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Child Vocabulary and Developmental Growth in Executive Functions During Toddlerhood

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ABSTRACT

Executive functions (EFs) emerge in the first years of life and are essential for many areas of child development. However, intraindividual developmental trajectories of EF during toddlerhood and their associations with ongoing development of language skills remain poorly understood. The present three-wave study examined these trajectories and their associations with language skills. Child EF and vocabulary were assessed around 13, 19, and 28 months of age in a sample of 145 toddlers (51% boys) from mostly White families. At each time point, mothers reported on child receptive and expressive vocabulary, and EF were assessed with three behavioral tasks targeting inhibitory control, cognitive flexibility, and working memory. Multilevel growth models revealed that toddlerhood is a period of significant developmental growth in child inhibitory control, cognitive flexibility, and working memory. The findings also provide evidence for a sustained relation between toddlers' language skills and their ongoing acquisition of inhibitory control and cognitive flexibility. This study offers novel insight into intraindividual developmental changes in EF during toddlerhood and the role of language in these meaningful, though neglected, changes.

1 | Child Vocabulary and Developmental Growth in Executive Functions (EFs) During Toddlerhood

EFs are involved in the self-regulated control of thoughts, emotions, and actions and are particularly salient for novel or complex problem-solving (Diamond 2013). These high-level cognitive skills emerge in the first years of life and are crucial for children's optimal functioning in several spheres (Diamond 2016; Zelazo et al. 2016). Better EF skills are notably related to later enhanced psychosocial adaptation, behavioral functioning, and academic achievement (Ahmed et al. 2019; Moffitt et al. 2011; Schoemaker et al. 2013). Given the crucial role of EF in many areas of child development, it is of paramount importance to document their patterns of growth and the factors that are associated with these patterns, particularly during periods of rapid developmental change (Zelazo et al. 2016).

The transition from infancy to toddlerhood involves heightened expectations for behavioral regulation in various social settings outside the home, which places greater demands on EF (Bruce and Bell 2022). As toddlers' mobility and inquisitiveness increase, they become more actively engaged with their environment, social interactions, and experiential learning, supporting growth in problem-solving and EF skills (Crotty et al. 2023; Morgan et al. 2024). At the same time, there is rapid development and high plasticity of the neural structures and circuits underpinning EF

(Fiske and Holmboe 2019; Fiske et al. 2024; Kolb et al. 2012). Accordingly, toddlerhood is a critical period for EF development (Shonkoff et al. 2011).

Three main components of EF emerge during toddlerhood: inhibitory control, cognitive flexibility, and working memory, which set the stage for the development of more complex EF, such as planning and logical reasoning (Korzeniowski et al. 2021). Inhibitory control makes it possible to resist internal or external distractions and to repress a dominant response (Diamond 2013). It also includes impulse control, which blocks motor and verbal responses that interfere with achieving a goal. Cognitive flexibility involves the capacity to alternate between tasks, change perspectives, and adapt to novelty and change (Diamond 2013; Garon et al. 2008). Working memory refers to the ability to mentally process and manipulate information over a short period of time (Best and Miller 2010). It allows one to follow a conversation effectively, solve problems mentally, and make mental calculations (Diamond 2013). Growing evidence suggests that these three components of EF during toddlerhood are predictive of a range of subsequent positive outcomes, including school success (Broomell et al. 2019; Paulus et al. 2015), greater social skills (Fitzpatrick and Pagani 2012; Jaekel et al. 2016), and fewer social-emotional problems (Thériault-Couture et al. 2024). Thus, healthy development of EF during toddlerhood is critical for later life outcomes. Even though EF emerge during the first year of life (Cuevas et al. 2018) and are associated with later optimal functioning, their development during toddlerhood remains poorly understood. To the best of our knowledge, no study has used a growth modeling approach to formally identify the developmental trajectories of EF during toddlerhood and the factors associated with individual differences in these trajectories. By describing interindividual differences in intraindividual change, growth modeling can offer a distinctive and superior way to characterize the development of EF and its risk and protective factors (see Bornstein et al. 2017; Hoffman 2015). This approach holds significant value for developmental research because it can provide a deeper comprehension of the developmental relations that evolve over time between each EF component and a presumed predictor. Tackling this gap, the current study investigates patterns of growth in child EF during toddlerhood and their associations with one of the best documented correlates of EF, namely child language skills.

1.1 | EF Development During Toddlerhood

Although the first manifestations of EF can be reliably measured in toddlerhood (Cuevas et al. 2018), the developmental trajectories of these crucial cognitive skills during this period remain poorly understood. Indeed, most research focuses on children older than 24 months or examines age-related differences cross-sectionally (Best and Miller 2010; Carlson 2005; Garon et al. 2008). Cross-sectional studies show growing gaps between older and younger toddlers in terms of their performance on EF tasks, suggesting sustained improvement in EF during this period (e.g., Garon et al. 2008; Mulder et al. 2014). However, these studies provide only indirect evidence of development in EF and cannot characterize changes that occur at the intraindividual level. Repeated measures are needed to document within-person developmental changes in EF across time and investigate interindividual differences in these developments. Some longitudinal studies have examined rank-order stability and mean-level changes in EF across toddlerhood (e.g., Frick et al. 2019; Hendry et al. 2022; Holmboe et al. 2021; Hughes et al. 2020; Johansson et al. 2016; Miller and Marcovitch 2015; Ribner et al. 2022; Wiebe et al. 2010). These studies found that performance on the same EF tasks was mostly weakly or not correlated over time, suggesting substantial relative instability in performance during this developmental period. Such instability might reflect significant interindividual variability in the rate of growth in EF during toddlerhood, which was not examined. As expected, previous studies also found that on average, children tended to perform more successfully on EF tasks as they aged (for a review, see Escobar-Ruiz et al. 2023). Although these longitudinal studies yield valuable knowledge about EF development at both the group and interindividual levels, these results do not provide insight into how EF performance evolves over time at the intraindividual level.

Summary

- The present study highlights that toddlerhood is a period of marked developmental growth in child inhibitory control, cognitive flexibility, and working memory.
- The findings also provide evidence for a sustained relation between toddlers' language skills and their ongoing acquisition of inhibitory control and cognitive flexibility.
- This research offers novel insight into intraindividual developmental changes in EF during toddlerhood and the role of language in these meaningful, though neglected, changes.

Research on the early development of EF typically uses variable-centered approaches (e.g., group-based averages) to infer intraindividual development. This approach often masks meaningful individual differences by assuming that group-level data accurately represents person-specific changes (Yu et al. 2020). Variability at the intraindividual level of developmental change is often overlooked in developmental science, despite its significance and impact on young children's cognitive development (Alibali and Sidney 2015; van Dijk and van Geert 2015). To the best of our knowledge, intraindividual patterns of change in EF during toddlerhood have yet to be characterized, as well as the factors associated with individual differences in these trajectories. Therefore, it remains unknown whether EF development proceeds at the same pace across toddlers and, if not, for which toddlers this development is more rapid.

1.2 | Links Between Language and EF in Toddlerhood

Toddlerhood is a period of rapid change in EF and language skills (Gleason and Ratner 2022). Language and EF are some of the earliest cognitive skills to emerge and contribute to a variety of outcomes across the lifespan (Hawa and Spanoudis 2014; Moffitt et al. 2011). Thus, these cognitive skills and their interrelations are of particular interest to developmental researchers. Positive associations between language and EF among children with language disorders (see meta-analysis, Pauls and Archibald 2016) and in community samples (Bruce and Bell 2022) are well established. Less clear, however, is when these relations emerge in the first years of life and how they evolve over time (Bruce, Savla et al. 2023; Slot and von Suchodoletz 2018). Although links between individual differences in child language and EF are empirically well-supported, whether these sets of cognitive skills fluctuate together (i.e., if intraindividual development in language is associated with intraindividual development in EF) during toddlerhood remains to be investigated. Although research on language development, like that on EF, has largely neglected the issue of intraindividual variability, there is empirical support for significant variability in language, especially throughout infancy and toddlerhood (van Geert and van Dijk 2002).

Language falls into three categories (i.e., form, content, and use), which allow one to adequately comprehend and produce communicative messages (Bloom and Lahey 1978). The content domain includes both components of vocabulary acquisition: receptive (i.e., comprehension of words) and expressive (i.e., production of words) skills (Bruce and Bell 2022). The content domain is of particular interest for research in toddlerhood, when vocabulary acquisition emerges and is followed by a rapid expansion (Shipley and McAfee 2021). Both receptive and expressive vocabulary skills are positively associated with EF in preschoolers (for a scoping review, see Bruce and Bell 2022). However, studies with toddlers are scarce, mostly cross-sectional, and do not examine associations between vocabulary and EF development at the intraindividual level (e.g., Miller and Marcovitch 2015; Peredo et al. 2015). Moreover, studies have investigated only one component of child vocabulary and EF or have used aggregate scores of child performance on multiple EF tasks (e.g., Bohlmann et al. 2015; Bruce, Ermanni et al. 2023; Kuhn et al. 2016; Vallotton and Ayoub 2011).

Several models have been proposed to explain the associations between vocabulary skills and EF. These models and corresponding empirical support are discussed in Bruce and Bell's (2022) scoping review of the unidirectional and bidirectional associations between vocabulary and EF across early childhood. That review revealed that a greater number of studies (76%) support a model where prior vocabulary predicts subsequent EF compared to the reverse. The authors note, however, that there is a dearth of longitudinal research in toddlerhood (<2 years). A recent study identified a predictive and unidirectional relation between expressive vocabulary at age 2 and EF (composite score) at age 3 (Bruce, Ermanni et al. 2023). Having sufficient vocabulary to hold a set of rules in mind and translate thoughts into actions might be essential for resolving problems involving EF. Moreover, for children to complete EF tasks successfully, they must also be able to comprehend task instructions. Yet, to our knowledge, studies examining the predictive role of vocabulary in the developmental trajectories of EF during the first 2 years of life have not yet been conducted. Furthermore, studies on both dimensions of child vocabulary (i.e., receptive and expressive) in association with all three basic components of EF (i.e., inhibitory control, cognitive flexibility, and working memory) are lacking, although it is well documented that these two dimensions of child vocabulary have different contributions to cognitive development (Bruce and Bell 2022). Therefore, it remains unclear whether receptive and expressive forms of vocabulary are related to all EF components as they emerge and whether the specific associations between these sets of cognitive skills change across time, particularly during toddlerhood, a period when these skills grow tremendously.

