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# The Contribution of Children's Time Specific and Longitudinal Expressive Language Skills on Developmental Trajectories of Executive Function

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## Abstract

To investigate if children's early language skills support the development of executive functions (EF), the current study used an epidemiological sample ($N$=1,121) to determine if two key language indicators, vocabulary and language complexity, were predictive of EF abilities over the preschool years. We examined vocabulary and language complexity as both time-varying covariates that predicted time-specific indicators of EF at 36 and 60 months and as time-invariant covariates that predicted children's EF at 60 months and change in EF from 36 to 60 months. We found that the rate of change in children's vocabulary between 15 and 36 months was associated with both the trajectory of EF from 36 to 60 months and with resulting abilities at 60 months. In contrast, children's language complexity only had a time-specific association with EF at 60 months. These findings suggest children's early gains in vocabulary may be particularly relevant for emerging EF abilities.

### Keywords

Executive Function; Language Development; Vocabulary; Syntax; Early Childhood

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Executive functions (EFs) refer to a set of abilities that are used in the service of problem solving and involve self-regulatory skills. This set of abilities typically includes aspects of working memory, attention shifting and inhibitory control; and there is rapid development (improvement) in these skills during the first five years of life (Best & Miller, 2010)

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that has been linked to brain maturation (Bell & Fox, 1992; Klingberg, Vaidya, Gabrieli, Moseley, & Hedehus, 1999). Recent research has highlighted that EF is a critical aspect of early child development that is associated with academic achievement (Bierman, Torres, Domitrovich, Welsh, & Gest, 2009; Brock, Rimm-Kaufman, Nathanson, & Grimm, 2009; Thorell & Wahlstedt, 2006), social-emotional development (Carlson, Mandell, & Williams, 2004; Hughes & Ensor, 2007; Riggs, Jahromi, Razza, Dilworth-Bart, & Mueller, 2006) and other cognitive abilities, like theory of mind (ToM; Carlson, Claxton, & Moses, 2013; Müller, Liebermann-Finestone, Carpendale, Hammond, & Bibok, 2012).

## Language and EF

Given its contribution to children's positive outcomes, there is interest in identifying factors that facilitate the early development of EF (Blair & Diamond, 2008). Doing so may create new opportunities for the development of early EF interventions. Zelazo and colleagues have previously developed a concept of EF that identifies language as a precursor (Zelazo & Frye, 1998; Zelazo, Müller, Frye, & Marcovitch, 2003). Specifically, the Cognitive Complexity and Control (CCC) theory contends that children's ability to take specific actions to resolve conflict are dependent upon their ability to use labels to create conscious representations of a problem (Zelazo, 1999). Further, language is needed to construct and use the embedded rule structures that denote EF tasks (Marcovitch & Zelazo, 2009; Zelazo & Frye, 1998). The Hierarchical Competing Systems Model (HCSM; Marcovitch & Zelazo, 2009), a developmental framework that extends the CCC theory, explains that children's early cognitive processes arise from a habit system, based exclusively on infants' previous experiences. During the course of development, this transforms into a representational system, in part through the use of language. In the context of EF development, children have a greater likelihood of overriding a prepotent response (e.g., moving to the representational system) when reflection occurs. This activation of the representational system occurs when children have the ability to verbally label a condition.

Although previous studies have established an association between children's language abilities and EF performance (for review see Müller, Jacques, Brocki, & Zelazo, 2009; Carlson, Davis, & Leach, 2005), much of that research does not inform questions about whether and how early language development may serve as a developmental precursor to EF. Many of the previous studies can be loosely categorized as focusing on contemporaneous associations between language use and EF. For example, there is a persistent positive association between children's receptive language, that is the language that children passively comprehend, and their performance on a variety of EF tasks during childhood (Hongwanishkul, Happaney, Lee, & Zelazo 2005; Lang & Perner, 2002). These studies suggest that language and EF skills reflect some shared indirect measure of children's general cognitive ability. Another line of inquiry has suggested that language use can also act as a facilitator of EF performance. For instance, language aids EF performance through the labeling of conditions during a task (Kirkham, Cruess, & Diamond, 2003; Müller, Zelazo, Hood, Leone, & Rohrer, 2004; Yerys & Munakta, 2006), the use of self-talk to scaffold performance (Alarcon-Rubio, Sanchez-Medina & Prieto-Garcia, 2014; Fernyhough & Fradley, 2005; Vygotsky, 1962), and by virtue of advanced cognitive flexibility and inhibitory control achieved through bilingualism (Bialystok, 2010; Carlson & Meltzoff, 2008; Foy & Mann, 2013). Despite their varied emphases, none of these studies have contributed to our understanding of emerging language as a precursor to later EF or how the maturation of language skills may be related to EF. More recent research has focused on the directionality of the relation between children's receptive vocabulary and EF (McClelland, et al., 2014; Weiland, Barata, & Yoshikawa, 2014). The important point is that although numerous studies have investigated language and EF, few have tested the question of whether emerging language, which occurs over toddlerhood and the preschool period, provides a foundation upon which EF skills develop.

The primary objective of the current study is to test the associations between early language and later EF. Previously, we established that children's early gesture use in infancy (15 months) was prospectively predictive of their EF in early childhood (48 months) and that this effect was entirely mediated by global measures of expressive language – language that children verbally produced – at ages 24 and 36 months (Kuhn, Willoughby, Wilbourn, Vernon-Feagans, & Blair, 2014). Here, we focus on direct language samples that were obtained from children at 24-, 36-, and 60-month assessments. Whereas the prior study relied on norm-referenced measurement of expressive language, the current study, by focusing on language samples, will permit a more nuanced understanding of how specific aspects of verbal communication, including individual differences in the rate of language acquisition, contribute to the developmental trajectories of EF from 36 to 60 months of age.

