HHS Public Access
Author manuscript
Dev Psychol. Author manuscript; available in PMC 2022 March 01.

Published in final edited form as:
Dev Psychol. 2021 March ; 57(3): 347–360. doi:10.1037/dev0000972.

The Role of Negative Emotionality in the Development of Child Executive Function and Language Abilities From Toddlerhood to First Grade: An Adoption Study

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Abstract

Understanding the role of negative emotionality in the development of executive functioning (EF) and language skills can help identify developmental windows that may provide promising opportunities for intervention. In addition, because EF and language skills are, in part, genetically influenced, intergenerational transmission patterns are important to consider. The prospective parent–offspring adoption design used in this study provides a unique opportunity to examine the intergenerational transmission of EF and language skills. Participants were 561 children adopted around the time of birth. Accounting for birth mother EF and language contributions, we examined the role of child negative emotionality in toddlerhood (age 9 to 27 months) and childhood (age 4.5 to 7 years) on child EF and language skills in first grade (age 7 years). There was continuity in EF from age 27 months to 7 years, and in language ability from age 27 months to 7 years, with no cross-lagged effects between child EF and language ability. Negative emotionality at age 9 months predicted lower EF and lower language abilities at age 7 years, and growth in negative emotionality from age 4.5 to 7 years predicted lower child EF at age 7 years. Overall, findings suggested that lower negative emotionality at age 9 months was associated with higher toddler and child EF and language skills and that preventing growth in negative emotionality from age 4.5 to 7 years may lead to improvements in child EF.

Keywords

negative emotionality; executive function; language; adoption; genetically informed

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Executive function (EF) encompasses the processes that underlie an individual's capacity to act in a goal-directed manner and to suppress basic reactionary responses in pursuit of that goal (Blair & Ursache, 2011; Hendry et al., 2016). Lower EF skills have been associated with multiple types of child psychopathology (Diamond, 2013; Martel et al., 2017; Penadés et al., 2007), whereas higher EF skills have been associated with both child social and academic success (Jacob & Parkinson, 2015; Willoughby et al., 2017). These findings highlight the importance of EF for children's behavioral and academic outcomes and suggest the need for research that identifies the antecedents of EF development. In early childhood, EF develops simultaneously with child language (Cole et al., 2017; Ferrier et al., 2014; Hernández et al., 2018; Willoughby et al., 2019). Specifically, a child's ability to express and interpret language enables a child to exert volitional control over their actions and emotions (Cole et al., 2010; Vygotsky & Luria, 1994). Parent–offspring adoption designs indicate that the combined development of EF and language is partially driven by genetic contributions passed on from parent to offspring (Jester et al., 2009; Leve et al., 2013). Further, twin studies have found evidence of overlap in genetic influences between EF and language ability (Lemery-Chalfant et al., 2008). Thus, it is important to account for the genetic transmission of factors that influence EF and language from biological parent to child when examining the development of these two distinct, yet related, developmental processes.

Child negative emotionality may interfere with healthy EF and language development. *Negative emotionality* refers to an individual's susceptibility to react negatively with anger, anxiety, fear, and sadness (Rothbart & Bates, 2006). Although using EF and language skills can facilitate children's strategic control over negative emotionality, ultimately, heightened negative emotionality limits a child's ability to strategically deploy advanced regulatory strategies (Cole et al., 2017). In addition, high levels of child negative emotionality across infancy and toddlerhood have been related to impairments in toddler EF and language (Leve et al., 2013; Salley & Dixon, 2007). However, there is limited information about the role of negative emotionality in the development of EF and language at the early school-age period.

This study used a parent–offspring adoption design that can distinguish between genetic and rearing environmental influences on EF and language. In this study, children were placed with genetically unrelated adoptive parents around the time of birth and were not raised by biological relatives. Thus, any associations between birth parent and child behaviors are best explained by their shared genes and/or by the prenatal environment. In this report, birth parent EF and language serve as indices of genetic influences on EF and language. Furthermore, including birth parent EF and language in analytical models permits inferences about the unique effects of negative emotionality on children's EF and language development, independent of genetic influences, and strengthens inferences regarding the role of child negative emotionality on child EF and language. Although twin and adoption studies have focused on the heritability and genetic transmission of child EF and language (e.g., Cutting & Scarborough, 2006; Willems et al., 2019), we are aware of only one prior study that has examined the associations between negative emotionality, EF, and language (Leve et al., 2013). Although accounting for the effects of birth parent EF and language skills, we focused on the role of negative emotionality in the development of child EF and language abilities in school-age children during a critical period in the development of EF and language abilities: the first grade. At this age, low EF and language skills have been associated with concurrent difficulties in social-emotional and behavioral difficulties, limitations in school and psychosocial functioning (McKean et al., 2017), and subsequent behavioral and academic challenges (Bull et al., 2008; Petersen et al., 2013).

The Etiology of Child EF and Language Abilities and Their Covariation

Child Executive Functioning

EF encompasses processes such as inhibitory control, working memory, and attention shifting, which underlie an individual's capacity to act in a goal-directed manner and to suppress basic reactionary responses in pursuit of that goal (Blair & Ursache, 2011; Hendry et al., 2016). A closely related temperament construct, *effortful control*, is defined as "the efficiency of executive attention, including the ability to inhibit a dominant response, to activate a subdominant response, to plan, and to detect errors" (Rothbart & Bates, 2006, p. 129). It has been argued that the distinction of EF and effortful control is largely the result of being studied by different disciplines, thus, calling for an integrated model of the two constructs (Zhou et al., 2012). As an example, the Stroop task has been operationalized as both a measure of EF and effortful control (Carlson, 2005; Kochanska et al., 2000). Children exhibit considerable improvements in their performance on this task across the second year of life (Kochanska et al., 2000). However, because performance on the Stroop task improves with age, a ceiling effect has been identified such that most children are able to correctly inhibit their responses by age 7 (Cioffi et al., 2020; Montgomery and Koeltzow, 2010). As parent report of effortful control on the Child Behavior Questionnaire (CBQ) has been associated with toddler performance on the Stroop task (Rothbart et al., 2001) and has been more consistently linked to negative emotionality than other indicators of EF or effortful control (Eisenberg et al., 2000). Child scores on the effortful control scale of the CBQ may be a useful indicator of EF in childhood that has either been disrupted by child negative emotionality or has remained stable over the course of development—or both.

Twin and adoption studies have shown that children's genetic makeup influences EF. Specifically, twin studies partition phenotypic variance into genetic, shared environmental, and nonshared environmental components, and genetic variance is used as an estimate of phenotypic heritability. Twin studies have yielded heritability estimates that range from 21% to 55% (Polderman et al., 2006; Wang et al., 2012), with higher estimates in adolescence and young adulthood (Engelhardt et al., 2015; Friedman et al., 2008; for a meta-analysis of genetic influences across development on self-control—an EF dimension—see Willems et al., 2019). The genetic contributions to EF are also indicated by adoption studies that have found correlations between biological parent and child EF when children are reared by unrelated adoptive parents and by studies without genetically sensitive designs that identify an association between parent and child EF, however, the latter are unable to separate genetic influences on EF from the environmental influence of being reared by a parent with higher or lower EF (Cuevas et al., 2014; Leve et al., 2013).

