Published in final edited form as:
Child Dev. 2014 September ; 85(5): 1898–1914. doi:10.1111/cdev.12249.

Early Communicative Gestures Prospectively Predict Language Development and Executive Function in Early Childhood

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Abstract

Using an epidemiological sample (*N* =1117) and a prospective longitudinal design, this study tested the direct and indirect effects of preverbal and verbal communication (15 months to 3 years) on EF at age 4 years. Results indicated that whereas gestures (15 months), as well as language (2 and 3 years) were correlated with later EF (ϕ_s >= .44), the effect was entirely mediated through later language. In contrast, language had significant direct and indirect effects on later EF. Exploratory analyses indicated that the pattern of results was comparable for low and not-low income families. The results were consistent with theoretical accounts of language as a precursor of EF ability, and highlighted gesture as an early indicator of EF.

Keywords

Executive Function; Gesture; Language Development; Early Childhood

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The nature of the relation between language and cognition and how it develops during childhood has been debated for centuries. Researchers have been keenly interested in the link between gesture and language (Bates, Thal, & Marchman, 1991; Iverson & Thelen, 1999), as well as the influence of language on a variety of cognitive abilities (Goldstein, Davidoff, & Roberson, 2009; Spaepen, Coppola, Spelke, Carey, & Goldin-Meadow, 2011). Historically, Piaget's (1962) research in gestural complexity, symbolic play and cognitive milestones suggested a common origin for linguistic and nonlinguistic symbols. Others, like Vygotsky (1962), examined how verbal scaffolding and shared communication assisted children in achieving cognitive milestones. These scholars advanced our understanding about what skills precede certain cognitive abilities. The current study continues with this line of inquiry by considering the prospective associations between children's gesture use,

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emerging language ability, and a specific dimension of cognitive development-executive functions (EF).

Recent research has demonstrated that language, specifically the timing of certain linguistic milestones, is associated with the development of numerous cognitive abilities, including children's conceptualization of objects, spatial relations, and numbers. For instance, infants as young as 12 to 13 months can use words to facilitate their object category formation (Waxman & Markow, 1995). Between 18 and 22 months, children can use verbal information to update or reorganize their representations of absent objects (Ganea, Shutts, Spelke, & DeLoache, 2007), object locations (Ganea & Harris, 2013), and spatial relations (Casasola, Wilbourn, & Yang, 2006). During the preschool years, language also plays a role in children's numerical understanding (Geary, Bow-Thomas, Liu, & Siegler, 1996) and in the development of higher-order cognitive abilities, like Theory of Mind (ToM; de Villiers & Pyers, 2002). For instance, Schick and colleagues (Schick, de Villiers, de Villiers, & Hoffmeister, 2007) found that deaf children who did not have experience with a formal language, like American Sign Language, exhibited significant delays in ToM. They argue that children's experience with syntax (e.g., complement clauses), from a formal language, promoted the ability to adapt multiple representations, one's own view and the view of another (Schick, de Villiers, de Villiers, & Hoffmeister, 2007). Taken together, these findings provide compelling evidence to suggest that language may afford children the ability to think in certain ways that advance perceptual and cognitive development.

Communicative Gestures and Language

Months before infants utter their first words, they communicate with caregivers via gestures (Acredolo, Goodwyn, & Brown, 2000; Blake, 2000). Communicative gesture use emerges as early as 8 to10 months, typically in the form of *giving*, *showing, or pointing* to objects (Bates, Benigni, Bretherton, Camaioni, & Volterra, 1979). These deictic gestures are considered intentional communication and are most often used to direct and maintain caregivers' attention to a particular object or referent (Bates et al., 1979). Moreover, these gestures both predate and predict infants' oral language skills (Colonnesi, Stams, Koster, & Noom, 2010; Goldin-Meadow, 2007). In fact, infants' deictic gestures have proven to be more reliable predictors of their later language development than the oral language input they receive from caregivers (Rowe et al., 2007), illustrating just how influential these gestures are in children's language development.

Numerous studies have demonstrated that infants' early pointing gestures predict their first words, the size of their vocabularies and the onset of two-word combinations (Iverson & Goldin-Meadow, 2005; Özçaliskan & Goldin-Meadow, 2005; Rowe, Özçaliskan, & Goldin-Meadow, 2008). For example, Iverson and Goldin-Meadow (2005) found that the objects infants first identified with points predictably appeared in their spoken vocabularies three months later. Findings from longitudinal research have also shown that the number of different objects infants point to at 14 months predicts the overall size of their vocabularies at 42 months (Rowe, Özçaliskan, & Goldin-Meadow, 2008). As infants' nonverbal communication becomes more complex, research has shown that the age at which infants begin to combine pointing gestures with spoken words (e.g., "ball") predicts the age at which they will produce two word utterances (Iverson & Goldin-Meadow, 2005). This robust relation between infants' early gesture use and later language development has led many scholars to conclude that infants' early deictic gestures (e.g., point, give, show) provide the foundation by which oral linguistic communication is built (Bates et al., 1987; Goldin-Meadow, 2007; Iverson & Goldin-Meadow, 2005).