## The Relation between Vocabulary and EF

Rapid growth in children's vocabularies occurs between the ages of 15 and 24 months, and this has long been recognized as a crucial period in development that is sometimes referred to as the 'vocabulary burst' (Bloom, 1973; Goldfield & Reznick, 1990). During this period, children learn to decontextualize words. That is, children learn to create a representation of an object, often with a verbal label, that can be applied across a variety of contexts. This process may be crucial for broader cognitive development. For example, in a longitudinal study, Nelson and colleagues (1973) found that children with a larger portion of general labels, rather than specific labels (e.g., knowing "doggie" versus "Spot" the family dog), also had larger lexicons. This suggests that children develop a hierarchy for labels and those who display a preference for general labels may have an advantage in their vocabulary building (Mervis, Golinkoff, & Bertrand, 1994; Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976). In another study, children who learned connected vocabulary words with an appropriate category (e.g., bandage, stethoscope, thermometer for medicine) used these words more often than children who did not have the category information (Christie & Roskos, 2006). In this way, vocabulary building serves as one of children's first opportunities to mentally represent objects into meaningful categories and to think symbolically about objects. Consistent with the CCC theory, it is plausible that children who make meaningful use of hierarchical category information at an early age have a cognitive advantage that may be indicated by a larger vocabulary. The first goal of the current study was to test if children's vocabularies (i.e., number of different words obtained from naturalistic language samples at 24 and 36 months) had a time-specific association with EF, taking into account individual differences in level and rate of change in EF.

## The Relation between Language Complexity and EF

After children gain experience with single word vocabularies, they then begin to combine words to express more complex relations. Around 18 to 20 months of age, children begin using two-word combinations. Syntax refers to the rules that govern how words are organized to express meaning (Hoff, 2005). Children initially use syntax in the form of grammar, or word order, to express relations and this marks a new understanding about the rules that govern verbal communication. Syntax is significant because it demonstrates children's ability to use a rule-based system. Once the rules have been mastered, children can also use syntax to determine the meanings of novel words based upon the relation expressed among the words in a phrase (Gelman & Taylor, 1984; Gelman & Markman, 1986). For example, children may be familiar with the syntactic structure of a possessor plus a possession, so that when the new word "crib" is introduced preceded by "my" they automatically attribute specific syntax to that word. This means children have the capacity to discern how an entire category of words (e.g., nouns) will operate in a sentence without ever having heard a particular word from that category before (Landau & Gleitman, 1985). Children also learn syntax when a familiar word is used within a novel linguistic context (Gillette, Gleitman, Gleitman, & Lederer, 1999). In this instance, children are using a familiar word as an anchor that enables them to identify a new rule.

Children's abilities to form hierarchical categories, apply rules based on category membership, and to use rules to make decisions are all part of learning to combine words. These same skills have also been identified as foundational aspects of EF by the CCC theory. It's possible that children who quickly learn to apply the rules that govern language, demonstrated by speaking in multiple-word phrases, may have an advantage in EF. As such, language complexity is an indicator of children's ability to apply hierarchical rule structures. The second goal of the current study was to test if children's language complexity (i.e., mean length utterance obtained from naturalistic language samples at 36 and 60 months) had a time-specific association with EF, taking into account individual differences in level and rate of change in EF.

## Are Rates of Change in Language Abilities Associated with EF?

In addition to evaluating the time-specific contributions of vocabulary and language complexity to EF, a related question is whether individual differences in the rate of language development were predictive of EF. Several studies have suggested a fluid relation best characterizes the association between language and EF. For example, younger children are not able to use labels as an effective tool for aiding in EF performance, while other simpler forms of nonverbal communication like gestures (O'Neill & Miller, 2013) and symbols (Carlson, Davis, & Leach, 2005) can be used to scaffold performance. Similarly, when controlling for initial EF ability in regression analyses, preschool-entry vocabulary did not predict resulting EF at age 4 years (Weiland, Barata, & Yoshikawa, 2014); while, other more advanced oral narrative skills do (Friend & Bates, 2014). These studies suggest that the influence of language on EF may not be expressed at a single point in time but rather over a period of time, and that rate of maturation in language abilities, demonstrated by mastery of different skills (e.g., vocabulary, narratives), may also need to be considered. The third goal of this study is to test whether individual differences in the degree of vocabulary growth from 24 to 36 months and/or language complexity from 36 to 60 months are associated with individual differences in the rates of change in EF across this period of childhood.

# Method

## Participants

This study is based upon a sample of 1,121 children who participated in at least one assessment of EF (i.e. at 36, 48, and/or 60 months of age) within the larger Family Life Project (FLP). The sample presented here does not differ from the total FLP sample in terms of poverty status at recruitment, child gender, or primary caregiver's race or education, ($ps > .05$).

## Study Design

The FLP was designed to study young children and families who lived in two of four major geographical areas of high child rural poverty (Dill, 1999). Specifically, three counties in Eastern North Carolina (NC) and three counties in Central Pennsylvania (PA) were selected to be indicative of the Black South and Appalachia, respectively. The FLP adopted a developmental epidemiological design. Complex sampling procedures were used to recruit a representative sample of 1,292 families at the time of the birth of the child enrolled in the study. Low-income families in both states and African American families in NC were over-sampled. However, African American families were not over sampled in PA, as the target communities were at least 95% non-African American. Families were designated as low income if they reported household income less than 200% the poverty rate, use of social services requiring a similar income requirement (e.g., food stamps, WIC, Medicaid), or had less than a high school education. Full details of recruitment are summarized elsewhere (Willoughby, et al., 2013).