Child Language

Early language includes the ability to understand and express components of language, including vocabulary and syntax, and is associated with children's later language and reading comprehension (Cutting & Scarborough, 2006; Share & Leikin, 2004). Similar to the EF literature, twin studies show that language development is genetically influenced, with heritability estimates ranging from 26% to 62%, and higher estimates emerging after age 2 (Stromswold, 2001). Moreover, using an adoption study, Leve et al. (2013) found that birth parent verbal intelligence predicted toddler EF, highlighting the potential shared genetic etiology of EF and language abilities.

Covariation Between Child Executive Functioning and Language

Substantial research has highlighted a link between language skills and EF in toddlerhood and during the school-age years (Henry et al., 2012; Kaushanskaya et al., 2017; Woodard et al., 2016). In toddlerhood, children advance their ability to express and interpret language and are able to use those expressive and receptive language skills to control their actions (e.g., a child verbalizes a need rather than screaming or crying, or a parent provides a directive and their child carries out the request; Cole et al., 2010). Research has established concurrent associations between language and EF skills during the preschool and early school years, such that children with language impairment show persistent EF deficits (Gooch et al., 2016). Moreover, in kindergarten, children with high reading achievement also demonstrate more advanced EF, a pattern that is maintained throughout the elementary school years (Willoughby et al., 2019). In addition, child language abilities may be inhibited by immature child EF (Woodard et al., 2016). However, these associations have been identified cross-sectionally, thus, examining reciprocal influences of toddler EF and language on child EF and language is important for understanding how EF and language might co-develop over time.

Prior work has indicated that both EF and language abilities in toddlerhood predict child EF during the school-age years (Fuhs & Day, 2011; Visu-Petra et al., 2012) and EF skills among preschool and school-age children predict literacy skills during later childhood and adolescence (Demoulin & Kolinsky, 2016; Willoughby et al., 2019). Thus, language skills may, in part, influence the development of EF, and vice versa. Further, language ability is associated with improvements in EF across 1 year of preschool (Fuhs & Day, 2011). It may be that this association occurs because language skills are needed to construct and use embedded rule structures that help children to solve a given problem or conflict (Zelazo et al., 2003). Given the available evidence, we expected reciprocal associations between EF and language from toddlerhood to school-age, even after accounting for stability in child EF and language over time.

Negative Emotionality May Limit the Expression of Executive Function and Language

Negative emotionality is a key temperament construct that describes a child’s propensity to experience and react with negative emotion, including anger, fearfulness, or sadness (Rothbart, 2007). It has been conceptualized as an individual’s range of biological and behavioral responsivity that influences how children appraise and respond to a range of situations across time (Nigg, 2006; Rothbart, 2007). In infancy, negative emotionality includes frustration and fearfulness, which are both reliably observed before infants reach the age of 9 months (Rothbart & Bates, 2006).

Throughout infancy and toddlerhood, negative emotionality increases (Braungart-Rieker et al., 2010), however, after toddlerhood, negative emotionality slightly decreases over the elementary school years (Murphy et al., 1999; Sallquist et al., 2009). Negative emotionality during infancy, toddlerhood, and kindergarten has been associated with deficits in both EF and language abilities (Hernández et al., 2018; Leve et al., 2013; Salley & Dixon, 2007). Moreover, school-age children with heightened negative emotionality are also likely to have attenuated literacy skills, relative to their peers (Hernández et al., 2018). Although EF has been conceptualized as an individual's ability to exert top-down control to manage emotional lability (Diamond, 2013; Ochsner & Gross, 2007), there is research to suggest that negative emotionality may also influence a child's ability to deploy EF (Bridgett et al., 2009). Specifically, negative emotionality may make children's ability to deploy executive functioning more challenging by interfering with engagement and regulatory behavior (Clark & Watson, 2008; Rabinovitz et al., 2016). This research suggests that although EF may also affect later negative emotionality, higher levels of negative emotionality may limit strategic attempts to deploy EF. Our study tests the role of heightened negative emotionality on EF and language development.

Current Study and Hypotheses

We sought to examine the development of EF and language—two distinct but related skills —while including the role of negative emotionality. Our prospective, longitudinal adoption design enabled us to examine the development and continuity of EF and language abilities at two critical development stages—toddlerhood (*M* age = 27 months), when these skills are still developing but can be reliably measured (Kochanska et al., 2000), and first grade (*M* age = 7 years), when these skills are critical for school success—while controlling for the genetic contributions of EF and language abilities from birth parents to the adoptee.

We hypothesized that (a) there would be stability in EF and language skills from age 27 months to first grade, and there would be cross-lagged associations from EF at 27 months to EF at first grade language and vice versa; (b) negative emotionality from age 9 to 27 months would be associated with lower EF and language skills at age 27 months; and (c) increases in negative emotionality from age 4.5 years to first grade would be associated with lower EF and language at first grade. We included measures of birth mother EF and language to account for genetic contributions on child EF and language and expected to replicate prior studies that have demonstrated genetic contributions.

Method

Participants and Procedures

This study used data from two cohorts, Cohort 1 (*n* = 361) and Cohort 2 (*n* = 200; Leve et al., 2019). The study was a prospective, longitudinal study consisting of 561 linked sets of families (adopted child, adoptive parents, and birth parents). Participants were recruited through 45 adoption agencies in 15 states across the United States (see Leve et al., 2019, for a more detailed description). Participants were eligible for participation if (a) the adoption was domestic, (b) the infant was placed with a non-relative adoptive family, (c) the infant was placed before 3 months of age (*M* = 7.11 days, *SD* = 13.28), (d) the infant had no known major medical conditions, and (e) the birth mother and adoptive parents could read or understand English at an eighth-grade level or higher. All protocols were reviewed and approved by University of Oregon institutional review board: 03042014.001, Early Growth and Development Study: Family Process, Genes, and School Entry; 04262013.031, Gene-Environment Interplay and Childhood Obesity: An Adoption Study; 09032019.002, Siblings Reared Apart: A Naturalistic Cross-Fostering Study of Young Children; 04262013.034, Genes, Prenatal Drug Exposure, and the Postnatal Environment: An Adoption Study, and 04262013.035, Gene-Environment Interplay and the Development of Psychiatric Symptoms in Children. The average age and sample size for the children included in this report are 9 months (*M* = 9.35, *SD* = 0.86, *n* = 539), 18 months (*M* = 18.09, *SD* = 1.09, *n* = 504), 27 months (*M* = 27.48, *SD* = 1.87, *n* = 493), 4.5 years (*M* = 56.95 months, *SD* = 3.22 months, *n* = 457), 6 years (*M* = 72.42 months, *SD* = 2.81 months, *n* = 455), and 7 years of age (*M* = 85.60 months, *SD* = 4.14 months, *n* = 347). The sample size at age 7 years is smaller than the earlier waves because the original studies only included funding for the assessment of *n* = 60 Cohort 2 participants for the constructs included in this report, so the maximum possible age 7 sample (assuming no attrition) was 421 (361 from Cohort 1, 60 from Cohort 2). The age 6 assessment occurred when children were in kindergarten, and the age 7 assessment occurred when they were in first grade.

