beta = .75$, $p < .001$). In contrast, the stability coefficient of EF was no longer significant at levels of positive parenting below the mean (−2 *SD*: $\beta = -.07$, $p = .728$; −1 *SD*: $\beta = .13$, $p =$.

288). Results indicated that higher stability of individual differences in EF was evident at higher levels of positive parenting at 6 years, controlling for positive parenting at 4 years.

Discussion

Parenting plays a critical role in the development of children's EF skills (Fay-Stammbach et al., 2014), and it is particularly salient when examining changes over the transition to school, a place where children are now being guided by adults other than their parents. In this study, we examined children's EF at age 4 and at age 6, and these two time-points provide insight into the changes which can occur after children begin formal schooling around age 5. Our results align with previous reports of the beneficial role of positive parenting on children's EF development (Blair et al., 2014). We also expand on prior research by demonstrating this association with behavioral measures of EF and observational measures of parenting at age 4 and age 6. To our knowledge, no other studies have examined this link between positive parenting and stability of individual differences in EF during this developmental period.

Children who had high EF at age 4 also had higher EF at age 6, even when controlling for child sex, maternal education, and child verbal ability as measured by the PPVT-IV. By the same token, children who had low EF at age 4 had lower EF at age 6 when controlling for all the same variables. This strong association between EF measured at these different ages is noteworthy because inhibitory control, cognitive flexibility, and working memory were assessed by slightly different tasks at age 4 and age 6, based on which tasks were developmentally appropriate for the age of the children.

Stability correlations in previous studies have been somewhat weaker compared to our findings when examining stability of individual differences in EF using different tasks across the early childhood years (Carlson et al., 2004). The current study fills in a developmental age gap from 4 to 6 years, as similar studies focus on EF in children 5 years of age and younger (Carlson et al., 2004; Kloo & Sodian, 2017; Willoughby et al., 2012). This age range is important to examine because the transition to school occurs within these years. With the suggestion that EF is moderately stable across this critical transition to formal schooling, our study aligns with prior research and can help inform future research.

With moderate stability of EF, children with higher EF may manage the transition to school better than their peers with lower EF. In the new context of a classroom, maintaining a high level of EF could protect against a tumultuous experience. These children are better at keeping their attention focused and their behavior in check. At the same time, these children with high EF stability may influence the people around them (Bronfenbrenner, 1974). Teachers, peers, and parents may have consistent high expectations for these children, thus encouraging them to stay within the set boundaries and meet those expectations. They might be more likely to succeed academically during this transition. For children with low EF stability across the transition to school, expectations might be less consistent because it is unclear to others how well these children can control their attention and behavior. The new environment in school could then become quite confusing and frustrating for these children, and their lifelong learning may suffer as a result of a poor transition.

Additionally, there was support for our hypothesis that higher levels of positive parenting across the transition to school would promote stability of individual differences in EF. Controlling for earlier levels of parenting, children who experienced average or higher levels of positive parenting at age 6 had substantial individual difference stability in EF. However, stability of individual differences in EF was much more modest or near zero among children whose positive parenting environment was below average.

This finding aligns with theories (e.g., Asendorpf, 1992; Scarr & McCartney, 1983) of development of individual differences that posit a key role of the home and parenting environment in the stabilization of EF and many other aspects of cognition, emotion, and behavior. Accordingly, in environments that have adequate supports for the learning and practicing of EF skills (such as those afforded by parents who provide ample warm, supportive attentive caregiving), individual differences between children that are due to environmental and genetic factors will be most stable over time. Thus, a home environment that is rich with warm, supportive parenting may not only promote higher levels of EF on average, but also stabilize children's EF skills and making their skillset more impervious to stressors and challenges that might otherwise interfere with or derail continued growth across the elementary school years. However, these results also imply that higher levels of positive parenting are associated with stability among young children with lower EF as well.