1.3 | The Current Study

The goals of the present study were to document intraindividual developmental changes in EF across toddlerhood and to determine whether these changes are associated with developmental variability in language. The current study addresses important gaps in the literature by examining (a) the intraindividual patterns of growth in three components of EF (i.e., inhibitory control, cognitive flexibility, and working memory) during toddlerhood and (b) their associations with both receptive and expressive vocabulary. To examine patterns of growth in child EF, a multilevel growth curve modeling (MLM) approach was used. MLM allows for the use of unbalanced data, meaning that participants can differ in age at the first point of data collection and do not need to be assessed at the same points in time subsequently. This feature of MLM allows change to be indexed as a function of precise child age, aiding in the detection of fine developmental patterns that might otherwise be obscured by using waves of data collection as the metric of time. Measurement invariance is required for performing MLM, meaning that variables need to be measured in the same way on each occasion—this entails using the same physical devices, tasks, and procedures when measuring observed quantities or using the same items (Hoffman 2015). Thus, we used the same tasks to assess EF and the same questionnaire to measure language skills throughout toddlerhood, starting at the earliest age at which the measures were validated. Assessments were conducted on three occasions (the minimum requirement to perform MLM), approximately 6 months apart, between the ages of 11 and 32 months. Developmental improvements in all three components of EF were expected across toddlerhood. Toddlers with greater receptive and expressive vocabulary were expected to perform better on EF tasks across time. Given the lack of previous research, no hypothesis was formulated regarding associations between vocabulary and the rate of growth in EF.

2 | Method

2.1 | Participants

The current study is part of a larger ongoing longitudinal project following a birth cohort of typically developing children. Participants were recruited from lists of parents applying for a Provincial Parental Insurance Program. Parents were contacted by phone 5 months after the birth of their infant. Criteria for participation were: living in the targeted Canadian city (Québec) at the time of recruitment, full-term pregnancy, and the absence of any known physical or mental disability or severe developmental delay in the infant. Written informed consent was obtained from the parents at the beginning of the study. The project was approved by the Université Laval's institutional review board.

In this study, we focus on three assessments conducted when children (51% boys) were aged between 11 and 16 months (T1; M = 13.28, SD = 0.91), between 17 and 21 months (T2; M = 18.92,

TABLE 1 | Descriptive statistics, correlations across ages, and concurrent correlations among the executive function task scores.

					Correlations across age			Concurrent correlations among EF tasks	
	N	***M***	**SD**	**Range**	**T1**	**T2**	**T3**	**CF**	**WM**
Inhibitory control									
T1	136	3.71	7.15	0–30	–	0.17	−0.09	−0.08	0.11
T2	126	8.73	12.09	0–30	—	—	0.05	0.05	0.09
T3	73	24.12	11.43	0–30	—	—	—	0.06	0.08
Average level		10.03	12.79	0–30	—	—	—	—	—
Cognitive flexibility									
T1	142	1.72	1.79	0–5	—	0.22*	−0.04	—	0.16
T2	131	3.45	1.65	0–5	—	—	0.17	—	0.07
T3	74	4.81	0.61	2–5	—	—	—	—	−0.09
Average level		3.04	1.96	0–5	—	—	—	—	—
Working memory									
T1	117	2.14	0.61	0–3	—	0.01	−0.01	—	—
T2	128	2.64	0.46	1.33–3	—	—	0.32**	—	—
T3	74	2.90	0.34	1.33–3	—	—	—	—	—
Average level		2.52	0.58	0–3	—	—	—	—	—

Note: T1 = 11–16 months; T2 = 17–21 months; T3 = 24–32 months; Average level = time points nested in one variable in MLM.
Abbreviations: CF, cognitive flexibility; WM, working memory.
*$p < 0.05$, **$p < 0.01$.

SD = 0.91), and between 24 and 32 months (T3; M = 27.63, SD = 1.97). Among the 145 families who participated in the T1 assessment, 6 dropped out of the study before completing the T2 assessment due to relocation or lack of time, 20 dropped out after T2, and 42 could not be assessed at T3 because of the COVID-19 pandemic. As explained in the procedure section, some EF data were also missing because the child did not cooperate during the task and/or the task was not administered correctly. The number of available EF data at each time point is provided in Table 1. Families with missing data (<50%) at T1, T2, and/or T3 did not differ (all $ps > 0.05$) from those with complete data on sociodemographic characteristics, EF task performance, or language scores. No variable had more than 50% missing. Missing data were handled, as per best practices (Enders 2022), using full information maximum likelihood (FIML) in Mplus, which allows for the estimation of model parameters using all available data. Among the unbiased estimation methods for handling missingness, FIML yields the most efficient estimates (Enders 2022). Simulation work suggests that the average estimates are effectively identical to the true population parameters, even with a small sample size (<100) and up to 50% missing data on any variable (Enders 2022). FIML allows for each participant to contribute to parameter estimation based on their available data. Therefore, all participants with at least one time point are included in analyses, which increases statistical power. In all, 145 children had usable data for at least one of the EF assessment time points. The size of the sample (N = 145) and the rate of missingness (<43%) were, thus, adequate to use FIML to obtain unbiased estimates.

At the time of recruitment, the participating mothers were, on average, 31 years old (SD = 4.09, varying from 25 to 49 years). The majority (89%) of these mothers were born in Canada and reported being of European descent (91%). Mothers had between 11 and 28 years of education (M = 17.38, SD = 3.06). The average annual gross income of the mothers was $45,278 (SD = $20,030, ranging from $0 to $125,000). The average gross family income was $105,272 (SD = $33,551, ranging from $43,000 to $246,000). Child gestational age at birth was, on average, 39 weeks (SD = 1.56, varying from 32 to 42 weeks).

2.2 | Procedure

At each time point, families were met at their homes by research assistants. Prior to each visit, parents were contacted to schedule the session at a time when the child was typically alert and rested. Parents were also instructed to ensure that the child would be alone with them during task administration. For families with other children, arrangements were requested to ensure that siblings were elsewhere during the visit to minimize potential distractions. Additionally, parents were advised to avoid scheduling the visit during times when interruptions, such as phone calls or deliveries, were likely to occur.

At the beginning of the visit, the three EF tasks described below were administered to the child. Toddlers were seated across a table from the examiner on a parent's lap. Parents were instructed to remain quiet during each task to avoid influencing their child's behavior. Toddlers were observed carefully and given breaks between tasks if required. To keep toddlers' interest, they were praised at the end of each task regardless of their performance.

During task administration, the experimenter maintained a detailed logbook of unwanted events, administration errors, or interruptions. If there were any doubts regarding the child's comprehension of the task or if interruptions or incidents occurred during task administration, which might have had a significant impact on child performance, the situations were reviewed carefully using video recordings. In cases where the quality of the data was uncertain, the participants were excluded from analyses.

During the home visit, mothers were also asked to complete a battery of questionnaires, including one measuring child receptive and expressive vocabulary.

2.3 | Measures

2.3.1 | Child EF

At each time point, toddlers' EF were assessed using a battery of three tasks (lasting approximately 15 min total) based on those previously reported (Devine et al. 2019; Friedman et al. 2011; Hughes et al. 2020; Johansson et al. 2016). These widely-used nonverbal EF tasks are sensitive to toddlers' limited attention, language, and motor skills and have been shown to provide reliable measurement of EF in low- and at-risk samples of infants and toddlers (Devine et al. 2019; Fernandez-Baizan et al. 2021; Johansson et al. 2016; Thériault-Couture et al. 2024). The instructions for performing these tasks are accompanied by visual demonstrations or gestures. The predictive, convergent, and construct validity of these tasks are well-supported (Fernandez-Baizan et al. 2021; Frick et al. 2019; Friedman et al. 2011; Johansson et al. 2016).

2.3.1.1 | Inhibitory Control. Children completed the well-known Prohibition task (Friedman et al. 2011). The experimenter placed an attractive toy (a colorful car) on the table and said, "Now, [child's name], don't touch," while shaking her/his head in a "no gesture," and then looked away for 30 s. Following the guidelines of Johansson et al. (2016), who have used this task with 12-month-old infants, we instructed parents to say "no" once if their child started reaching for the toy. After 30 s, if the child had not touched the toy, the experimenter released the prohibition by saying, "It's okay, you can touch it now." The latency to the first time the toddler touched the toy was recorded (possible range: 0–30 s). 61% of randomly selected cases were coded by two independent raters at T1. The first rater was the experimenter, who used a stopwatch during the home visit. The second rater employed video recordings of the task along with the time tape of the viewing software to code the task. Single-measurement inter-rater reliability was considered moderate, with an intraclass correlation coefficient (*ICC*) of 0.72.