## Procedure

The current study used child and caregiver measures assessed at the 15-, 24-, 36-, 48- and 60-month home visits. Two separate visits were conducted when children were 24 and 36 months of age, usually within two weeks of each other. One home visit was conducted when children were 15, 48 and 60 months of age. Home visits were conducted by two research assistants (RAs), who simultaneously collected a variety of data from interviews and questionnaires given to caregivers, caregiver-child interactions and child-based tasks. The majority of the child assessments during the home visits were completed at a small portable table with the children sitting across from the RA. Primary caregiver was defined as the individual who was most responsible for the care (i.e., bathing, feeding) of the child enrolled in the study. Ninety-seven percent of primary caregivers were the biological mother of the child at 15 months.

Child language measures were drawn from a 10-minute wordless picture book activity with primary caregivers who were filmed through a DVD video recorder for later coding and transcription. While seated in a comfortable location, a wireless microphone was either attached to the child or caregiver, and caregivers were instructed to go through the book with their child, try not to whisper, and to signal when they were finished. If the caregivers did not signal they were finished by 10 minutes, the task was terminated. At 15 months, the picture book *No, David!* (Shannon, 1998) was used. At 24 months, the picture books were *Just a Thunderstorm* and *The New Baby* (Mayer & Mayer, 1993; Mayer, 1983). At 36 months, the picture books were *A Boy, a Dog, a Frog and a Friend* (Mayer & Mayer, 1971) and *Frog, Where Are You?* (Mayer, 1969). Finally, at 60 months the picture books *Frog on His Own* (Mayer, 1973) and *A Boy, a Dog, and a Frog* (Mayer, 1967) were used.

The EF assessment occurred at the 36-, 48- and 60-month home visit. Children were presented with stimuli in the format of an open spiral bound flipbook, each page measuring 8 inches by 14 inches, allowing for stimuli on one page and administration text on the other. One RA was responsible for administering EF tasks (in a fixed order) to children. A second RA was responsible for recording children's responses to each task into a laptop computer. Neither RA was responsible for evaluating the accuracy of children's responses. Computerized scoring, which took place when data for the entire visit were processed, was used to evaluate the accuracy of child responses to each tasks. Breaks included, the EF assessments took up to 45 minutes to complete.

## Measures

We describe three types of measures. First, measures that were included as covariates are described; these included family income, caregiver education, child cognitive ability, and caregiver reading ability. Second, two measures of child language are described as independent variables. And, third, the EF battery, encompassing six tasks, is described as a dependent variable.

### Covariates

**Income-to-needs ratio:** At each home visit, primary caregivers were asked to provide detailed information about all sources of household income (e.g., employment income, cash welfare/Temporary Assistance for Needy Families, social security retirement, help from relatives, etc.). This total annual income was divided by the federal poverty threshold, based on the number of adults and children in the household, to create the family's income-to-needs ratio (INR). INRs above 1.0 indicated that a family was able to provide for basic needs, whereas values below 1.0 indicated that they were unable. In the current analyses, the average INR across 15- to 48-month assessments was used.

**Caregiver education:** Caregivers' education level was derived from the home interview at the 15-month assessment. During this interview, primary caregivers reported the highest level of education that they had obtained at the date of the interview. The mean level of educational attainment was14.6 years (SD = 2.8 years), where 14 years reflected a high school diploma.

**Bayley Scales of Infant Development (BSID–II):** The BSID-II (Bayley, 1993) was administered at the15-month assessment as a measure of infants' cognitive abilities. The BSID–II is a widely used standardized measure of children's cognitive development, with well-established reliability and validity (Bayley, 1993). In the current analyses, the total score (i.e., the Mental Development Index [MDI]) was used as a covariate to ensure that early language measures were not simply a proxy for early general cognitive ability.

**Woodcock-Johnson III Test of Achievement – Passage Comprehension (WJIII-PC; Woodcock, McGrew, & Mather, 2001; 2007):** The WJIII is a measure of academic abilities norm-referenced from the age of 2 years to university graduate students. In the Passage Comprehension test, initial items measure symbolic learning, or the ability to match a rebus with an actual picture of the object. As difficulty increases, items are presented in a multiple-choice format and pictures are matched to phrases. For the most difficult items, short passages are read and missing key words are identified. The median test reliability for the PC test was found to be .88. The WJIII-PC was administered to primary caregivers at the 24-month assessment and was used as a covariate to account for caregivers' language abilities.

## Independent Variables

**Child language:** Systematic Analysis of Language Transcripts (SALT; Miller & Chapman, 1985) was used to transcribe all recordings of the picture book activity. Transcription began after the RA had given the book to the caregiver and completed reading the instructions. Transcription ended when the caregiver signaled the end of the activity or at 10 minutes. All language directed to the child during the session was transcribed by highly-trained graduate students. Transcribers underwent an extensive training process conducted by a senior graduate student who spent 1 year learning SALT conventions and developing a training manual. The training process involved transcribing 20 training transcripts that were then reviewed by a senior graduate student. As an ongoing check, this review process continued regularly with all transcribers periodically transcribing the same recording and then discussing discrepancies at biweekly research meetings to ensure consistency in transcription. Language was transcribed at the unit of an utterance, or at a sequence of words followed by a pause or a change in speaker turn. Onomatopoeic sounds (e.g., vroom) and evaluative sounds (e.g., uhhuh) were also transcribed as words. Omitted and unintelligible words were not included.