Children's points may facilitate their language learning in several ways. Werner and Kaplan (1963) contend that, in addition to singling out objects and directing others' attention, infants' communicative pointing denotes an important first step towards true symbolic understanding. The link between early pointing and symbolic understanding may develop because points often elicit clear labels or referent-specific language from caregivers (Goldin-Meadow, 2007), increasing infants' exposure to word-object relations. Infants' ability to rapidly learn word-object associations (i.e., "goes with") has been argued to be a necessary precursor to understanding that words are symbols or "stand for" objects (Oviatt, 1980; Werker, Cohen, Lloyd, Casasola, & Stager, 1998). Therefore, by increasing infants' exposure to word-object pairings, infants' pointing may ultimately facilitate their transition from "goes with" to a "stands for" understanding of word-object relations (Blake, 2000). This suggestion is supported by research indicating that several months after infants begin using deictic gestures, they begin to spontaneously produce symbolic or representational gestures (Acredolo & Goodwyn, 1990; Blake, 2000). These *symbolic gestures* (e.g., flapping hands to represent "bird") are decontexualized from the referent and are used to represent an object that may or may not be present (Blake, 2000; Werner & Kaplan, 1963).

In typically developing infants, symbolic gesture use emerges between the ages of 13 to 16 months. Given the complementary function symbolic gestures have with first words, scholars posit that the onset of symbolic gesturing, just before the naming burst, is not coincidental (Blake, 2000; Rowe & Goldin-Meadow, 2009) and is likely reflective of a common underlying cognitive ability (e.g., symbolic understanding). This proposal is supported by recent brain imaging research with adults demonstrating that symbolic gestures and spoken language glosses (i.e., labels) are processed in similar, overlapping brain regions (Xu, Gannon, Emmorey, Smith, & Braun, 2009). Similar brain regions were not active when the spoken labels were conceptually *unrelated* to the symbolic gestures. Based on these findings, Xu and colleagues (2009) propose that a common, modality-independent system for symbolic communication drives the relation between symbolic gestures and spoken language. This modality-independent communication system may also explain why infants' symbolic gesturing is so highly predictive of their vocabulary and conceptual development (Blake, 2000). Taken together, these findings indicate that infants' early deictic and symbolic gesturing both predicts and contributes to their understanding of symbolic relations and language learning (Bates et al., 1979; Blake, 2000; Özçaliskan & Goldin-Meadow, 2005). How then is this modality-independent communication system related to certain cognitive abilities, like EF?

Executive Function

Executive functions refer to cognitive abilities involved in the control and coordination of information in the service of goal-directed actions. Although EF is typically conceptualized as a multidimensional construct - including inhibitory control, working memory, and attention shifting - during middle childhood and adulthood, it is considered an unidimensional (undifferentiated) construct in early childhood (Hughes, Ensor, Wilson, & Graham, 2010; Wiebe, Espy, & Charak, 2008). This period during early and middle childhood is specifically characterized by substantial developmental changes (improvements) in EF abilities (Best & Miller, 2010). This protracted course of development is supported by neuroimaging that demonstrates the brain regions associated with EF, such as the prefrontal cortex, are activated during infancy (Bell & Fox, 1992) and that the myelination of prefrontal connections continues well into adolescence (Klinberg, Vaidya, Gabrieli, Moseley, & Hedehus, 1999). It is particularly relevant to study the individual differences in EF during the preschool years because both concurrent and prospective measures have been related to aspects of school readiness (Bierman, Torres, Domitrovich, Welsh, & Gest, 2009; Brock, Rimm-Kaufman, Nathanson, & Grimm, 2009; Welsh, Nix, Blair, Bierman, & Nelson, 2010).