At the time of the adoptee's birth, adoptive parents' median total household income was between $100,000 and $125,000 and median educational attainment for adoptive mothers and adoptive fathers was at least a 4-year college degree (40% and 40%, respectively). Adoptive mother and adoptive father mean ages were 37.43 (*SD* = 6.03) and 38.28 (*SD* = 5.83) years old, respectively. Most adoptive mothers and adoptive fathers were White (92% and 90%, respectively), and the remainder were African American (4% and 5%, respectively), Latinx (2% and 2%, respectively), and "other" (2% and 3%, respectively). Adoptive parents were assessed when the adopted child was the following ages 9 months, 18 months, 27 months, 4.5 years, 6 years, and 7 years. All available data were included in analyses.

For birth parents, the median total household income was between $25,001 and $40,000 and the median educational attainment was a high school diploma (measured at 3 to 6 months postpartum). Birth parents typically had household incomes of less than $25,000. Birth mothers were 24.35 (*SD* = 6.03) years old at the time of birth of the child. The majority of birth mothers were White (70%), and the remainder were African American (13%), Latinx (7%), and "other" (10%). Birth mothers were assessed in-person when adoptees were ages 3 to 6 months, age 18 months, and again between ages 4 to 7 years old. Birth mother self-report, adoptive parent report of child, and observational data of the child were used in this study. Retention rates remained high throughout this study (18 months, 89%; 27 months, 87%; 4.5 years, 81%; 6 years, 81%; 7 years, 82% for adoptive families (out of 421, due to funding limitations at child age 7 years for Cohort 2, as noted earlier).

Measures

Child Executive Functioning—Toddler EF was assessed at age 27 months using the shape Stroop task (modeled after Carlson et al., 2004; Kochanska et al., 2000). The interviewer showed the child three large and three small pictures of the same fruits (e.g., apple, banana, orange). After reviewing the names and the meaning of each big–little dimension, the interviewer showed the child three pictures, each containing a small fruit embedded within a different large fruit (e.g., a small orange inside of a large apple). The interviewer then asked the child to point to each of the little fruits (e.g., "show me the little orange"). After the fruit trials, the interviewer repeated the activity with a similar set of three trials with pictures of big and little animals (bunny, dog, teddy bear). Each trial was scored on a scale of 1 to 3 ranging from "ambiguous or incorrect response on both item and size of object" to "correct item and correct size." Items demonstrated strong internal consistency (Cronbach's α = .86) and were averaged to compute a composite score.

Child EF was assessed at age 7 years with the effortful control scale from the CBQ (Rothbart et al., 2001) which demonstrates consistent associations with EF task performance (Lin et al., 2019). The effortful control scale used adoptive parent report on 115 items that included attentional focusing, inhibitory control, low-intensity pleasure, and perceptual sensitivity. Adoptive mother and adoptive father reports demonstrated strong internal consistency (Cronbach's α = .84 and .86, respectively) and were correlated ($r = .49$, $p < .01$). Thus, when data were available from both adoptive mothers ($n = 342$) and fathers ($n = 293$) a mean score was used.

Child Language—Toddler language ability was assessed at age 27 months with the language ability scale on the Language Development Survey of the Child Behavior Checklist (Achenbach & Rescorla, 2000). Adoptive parents reported on 310 items that list a series of words (e.g., foods, body parts, actions, animals) and asks parents to indicate which words the child says spontaneously. Total scores were converted to reflect the child's percentile relative to same-age peers using nationally standardized norms. Adoptive mother and adoptive father reports demonstrated high internal consistency (Cronbach's α = .99 and 1.00, respectively) and were highly correlated ($r = .79$, $p < .01$). Thus, when data were available from both adoptive mothers ($n = 494$) and fathers ($n = 466$) a mean score was used.

Language ability was assessed at age 7 years with the Woodcock Johnson III (WJ-III) Achievement Test basic reading skills standardized score (Woodcock et al., 2001). The basic reading skills standardized score included both children's letter-word identification skills and basic reading fluency (i.e., their ability to apply letter-word identification to sets of words). The standardized score was computed with the WJ-III Compu-score and Profiles Program.

Child Negative Emotionality—Negative emotionality was assessed at 9 months, 18 months, and 27 months of age and 4.5 years, 6 years, and 7 years of age using widely-used, well-validated, and developmentally appropriate temperament questionnaires from the same family of temperament measures which include slightly different items to reflect developmental changes (Putnam & Stifter, 2008). At age 9 months, the Infant Behavior

Questionnaire (Rothbart, 1981, 1986) was used to assess child negative emotionality with the 20-item Distress to Limitations scale (Cronbach's α = .83 and .83, respectively) and the 20-item Fearfulness scale (Cronbach's α = .73 and .72, respectively). These scales were combined to reflect multiple aspects of negative emotionality. When data were available, a mean score of adoptive mother (n = 534) and father (n = 493) reports of distress to limitations (r = .56, p < .01) and fearfulness (r = .55, p < .01) were computed prior to averaging distress to limitations and fearfulness (r = .38, p < .01) to create an overall composite of negative emotionality in infancy.

At age 18 months and age 27 months, the Toddler Behavior Assessment Questionnaire (TBAQ; Goldsmith, 1996) was used to assess mother and father report of child negative emotionality with the 28-item Anger Proneness scale (18 months: Cronbach's α = .89 and .89; 27 months: α = .85 and .87) and 28-item Social Fearfulness scale (18 months: Cronbach's α = .82 and .84; 27 months: α = .83 and .80). These scales were combined to reflect multiple aspects of negative emotionality. When available, mean scaled scores of adoptive mother (18 months: n = 449; 27 months: n = 477) and father (18 months: n = 423; 27 months: n = 448) reports of anger proneness and social fearfulness were computed at age 18 months (r = .42 and .63, p < .01, respectively) and age 27 months (r = .44 and .59, p < .01, respectively) prior to averaging anger and social fearfulness (18 months: r = .27, p < .01; 27 months: r = .21, p < .01).