Considering these theories and our findings, it is easy to suggest that children with high EF early in life maintain higher EF. It is not hard to fathom that positive parenting practices are beneficial for the stability of EF as well. However, there are also children with lower EF who maintain low EF. It is important to consider implementing targeted interventions to boost EF among these children, especially following the stressful transition to formal schooling. These interventions should aim to provide children with opportunities to engage and challenge their EF skills. For those children who do not experience high levels of positive parenting, the best time for parenting interventions would likely be before the transition to school in order to support parents and children alike.

Prior studies have also shown evidence that EF development is positively associated to scaffolding (Bindman et al., 2015; Hammond et al., 2012), stimulation (Clark et al., 2013), sensitivity (Blair et al., 2014; Camerota et al., 2015; Cuevas et al., 2014), and positive control (Hughes & Ensor, 2009). These studies also measured the parenting dimensions through coding of video-recorded interaction tasks similar to those used in the current study. In contrast, the association between children's EF development and parenting dimensions, such as sensitivity (Bernier et al., 2012; Blair et al., 2014) and positive control (Vernon-Feagans et al., 2016), has also been examined through parent interviews (i.e., Home Observation Measurement of the Environment - HOME; Caldwell & Bradley, 1984). There also is evidence that parental hostility has negative associations with children's EF development (Blair et al., 2011; Holochwost, 2013; Hopkins et al., 2013). Our findings align with this literature and provide further insight into the complexity of EF development by including measures of prior levels of parenting as control variables.

Several limitations of the current study should be considered. First, there are only two time points at which EF and parenting were measured. Thus, we were limited to few representations of behavior. An additional time point at age 5 would have allowed us to examine the change in individual differences in parenting environments and EF far more thoroughly. Second, the brief observations of parenting behavior show only a glimpse into the dyadic relationship. Extending the length of parenting observations would have provided additional information about parenting practices. In addition, home-based (rather than lab-based) observations could have allowed parents and children to relax in a familiar setting and perhaps act more as they normally would, giving us different insight into their relationships.

Additionally, the behavioral measures at both time points were limited. For the EF tasks, children completed different versions of tasks aimed at measuring the same components of EF in developmentally appropriate ways. Based on prior research, we utilized different tasks to represent the same EF components, but the design would have been stronger if children could have completed the same tasks at both time points. However, that is challenging, given that it is difficult to find tasks that are the same at 4 and 6 years of age, that can yield normal distributions of performance at both ages (Carlson, 2005; Petersen, Hoyniak, McQuillan, Bates, & Staples, 2016). Additionally, the design would have been stronger if we had more tasks, which would provide more data points to draw from to determine the level of skill for each component and for EF as a general composite as well.

Further, observed parenting dimensions were restricted. Particularly for maternal negativity, data were highly skewed and kurtotic. This is not surprising and is common in the literature (Chen, Deater-Deckard, & Bell, 2014; Combs-Ronto, Olson, Lukenheimer, & Sameroff, 2009). It is possible that the tasks used in the current study to measure dimensions of parenting are too stress-free to reliably elicit observable negative parenting behaviors. Future studies interested in measuring parental negativity should consider this when designing parent-child interaction tasks.

Finally, the residualized change score analysis has limitations. It can only consider unidirectional prediction of change between two variables (e.g., parenting predicting change in child EF), and it is not able to take into consideration potential developmental changes in the measurement of the constructs (i.e., it does not address measurement invariance). Future work should consider formal testing of measurement invariance and use of latent change analysis methods to address these limitations (Blair et al., 2014).

With these caveats in mind, the current study provides several important new pieces of information to the literature. As shown in previous work, children's EF shows improvement over the transition to school. Furthermore, positive parenting can be linked with the stability of individual differences in children's EF during this transition. With this combination of EF improvement and individual difference stability, children are steadily growing and stabilizing in their EF skill levels during a very substantial contextual developmental transition, thanks in part to the positive guided support provided by their parents. In addition, it is also critical to acknowledge that higher levels of positive parenting were linked to stability for children with lower EF. If positive parenting is contributing to stabilization even at lower levels of children's EF, additional support must be introduced for these children to show growth in EF as well.