2.3.1.2 | Cognitive Flexibility. A simplified version of the Reverse Categorization task (Carlson et al. 2004) developed by Johansson et al. (2016) was completed by children. The task requires the child to sort yellow blocks in a yellow bucket (preliminary trials building the prepotent response) and then classifying them in a red bucket (experimental trials). The child was presented with two buckets (one red and one yellow) and a set of six yellow blocks. First, the experimenter showed how to put one of the yellow blocks in the yellow bucket, then invited the child to sort the blocks by handing him or her one block at a time and saying, "Can you place this into the bucket?," while pointing to the yellow bucket. The child was corrected if he/she put one of the blocks in the red bucket. After six successful trials building up the prepotent response, the rule was reversed, and the child was instructed to place four yellow blocks into the red bucket. The experimenter invited the child to sort the blocks by handing him or her one block at a time and saying, "Now, we're going to place the yellow blocks in the red bucket. Can you place this into this bucket?," while pointing to the red bucket. The child was handed the blocks one at a time. In these experimental trials, the child was not corrected for placing a block in the wrong bucket. During both the preliminary and experimental trials, the two buckets were accessible. The final score is the number of blocks correctly sorted on the first try during the experimental trials, adding one point if children succeeded in preliminary trials. Thus, performance scores on this task ranged from 0 to 5, with higher scores indicating better cognitive flexibility. Two independent raters coded 20% of randomly selected cases at T1. One of the raters was the experimenter during the visit. The other rater used video recordings of the task. Single-measurement inter-rater reliability was excellent (*ICC* = 1).

2.3.1.3 | Working Memory. Children completed a multilocation search task called Hide-and-Seek developed by Johansson et al. (2016) based on similar tasks (e.g., Garon et al. 2014; Miller and Marcovitch 2015). Children were asked to search for a toy that was hidden underneath small opaque plastic glasses. Children were presented with three glasses of different colors, standing upside down next to each other on a tray, out of reach. During the child watched, and after the experimenter said, "Watch carefully," a toy was hidden beneath one of the glasses (which was different for each of the three trials). The experimenter then clapped his or her hands to get the child's attention and to get him or her to look away from the glasses. The tray was next moved toward the child, and the experimenter encouraged the child to search for the toy, saying, "Where's the toy?". The child was allowed to lift one glass at a time until the toy was found or a maximum of three times. The lifted glass was placed back on the tray if the toy was not hidden beneath it. Immediately finding the toy gave three points. There was a decrease in points as more glasses had to be lifted before the toy was located (more than three glasses lifted yielded 0 points). Scores across the three trials were averaged and ranged from 0 to 3, with higher scores representing better working memory skills. Two independent raters coded 31% of randomly selected cases at T1. One of the raters was the experimenter during the visit. The other rater used video recordings of the task. Single-measurement inter-rater reliability was excellent (*ICC* = 0.96).

2.3.2 | Child Receptive and Expressive Vocabulary

At each time point, child's receptive and expressive vocabulary was measured using the French-Canadian adaptation (Trudeau et al. 1999) of the MacArthur Communicative Development Inventory (MCDI) Short-Form (Fenson et al. 2000) completed by mothers. The MCDI is a widely used parent-report vocabulary checklist containing 89 words that is used to gauge infants' and toddlers' receptive (understanding of a word) and expressive (production of a word) vocabulary. Mothers had to indicate from a list the words that their child "understands" (receptive vocabulary) or "understands and says" (expressive vocabulary). Total receptive and expressive vocabulary scores were extracted. The excellent psychometric properties of this measure are well documented both in the original version and in several linguistic adaptations worldwide (Trudeau 2008). Excellent test-retest reliability and good convergent and predictive validity have been demonstrated (Boudreault et al. 2007; Fenson et al. 2006; Trudeau 2008).

2.4 | Analytic Plan

First, descriptive and correlational analyses were carried out. Then, MLM, following Hoffman's (2015) guidelines, was performed in Mplus (Muthén and Muthén 2012) to examine patterns of growth in child EF and their relations with child receptive and expressive vocabulary. This statistical approach allows one to model the average growth curve of each EF and the interindividual variability (between-person differences) around it. MLM was chosen here over SEM because it can handle partially missing data and unequally spaced time points efficiently (Burchinal et al. 2006), which allowed us to take advantage of the 21-month period covered by this study and model trajectories covering the full range of ages (11–32 months), rather than using assessment wave as the fixed unit of time as with SEM. In addition, MLM can easily handle small samples (see Arend and Schäfer 2019 for a simulation study and more information on the statistical power of two-level models). These analyses require as few as 30–50 level-2 units (Burchinal et al. 2006). In this study, because assessment time points are nested within children, each child constitutes a level-2 unit; hence, the sample size was more than adequate.

MLM treats repeated observations as nested within individuals and models change over time on two distinct levels: at Level 1, intraindividual (within-person) change over time is modeled, and the extent to which this change varies across individuals (between-person) is described at Level 2 (Burchinal et al. 2006; Singer and Willett 2003). MLM allows for the examination of both time-varying (i.e., variables that are measured repeatedly across time) and time-invariant predictors (i.e., variables that do not change over time and that were measured only once) of developmental patterns of change. The steps by which MLM was carried out are presented below.

First, an intercept-only model (Model A) that does not include any predictor and postulates no change over time was specified. This model helps calculate the *ICC* (i.e., the average intraindividual stability across all assessment points). Next, two unconditional growth models were specified for each EF: (1) a fixed linear model (Model B), which includes child exact age in months as a predictor, such that the intercept represents average EF performance at T1 and the slope signifies average monthly decrease or increase in performance, and (2) a random linear model (Model C), including the random effect of time (i.e., between-person variability in individual intercepts and slopes). The random effects were retained if the model's Log-likelihood (LL) differed significantly ($p < 0.05$) with the addition of the random terms, based on an adjusted Chi-square difference test.

Once the best-fitting growth curve of each EF was identified, we fitted a series of nested multilevel models in which the effect of each predictor (covariates and child receptive and expressive vocabulary) was examined. Continuous time-invariant predictors (covariates, such as gestational age, mother's income, and education) were centered on their mean for ease of interpretation before being entered at Level 2. The between-person and within-person effects of time-varying predictors (child receptive and expressive vocabulary) were disaggregated using the strategy of person-mean centering before being entered into the models. When a set of measures is collected at multiple points in time, the resulting data contain information about between-person and within-person differences (Curran and Bauer 2011; Raudenbush and Bryk 2002). Thus, the statistical models fitted to these data must be specified to avoid confounding the two sources of variability (see Curran and Bauer 2011 for more details). In order to efficiently disaggregate the between- and within-person effects of time-varying predictors, the average level of the predictor across all assessment points is entered at Level 2. Doing so allows for examining between-person variations in the intraindividual developmental patterns of EF created by the predictor. Also, the within-person-centered time-varying predictor must be entered at Level 1. This allows capturing the mean relation between the outcome and a person's time-specific deviation in the predictor, relative to the overall person-mean across all measurement points. This procedure is considered the most refined technique for disaggregating between-person and within-person effects in multilevel growth models (Curran and Bauer 2011).

Potentially confounding variables (child sex, gestational age, and mother's income and education) were first examined in relation to EF growth models and retained in subsequent analyses when significantly associated with the growth parameters. Next, child receptive (Model D) and expressive (Model E) vocabulary were entered as predictors separately. As multilevel models include multiple variance components (e.g., within-subject and between-subject variances), standardized coefficients and, thus effect sizes are not readily available. To calculate an estimate of the proportion of the variance in child EF explained by age, we computed pseudo-R2 estimates, following Hoffman's (2015) procedure and Rights and Sterba's (2020) guidelines.

3 | Results

3.1 | Preliminary Analyses

Descriptive statistics for EF task performance are provided in Table 1. In MLM, the repeated assessments of the outcome are nested in one variable (called *average level* in Table 1) for which the intraindividual and interindividual variance is decomposed, and this variable does not need to be normally distributed, nor do the data collected at each time point. However, data distributions for all variables were still examined. All variables in the MLM demonstrated good variability and normal distributions (skewness and kurtosis values ranging from −1.45 to +0.82). Cognitive flexibility and working memory showed moderate skewness at T3, but all other variables were normally distributed at each time point. Although the normality of the variables in MLM is not an assumption (Hoffman 2015), all models were estimated using robust maximum likelihood estimation (MLR), which yields standard errors that are robust to non-normality.

There was an increase in mean levels of performance on the three EF tasks across the three time points. As expected, the inhibitory control task was particularly challenging for toddlers at the first time point (i.e., average latency before touching the attractive toy was 3 s), but became easier across time, with mean performance reaching 24 s by the end of the examined period. Similarly, toddlers demonstrated progressive improvement on the cognitive flexibility and working memory tasks, with over 87% achieving maximum scores on these tasks by the end of toddlerhood. Therefore, performance across the tasks ranged from low at the initial assessment to moderate at the mid-point, to finally reach high levels by the end of toddlerhood. This suggests that each task was successful at capturing the emergence of the underlying skill in early toddlerhood and its subsequent development.

Descriptive statistics for receptive and expressive vocabulary are not presented in tables but are described here. On average, toddlers' receptive vocabulary size was 32.04 at T1 (SD = 19.95, ranging from 1.00 to 95.00), 63.54 at T2 (SD = 19.24, ranging from 8.00 to 95.00), and 83.72 at T3 (SD = 6.67, ranging from 55.00 to 89.00). Toddlers' expressive vocabulary size was 3.45 at T1 (SD = 3.89, ranging from 0.00 to 21.00), 23.61 at T2 (SD = 18.15, ranging from 1.00 to 89.00), and 69.38 at T3 (SD = 15.77, ranging from 14.00 to 89.00).

Correlations for toddlers' performance on concurrent EF tasks and correlations across time points are presented in Table 1. There were no or low significant correlations between EF tasks within time points. This pattern of results is expected, especially among toddlers (Escobar-Ruiz et al. 2023), and supports the specificity of each task in measuring a unique executive indicator. It also supports the importance of running separate growth models for each task. The low or moderate coefficients ($r \leq 0.32$) of stability for EF performance scores indicate changes in interindividual differences across time, which will be examined next using MLM.