At age 4.5 years, 6 years, and 7 years, adoptive mother and father reports on the 12-item Negative Affect scale in the Children's CBQ-Short Form (CBQ-SF; Putnam & Rothbart, 2006) was used to assess negative emotionality (at 4.5 years: Cronbach's α = .69 and .74; 6 years: α = .76 and .74; 7 years: α = .82 and .88). Note that although we used the full CBQ for effortful control scale at age 7 years, as described earlier, at 4.5 years and 6 years, only the CBQ-SF Negative Affect scale was administered. Accordingly, we used the short form scale of the Negative Affect scale at 7 years for consistency.

The CBQ-SF Negative Affect scale includes items that measure child anger, fearfulness, sadness, and it is often used to measure negative emotionality. When ratings from both adoptive mother (4.5 years: n = 443; 6 years: n = 445; 7 years: n = 344) and father (4.5 years: n = 414; 6 years: n = 409; 7 years: n = 295) were available, a mean score was computed (4.5 years: r = .38: 6 years: r = .43; 7 years: r = .45, ps < .01).

Birth Mother Executive Functioning—Reaction time during the interference trial of the computerized color word Stroop task (MacLeod, 1991) was used to measure birth mother executive functioning. In the task, interference is created between a word's color and its meaning. The Stroop task was administered on a laptop computer. Letter strings composed of the color words "RED," "BLUE," "GREEN," and "YELLOW" appeared in color on the screen. In the control trials, the word and color were congruent, with each word printed in the color identified by the word. In the interference trials, the word and color were noncongruent, with each word printed in a color different from that identified by the word. Reaction time was computed as the interval in milliseconds between a word's appearance on the screen and a key press that indicated the font color in which the word was printed. Responses were reverse scored so that higher scores indicated greater EF skills.

Birth Mother Verbal Intelligence—The Vocabulary scale from the Wechsler Adult Intelligence Scale–III (WAIS; Wechsler, 1997) was administered during the birth mother assessments at child age 18 months or child ages 4 to 7 years to obtain an estimate of her verbal intelligence. This scale consists of 33 items that measure the degree to which one has learned, been able to comprehend, and verbally express vocabulary (Kaufman & Lichtenberger, 1999). Scaled scores were computed for each birth parent based on age. This study uses the Vocabulary subscale, rather than the Information subscale used by Leve et al. (2013) because the Information subscale was not administered to Cohort 2. In addition, the Vocabulary scale is considered to be the single best subscale of the WAIS to measure verbal intelligence (Tulsky & Price, 2003).

Additional Covariates—Three covariates were included—prenatal risk, child sex, and openness in the adoption (contact between birth and adoptive parents). It is important to control for prenatal risk because in utero exposures to toxins, maternal depression and anxiety, and medical complications are associated with low EF and language (Baron et al., 2012). Prenatal risk was assessed at 3 and 6 months postpartum using birth mother report of pregnancy complications (e.g., prenatal illness and fetal distress during pregnancy) and prenatal drug use (e.g., illicit substances/alcohol) using a pregnancy screener and a pregnancy history calendar method to enhance recall. Scoring was derived from the McNeil-Sjostrom Scale for Obstetric Complications (McNeil et al., 1994). Responses to each item were assigned a score from 1 (*not harmful or relevant*) to 6 (*very great harm to or deviation in offspring*), indicating the level of risk indicated by each response. Consistent with McNeil-Sjostrom scoring protocols, a prenatal risk score that reflected the severity of risk was created by summing items with a score of 3 or greater. See Marceau et al. (2016) for details. Child sex was also included as a covariate (54% male), given the known sex difference in children's language skills.

Openness in the adoption was included as a covariate to control for similarities between birth parents and adopted children that might result from contact between the two parties. This was measured using a composite of birth mother, adoptive mother, and adoptive father ratings of perceived adoption openness (Ge et al., 2008) during early childhood, where each participant rated the degree and nature of contact and communication with their counterpart on a 7-point scale ranging from 1 (*very closed; you have no information about the adoptive parents*) to 7 (*very open; you have visits with the family at least once a month and communicate several times a month by phone, letters, or emails*). Adoptive mother, adoptive father, and birth mother reports were averaged to arrive at the final score (*r*s = .71–.85, $p < .01$).

Data Analyses

Structural equation models were tested in R using the "lavaan" package (Rosseel, 2012) to examine the role of child negative emotionality on child EF and language ability while accounting for genetic contributions and associations between EF and language over time. Little's (1988) test of Missing Completely at Random indicated that data were missing completely at random (χ^2 = 1,784.88, *df* = 1,795, *p* = .56). We used full information maximum likelihood to account for missing data. To assess for selective attrition effects, we compared 347 families with complete data on all study variables and 214 families missing data on one or more variables. Analyses revealed that among the baseline measures (birth mother EF, birth mother verbal intelligence, birth mother Stroop reaction time, infant negative emotionality, openness in adoption, and sex of child), no differences were obtained except for openness in adoption. Specifically, families with missing data at later waves scored slightly higher on openness in adoption ratings, $t(560) = 2.12$, $p = .03$.

As a preliminary step, we estimated a latent piece-wise growth model determined a priori, based on theory, to evaluate levels and changes in negative emotionality across infancy (ages 9 months, 18 months, and 27 months) to childhood (ages 4.5 years, 6 years, and 7 years). The piecewise growth model estimated an intercept, a slope for growth in negative emotionality for toddlerhood (ages 9 months, 18 months, and 27 months; S1), and a slope for childhood (ages 4.5 years, 6 years, and 7 years; S2). To model the piecewise growth curve, the estimates were fixed as follows for each term intercept (1 at 9 months, 1 at 18 months, 1 at 27 months, 1 at 4.5 years, 1 at 6 years, 1 at 7 years), slope 1 (0 at 9 months, 1 at 18 months, 2 at 27 months, 2 at 4.5 years, 2 at 6 years, 2 at 7 years), slope 2 (0 at 9 months, 0 at 18 months, 0 at 27 months, 5 at 4.5 years, 5.5 at 6 years, 5.8 at 7 years). Thus, for Slope 1, we fixed the estimates at 2 to model the absence of growth from 27 months on, so that we could have a separate estimate for growth from 4.5 to 7 years. The intercept term is an indicator of the initial or baseline negative emotionality in infancy but can also be thought of as an indicator of stability in negative emotionality overtime. Then, we incorporated paths to test the primary hypotheses examining longitudinal associations between EF and language and the role of negative emotionality in the development of child EF and language.

Model fit was assessed using comparative fit index (CFI), root mean square error of approximation (RMSEA), and chi-square values. The CFI ranges in value from 0 to 1 and indicates the proportion of improvement in the overall fit of the hypothesized model relative to a null model in which all covariances between variables are zero. Values of .95 or greater are desirable for the CFI (Bentler, 1990; Hu & Bentler, 1999). The RMSEA is a measure of lack of fit per degrees of freedom; values that range upwards from 0 through to 0.05 indicate a good fit, and up to 0.08, a fair fit (Browne & Cudeck, 1993). Chi-square is reported but is highly sensitive to sample size and distributional assumptions (Hu & Bentler, 1995), thus we relied on the two other measures of the overall goodness-of-fit to provide accurate fit estimates.