In contrast to a focus on the development and predictive ability of early EF, far fewer studies have considered the developmental processes that precede and facilitate the normative acquisition of EF abilities in early childhood. A small number of studies have demonstrated that whereas socioeconomic status (SES) risks compromise the development of EF, the quality and nature of early parent-child interactions may facilitate its development (Bernier, Carlson, & Whipple, 2010; Raver, Blair, & Willoughby, 2013). In addition to these environmental inputs, a number of child characteristics likely contribute to individual differences in EF during early childhood. Individual differences in temperament, especially the development of attention in infancy and early toddlerhood, have been implicated as relevant for EF in early childhood (Rueda, Posner, & Rothbart, 2005). A recent study, involving the current sample, demonstrated that temperamental reactivity interacted with regulatory strategies, which has strong attentional components, to predict EF in early childhood (Ursache, Blair, Stifter, & Voegtline, 2012). This work highlights the need for early indicators of EF.

Language Development and EF

Substantial research has established that early language development is associated with children’s performance on EF tasks. For example, a number of experimental studies have demonstrated how children’s use of language during EF tasks facilitated their performance (Brace, Morton, & Munakata, 2006; Kirkham, Cruess, & Diamond 2003; Zelazo, Reznick, & Pinon, 1995). Moreover, a number of studies have demonstrated that expressive and receptive language proficiency is correlated with better EF performance, and that children with specific language deficits score poorly on EF tasks (Carlson, Davis & Leach, 2005; for review see Muller, Jacques, Brocki, & Zelazo, 2009). While these studies have demonstrated associations between language skills and EF, they have not informed questions regarding the contribution of early language development to the emergence of EF during early childhood.

Zelazo and colleagues have long argued that children’s language is a fundamental precursor to the development of EF (Zelazo & Frye, 1998; Zelazo, Muller, Frye, & Marcovitch, 2003). In their Cognitive Complexity and Control theory (CCC theory), Zelazo and colleagues posit that children's language skills are related to their EF abilities through the formation of a mental representation of the problem or conflict to be solved. Further, language is needed for the construction and use of the embedded rule structures that helps children to solve a given problem or conflict (Zelazo & Frye, 1998). This idea is expanded in the Hierarchical Competing Systems Model (HCSM; Marcovitch & Zelazo, 2009), which proposes that children's first cognitive processes arise from a habit system, based exclusively on infants' previous experiences. However, with maturation, this initial habit system transforms into a representational system (Marcovitch & Zelazo, 2009). Children's language plays an active role in this transformation because the strength of a representation can be increased if children label it (Marcovitch & Zelazo, 2009). Although Zelazo and colleagues theoretical work provides a basis for predicting that early language development should facilitate subsequent EF abilities, we are unaware of any prospective longitudinal studies that have empirically tested these ideas.

Communicative Gestures and EF

Research on language and EF is typically conducted with children who are already fluent speakers. This leaves open questions to how preverbal indicators, such as gestures, may also provide insight into the development of the relation between language and EF. To explore the degree to which gesture may scaffold children's EF skills, O'Neill and Miller (2012) examined children's gesture use during an EF task. In their study, 2.5 to 6-year-olds' gestures, oral language and performance on the Dimensional Change Card Sort (DCCS) task were analyzed. The findings revealed that gesture use predicted children's performance on the task, above and beyond age. While children performed equally well during the initial pre-switch phase of the task, children who gestured more were more accurate and efficient when shifting to the new sorting rule. Moreover, younger children who were "high gesturers" performed comparable to (or better than) older children who were "low gesturers". These findings suggest that children's gestures may provide insight into, or bolster, the cognitive abilities needed for successful performance on EF tasks. Thus, individual differences in gesture use may have predictive capacities for the emergence of children's EF abilities.

To understand the complex and dynamic relation between language and EF, early indicators, such as communicative gestures, are needed. However, the nearly exclusive focus on contemporaneous measurement and cross sectional designs (for exceptions see Fuhs & Day, 2010; Hughes, 1998) makes it difficult to pinpoint the degree to which language may influence EF throughout development, withholding the potential contribution from gesture. Intuitively, children's developing language skills reflect advances in their conceptual development, which in turn reflects changes in EF. Given the established associations between communicative gestures and language, as well as other cognitive abilities, gestures may also influence the relation between language and EF. Longitudinal research provides an ideal opportunity to more fully investigate how these abilities may emerge and influence each other over time.

The Current Study

The primary objective of this study was to determine whether individual differences in children's early communicative gestures (measured at 15 months) prospectively predict language development (measured at 2 and 3 years) and individual differences in EF (measures at 4 years). In addition to exploring bivariate associations, we also tested whether early indicators of language are directly related to subsequent EF and/or whether the relation between children's early gesture use and language development are directly and/or indirectly related to subsequent EF. We were also interested in determining whether children's communicative gestures are indirectly related to their later EF through "downstream" effects on subsequent language (e.g., the effect of communicative gestures and EF may be entirely mediated through subsequent language). In order to provide a more rigorous test of whether it is language development, per se, that predicts later EF, we also control for a number of potential confounders including early (infant/toddler) cognitive development, family income, and caregiver education.