3.2 | EF Growth Curves During Toddlerhood

Table 2 presents the unconditional growth models, including the intercept-only (Model A), fixed linear (Model B), and random linear (Model C) models, which were estimated and compared. The low (≤0.01) intraclass correlation coefficients (*ICC*s) indicated high within-person variability in EF performance, that is, high variation and low stability in individual performance across time points. The pseudo-R2 estimates (presented below, ranging from 24.2% to 41.4%) indicated that a substantial proportion of that within-person variability in EF was accounted for by child age. Compared to the intercept-only (Model A) and fixed linear (Model B) models, the best-fitting growth model for all three EF components was the random linear model (Model C), which revealed a significant increase in child performance between 11 and 32 months. There was no interindividual variability around the rate of change for any EF (σ_1^2), but there was significant variability around the initial status for cognitive flexibility and working memory (σ_0^2 = 1.15, and 0.10, respectively). Although variability around the slope was not significant in Model C for any EF, removing the random effects decreased the fit of the models, indicating that Model C is more appropriate compared to Model B. The covariance between the slope and intercept was not significant for inhibitory control and cognitive flexibility, which indicated that children who had better initial performance did not show a faster or slower increase in performance across time than those who had lower performance at baseline. The significant negative covariance between the slope and the intercept ($\sigma_{01} = -0.01$) for working memory performance indicated that children with better initial performance on this task subsequently displayed a slower increase in performance across time.

On average, latency on the inhibitory control task started at 3.01 s (γ_{00}) and increased by 1.37 s (γ_{10}) per month. Within-person variance (σ_E^2) in inhibitory control scores was significant and the pseudo-R^2 estimate indicated that child age explained 41.1% of this variance. On average, performance on the cognitive flexibility task increased by 0.21 (γ_{10}) per month, starting with an average score of 1.93 (γ_{00}) at baseline. The within-person variance in cognitive flexibility performance was significant, with child age explaining 41.1% of this variance. On average, performance on the working memory task increased by 0.05 (γ_{10}) per month, starting with an average score of 2.23 (γ_{00}) at baseline. The within-person variance in working memory performance was significant, with child age explaining 24.2% of this variance.

3.3 | Predicting Patterns of Growth in Toddlers' EF

The effects of potential covariates (i.e., child sex and gestational age, maternal income and education) on child EF growth curves were first examined. Child gestational age was found to be positively related to the initial status of cognitive flexibility. The other covariates were not related to any EF growth curve parameters. Thus, only child gestational age was included as a covariate in the final models (D and E). Next, child receptive (Model D) and expressive (Model E) vocabulary were entered (variation across time entered at Level 1 and average level over time entered at Level 2) as predictors in two separate growth models. The conditional models predicting each EF growth curve are shown in Table 3. No association was found between child receptive and expressive vocabulary and the pattern of growth in child working memory. Thus, results pertaining to this EF component will not be discussed further.

3.3.1 | Toddlers' Receptive Vocabulary as a Predictor of EF Patterns of Growth

At Level 1, intraindividual variations in child receptive vocabulary across time were found to be associated with intraindividual variations in child cognitive flexibility ($\gamma20 = 0.02$, $p < 0.001$) across time. That is, children were likely to obtain higher scores on the cognitive flexibility task at one time point if they had a larger receptive vocabulary at the same time point. At Level 2, after accounting for child gestational age, the mean level of receptive vocabulary across time was found to be associated with initial performance on the cognitive flexibility task ($\gamma02 = 0.02$, $p < 0.01$). Thus, children with higher receptive skills showed better

TABLE 2 | Unconditional growth models of child EF between 11 and 32 months (N =145).

		Child EF								
		Inhibitory control (ICC = 0.01)			Cognitive flexibility (ICC = 0.00)			Working memory (ICC = 0.01)		
		Model A	Model B	Model C	Model A	Model B	Model C	Model A	Model B	Model C
Initial status, π_{0i}										
Intercept	γ_{00}	9.99*** (0.72)	3.07*** (0.76)	3.01*** (0.73)	3.04*** (0.11)	1.94*** (0.12)	1.93*** (0.14)	2.51*** (0.03)	2.23*** (0.04)	2.23*** (0.05)
Rate of change, π_{1i}										
Linear slope (age effect)	γ_{10}		1.40*** (0.10)	1.37*** (0.11)		0.21*** (0.02)	0.21*** (0.02)		0.05*** (0.01)	0.05*** (0.01)
Variance components										
Within-person (residual)	σ_E^2	160.71*** (15.13)	94.59*** (9.49)	86.95*** (10.37)	3.82*** (0.34)	2.25*** (0.25)	1.82*** (0.22)	0.33*** (0.03)	0.25*** (0.03)	0.21*** (0.03)
In initial status	σ_0^2		5.22 (6.16)	2.66 (15.60)		0.24 (0.20)	1.15** (0.39)		0.01 (0.02)	0.10* (0.04)
In rate of change	σ_1^2			0.13 (0.28)			0.01 (0.01)			0.00 (0.00)
Slope intercept covariance	σ_{01}			0.35 (1.68)			−0.08 (0.05)			−0.01* (0.04)
Goodness-of-fit	LL	−1328.93	−1153.08	−1151.20	−725.90	−602.44	−596.41	−279.13	−219.96	−215.25

Note: Standard errors are within parentheses. Model A: intercept-only model; Model B: fixed linear model; Model C: random linear model.
Abbreviations: ICC, intraclass correlation coefficient; LL, log likelihood.
*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

initial cognitive flexibility performance. On average, for every 1-word increase in receptive vocabulary, toddlers' performance score at baseline increased by 0.02 point. As receptive vocabulary did not interact with time (i.e., had no effect on the rate of change), performance on the cognitive flexibility task remained consistently higher across time for children with higher receptive vocabulary. For inhibitory control, no association was found with child receptive vocabulary.

3.3.2 | Toddlers' Expressive Vocabulary as a Predictor of EF Patterns of Growth

At Level 1, variation across time in expressive vocabulary was only associated with variation across time in cognitive flexibility ($\gamma 20 = 0.02$, $p < 0.05$), indicating that children were likely to obtain higher scores on the cognitive flexibility task at one time point if they had higher expressive skills at the same time point. At Level 2, after accounting for child gestational age, expressive vocabulary mean level across time was associated with initial performance on the inhibitory control ($\gamma 02 = 0.15$, $p < 0.05$) and cognitive flexibility ($\gamma 02 = 0.04$, $p < 0.001$) tasks. Hence, children with higher expressive skills demonstrated better cognitive flexibility and inhibitory control capacities at baseline. Every 1-word increase in expressive vocabulary was associated with a 0.15 and 0.04 point increase in performance on the inhibitory control and cognitive flexibility tasks, respectively. As expressive vocabulary did not interact with time, performance on the cognitive flexibility and inhibitory control tasks remained consistently higher across time for children with higher levels of expressive skills. The patterns of growth in inhibitory control and cognitive flexibility for children having expressive vocabulary skills one standard deviation above and below the mean are illustrated in Figures 1 and 2.

4 | Discussion

EFs are related to numerous aspects of adaptation and mental health across the lifespan (Diamond 2016). Hence, identifying the normative developmental course of EF and the factors related to this development is crucial. Using a multilevel growth modeling approach and a longitudinal design, the present study sheds light on the developmental trajectories of three distinct components of EF and their intra- and inter-individual associations with receptive and expressive vocabulary. Findings revealed that toddlerhood is a period of marked developmental growth in all three components of EF and that toddlers with larger vocabulary tend to have better inhibitory control and cognitive flexibility capacities throughout this period.

4.1 | Patterns of Growth in EF During Toddlerhood

By modeling age-related development in EF, the current longitudinal study revealed notable improvements in inhibitory control, cognitive flexibility, and working memory as early as

TABLE 3 | Predicting patterns of growth in child EF between 11 and 32 months from child receptive and expressive vocabulary ($N = 145$).

		Child EF					
		Inhibitory control		Cognitive flexibility		Working memory	
		Model D	Model E	Model D	Model E	Model D	Model E
Initial status, π_{oi}							
Intercept	γ_{00}	3.36** (1.16)	4.99** (1.48)	2.32*** (0.00)	2.29*** (0.22)	2.26*** (0.06)	2.25*** (0.08)
Child gestational age at birth	γ_{01}	0.08 (0.40)	0.25 (0.38)	0.13* (0.06)	0.16* 0.07	0.01 (0.02)	0.01 (0.02)
Receptive (D) or expressive (E) vocabulary mean level	γ_{02}	0.01 (0.04)	0.15* (0.07)	0.02** (0.01)	0.04** (0.01)	0.00 (0.00)	0.01 (0.00)
Rate of change, π_{1i}							
Linear slope (age effect)	γ_{10}	1.31*** (0.21)	0.89*** (0.25)	0.13*** (0.03)	0.14** (0.04)	0.04*** (0.01)	0.05*** (0.01)
Time-varying covariate, $\pi 2i$							
Receptive (D) or expressive (E) vocabulary variation across time	γ_{20}	0.01 (0.05)	0.08 (0.06)	0.02*** (0.01)	0.02* (0.01)	0.00 (0.00)	0.00 (0.00)
Within-person: residual	σ_E^2	88.14*** (10.82)	87.55*** (10.56)	1.72*** (0.17)	1.80*** (0.13)	0.19*** (0.02)	0.20*** (0.02)
Variance in initial status	σ_0^2	2.77 (16.31)	1.39 (15.59)	0.90** (0.33)	0.82*** (0.22)	0.11** (0.04)	0.11** (0.04)
Variance in rate of change	σ_1^2	0.14 (0.30)	0.13 (0.26)	0.01 (0.01)	0.00 (0.02)	0.00 (0.00)	0.01 (0.00)
Goodness-of-fit	LL	−1120.94	−1114.54	−564.72	−568.17	−202.58	−203.22

Note: Standard errors are within parentheses. Model D: predictive model including receptive vocabulary; Model E: predictive model including expressive vocabulary. Effects on the rate of change were examined, but were not significant and near zero.
Abbreviation: LL, log likelihood.
*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