Results

Descriptive Analyses

Table 1 presents means and standard deviations for main study variables based on raw data and the pairwise bivariate correlations after controlling for covariates (i.e., prenatal risk, child sex, and openness in adoption). There were several correlations of note in regard to study hypotheses.

Birth mother EF was positively correlated with child EF at age 27 months ($r = .13$, $p < .004$) and age 7 years ($r = .20$, $p < .001$), birth mother verbal intelligence was positively correlated with child language ability at age 27 months ($r = .11$, $p = .02$) and age 7 years ($r = .26$, p

$< .001$). There was evidence for associations between birth mother EF and child language and vice versa. Specifically, birth mother EF was associated with child language at age 7 years ($r = .12$, $p = .04$) and birth mother verbal intelligence was associated with child EF at age 27 months ($r = .15$, $p = .001$) and age 7 years ($r = .18$, $p = .002$). There was stability in child EF and language ability. Toddler EF at age 27 months was correlated with child EF at age 7 years ($r = .19$, $p < .001$) and toddler language ability at age 27 months was correlated with child language ability at age 7 years ($r = .22$, $p < .001$). In addition, there were time-specific correlations between toddler EF and language ability at age 27 months ($r = .32$, $p < .001$) and age 7 years ($r = .19$, $p < .001$).

Consistent with expectations child negative emotionality at ages 18 and 27 months was inversely associated with toddler EF at age 27 months ($r = -.10$, $p = .03$; $r = -.16$, $p < .001$, respectively) and negative emotionality at age 27 months was inversely associated with toddler language ability at age 27 months ($r = -.17$, $p < .001$). Likewise, there were associations in the expected direction between negative emotionality at ages 4.5 years, 6 years, and 7 years and EF at age 7 years ($r = -.13$, $p = .02$; $r = -.25$, $p < .001$; $r = -.28$, $p < .001$, respectively). In contrast with Hypothesis 3, negative emotionality at ages 4.5 years, 6 years, or 7 years and child language ability at age 7 years were not significantly associated. Significant longitudinal associations emerged for negative emotionality at age 9 months and child EF and language ability at age 7 years ($r = -.16$, $p = .003$; $r = -.14$, $p = .01$, respectively).

Preliminary Analyses: Negative Emotionality Growth Curve Model

First, latent growth curve models were estimated to evaluate the initial intercept and slope for negative emotionality across infancy (ages 9, 18, and 27 months) and across childhood (ages 4.5, 6, and 7 years). Based on a priori theory, a model was estimated with growth terms to represent each of the three parameters of the model. Compared to the unconditional growth curve, $\chi^2(14) = 322.99$, $p < .001$, CFI = 0.68, RMSEA = .20, the piecewise growth model improved the model fit to the data, $\chi^2(12) = 31.39$, $p < .01$, CFI = 0.98, RMSEA = .05. Te piecewise growth model included growth in negative emotionality from ages 9, 18, and 27 months as one slope (initial slope; S1), growth from ages 4.5, 6, and 7 years as another slope (second slope; S2), and an intercept capturing the average level of negative emotionality from age 9 months to age 7 years. This model is depicted in Figure 1 and was included in the primary hypothesis testing described in the next section.

Primary Hypothesis Testing

After the negative emotionality growth curve was estimated, the full model was estimated which included the effects of negative emotionality, birth mother EF and verbal intelligence, and child EF and language ability at age 27 months on child EF and language abilities at 7 years (see Figure 2). The full model demonstrated adequate fit to the data, $\chi^2(45) = 109.41$, $p < .01$, CFI = .94, RMSEA = .05. Although there was misfit indicated by the chi-square test, this index is not a reliable indicator of fit with large sample sizes (i.e., more than 200; Barrett, 2007). The full model explained 9% of the variance in EF at 27 months, 10% of the variance in language ability at age 27 months, 27% of the variance in EF at age 7 years, and 14% of the variance in language ability at age 7 years.

Intergenerational and Developmental Continuity in EF and Language Abilities—The structural model confirmed the zero-order correlations. Specifically, there were associations between birth mother EF and child EF and birth mother verbal intelligence and child language ability. Birth mother EF was associated with toddler EF at age 27 months ($b = 0.11$, $p = .03$) and child EF at age 7 years ($b = 0.12$, $p = .01$). Birth mother verbal intelligence was associated with child language ability at age 7 years ($b = 0.19$, $p < .01$), with toddler EF at 27 months ($b = 0.12$, $p = .03$), and with child EF at 7 years ($b = 0.11$, $p = .05$). There was no association between birth mother verbal intelligence and child language ability at age 27 months.

There was modest stability in EF from age 27 months to age 7 years ($b = 0.11$, $p = .01$) and in language ability from age 27 months to age 7 years ($b = 0.17$, $p < .01$). Cross-lagged effects were not detected from EF at age 27 months to language ability at age 7 years was ($b = 0.11$, $p = .06$) nor from language ability at age 27 months to EF age 7 at years ($b = 0.07$, $p = .22$). EF and language ability covaried at age 27 months ($r = 0.25$, $p < .01$) but only marginally at age 7 years ($r = 0.11$, $p = .06$).

Negative Emotionality as a Predictor of Child Ef and Language Abilities—For EF and language ability at age 27 months, only associations with S1 were examined and not I or S2, as these latent variables included negative emotionality data collected after age 27 months (at ages 4.5, 6, and 7 years), and, thus, were not in appropriate temporal order to test. Consistent with hypothesis 2, increases in negative emotionality, estimated by S1, were associated with lower language ability at age 27 months ($b = -0.23$, $p < .01$) and lower EF at age 27 months ($b = -0.23$, $p < .01$). For child EF and language ability at age 7 years, associations with the intercept, S1, and S2 were examined. The intercept for negative emotionality was associated with lower language ability at age 7 years ($b = -0.17$, $p = .01$) and lower EF at age 7 years ($b = -0.28$, $p < .01$). Consistent with Hypothesis 3, S2 was associated with lower EF at age 7 years ($b = -0.31$, $p < .01$), however it was not associated with language ability at age 7 years ($b = -0.08$, $p = .35$).

Discussion

Our study used a parent–offspring adoption design to examine the development of child EF and language abilities from toddlerhood to first grade. The design allowed us to focus on the prediction of child EF and language ability from negative emotionality while controlling for genetic contributions conveyed via the birth mother's EF and language abilities. Our results indicated modest stability in EF and language ability from age 27 months to age 7 years. In addition, we found an association between negative emotionality in infancy and both child EF and language ability at 7 years of age, which has implications for the timing of preventive intervention targets, as is further discussed later. Finally, there was an association between increases in negative emotionality from ages 4.5 years to 7 years and lower child EF at 7 years of age, but not child language at 7 years of age. Our data were collected prospectively, which enabled us to model latent growth in negative emotionality over time to account for developmental stability and change, and to separate the influences of negative emotionality from age 9 months to age 27 months, and from age 4.5 years to age 7 years. The implications of these findings are discussed in the next sections.