***Vocabulary and language complexity:*** Two measures of children's language were derived from the transcripts at 15-, 24-, 36- and 60-month assessments. Number of different word roots (NDW), a measure of children's vocabulary, and mean length utterance (MLU), a measure of language complexity. The NDW was determined by calculating the number of unique free morphemes over the entire transcript. Variations in the same word were not counted as separate root words. For example, "run" and "running" were considered the same root word. The NDW is used as an indicator of vocabulary because it represents the number of different words used by children during an interaction with their primary caregiver and represents an overall lexical diversity used during the picture book activity. Difference scores, calculated by subtracting 15 month NDW from 36 month NDW, were used to represent change in children's vocabulary. We used difference scores from 15 to 36 months because we specifically wanted to characterize the vocabulary burst, which typically occurs during this period. The MLU is a general measure of complexity in utterances used by children. It was calculated by dividing the total number of utterances by the total number of morphemes (smallest meaningful unit of language). The MLU is used as an indicator of language complexity because the average length of children's utterances, which is highly related to the complexity of their utterances used during the picture book activity, represents their ability to put words together into larger phrases. We wanted to characterize maturation in language skills as children develop and therefore used language complexity as an indicator of later ability (i.e., few children spoke in phrases at 15 months). Difference scores, again calculated by subtraction, were used to represent changes in children's language complexity between 36 to 60 months.

### Dependent Variable

**Executive Function Battery:** The battery of EF tasks included two measures of working memory, three measures of inhibitory control, and one measure of attention shifting. For each task, children had to pass a set of training items, assessing their comprehension of task constructs and procedures, before continuing on to the scored trials. Because the details of this battery have been described elsewhere (see Willoughby, Blair, Wirth, & Greenberg, 2010), we provide an abbreviated description.

***Working memory span (WM):*** Children are shown a picture of a house with an animal and a colored dot inside of it. Next, they are shown an empty house and asked to remember the animal or color that was previously in the house. This task requires working memory because children must activate a part of information (i.e., animal name) while overcoming interference from the other (i.e., color name). Children received one 1-house trial, two 2-house, two 3-house, and two 4-house trials.

***Pick the picture (PTP):*** A self-ordered pointing task in which children are presented with a set of pictures and are instructed to pick each picture so that all of the pictures "get a turn.". The arrangement of pictures within each set is randomly changed across trials (including some trials not changing) so that spatial location is not informative. Children received two each of two-picture, three-picture, four-picture, and six-picture sets (the first item in each set was not scorable and only used to define the accuracy of the remaining responses in each picture set). This task was only administered at the 48- and 60-month assessments.

***Spatial conflict arrows (SCA):*** Children respond to the initial set of items by touching a response card located in the same position as the stimuli (e.g., the stimuli is presented on the left side of the test booklet and the correct response requires that the child touch the left side of his/her response card). During the test items, children are required to activate a contra-lateral response (e.g., the stimuli is presented on the left side of the test booklet and the correct response requires that the child touch the right side of his/her response card; spatial location is no longer informative). At 36 months, the task stimuli were boats and cars, while at 48 and 60 months, the task stimuli were arrows.

***Silly sounds stroop (SSS):*** Children are instructed to point to the dog picture when they hear a "meow" and to point to the cat picture when they hear a "woof." Thus, children are required to inhibit the natural pairing of an animal picture with that animal sound. Due to a high degree of local dependence, only the first animal on each page is used for purposes of scoring.

***Animal go no-go (GNG):*** Children are instructed to click a button every time they see an animal, but not when that animal is a pig. The task includes varying numbers of go trials prior to each no-go trial, in standard order: 1-go, 3-go, 3-go, 5-go, 1-go, 1-go, and 3-go trials. No-go trials require inhibitory control.

***Something's the same (STS):*** Children are shown two pictures that match on one of several dimensions (e.g., shape). Next, children are shown the same two pictures, but now with a new third picture. The third picture is similar to one of the first two pictures but along a different dimension (e.g., color). Children must choose which one of the two original pictures is the same as the new picture along this new dimension. This task requires children to shift their focus from the first dimension of similarity to a second dimension of similarity.

***Task scoring:*** EF tasks were scored based on advanced psychometric scoring techniques, specifically Item Response Theory, to yield *expected a-posteriori* (EAP) scores for each task. The EAP scores were scaled on a z-score metric, where a value of 0 represents the average performance at the sample's 48 month assessment. Negative and positive values corresponded to below and above average performance in relation to the sample mean at 48 months. This is consistent with other recent studies (Berry, et al., 2014; Towe-Goodman, 2014). Here we focused on aggregate EF which was represented as a mean of EAP scores at each assessment (i.e., average EAP at 36, 48 and 60 months).

## Analytic Strategy

Analyses proceeded in three steps. First, an unconditional latent growth curve (LGC) model was estimated to establish linear changes in EF from 36 to 60 months of age. Second, a conditional LGC was estimated to test the contributions from language on time specific measures of EF. This model allowed us to evaluate a time-specific question (Curran, Lee, Howard, Lane, & MacCallum, 2012), at what time does child language contribute to EF? Third, another conditional LGC model was estimated to test whether the rates of change in vocabulary (15 to 36 months) and language complexity (36 to 60 months) had an impact on resulting EF abilities (intercept) and growth in EF from 36 to 60 months (slope). This model allowed us to evaluate if differences in the degree of growth in language were associated with EF. All models were estimated using Mplus version 7 (Muthen & Muthen, 1998–2007), and took into account the complex sampling design (stratification, over-sampling of low income, in North Carolina, and African American families). Full information maximum likelihood (FIML) was used to account for missing data. A standard set of covariates composed of INR, child cognitive abilities, gender and maternal reading abilities were included in the estimation of all conditional LGC models. We used Hu and Bentler's (1999) recommendations (i.e., comparative fit index (CFI) $> .95$, root mean square error of approximation (RMSEA) $\leq .05$) as a guide for evaluating model fit.