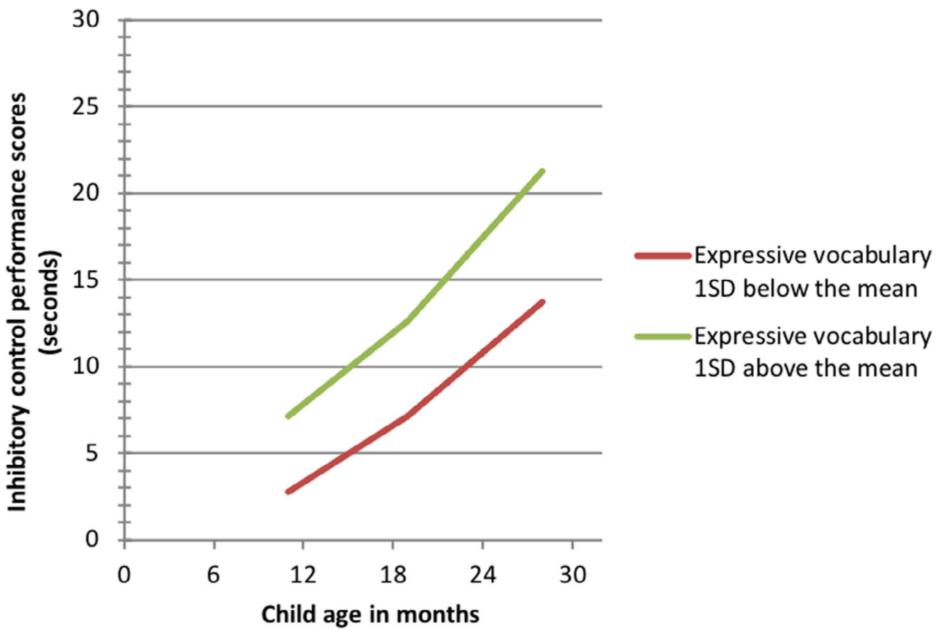

FIGURE 1 | Relations between child expressive vocabulary and growth in performance on the inhibitory control task. *Note:* Figure illustrates the estimates derived from growth models for a child having an expressive vocabulary score one standard deviation below or above the mean.

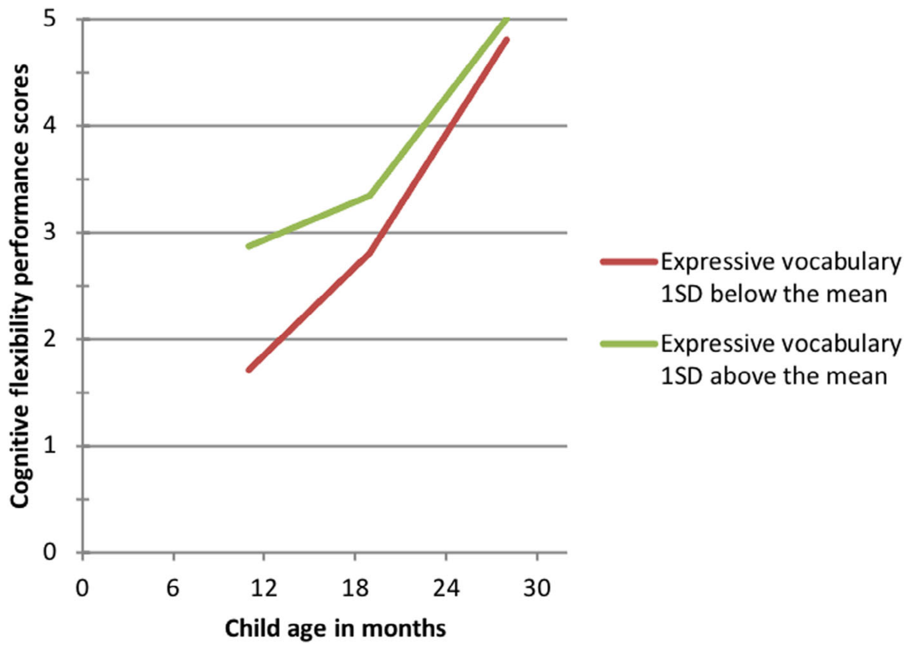

FIGURE 2 | Relations between child expressive vocabulary and growth in performance on the cognitive flexibility task. *Note:* Figure illustrates the estimates derived from growth models for a child having an expressive vocabulary score one standard deviation below or above the mean.

toddlerhood. Those results are in line with cross-sectional studies in which substantial age-related differences in EF performance were observed between 1 and 5 years (Best and Miller 2010; Garon et al. 2008). The monthly improvement in EF performance was found to be significant for all three components of EF and to be relatively uniform across toddlers, with non-significant variance around the rate of change. Thus, findings suggest that toddlers develop EF at approximately the same pace. Performance on the three tasks grew over time, indicating that these tasks are appropriate to detect the emergence and subsequent development of the underlying skills from early to late toddlerhood. In addition, all three tasks did capture significant developmental changes in EF skills across time, further supporting their validity. However, other tasks should be used after age 2.5 years to capture continued development, especially in cognitive flexibility and working memory. Overall, despite the challenges associated with reliable measurement of EF across this age period (Devine et al. 2019), which is only amplified by the need to use the same tasks (measurement invariance) across at least three time points, the findings of the present study reveal that toddlerhood is a period of marked developmental improvement in the three basic components of EF, with a relatively uniform pace of development across toddlers.

There is still debate in the literature about the unified versus fractionated nature of EF during the first years of life (Miller et al. 2023). Some authors conceptualize EF in toddlerhood as unidimensional, whereas others suggest a bidimensional or tridimensional structure (Escobar-Ruiz et al. 2023; Pozzetti et al. 2014; Scionti and Marzocchi 2021). Although the unidimensional model has been more frequently used during this period, the present findings, which reveal distinct associations with language skills for inhibitory control, cognitive flexibility, and working memory, suggest that further investigation of multidimensional models of EF during the toddler years is worth pursuing.

4.2 | Vocabulary and Patterns of Growth in EF During Toddlerhood

Consistent with previous findings (Bruce, Ermanni et al. 2023; Bruce, Savla et al. 2023; Kuhn et al. 2016; Miller and Marcovitch 2015; Peredo et al. 2015), receptive and expressive vocabulary were both found to be associated with some components of EF during toddlerhood. However, the analytical strategy used in this study allowed us to observe different associations between these two dimensions of language and distinct components of EF at the intra- and inter-individual levels. At the intraindividual level, both receptive and expressive vocabulary were found to be associated with cognitive flexibility but not with inhibitory control or working memory. At the interindividual level, expressive vocabulary was associated with both inhibitory control and cognitive flexibility, while receptive vocabulary was only associated with cognitive flexibility. These interindividual relations persisted across time, reflecting static effects, whereas intraindividual relations between vocabulary and cognitive flexibility suggest more dynamic change-based effects. These differential associations are discussed in more detail below but globally support the relevance of investigating intraindividual associations, not just interindividual associations, between components of language and of EF.

At the intraindividual level, growth models revealed that cognitive flexibility grew along with increases in receptive and expressive vocabulary. To the best of our knowledge, this is the first study to show intraindividual associations (vs. associations between interindividual differences in each construct) between child vocabulary and EF during toddlerhood. Although novel, these intraindividual associations are consistent with studies showing simultaneous developmental improvement in language and EF skills in older children (Gooch et al. 2016; Guedes and Cadima 2022; Xing et al. 2022). The joint fluctuations in children's vocabulary and cognitive flexibility across time might reflect a bidirectional process, where a larger vocabulary predicts greater cognitive flexibility subsequently and vice versa. For instance, it is postulated that children need language to form and use embedded rule structures to adequately solve a problem (Zelazo and Frye 1998). In order to perform most cognitive flexibility tasks successfully, children must build embedded conditional rules that follow an "if-if-then" structure. For instance, while doing a reverse-categorization task, children have to sort blocks one way and then are instructed to switch and sort the same blocks in a new way. More mature language abilities likely help toddlers understand the new rule (receptive skills) and use strategies such as self-talk (expressive skills) to remember it and apply it correctly.

Interestingly, the EF task found here to show the most consistent association with vocabulary skills (Reverse Categorization, Johansson et al. 2016) is also the one that requires the most language skills to understand the instructions. These findings align with previous ones showing that expressive vocabulary at age 2 predicted EF at age 3, but only for tasks with high verbal demands (Bruce, Ermanni et al. 2023). Nonetheless, future research is needed to establish the direction of the associations between vocabulary and cognitive flexibility. Indeed, children who can flexibly switch their attention between two speakers may pick up more words, enabling them to develop a richer vocabulary. Thus, the associations observed here between cognitive flexibility and vocabulary might reflect a process in which cognitive flexibility contributes to the development of language. However, these intraindividual associations can also reflect overlapping cognitive developmental processes (Bruce and Bell 2022). Broader cognitive mechanisms, such as processing speed or IQ, might drive both language and EF growth. A similar genetic risk could also interfere with the maturation of brain systems responsible for the development of both language and EF skills (Bishop et al. 2014). Thus, if both sets of cognitive skills are affected by shared causal factors, common underlying mechanisms could be at play in their joint development. For instance, a developmental delay or deficit in frontotemporal brain areas might compromise structures and networks fundamental to the development of both cognitive flexibility and language, thus producing simultaneous courses of development within individuals. However, intraindividual associations were only observed for one EF component, namely, cognitive flexibility. More research is needed to clarify why vocabulary does not grow along with the other components of EF during toddlerhood when considered at the intraindividual level.

At the interindividual level, average differences in receptive and expressive skills between toddlers were associated with initial levels of cognitive flexibility, although not with their rate of change. Thus, children with a larger vocabulary relative to their peers across toddlerhood demonstrated superior performance on the cognitive flexibility task at baseline, which remained consistently higher across time. For inhibitory control, children with better expressive skills across time demonstrated superior baseline performance on the task, which also remained consistently superior across time. Hence, toddlers with superior expressive skills relative to their peers seem to be better equipped to solve problems calling upon cognitive flexibility and inhibitory control. The persistent nature of these interindividual differences raises intriguing questions about whether early developmental factors (e.g., parental SES and behaviors) could contribute to growth in both language and EF.