EF and Language Abilities: Stability, Co-Occurrence, and Genetic Contributions

EF and language ability were identified as discrete constructs due to domain-specific genetic contributions from birth mother to child and the domain-specific continuity of both EF and language from age 27 months to age 7 years. Replicating twin studies that have shown genetic influences on child EF and language (Engelhardt et al., 2015; Stromswold, 2001), genetic contributions were supported by associations between birth mother EF and child EF at ages 27 months and 7 years, and by associations between birth mother verbal intelligence and child language ability at age 7 years but not at age 27 months. That birth mother EF was associated with EF in both toddlerhood and first grade was surprising, as evidence from twin studies indicates that toddlers' EF abilities are less heritable than school-age EF (Engelhardt et al., 2015; Friedman et al., 2008; Polderman et al., 2006; Wang et al., 2012). This finding suggests that our measures and study design were sensitive to detecting genetic contributions as early as toddlerhood.

Based on the stability in EF and language abilities within child our study provides additional evidence that EF and language abilities are discrete constructs that develop in tandem. Specifically, we observed continuity in child EF from age 27 months to age 7 years and in language ability from age 27 months to age 7 years. This finding is notable because different methods were used to assess both behaviors over a 5-year period. Although prior work has identified EF and language abilities as stable and related (Gooch et al., 2016; Harms et al., 2014; Roman et al., 2016), no studies, to our knowledge, have examined whether EF and language exhibit stability after accounting for the similarity between birth mother and offspring. Stability in child EF and language, over and above genetic contributions, clarifies that the child's environment may also be related to stability in EF and language over time. For example, environmental exposure to toxins, socioeconomic circumstances, rearing parenting approaches and characteristics, and educational experiences may all influence the stability of EF and language. This finding is important because twin studies have provided conflicting evidence that EF and language stability remain functions of only genetic factors, while others have suggested that stability occurs because of both genetic and environmental factors (Kan et al., 2013; Rimfeld et al., 2018). Our findings reinforce the importance of the rearing environment. Cross-lagged effects from EF at age 27 months to language skills at age 7 years, or from language ability at age 27 months to EF at age 7 years, were not observed in contrast with prior work that found reciprocal effects between EF and language (Fuhs & Day, 2011; Visu-Petra et al., 2012; Willoughby et al., 2019). The absence of reciprocal (cross-lagged) effects between EF and language abilities in our study may indicate that negative emotionality accounts for some of the shared variance between these two constructs. Negative emotionality is typically not accounted for in prior studies of EF and language (Dixon & Smith, 2000; Karrass & Braungart-Rieker, 2003; Leve et al., 2013; Rabinovitz et al., 2016; Salley & Dixon, 2007), which may explain the difference in findings.

The current study also found an association between EF and language skills in toddlerhood, but not in first grade. In toddlerhood, EF and language abilities are rapidly developing, thus, there may be greater overlap between EF and language during early childhood (Gooch et al., 2016; Visu-Petra et al., 2012) compared to when EF and language skills are more established and distinct at age 7 years (Lerner & Lonigan, 2014; Wiebe et al., 2011). The absence of an association between EF and language skills at 7 years of age may reflect the divergence of the two, which may emerge because of the increasing heritability of EF and language ability over time or because there may be distinct genes associated with EF or language at age 27 months and EF or language at age 7 years (Engelhardt et al., 2015; Friedman et al., 2008; Polderman et al., 2006; Stromswold, 2001; Wang et al., 2012). In addition, the lack of association may be because of the use of parent report to measure EF at 7 years of age and a more direct measure of language at 7 years of age. However, at age 27 months, when language was measured using parent-report and EF was measured via observation, an association was still identified.

Negative Emotionality Disrupts Typical Development

Our study uniquely sought to examine the role of child negative emotionality in predicting child EF and language abilities. Specifically, we investigated associations between negative emotionality at age 9 months, from ages 9 months to 27 months, and from ages 4.5 years to 7 years on child EF and language abilities at age 7 years and from ages 9 months to 27 months on toddler EF and language abilities at age 27 months. Our results suggested that child negative emotionality plays a significant role in disrupting paths to both child EF and language abilities. Further, the predictive role of negative emotionality on both child EF and language abilities can be detected in toddlerhood. By using a growth curve model, we were able to observe distinct fluctuations in negative emotionality over time and during specific developmental windows. We found that heightened negative emotionality in infancy predicts lower EF and language in children at age 7 years. Growth in negative emotionality across toddlerhood predicted toddler EF and language. Growth in negative emotionality from 4.5 to 7 years predicted lower EF at 7 years of age. We describe associations between child negative emotionality, EF, and language abilities with respect to each developmental window examined.

Negative Emotionality in Infancy—Extant research has identified associations between infant negative emotionality and EF and language in infancy, toddlerhood, and preschool (Gartstein et al., 2009; Peterson et al., 2017). Our work highlights that associations exist between infant negative emotionality and child EF and language abilities beyond the preschool years to 7 years of age. Our findings suggest that heightened negative emotionality in infancy forecasts lower EF and language 6 years later. Thus, interventions to prevent heightened negative emotionality in infancy should be identified. For example, there is evidence for prenatal programming effects on infant negative emotionality for offspring exposed to maternal stress which are dependent on child sex (Braithwaite et al., 2017; Pluess et al., 2011); thus, interventions to attenuate prenatal stress may reduce infant negative emotionality, which may, in turn, improve EF and language outcomes for children. In addition, when heightened infant negative emotionality is present, interventions that enhance child emotion regulation may attenuate the impact of dysregulated negative affect on development.

Changes in Negative Emotionality Through Toddlerhood—Negative emotionality has been found to increase rapidly from infancy through toddlerhood before plateauing or slightly decreasing through the preschool years into school-age (Braungart-Rieker et al., 2010; Hernández et al., 2018; Murphy et al., 1999; Sallquist et al., 2009). Our data suggested a similar trend, where negative emotionality increased from ages 9 to 27 months and plateaued from ages 4.5 to 7 years. Increases in negative emotionality from ages 9 to 27 months were associated with both toddler EF and language abilities but were not related to EF or language abilities at 7 years of age. Prior research has identified similar associations between high negative emotionality and deficits in both EF and language abilities in toddlerhood (Hernández et al., 2018; Leve et al., 2013; Salley & Dixon, 2007).