## Results

### Descriptive Statistics

A summary of unweighted descriptive statistics for the variables used in the current study is presented in Table 1. The children in this study scored in the average, or slightly below average range, on a norm-referenced assessment of cognitive abilities, Bayley MDI (M = 96.2, SD = 10.7) at 15 months. On average, families reported a mean INR of 1.8 (SD = 1.4), which indicated a household income that met basic needs but that was closer to working poor than solidly in the middle class. Caregivers had a mean education level of 14.6 years (SD = 2.8 years), which indicated some schooling beyond high school but not a college degree. Caregivers scored in the average, or slightly below average range, on a norm-referenced assessments of language abilities, WJIII-PC (M = 93.6, SD = 16.5). The correlations among all indicators are also presented in Table 1. Three points are noteworthy. First, as expected, the covariates of maternal education, maternal reading ability, family income and child cognitive abilities were moderately correlated with EF at all ages (r = .20 – .37). The strongest association was between child cognitive ability and EF. Second, measures of child language (NDW and MLU) were weakly to moderately correlated with each other across time ($r$ = .00 to .56). Third, child language was also moderately correlated with the EF tasks at 48 and 60 months ($r$ = .18 to .22).

### Unconditional LGC of EF

We first estimated an unconditional linear LGC model for our repeated measures of EF. The model was parameterized such that the intercept term represented EF at the 60-month assessment, because we were interested in resulting EF ability. This model fit the data well, $\chi^2$ (1, $N$ = 1,121) = 1.18, $p$ = .28, CFI = 1.00, RMSEA = .01. The means and variances of the intercept ($\mu_{Int}$ = .36, $p$ < .001; $\varphi_{Int}$ = .20, $p$ < .001) and slope factors ($\mu_{Slope}$ = .41, $p$ < .001; $\varphi_{Slope}$ = .04, $p$ < .001) were significant, indicating variability in children's EF ability at age 60 months and in the rate at which children reached their 60-month ability. The intercept and slope terms were correlated ($\varphi_{Int, Slope}$ = .65, $p$ < .001) suggesting that children with higher EF scores at 60 months exhibit faster rates of growth in EF from 36 to 60 months. This model accounted for 42% of the variance in EF at 36 months, 47% at 48 months, and 93% at 60 months.

### Children's Language Associations with Time Specific EF over the Preschool Years

A conditional LCG model was estimated in which repeated indicators of children's vocabulary and language complexity were parameterized as time-varying covariates that predicted time-specific indicators of EF at 36 and 60 months. The model fit the data well, $\chi^2$ (14, $N$ = 1,121) = 28.01, $p$ =.01, CFI = .98, RMSEA = .03, see Figure 1. Children's vocabulary at 36 months was negatively associated with EF at 36 months (β = −.09, $p$ =.02) and not significantly associated with EF at 60 months (β = −.04, $p$ = .16). Children's language complexity at 36 months was not uniquely associated with EF at 36 months (β = −.03, $p$ =.41), but language complexity at 60 months was significantly associated with EF at 60 months (β = .08, $p$ < .001).

### Changes in Children's Language as Predictors of EF over the Preschool Years

A second conditional LCG model was estimated in which changes in children's vocabulary, from 15 to 36 months, and changes in language complexity, from 36 to 60 months, were parameterized as time-invariant covariates that predicted children's level of EF at 60 months and rates of change in EF net of covariates. This model fit the data well, $\chi^2$ (8, $N$ = 1,121) = 19.04, $p$ = .01, CFI = .99, RMSEA = .04. see Figure 2. Individual differences in rate of vocabulary development were positively associated with level of EF at age 60 months (β = .12, $p$ = .001), as well as with changes in EF from age 36 months (β = .21, $p$ = .004). In contrast, changes in children language complexity were not uniquely related to children's level of EF at 60 months (β = .02, $p$ =.61) or with changes between the ages of 36 to 60 months β = .05, $p$ =.48).

## Discussion

The overarching goal of the current study was to determine if two key indicators of children's early expressive language, vocabulary and language complexity, were predictive of children's EF over the preschool years. These indicators of language were chosen because of their theoretical relevance to EF development according to the CCC theory (Zelazo, et al., 2003) and because of their developmental appropriateness in the language literature (Rowe & Goldin-Meadow, 2009; Waxman & Markow, 1995). We considered both time-specific associations between language and EF, as well as if rates of change in language were related EF. In regards to the time-specific associations between language and EF, we found that child vocabulary at 36 and 60 months were either negatively associated or not significantly associated with EF. We found that children's language complexity at 36 months was not uniquely associated with early EF, but later language complexity was positively associated with EF at 60 months. When examining rates of change in vocabulary and language complexity, we found that children's rate of change in vocabulary was positively associated with growth in EF and with EF abilities at 60 months. The rate of change in language complexity was not uniquely associated with EF.

Broadly speaking, our findings support the tenants put forth by the CCC theory and the notion that early language is associated with later EF abilities. The developmental framework put forth by Zelazo and colleagues highlights the use of labels as a mechanism by which the transition to representational thinking occurs (Marcovitch & Zelazo, 2009). When examining time-specific points our results diverted from the framework; we found that children's vocabularies at 36 and 60 months were not positively associated with EF abilities at either point in time. In fact, children's vocabulary had a negative association with EF abilities at 36 months. This finding is somewhat surprising. However, previous studies have documented a non-significant association between vocabulary and EF at a single point in time and prior EF associated with later vocabulary (McClelland et al., 2014; Weiland, et al., 2014). Receptive vocabulary at the beginning of preschool was not predictive of children's EF abilities 6 or 12 months later. One explanation for this non-significant finding, or even for a negative association between vocabulary and EF, is that the cognitive abilities represented by children's diversity in vocabulary are not well represented by a single-point-in-time measure.