The predictive role of vocabulary skills in cognitive flexibility and inhibitory control developmental trajectories is consistent with previous studies showing that toddlers' early vocabulary abilities predict later EF skills, including cognitive flexibility and inhibitory control (Kuhn et al. 2016; Miller and Marcovitch 2015; Peredo et al. 2015). Although the current correlational design does not allow for causal inference, these findings could support the notion that language is a tool that enables young children to control their behavior, thoughts, and emotions (Vallotton and Ayoub 2011). Indeed, vocabulary allows toddlers to use labels to create representations of a problem, which can help them choose proper actions to resolve a conflict (Kuhn et al. 2016). Receptive abilities could also facilitate children's comprehension of instructions, which can in turn increase performance on EF tasks targeting cognitive flexibility (Bishop et al. 2014; Miller and Marcovitch 2015; Zelazo and Frye 1998)—although in this study, any such effect was probably minimized by the visual demonstrations and gestures used in the administration of the EF tasks. For inhibitory control, expressive vocabulary could help children form symbolic representations that enable them to regulate their emotions and impulses efficiently, assert more control over their environment, and become less frustrated (Vallotton and Ayoub 2011). Moreover, expressive skills could help children use self-directed speech to keep track of instructions or talk to themselves during activities, which in turn could allow them to inhibit their behaviors more efficiently (Müller et al. 2009).

As was discussed above regarding the intraindividual-level relations between vocabulary and cognitive flexibility, the findings that vocabulary is related to cognitive flexibility and inhibitory control at the interindividual level may suggest bidirectional associations (Guedes and Cadima 2022; Shokrkon and Nicoladis 2022). For instance, greater inhibitory control could help children better focus on relevant environmental cues and be more attentive during conversations with others, enabling them to retain and learn more words (Bruce and Bell 2022). Moreover, cognitive flexibility may help children navigate more flexibly between different rules of language (e.g., some words are relevant only in given contexts; Blair and Raver 2015). Research into the direction of the associations between vocabulary and EF during toddlerhood is necessary, but the current study suggests that this research avenue is promising and that the unidirectional or bidirectional nature of these associations may vary across the intra- and interindividual levels.

Furthermore, toddlers' vocabulary was not related to their working memory at either the intra- or interindividual level. Previous studies examining the predictive role of language skills in EF in toddlerhood relied on a composite score of EF or did not assess working memory distinctly (Kuhn et al. 2016; Miller and Marcovitch 2015; Peredo et al. 2015). However, some studies with older children found associations between child vocabulary and performance on working memory tasks that were similar but more complex than the one used in the present study (Białecka-Pikul et al. 2016; Slot and von Suchodoletz 2018). Although language skills might not be useful for holding and manipulating simple nonverbal information in working memory, they might support verbal working memory, which was not assessed here.

Future studies using more complex working memory tasks requiring to hold and mentally play with verbal information are needed to establish the role of language skills in the early development of this EF component.

Finally, although the longitudinal design, growth modeling approach, and repeated task-based measures of EF used in the present study are important strengths, there were also some limitations. First, the generalizability of the results is limited since the sample was relatively small and comprised predominantly of White, low-risk typically developing children. Second, three time points did not make it possible to explore nonlinear patterns of growth in EF. Curvilinear trajectories in EF are documented in older children (Matte-Gagné et al. 2018; Reilly et al. 2022), but research has yet to investigate whether quadratic growth in EF is present during toddlerhood. Third, the length of time the child looked away after the experimenter clapped their hands during the working memory task was not controlled for in the present study and may have introduced measurement error. Lastly, although the variance around the rate of change in EF was not significant in this sample, heterogeneity in growth trajectories might still exist within the larger population. Describing an entire population using a single growth trajectory estimate may not capture complex growth patterns that reflect continuity and change among members of different groups. Instead, a latent class or growth mixture modeling approach might be used for fully capturing interindividual differences in intraindividual change, taking into account unobserved heterogeneity (i.e., different groups) within the larger population.

5 | Conclusion

The present study provides a deeper insight into the normative developmental trajectories of EF in toddlerhood and their associations with language skills. Based on a longitudinal design and growth modeling approach, the current results reveal notable age-related intraindividual changes in all three components of EF during toddlerhood. Thus, this developmental transition marked by significant intraindividual variability may provide a particularly appropriate window for intervention. Indeed, efforts to promote optimal EF development might be more effective during periods of rapid growth, where there may be greater malleability in these cognitive skills. Findings also underscore that children with a smaller vocabulary may be at higher risk of inhibitory control and cognitive flexibility deficits and that language and cognitive flexibility skills may co-develop and even influence one another early on in life. Future studies are needed to shed light on the etiology and mechanisms that underlie the simultaneous development of vocabulary and EF skills in toddlerhood, but the current study suggests that these avenues of research are promising. Research on intraindividual variability will remain at the forefront of innovative designs for finely characterizing the nature of cognitive development. The current study found significant intraindividual variations in EF across time and different results at the intra- and interindividual levels, highlighting the importance of analyzing intraindividual development prior to aggregating data and the need for caution in extrapolating from aggregate statistics (group mean-level approach) to individuals (intraindividual approach). Language and EF are among the earliest cognitive skills to emerge and are foundational for a wide range of life outcomes (Moffitt et al. 2011; Moll et al. 2015; Schoemaker et al. 2013). Understanding trajectories of intraindividual developmental changes in these skills, interindividual differences in these changes, and the nature, onset, and evolution of their associations across time is thus essential to establishing effective and efficient early childhood intervention programs (Bruce and Bell 2022; Shokrkon and Nicoladis 2022).

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Ethics Statement

The research protocol complied with the American Psychological Association's ethical standards for the treatment of participants and was approved by the ethics committees of the Université Laval.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data necessary to reproduce the analyses presented here are not publicly accessible. The analytic code and materials necessary to reproduce the analyses presented in this paper are available from the first author upon reasonable request.

References

Ahmed, S. F., S. Tang, N. E. Waters, and P. Davis-Kean. 2019. "Executive Function and Academic Achievement: Longitudinal Relations From Early Childhood to Adolescence." *Journal of Educational Psychology* 111, no. 3: 446–458. https://doi.org/10.1037/edu0000296.

Alibali, M. W., and P. G. Sidney. 2015. "The Role of Intraindividual Variability in Learning and Cognitive Development." In *Handbook of Intraindividual Variability Across the Life Span*, edited by M. Diehl, K. Hooker, and M. J. Sliwinski, 84–102. Routledge/Taylor & Francis Group.

Arend, M. G., and T. Schäfer. 2019. "Statistical Power in Two-Level Models: A Tutorial Based on Monte Carlo Simulation." *Psychological Methods* 24, no. 1: 1–19. https://doi.org/10.1037/met0000195.

Best, J. R., and P. H. Miller. 2010. "A Developmental Perspective on Executive Function." *Child Development* 81, no. 6: 1641–1660. https://doi.rg/10.1111/j.1467-8624.2010.01499.x.

Białecka-Pikul, M., M. Kosno, and K. Byczewska-Konieczny. 2016. "Where Was It? Working Memory as a Predictor of Passive Vocabulary Development in the Third Year of Life." *Polish Psychological Bulletin* 47, no. 1: 92–102. https://doi.org/10.1515/ppb-2016-0010.

Bishop, D. V., K. Nation, and K. Patterson. 2014. "When Words Fail Us: Insights Into Language Processing From Developmental and Acquired Disorders." *Philosophical Transactions of the Royal Society London. Series B, Biological Sciences* 369, no. 1634: 20120403. https://doi.org/10.1098/rstb.2012.0403.

Blair, C., and C. C. Raver. 2015. "School Readiness and Self-Regulation: A Developmental Psychobiological Approach." *Annual Review of Psychology* 66: 711–731. https://doi.org/10.1146/annurev-psych-010814-015221.

Bloom, L., and M. Lahey. 1978. *Language Development and Language Disorders*. John Wiley & Sons.

Bohlmann, N. L., M. F. Maier, and N. Palacios. 2015. "Bidirectionality in Self-Regulation and Expressive Vocabulary: Comparisons Between Monolingual and Dual Language Learners in Preschool." *Child Development* 86, no. 4: 1094–1111. https://doi.org/10.1111/cdev.12375.

Bornstein, M. H., D. L. Putnick, and G. Esposito. 2017. "Continuity and Stability in Development." *Child Development Perspectives* 11, no. 2: 113–119. https://doi.org/10.1111/cdep.12221.

Boudreault, M.-C., É.-A. Cabirol, N. Trudeau, D. Poulin-Dubois, and A. Sutton. 2007. "Les Inventaires MacArthur du Développement de la communication: Validité et Données Normatives Préliminaires [MacArthur Communicative Development Inventories: Validity and preliminary normative data]." *Canadian Journal of Speech-Language Pathology and Audiology* 31, no. 1: 27–37.

Broomell, A. P. R., J. Savla, and M. A. Bell. 2019. "Infant Electroencephalogram Coherence and Toddler Inhibition are Associated With Social Responsiveness at Age 4." *Infancy* 24, no. 1: 43–56. https://doi.org/10.1111/infa.12273.

Bruce, M., and M. A. Bell. 2022. "Vocabulary and Executive Functioning: A Scoping Review of the Unidirectional and Bidirectional Associations Across Early Childhood." *Human Development* 66, no. 3: 167–187. https://doi.org/10.1159/000524964.

Bruce, M., B. Ermanni, and M. A. Bell. 2023b. "The Longitudinal Contributions of Child Language, Negative Emotionality, and Maternal Positive Affect on Toddler Executive Functioning Development." *Infant Behavior & Development* 72: 1–15. https://doi.org/10.1016/j.infbeh.2023.101847.