Changes in Negative Emotionality From 4.5 to 7 Years—Increases in negative emotionality from age 4.5 to 7 years predicted lower EF, but not language ability, at age 7 years. EF, in contrast with language ability, may be more directly susceptible to fluctuations in negative emotionality throughout early development, in toddlerhood, and from ages 4.5 to 7 years. Changes in negative emotionality from ages 4.5 to 7 years appear as deviations from the stable aspects of temperament that predict child's EF, as reflected in the negative association between age 9 months negative emotionality (e.g., intercept or baseline negative emotionality) and changes in negative emotionality from ages 4.5 to 7 years. The exertion of negative emotion on a child's ability to deploy EF is consistent with the idea of bottom-up regulation (Clark & Watson, 2008; Cole et al., 2017; Rabinovitz et al., 2016). However, the process by which negative emotionality and EF develop is certainly bi-directional (Cole et al., 2019).

Compared to EF, language processes at age 7 years may be less susceptible to fluctuations in negative emotionality from ages 4.5 to 7 years. However, the lack of association between negative emotionality and language ability at age 7 years was surprising because the expression of negative emotions in kindergarten (based on observed negative emotion in a classroom setting) has been associated with lower literacy skills in the first grade (Hernández et al., 2018). The expression of negative emotionality in a classroom setting may directly interfere with a child's ability to engage with teacher instruction, whereas more stable aspects of negative emotionality, observed by parents, may capture aspects of negative emotionality that are more nuanced (such as fearfulness and social distress) and, thus, less associated with language ability. Moreover, if Hernández and colleagues had accounted for infant negative emotionality, they may have found that kindergarten negative emotionality was no longer related to literacy skills in the first grade.

Strengths, Limitations, and Future Directions

Our study provided novel insights into the role of negative emotionality on the development of EF and language abilities across childhood. We used a parent–offspring adoption design to examine genetic influences, which allowed us to examine whether children's negative emotionality predicted EF and language development above and beyond genetic contributions conferred from birth mother EF and language skills. Despite the strength of the adoption design approach, prospective longitudinal design, and use of multiple types of measures (e.g., parent report and child tasks), there were limitations. Both EF and language abilities comprised multiple components, especially following the preschool years (Visu-Petra et al., 2012; Wiebe et al., 2008). Thus, our findings are only generalizable to aspects of

EF and language abilities measured by the respective tasks. The task we used to measure EF in toddlerhood required a child to access language skills, thus, the relation between EF and language ability at age 27 months may signify an overlap in language ability rather than an overlap in the two distinct constructs. At age 7 years, EF was measured using parent report of EF, thus, associations between growth terms in negative emotionality and language ability at age 27 months as well as EF at age 7 years may have occurred, in part, because of shared method variance bias. However, the association between EF in toddlerhood, measured by direct assessment, was also associated with negative emotionality, thus, it is plausible that only some of the explained variance was due to shared method variance. Only the short form of the CBQ was available at 4.5 years and 6 years to measure negative emotionality. This may have limited variability associated with negative emotionality, thus, using the full CBQ may result in different findings. Finally, because of limited data and modeling constraints, we were unable to model growth in EF and language over time. Future research should examine the influence of growth in negative emotionality on growth in EF and language.

The correlations between adoptive mother and father reports of child negative emotionality ranged from modest to high (*r*s = .38 to .63). However, although much of the developmental literature relies on mother report of child behavior, using multiple reporters of child behaviors decreases bias related to factors such as parent psychological distress such as depression (Taraban et al., 2019). Thus, we believe that a combination of mother and father report would provide a more accurate representation of child behavior than mother report alone. There were demographic differences in our sample because adoptive families had higher annual incomes than birth parents in our study. The effect of socioeconomic status on EF and language has been well documented (Larson et al., 2015; Willoughby et al., 2017; Willoughby et al., 2019). Thus, the children in our study had an overall advantage in EF and language abilities compared to children reared in conditions of socioeconomic strain. Future investigations with children who are experiencing greater economic hardship may result in different findings because socioeconomic disadvantage may increase child negative emotionality and decrease child EF and language abilities as a result of systematic oppression such as food insecurity, increased neighborhood violence, and inadequate education systems (Schenck-Fontaine & Panico, 2019).

Future studies may benefit by incorporating specific biomarkers, such as prenatal risks and markers of elevated stress, to gain more nuanced insights into the mechanisms underlying the associations identified in this study (Pauli-Pott et al., 2009). In addition, although the focus of this paper was specific to the examination of child-specific behaviors that interact over the course of early development, certainly there are environmental influences that also predict the development of EF, language, and negative emotionality. These include parenting influences (e.g., parental scaffolding behaviors), rearing parent EF and language, and contextual influences (e. g., parent psychopathology, socioeconomic status, and the built environment). Thus, it is important for future research to investigate whether child negative emotionality serves as a moderator or mediator between these interpersonal and contextual experiences on child EF and language.

Conclusion

This study adds to the field of child development by providing new knowledge about the unique role of negative emotionality on the development of EF and language abilities from toddlerhood to first grade. We found that (a) there are domain-specific genetic pathways from birth mother EF to child EF and from birth mother verbal intelligence to child language ability; (b) EF and language abilities co-vary and demonstrate stability over time; (c) EF in toddlerhood does not predicate language ability at 7 years of age and language ability in toddlerhood does not predicate EF at 7 years of age; and (f) heightened negative emotionality broadly hinders EF and language abilities over the course of early childhood and early school-age development. Thus, preventive interventions that include a component to target the amelioration of negative emotionality may ultimately prove successful in supporting the development of child EF and language abilities.

Acknowledgments

This project was supported by Grant R01 HD042608 from the National Institute of Child Health and Human Development and the National Institute on Drug Abuse (PI Years 1–5: David Reiss; PI Years 6–10: Leslie D. Leve); R01 DA035062 from the National Institute on Drug Abuse (PI: Leslie D. Leve); R01 DA020585 from the National Institute on Drug Abuse (PI: Jenae M. Neiderhiser); R01 MH092118 from the National Institute of Mental Health (PIs: Jenae M. Neiderhiser, Leslie D. Leve); R01 DK090264 from the National Institute of Diabetes and Digestive and Kidney Diseases (PI: Jody M. Ganiban). Additional support was provided by UH3 OD023389 from the Office of the Director (PIs: Leslie D. Leve, Jenae M. Neiderhiser, Jody M. Ganiban) and F32 HD093347 from the National Institute of Child Health and Human Development (PI: Amanda M. Griffin). The content is solely the responsibility of the authors and does not necessarily represent the official views of the Eunice Kennedy Shriver National Institute of Child Health and Human Development or the National Institutes of Health.