By incorporating a broader developmental perspective of language, our findings provide support for and extend the CCC theory. Recall that a typical 4-year-old has a well-developed vocabulary and is well beyond the vocabulary burst. The cognitive development that is represented by children's vocabularies (i.e., representational thinking) may only be salient for EF at early points in development. In other words, vocabulary building is a critical skill for children from 15 to 24 months and we see a predictive relation between vocabulary and EF during this period. However, the vocabulary burst is well over by 60-months and the association between children's vocabularies and EF is no longer significant at this advanced age. Our results support this type of developmental interpretation; we found that the changes in children's vocabularies from 24 to 36 months were predictive of EF abilities at 60 months and with the rate of change in EF from 36 months to 60 months. Taken together, these findings indicate that it is children's early vocabulary, and rate of change in vocabulary specifically, that acts as a precursor to EF abilities. Children's vocabularies at later points in development are not uniquely associated with EF, but other more advanced indicators of language development may have an association.

In contrast to the findings for vocabulary, children's language complexity at 60 months was positively associated with EF abilities at 60 months, but not at 36 months. These findings are consistent with previous studies that have found a significant positive association between advanced language skills, like oral narratives, and EF at points in development between 48 and 60 months (Friend & Bates, 2014). Our findings also indicated that earlier changes in language complexity from 36 to 60 months were not uniquely associated with growth in EF. Linking back to Zelazo and colleagues' framework, this suggests that the rule use and hierarchical thinking that is denoted by language complexity may not be associated with EF until later in children's cognitive development. It is important to note that neither the HCSM nor the CCC theory explicitly identifies language complexity as a precursor to children's EF. However, our expanded perspective of language development identifies language complexity as a skill that is likely to facilitate the emergence of EF after 48 months. The current results suggests that even though children begin combining words around 24 months, a mastery of syntax that demonstrates an understanding about hierarchical thinking may not occur until closer to 60 months.

## Implications

Overall our findings revealed complex associations between language and EF. It does not appear that simply having more vocabulary or more complex language at a given time point necessarily leads to better EF skills. Early in cognitive development, there is a clear positive association between children's vocabularies and later EF skills. Specifically, the cognitive skills that children gain during vocabulary building prior to 36 months of age are associated with later EF abilities. Further, the rate of change in vocabulary skills during this early period may be a better predictor of later EF than any single measure of vocabulary. The finding that rate of change in vocabulary is associated with EF is a novel one and points to an advantage for children who quickly master representational thinking. Conversely, later in cognitive development children's language complexity is positively related to EF abilities at 60 months, and there is not an association between language complexity and EF prior to this age. Our findings fit within a larger developmental picture that depicts an evolution in the relation between language and EF. Beginning around 15 months, children's gestures are associated with EF (Kuhn et al., 2014; O'Neill & Miller, 2013) and around 24 months an association between children's vocabularies and EF begins to emerge (Carlson, Mandell, & Williams, 2004; Hughes & Ensor, 2007). However, by 36 months this relation is no longer significant and by 60 months, other more advanced indicators of language are positively associated with EF. Yet, the relation between early vocabulary building and EF is an important one as it continues to predict children's EF abilities through age 5 years and may transform into a reciprocal relation, such that EF also predicts later vocabulary skills (McClelland et al., 2014; Weiland, et al., 2014).

The current findings add to this developmental thinking in several important ways. First, much of the current literature relies upon standardized measures of language to draw conclusions about the relation between language and EF. We extended the literature by including naturalistic measures of children's language, which we obtained through observed caregiver-child interactions between the ages of 15 and 60 months. Substantial changes in language occur during this time period and the use of more descriptive assessments may assist in teasing apart the complex associations between language and EF. Second, the current study highlights that cross-sectional methodologies and reliance upon receptive language measures may be problematic in ascertaining how language influences emerging EF. Markers of children's changing cognitive abilities may be best captured by rates of change in language and by the inclusion of diverse language indicators. Third, previous work, including our own, has highlighted the strength of the relation between a variety of indicators of children's vocabulary and concurrent or later EF (Carlson, et al., 2004; Hughes & Ensor, 2007; Kuhn et al., 2014); the current findings temper the strength of that association. At a minimum, caution should be exercised in assumptions about associations between vocabulary and EF, particularly later in development.

## Limitations and Future Directions

There are several noteworthy limitations to the current study. First, the language samples used to create variables of vocabulary and language complexity were drawn from a brief picture book task. Future research should strive to obtain longer language samples across diverse contexts to present a more complete picture of children's language development. Second, the current study lacked a language measure at 48 months. This is a crucial period in cognitive development and our understanding about the nature of the relation between language and EF would be greatly enhanced by future longitudinal research that encompasses more frequent time points. In particular, we anticipate that the inclusion of language at 48 months would significantly improve our measurement of change in language diversity, and perhaps lead to alternative findings. Finally, the current findings are based on measures of children's expressive language, where much of the previous literature has focused on receptive language. Although, the current study suggests that there may be some agreement across these types of language, it may also be that different cognitive abilities are represented by children's expressive and receptive language skills and they have different relations to EF.

The current study is the first to examine the relation between specific measures of children's expressive language and EF between the ages of 24 and 60 months. The findings support the notion that there is an underlying cognitive process that is best characterized by a dynamic relation between language and EF. However, caution should be used to not overstate our findings, as the amount of overall variance explained in EF is relatively small. The current study also illuminates our understanding about how different aspects of language may act as a precursor to EF, and underscores the potential for early language interventions. Early interventions that teach communicative gestures to children or focus on increasing early vocabulary may be particularly useful. The current findings suggest that an opportunity for changing the trajectory of EF through language occurs during the first three years of life. This finding is in line with previous research that has established the roots of EF are formed prior to age three years and that a child's EF abilities have a significant indirect effect on school readiness. Given our understanding about early EF and language, and the significance of EF for later academic success, perhaps future interventions should be tailored to children's specific language needs. For example, rather than a single-minded focus on increasing children's vocabularies, an intervention could strive to build children's symbolic understanding through multiple modes of communication, like gestures and labels, with the goal of increasing downstream EF.