Bruce, M., J. Savla, and M. A. Bell. 2023a. "From Terrible Twos to Sassy Sixes: The Development of Vocabulary and Executive Functioning Across Early Childhood." *Developmental Science* 26, no. 6: e13396. https://doi.org/10.1111/desc.13396.

Burchinal, M. R., L. Nelson, and M. Poe. 2006. "IV. Growth Curve Analysis: An Introduction to Various Methods for Analyzing Longitudinal Data." *Monographs of the Society for Research in Child Development* 71: 65–87. https://doi.org/10.1111/j.1540-5834.2006.00405.x.

Carlson, S. M. 2005. "Developmentally Sensitive Measures of Executive Function in Preschool Children." *Developmental Neuropsychology* 28, no. 2: 595–616. https://doi.org/10.1207/s15326942dn2802_3.

Carlson, S. M., D. J. Mandell, and L. Williams. 2004. "Executive Function and Theory of Mind: Stability and Prediction From Ages 2 to 3." *Developmental Psychology* 40, no. 6: 1105–1122. https://doi.org/10.1037/0012-1649.40.6.1105.

Crotty, J. E., S. P. Martin-Herz, and R. J. Scharf. 2023. "Cognitive Development." *Pediatrics in Review* 44, no. 2: 58–67. https://doi.org/10.1542/pir.2021-005069.

Cuevas, K., V. Rajan, and L. J. Bryant. 2018. "Emergence of Executive Function in Infancy." In *Executive Function: Development Across the Life Span*, edited by S. A. Wiebe and J. Karbach, 11–28. Routledge.

Curran, P. J., and D. J. Bauer. 2011. "The Disaggregation of Within-Person and Between-Person Effects in Longitudinal Models of Change." *Annual Review of Psychology* 62: 583–619. https://doi.org/10.1146/annurev.psych.093008.100356.

Devine, R. T., A. Ribner, and C. Hughes. 2019. "Measuring and Predicting Individual Differences in Executive Functions at 14 Months: A Longitudinal Study." *Child Development* 90, no. 5: e618–e636. https://doi.org/10.1111/cdev.13217.

Diamond, A. 2013. "Executive Functions." *Annual Review of Psychology* 64: 135–168. https://doi.org/10.1146/annurev-psych-113011-143750.

Diamond, A. 2016. "Why Improving and Assessing Executive Functions Early in Life is critical." In *Executive Function in Preschool-Age Children: Integrating Measurement, Neurodevelopment, and Translational Research*, edited by J. A. Griffin, P. McCardle, and L. S. Freund, 11–43. American Psychological Association. https://doi.org/10.1037/14797-002.

Enders, C. K. 2022. *Applied Missing Data Analysis*. 2nd ed. The Guilford Press.

Escobar-Ruiz, V., P. I. Arias-Vázquez, C. A. Tovilla-Zárate, E. Doval, and M. C. Jané-Ballabriga. 2023. "Advances and Challenges in the Assessment of Executive Functions in Under 36 Months: A Scoping Review." *Advances in Neurodevelopmental Disorders* 8: 365–383. https://doi.org/10.1007/s41252-023-00366-x.

Fenson, L., V. A. Marchman, D. J. Thal, P. S. Dale, J. S. Reznick, and E. Bates. 2006. *MacArthur-Bates Communicative Development Inventories*. 2nd ed. [Database record]. APA PsycTests.

Fenson, L., S. Pethick, C. Renda, J. L. Cox, P. S. Dale, and J. S. Reznick. 2000. "Short-Form Versions of the MacArthur Communicative Development Inventories." *Applied Psycholinguistics* 21, no. 1: 95–115. https://doi.org/10.1017/S0142716400001053.

Fernandez-Baizan, C., M. Caunedo-Jimenez, J. A. Martinez, J. L. Arias, M. Mendez, and G. Solis. 2021. "Development of Visuospatial Memory in Preterm Infants: A New Paradigm to Assess Short-Term and Working Memory." *Child Neuropsychology* 27, no. 3: 296–316. https://doi.org/10.1080/09297049.2020.1847264.

Fiske, A., L. Collins-Jones, C. de Klerk, et al. 2024. "The Neural Correlates of Response Inhibition Across the Transition From Infancy to Toddlerhood: An fNIRS Study." *Imaging Neuroscience* 2: 1–21. https://doi.org/10.1162/imag_a_00206.

Fiske, A., and K. Holmboe. 2019. "Neural Substrates of Early Executive Function Development." *Developmental Review* 52: 42–62. https://doi.org/10.1016/j.dr.2019.100866.

Fitzpatrick, C., and L. S. Pagani. 2012. "Toddler Working Memory Skills Predict Kindergarten School Readiness." *Intelligence* 40, no. 2: 205–212. https://doi.org/10.1016/j.intell.2011.11.007.

Frick, M. A., G. Bohlin, M. Hedqvist, and K. C. Brocki. 2019. "Temperament and Cognitive Regulation During the First 3 Years of Life as Predictors of Inattention and Hyperactivity/Impulsivity at 6 Years." *Journal of Attention Disorders* 23, no. 11: 1291–1302. https://doi.org/10.1177/1087054718804342.

Friedman, N. P., A. Miyake, J. L. Robinson, and J. K. Hewitt. 2011. "Developmental Trajectories in Toddlers' Self-Restraint Predict Individual Differences in Executive Functions 14 Years Later: A Behavioral Genetic Analysis." *Developmental Psychology* 47, no. 5: 1410–1430. https://doi.org/10.1037/a0023750.

Garon, N., S. E. Bryson, and I. M. Smith. 2008. "Executive Function in Preschoolers: A Review Using an Integrative Framework." *Psychological Bulletin* 134, no. 1: 31–60. https://doi.org/10.1037/0033-2909.134.1.31.

Garon, N., I. M. Smith, and S. E. Bryson. 2014. "A Novel Executive Function Battery for Preschoolers: Sensitivity to Age Differences." *Child Neuropsychology* 20, no. 6: 713–736. https://doi.org/10.1080/09297049.2013.857650.

Gleason, J. B., and N. B. Ratner. 2022. *The Development of Language*. 10th ed. Plural Publishing Inc.

Gooch, D., P. Thompson, H. M. Nash, M. J. Snowling, and C. Hulme. 2016. "The Development of Executive Function and Language Skills in the Early School Years." *Journal of Child Psychology and Psychiatry* 57, no. 2: 180–187. https://doi-org/10.1111/jcpp.12458.

Guedes, C., and J. Cadima. 2022. "The Bidirectional Interplay Between Self-Regulation and Expressive Vocabulary During Toddlerhood." *Developmental Psychology* 58, no. 9: 1652–1664. https://doi.org/10.1037/dev0001062.

Hawa, V. V., and G. Spanoudis. 2014. "Toddlers With Delayed Expressive Language: An Overview of the Characteristics, Risk Factors and Language Outcomes." *Research in Developmental Disabilities* 35, no. 2: 400–407. https://doi.org/10.1016/j.ridd.2013.10.027.

Hendry, A., I. Greenhalgh, R. Bailey, A. Fiske, H. Dvergsdal, and K. Holmboe. 2022. "Development of Directed Global Inhibition, Competitive Inhibition and Behavioural Inhibition During the Transition Between

Infancy and Toddlerhood." *Developmental Science* 25, no. 5: e13193. https://doi-org/10.1111/desc.13193.

Hoffman, L. 2015. *Longitudinal Analysis: Modeling Within-Person Fluctuation and Change*. Routledge/Taylor & Francis Group.

Holmboe, K., C. Larkman, C. de Klerk, et al. 2021. "The Early Childhood Inhibitory Touchscreen Task: A New Measure of Response Inhibition in Toddlerhood and Across the Lifespan." *PLoS ONE* 16, no. 12:e0260695. https://doi.org/10.1371/journal.pone.0260695.

Hughes, C., R. T. Devine, J. Mesman, and C. Blair. 2020. "Understanding the Terrible Twos: A Longitudinal Investigation of the Impact of Early Executive Function and Parent–Child Interactions." *Developmental Science* 23, no. 6: e12979. https://doi.org/10.1111/desc.12979.

Jaekel, J., S. Eryigit-Madzwamuse, and D. Wolke. 2016. "Preterm Toddlers' Inhibitory Control Abilities Predict Attention Regulation and Academic Achievement at Age 8 Years." *Journal of Pediatrics* 169: 87–92. https://doi.org/10.1016/j.jpeds.2015.10.029.

Johansson, M., C. Marciszko, K. Brocki, and G. Bohlin. 2016. "Individual Differences in Early Executive Functions: A Longitudinal Study from 12 to 36 Months." *Infant and Child Development* 25, no. 6: 533–549. https://doi.org/10.1002/icd.1952.

Kolb, B., R. Mychasiuk, A. Muhammad, Y. Li, D. O. Frost, and R. Gibb. 2012. "Experience and the Developing Prefrontal Cortex." *PNAS Proceedings of the National Academy of Sciences of the United States of America* 109, no. 2: 17186–17193. https://doi.org/10.1073/pnas.1121251109.

Korzeniowski, C., M. S. Ison, and H. D. de Anglat. 2021. "A Summary of the Developmental Trajectory of Executive Functions From Birth to Adulthood." In *Psychiatry and Neuroscience Update: From Epistemology to Clinical Psychiatry*, edited by P. Á. Gargiulo and H. L. Mesones Arroyo. 459–473. Springer Nature Switzerland AG. https://doi.org/10.1007/978-3030-61721-9_33.

Kuhn, L. J., M. T. Willoughby, L. Vernon-Feagans, C. B. Blair, and Family Life Project Key Investigators. 2016. "The Contribution of Children's Time-Specific and Longitudinal Expressive Language Skills on Developmental Trajectories of Executive Function." *Journal of Experimental Child Psychology* 148: 20–34. https://doi.org/10.1016/j.jecp.2016.03.008.