The strength-based approach of the study also aims to show that programs and interventions should strive to boost positive parenting in order to assist children's EF at this critical time. By focusing on the benefits of positive parenting, research can provide useful suggestions to parents on constructive practices, rather than criticizing their current parenting. It is also important to emphasize that parenting trainings or EF development programs should begin early in development to assist the growth of EF and the success for children as well as parents. If parenting is more positive earlier in a child's life, there will be a decreased need for a parenting intervention or other types of interventions later in childhood. In cases where positive parenting is already high but children's low EF could maintain stability, these children would benefit most from EF interventions built to train and boost their skills from an early age.

As evidenced by the severely limited literature on the stability of individual differences in children's EF, additional research on this topic is essential. Examining the involvement of parenting during this time when children transition to school offers rich information about the ways in which context is constantly playing a vital role in children's EF development. Future work should examine this association in close detail to provide additional information and resources for parents.

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Highlights:

- This study investigated the association between parenting and the development of children's executive function skills across the transition to school.
- Children's executive function and mothers' parenting were assessed at ages 4 and 6.
- The stability of individual differences in executive function was linked to positive parenting.
- Parenting practices may be related to the stability of individual difference in EF across the transition to school.

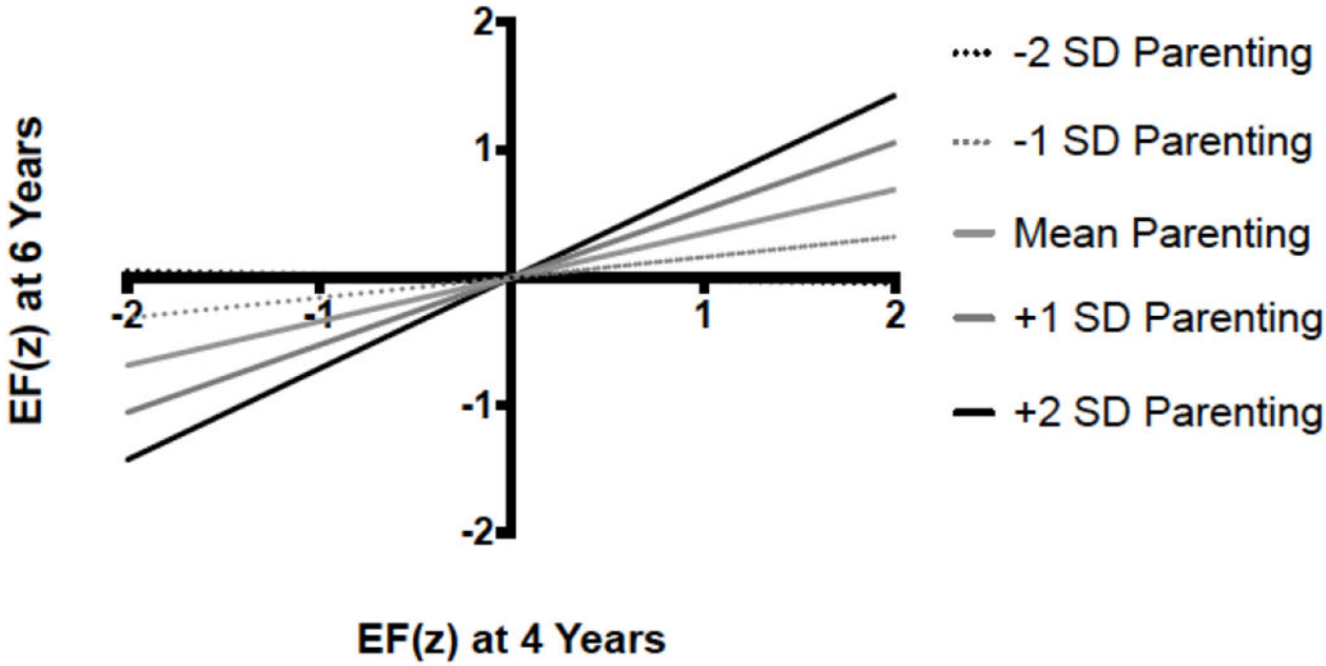

Figure 1:

Standardized slopes (b) of the stability of individual differences in EF as a function of positive parenting at age 6 years controlling for parenting at age 4 years. All solid lines were significant at $p < 0.05$, dashed lines were not significant.

Table 1:

Correlations and Descriptive Statistics for Variables Used in Analysis

	1	2	3	4	5	6	7
1. EF Composite Age 4 (z)	1						
2. EF Composite Age 6 (z)	.36**	1					
3. Parenting Age 4 (z)	.16	.10	1				
4. Parenting Age 6 (z)	.28**	.18*	.30**	1			
5. PPVT Score Age 6 (z)	.35**	.29**	.19*	.28**	1		
6. Mother Education (z)	.26**	.15	.18*	.18*	.36**	1	
7. Child Sex	.02	.02	.09	.10	.01	.07	1
M	0.00	0.00	0.00	0.00	0.00	0.00	1.47
SD	1.00	1.00	1.00	1.00	1.00	1.00	0.50

Note:

** indicates significance at the .001 level

* at the .01 level. For child sex, male is coded as 1 and female as 2.

Table 2:

Correlations and Descriptive Statistics for Executive Function Variables

	1	2	3	4	5	6
Age 4 EF						
1. Pig/Bull	1					
2. Digit Span	.20*	1				
3. DCCS	.34**	.23**	1			
Age 6 EF						
4. Stroop	−.22**	−.09	−.19*	1		
5. Digit Span	.22**	.20*	.23**	−.18*	1	
6. DCCS	.17*	.13	.21**	−.18*	.20*	1
M	0.87	3.91	0.56	3821.74	3.24	0.67
SD	0.30	0.79	0.46	1469.36	0.96	0.20
Skew *(SE)*	−2.22 (0.19)	−0.08 (0.19)	−0.23 (0.19)	2.20 (0.19)	−0.55 (0.19)	−0.15 (0.19)
Kurt *(SE)*	3.46 (0.38)	2.53 (0.39)	−1.86 (0.38)	7.65 (0.38)	0.10 (0.38)	−0.43 (0.39)

Note:

** indicates significance at the .01 level

* at the .05 level. For child sex, male is coded as 1 and female as 2.

Table 3:

Correlations and Descriptive Statistics for Age 4 Parenting Variables

	1	2	3	4	5	6	7	8	9
1. Positivity, Puzzle	1								
2. Attention, Puzzle	.66**	1							
3. Negativity, Puzzle	−.20*	−.37**	1						
4. Positivity, Etch - Sq	.52**	.40**	−.08	1					
5. Attention, Etch - Sq	.45**	.48**	−.16*	.59**	1				
6. Negativity, Etch - Sq	−.09	−.25**	.31**	−.17*	−.21**	1			
7. Positivity, Etch - Cir	.51**	.39**	−.17*	.45**	.40**	−.12	1		
8. Attention, Etch - Cir	.37**	.40**	−.23	.36**	.39**	−.13	.65**	1	
9. Negativity, Etch - Cir	−.08	−.23**	.43**	−.05	−.08	.33**	−.15	−.22**	1
M	2.21	2.76	1.03	2.50	2.68	1.03	2.77	2.67	1.07
SD	0.58	0.50	0.10	0.72	0.60	0.16	0.83	0.63	0.27
Skew *(SE)*	−0.24 (0.19)	−0.62 (0.19)	4.21 (0.19)	−0.23 (0.19)	−0.06 (019)	5.03 (0.19)	−0.19 (0.20)	−0.16 (0.20)	4.55 (0.20)
Kurt *(SE)*	−0.78 (0.38)	0.35 (0.38)	19.42 (0.38)	−0.30 (0.38)	0.06 (0.38)	25.78 (0.38)	−0.65 (0.39)	0.19 (0.39)	23.25 (0.39)