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- Children’s vocabulary and language complexity may facilitate early development of EF.
- We examined if individual differences in the rate of language acquisition contributed to EF.
- At 36 months of age children’s vocabularies were negatively associated with EF.
- Children’s language complexity was positively associated with EF at 60 months.
- Children’s rate of vocabulary was positively associated with growth in EF (36 to 60 months).

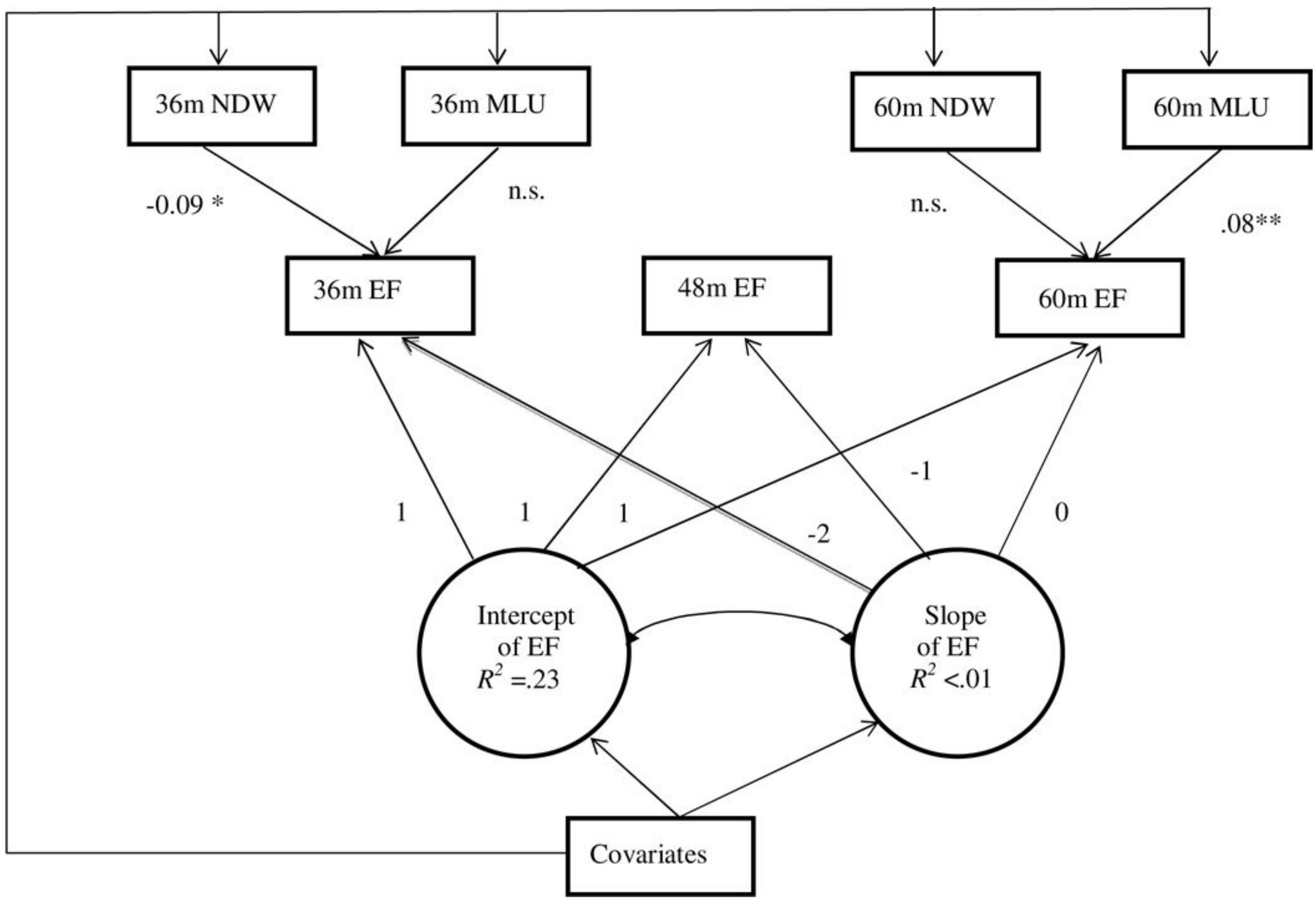


**Figure 1. Conditional LGC Model**

*Note*: $\chi^2(14, N = 1{,}121) = 28.01$, $p$ =.01, CFI = .98, RMSEA = .03. NDW=Number of Different Words, MLU=Mean Length Utterance. Covariates included were average household INR, child BSID-II score at 15m, primary caregiver education and WJ-III PC score.