Matte-Gagné, C., A. Bernier, M.-S. Sirois, G. Lalonde, and S. Hertz. 2018. "Attachment Security and Developmental Patterns of Growth in Executive Functioning During Early Elementary School." *Child Development* 89, no. 3: e167–e182. https://doi.org/10.1111/cdev.12807.

Miller, S. E., L. G. Galvagno, and Á. Elgier. 2023. "Universality and Context-Specificity in Early Executive Function Development." *Infant Behavior & Development* 71: 1–22. https://doi-org/10.1016/j.infbeh.2023.101841.

Miller, S. E., and S. Marcovitch. 2015. "Examining Executive Function in the Second Year of Life: Coherence, Stability, and Relations to Joint Attention and Language." *Developmental Psychology* 51, no. 1: 101–114. https://doi.org/10.1037/a0038359.

Moffitt, T. E., L. Arseneault, D. Belsky, et al. 2011. "A Gradient of Childhood Self-Control Predicts Health, Wealth, and Public Safety." *PNAS Proceedings of the National Academy of Sciences of the United States of America* 108, no. 7: 2693–2698. https://doi.org/10.1073/pnas.1010076108.

Moll, K., M. J. Snowling, S. M. Göbel, and C. Hulme. 2015. "Early Language and Executive Skills Predict Variations in Number and Arithmetic Skills in Children at Family-Risk of Dyslexia and Typically Developing Controls." *Learning and Instruction* 38: 53–62. https://doi.org/10.1016/j.learninstruc.2015.03.004.

Morgan, B., A. Fiske, and K. Holmboe. 2024. "Early Executive Function Development: The First Three Years." *In Reference Module in Neuroscience and Biobehavioral Psychology*, edited by J. H. Grafman. Forthcoming in *Encyclopaedia of the Human Brain*. 2nd ed. Elsevier. https://doi.org/10.1016/B978-0-12-820480-1.00078-4.

Mulder, H., H. Hoofs, J. Verhagen, I. van der Veen, and P. P. M. Leseman. 2014. "Psychometric Properties and Convergent and Predictive Validity of an Executive Function Test Battery for Two-Year-Olds." *Frontiers in Psychology* 5: 733. https://doi.org/10.3389/fpsyg.2014.00733.

Müller, U., S. Jacques, K. Brocki, and P. D. Zelazo. 2009. "The Executive Functions of Language in Preschool children." In *Private Speech, Executive Functioning, and the Development of Verbal Self-Regulation*, edited by A. Winsler, C. Fernyhough, and I. Montero. 53–68. Cambridge University Press. https://doi.org/10.1017/CBO9780511581533.005.

Muthén, L. K., and B. O. Muthén. 2012. *Mplus User's Guide*. 7th ed. Muthén & Muthén.

Pauls, L. J., and L. M. D. Archibald. 2016. "Executive Functions in Children With Specific Language Impairment: A Meta-Analysis." *Journal of Speech, Language, and Hearing Research* 59, no. 5: 1074–1086. https://doi.org/10.1044/2016_JSLHR-L-15-0174.

Paulus, M., M. Licata, S. Kristen, C. Thoermer, A. Woodward, and B. Sodian. 2015. "Social Understanding and Self-Regulation Predict Pre-Schoolers' Sharing With Friends and Disliked Peers: A Longitudinal Study." *International Journal of Behavioral Development* 39, no. 1: 53–64. https://doi.org/10.1177/0165025414537923.

Peredo, T. N., M. T. Owen, R. Rojas, and M. O. Caughy. 2015. "Child Vocabulary, Maternal Behavior, and Inhibitory Control Development Among Spanish-Speaking Children." *Early Education and Development* 26, no. 5-6: 749–769. https://doi.org/10.1080/10409289.2015.1009319.

Pozzetti, T., A. Ometto, S. Gangi, et al. 2014. "Emerging Executive Skills in Very Preterm Children at 2 Years Corrected Age: A Composite Assessment." *Child Neuropsychology* 20, no. 2: 145–161. https://doi.org/10.1080/09297049.2012.762759.

Raudenbush, S. W., and A. S. Bryk. 2002. *Hierarchical Linear Models: Applications and Data Analysis Methods*. 2nd ed. Sage Publications.

Reilly, S. E., J. T. Downer, and K. J. Grimm. 2022. "Developmental Trajectories of Executive Functions From Preschool to Kindergarten." *Developmental Science* 25, no. 5: e13236. https://doi.org/10.1111/desc.13236.

Ribner, A., R. T. Devine, C. Blair, and C. Hughes. 2022. "Mothers' and Fathers' Executive Function Both Predict Emergent Executive Function in Toddlerhood." *Developmental Science* 25: e13263. https://doi.org/10.1111/desc.13263.

Rights, J. D., and S. K. Sterba. 2020. "New Recommendations on the Use of R-Squared Differences in Multilevel Model Comparisons." *Multivariate Behavioral Research* 55, no. 4: 568–599. https://doi.org/10.1080/00273171.2019.1660605.

Schoemaker, K., H. Mulder, M. Deković, and W. Matthys. 2013. "Executive Functions in Preschool Children With Externalizing Behavior Problems: A Meta-Analysis." *Journal of Abnormal Child Psychology* 41, no. 3: 457–471. https://doi.org/10.1007/s10802-012-9684-x.

Scionti, N., and G. M. Marzocchi. 2021. "The Dimensionality of Early Executive Functions in Young Preschoolers: Comparing Unidimensional Versus Bidimensional Models and Their Ecological Validity." *Child Neuropsychology* 27, no. 4: 491–515. https://doi.org/10.1080/09297049.2020.1868419.

Shipley, K., and J. McAfee. 2021. *Assessment in Speech-Language Pathology: A Resource Manual*. 6th ed. Plural Publishing.

Shokrkon, A., and E. Nicoladis. 2022. "The Directionality of the Relationship Between Executive Functions and Language Skills: A Literature Review." *Frontiers in Psychology* 13: 848696. https://doi.org/10.3389/fpsyg.2022.848696.

Shonkoff, J. P., G. G. Duncan, P. A. Fisher, K. Magnuson, C. C. Raver, and H. Yoshikawa. 2011. Building the Brain's "Air Traffic Control" System: How Early Experiences Shape the Development of Executive Function. Working Paper No. 11. Center on the Developing Child, Harvard University.

Singer, J. D., and J. B. Willett. 2003. *Applied Longitudinal Data Analysis: Modeling Change and Event Occurrence*. Oxford University Press.

Slot, P. L., and A. von Suchodoletz. 2018. "Bidirectionality in Preschool Children's Executive Functions and Language Skills: Is One Developing

Skill the Better Predictor of the Other?" *Early Childhood Research Quarterly* 42: 205–214. https://doi.org/10.1016/j.ecresq.2017.10.005.

Thériault-Couture, F., C. Matte-Gagné, and A. Bernier. 2024. "Executive Functions and Social-Emotional Problems in Toddlerhood: Nature, Persistence, and Direction of Associations." *Research on Child and Adolescent Psychopathology* 52: 1383–1395. https://doi.org/10.1007/s10802-024-01198-6.

Trudeau, N. 2008. *Les Inventaires MacArthur-Bates Du Développement de la Communication (IMBCD)*. Canadian Language & Literacy Research Network.

Trudeau, N., I. Frank, and D. Poulin-Dubois. 1999. "Une Adaptation En FrançAis QuébéCois Du MacArthur Communicative Development Inventory." *La Revue D'orthophonie Et D'audiologie* 23: 61–73.

Vallotton, C., and C. Ayoub. 2011. "Use Your Words: The Role of Language in the Development of Toddlers' Self-Regulation." *Early Childhood Research Quarterly* 26, no. 2: 169–181. https://doi.org/10.1016/j.ecresq.2010.09.002.

van Dijk, M., and P. van Geert. 2015. "The Nature and Meaning of Intraindividual Variability in Development in the Early Life Span." In *Handbook of Intraindividual Variability Across the Life Span*, edited by M. Diehl, K. Hooker, and M. J. Sliwinski. 37–58. Routledge/Taylor & Francis Group.

van Geert, P., and M. van Dijk. 2002. "Focus on Variability: New Tools to Study Intra-Individual Variability in Developmental Data." *Infant Behavior & Development* 25, no. 4: 340–374. https://doi.org/10.1016/S0163-6383(02)00140-6.

Wiebe, S. A., A. F. Lukowski, and P. J. Bauer. 2010. "Sequence Imitation and Reaching Measures of Executive Control: A Longitudinal Examination in the Second Year of Life." *Developmental Neuropsychology* 35, no. 5: 522–538. https://doi.org/10.1080/87565641.2010.494751.

Xing, X., Y. Wei, and M. Wang. 2022. "Reciprocal Relation Between Executive Function and Receptive Vocabulary in Chinese Preschoolers: Evidence From a Two-Year Longitudinal Study." *Developmental Psychology* 58, no. 1: 83–95. https://doi-org/10.1037/dev0000996.

Yu, D., P.-J. Yang, G. J. Geldhof, et al. 2020. "Exploring Idiographic Approaches to Children's Executive Function Performance: An Intensive Longitudinal Study." *Journal for Person-Oriented Research* 6, no. 2: 73–87. https://doi.org/10.17505/jpor.2020.22401.

Zelazo, P. D., C. B. Blair, and M. T. Willoughby. 2016. *Executive Function: Implications for Education (NCER 2017–2000)*. National Center for Education Research, Institute of Education Sciences, US Department of Education.

Zelazo, P. D., and D. Frye. 1998. "Cognitive Complexity and Control: II. The Development of Executive Function in Childhood." *Current Directions in Psychological Science* 7, no. 4: 121–126. https://doi.org/10.1111/1467-8721.ep10774761.