Note:

** indicates significance at the .001 level and

* at the .01 level

Table 4:

Correlations and Descriptive Statistics for Age 6 Parenting Variables

	1	2	3	4	5	6	7	8	9
1. Positivity, Marble	1								
2. Attention, Marble	.45**	1							
3. Negativity, Marble	−.27**	−.34**	1						
4. Positivity, Etch - Sq	.31**	.15*	.08	1					
5. Attention, Etch - Sq	−.01	.27**	−.25	.65	1				
6. Negativity, Etch - Sq	−.04	−.13	.22**	−.08	−.12	1			
7. Positivity, Etch - House	.47**	.29**	−.20*	.34**	.16*	−.16*	1		
8. Attention, Etch - House	.21**	.51**	−.34**	.04	.38**	−.16*	.35**	1	
9. Negativity, Etch - House	−.12	−.23**	.31**	−.10	−.05	.34**	−.29**	−.21*	1
M	2.27	2.29	1.03	1.91	2.28	1.01	2.12	2.29	1.02
SD	0.33	0.28	0.09	0.35	0.43	0.07	0.28	0.32	0.06
Skew *(SE)*	0.13 (0.19)	0.54 (0.19)	4.01 (0.19)	−0.54 (0.19)	1.41 (019)	8.45 (0.19)	0.29 (0.19)	0.99 (0.19)	5.04 (0.19)
Kurt *(SE)*	0.62 (0.38)	1.22 (0.38)	18.12 (0.38)	0.87 (0.38)	2.41 (0.38)	74.47 (0.38)	2.11 (0.38)	1.97 (0.38)	26.94 (0.38)

Note:

** indicates significance at the .001 level

* at the .01 level

Table 5:

Hierarchical Multiple Regression Predicting Child Executive Function at Age 6 from Age 4 Executive Function and Age 6 Parenting (Controlling for Age 4 Parenting)

	B	S.E.	β	t	p
Step 1:					
EF Age 4 (z)	0.295	0.083	0.292	3.561	.001
Maternal Education (z)	0.001	0.084	0.001	0.008	.994
PPVT Score Age 6 (z)	0.205	0.085	0.205	2.400	.018
Parenting Age 4 (z)	−0.009	0.080	−0.009	−0.117	.907
Parenting Age 6 (z)	0.076	0.082	0.076	0.922	.358
Child Sex	−0.035	0.153	−0.017	−0.230	.820
Step 2:					
EF Age 4 (z)	0.274	0.082	0.272	3.344	.001
Maternal Education (z)	0.031	0.083	0.031	0.367	.714
PPVT Score Age 6 (z)	0.205	0.084	0.206	2.442	.016
Parenting Age 4 (z)	0.001	0.079	0.001	0.001	.994
Parenting Age 6 (z)	0.097	0.081	0.097	1.195	.227
Child Sex	−0.004	0.151	−0.002	−0.028	.978
EF X Parenting Age 6	0.210	0.086	0.182	2.383	.018

Note: For child sex, male is coded as 1 and female as 2.

Table 6:

Intra-class Correlations for Age 4 Parenting Variables

	Puzzle	Etch-Square	Etch-Circle
Positivity	.96	.93	.90
Attention	.96	.88	.92
Negativity	.93	1.00	.89

Table 7:

Intra-class Correlations for Age 6 Parenting Variables

	Marble	Etch-Square	Etch-House
Positivity	.96	.97	.95
Attention	.95	.96	.98
Negativity	1.00	1.00	1.00