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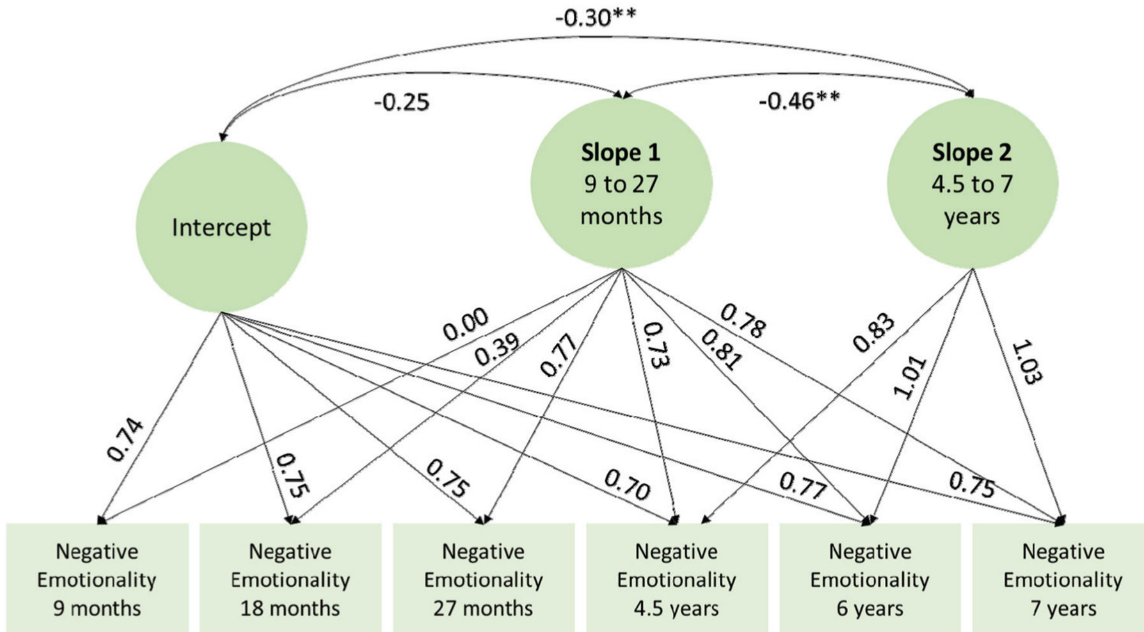

Figure 1.

Piecewise Latent Growth Curve Model for Negative Emotionality From Age 9 Months to Age 7 Years

Note. ** $p < .01$.

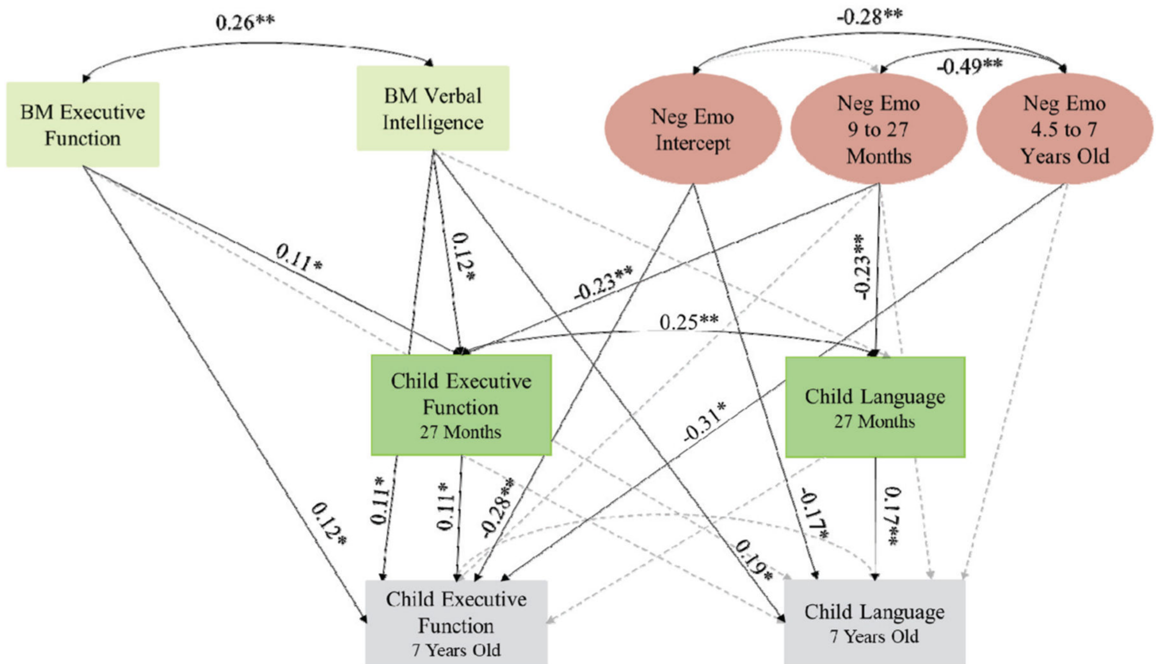

Figure 2.

The Effects of Birth Mother Cognitive Ability, Negative Emotionality, and Cognitive Skills at 27 Months on Executive Functioning and Language at 7 Years

Note. Regression paths are indicated by the one-headed arrows, correlations are indicated by the double-headed arrows, and dashed lines indicate non-significant paths. Ovals indicate latent factors. Items used to estimate latent factors are not depicted for clarity. All child outcomes (EF and language) were regressed on all birth parent variables (EF and verbal intelligence), however, only significant paths are depicted for clarity. Negative Emo Intercept = Intercept, Neg Emo 9 to 27 Months = Slope 1, Neg Emo 4.5 to 7 Years Old = Slope 2. BM = birth mother. * $p < .05$. ** $p < .01$.

Table 1

Means, Standard Deviations, and Correlations

Variable	*M*	*SD*	1	2	3	4	5	6	7	8	9	10	11
1. Neg emo 9 m	0.00	0.99											
2. Neg emo 18 m	0.00	0.99	.50**										
3. Neg emo 27 m	−0.00	1.00	.41**	.66**									
4. Neg emo 4.5 y	3.86	0.66	.25**	.23**	.30**								
5. Neg emo 6 y	3.80	0.60	.21**	.23**	.31**	.63**							
6. Neg emo 7 y	3.83	0.57	.23**	.30**	.38**	.58**	.76**						
7. EF 27 m	1.81	0.96	.04	−.10*	−.16**	−.02	−.09	−.11					
8. Lang 27 m	196.06	81.32	.00	−.04	−.17**	.10*	.10*	.03	.32**				
9. EF 7 y	4.96	0.50	−.16**	−.03	−.08	−.13*	−.25**	−.28**	.19**	.10			
10. Lang 7 y	109.67	13.92	−.14**	−.08	−.13	−.09	−.07	−.08	.19**	.22**	.19**		
11. BM EF	793.28	129.73	−.05	−.03	−.02	−.03	−.05	−.08	.13**	.08	.20**	.12*	
12. BM verbal IQ	9.53	3.02	−.01	−.03	−.07	−.00	−.10*	−.15**	.15**	.11*	.18**	.26**	.26**

Note. Means and standard deviations are based on raw data. Correlations are based on variables after accounting for covariates. m = month; y = years; Neg emo = negative emotionality; Lang = language; BM = birth mother; EF = executive function.

* $p < .05$.

** $p < .01$.