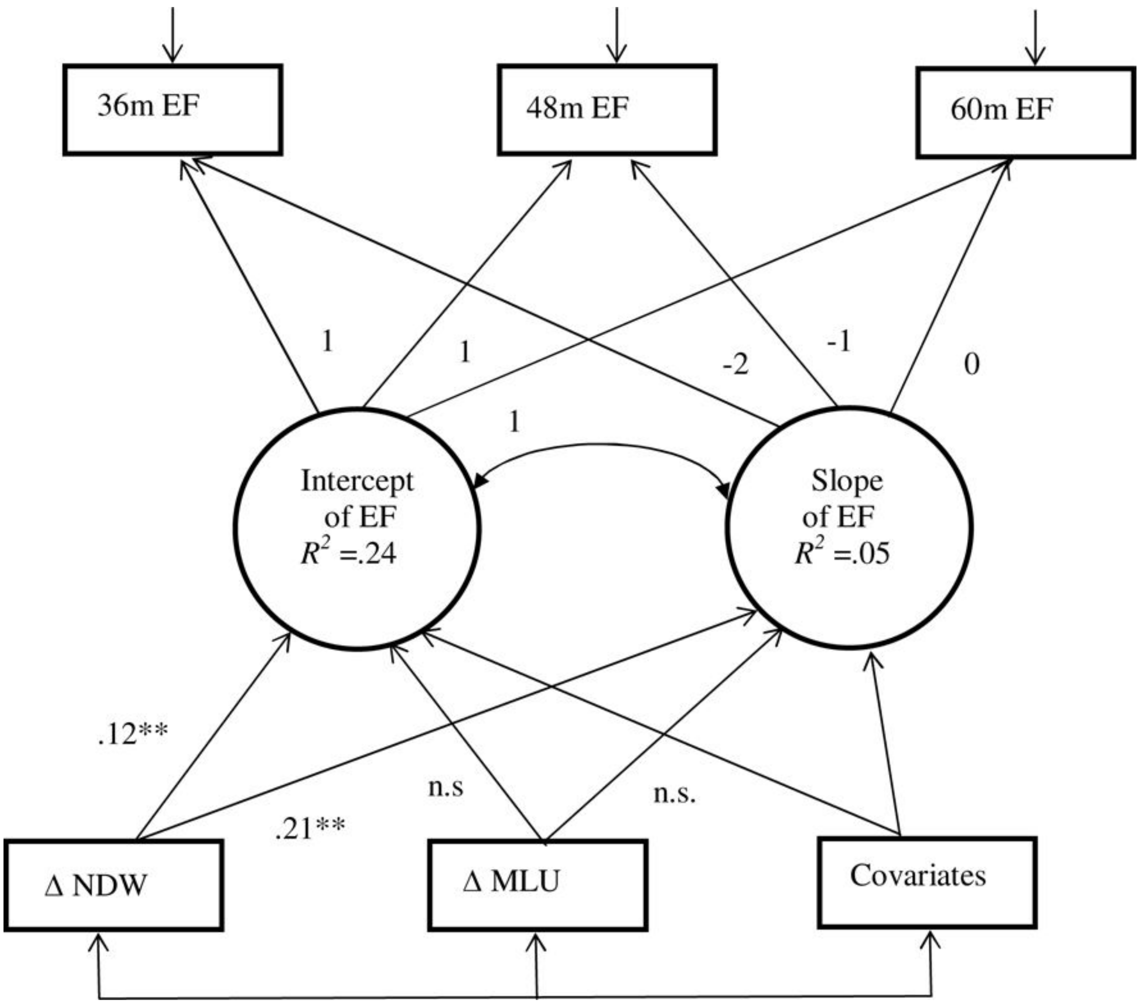


**Figure 2. Conditional LGC Model**

*Note*: $\chi^2$ (8, $N$ = 1,121) = 19.04, $p$ = .01, CFI = .99, RMSEA = .04. Δ NDW= Change in Number of Different Words from 15 to 36 months, Δ MLU= Change in Mean Length Utterance from 24 to 60 months. Covariates included were average household INR, child BSID-II score at 15m, primary caregiver education and WJ-III PC

**Table 1**

Means and Correlations Among Variables

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. NDW24 | – | | | | | | | | | | | | | |
| 2. NDW36 | .42 | – | | | | | | | | | | | | |
| 3. NDW60 | .26 | .38 | – | | | | | | | | | | | |
| 4. MLU36 | .32 | .56 | .25 | – | | | | | | | | | | |
| 5. MLU60 | .20 | .18 | .33 | .27 | – | | | | | | | | | |
| 6. EF36 | .12 | .01 | .01 | .06 | −.01 | – | | | | | | | | |
| 7. EF48 | .22 | .18 | .10 | .19 | .10 | .37 | – | | | | | | | |
| 8. EF60 | .19 | .19 | .08 | .21 | .14 | .32 | .59 | – | | | | | | |
| 9. Δ NDW | .40 | .99 | .37 | .54 | .17 | −.01 | .18 | .19 | – | | | | | |
| 10. Δ MLU | −.06 | −.25 | .12 | −.53 | .67 | −.05 | −.06 | −.04 | −.25 | – | | | | |
| 11. MDI | .25 | .19 | .12 | .16 | .06 | .22 | .37 | .34 | .18 | −.08 | – | | | |
| 12. PmEdu | .14 | .19 | .16 | .14 | .00 | .21 | .30 | .27 | .18 | −.11 | .21 | – | | |
| 13. INR | .14 | .14 | .13 | .09 | .01 | .20 | .26 | .25 | .14 | −.06 | .23 | .55 | – | |
| 14. WJ-PC | .11 | .13 | .19 | .12 | .01 | .24 | .28 | .28 | .13 | −.10 | .22 | .50 | .13 | – |
| Mean (SD) | 16.5 (16.5) | 41.2 (23.4) | 63.5 (25.9) | 2.4 (.7) | 3.5 (.9) | −.5 (.5) | −.1 (.5) | .3 (.5) | 40.0 (23.0) | 1.0 (1.0) | 96.2 (10.7) | 14.6 (2.8) | 1.8 (1.4) | 91.6 (11.0) |
| Range | 0 – 98 | 0 – 140 | 0–162 | 1 – 6.3 | 1 – 8 | −2.0 – 1.2 | −2.1 – 1.2 | −2.0 – 1.4 | −5.0 – 139.0 | −3.8 – 5.2 | 59 – 132 | 6 – 22 | 0 – 12.4 | 30 – 134 |

*Note*: NDW=Number of Different Words, MLU=Mean Length Utterance, MDI =Metal Developmental Index, PmEdu=Primary caregiver education, INR=income to needs ratio, WJ-PC=Woodcock Johnston Passage Comprehension. |r|s > .06, all p < .05”