In addition to testing the relations among variables, we were also interested in determining whether the developmental course of these relations was similar across economically diverse populations. Previous research has shown that poverty is negatively associated with mean level differences in child gesture use (Rowe & Goldin-Meadow, 2009), the quantity and complexity of vocabulary (Hoff, 2006; Raviv, Kessenich, & Morrison, 2004; Vernon-Feagans, Cox, Blair, Burchinal, Burton, Crnic, Crouter, … Willoughby, 2013), as well as EF skills (Blair & Razza, 2007; Raver, Blair, & Willoughby, 2013). Despite these mean differences, it is not clear whether the pattern of covariance between these relations would differ as a function of poverty. To capitalize on our unique sampling design (over-sampling of low income families), we conducted an exploratory test to determine whether the associations between gesture, language, and EF were invariant across poverty groups.

Method

Participants

The Family Life Project (FLP) was designed to study young children and their families who lived in two of the four major geographical areas of the United States with high poverty rates (Dill, 2001). Specifically, three counties in Eastern North Carolina and three counties in Central Pennsylvania were selected to be indicative of the Black South and Appalachia, respectively. The FLP adopted a developmental epidemiological design in which sampling procedures were employed to recruit a representative sample of 1292 children whose families resided in one of the six counties at the time of the child's birth. Low-income families in both states and African American families in NC were over-sampled (African American families were not over-sampled in PA because the target communities were at least 95% non-African American). Full details of recruitment are summarized elsewhere (Vernon-Feagans, et al., 2013).

Procedures

All data were collected during home visits, conducted by two experimenters, when children were approximately 15 months (*M* =15.7 months, *SD* = 1.3 months), 2 years (*M* = 24.8 months, *SD* = 1.8 months), 3 years (*M* = 37.0 months, *SD* = 1.7 months) and 4 years (*M* = 48.3 months, *SD* = 1.3 months) old. At the 15-month assessment, caregivers completed a checklist assessing children's communicative gestures and participated in a picture book activity with their child. A detailed description of the picture book activity is provided elsewhere (Vernon-Feagans, Pancsofar, Willoughby, Odom, Quade, & Cox, 2008). These two measures captured children's communicative gestures with both naturalistic (picture book) and standardized (checklist) methodologies. At the 2-year assessment, children were administered two tasks assessing EF and one standardized language assessment. At the 3-year assessment, children completed the same standardized language assessment. At the 4-year assessment an EF battery was administered. The full details regarding the administration rules, psychometric properties and scoring approach of the EF battery has been presented elsewhere (Willoughby, Wirth, & Blair, 2012).

Measures

Covariates—To account for both contextual and within-child factors that may also account for the association between language development and EF, household income, caregivers' education level and children's cognitive abilities were includes as 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/TANF, social security retirement, help from relatives, etc.). This total annual income was divided by the federal poverty threshold to create the family's income-to-needs ratio (INR). Income-to-needs ratios 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, averages of the income-to-needs ratios from the 15-month to 4-year assessments were 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 was 14.6 years (*SD* = 2.8 years), where 14 years reflected a high school diploma.

Bayley Scale of Infant Development: The Bayley Scale of Infant Development (BSID-II; Bayley, 1993) was administered at 15-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.

Parenting: Primary caregiver interactions were coded from a 10-minute free play activity at the 15-month assessment. Consistent with previous research from this sample, the seven global rating scales (Sensitivity/Supportive Presence, Detachment/Disengagement, Intrusiveness, Stimulation of Cognitive Development, Positive Regard, Negative Regard, and Animation; Cox & Crnic, 2002) were adapted from those used by the NICHD Study of Early Child Care (NICHD ECCRN, 1999). Coders rated parenting behaviors on a 5-point scale (where 1 = not at all characteristic and 5 = very characteristic). The subscales were combined to create overall Sensitive and Harsh-Intrusive composites. Only the Sensitive composite, which had acceptable inter-rater reliability (ICC = .89), was used in the current analyses. The Sensitive composite was used as a covariate to ensure that language measures were not a reflection of a more sensitive caregiving environment.

Communicative Gestures: Observed at 15 months

Picture Book Activity—Children's communicative gestures were recorded during a 10-minute wordless picture book activity with their primary caregivers, using the book *No, David* (Shannon, 1998). The book was modified so that the characters were racially ambiguous. All interactions were videotaped for subsequent offline coding. Trained research assistants observed the picture book activity from videotapes and coded the gestures into a transcript. Only gestures, such as point, nod, shake, shrug and give, which were used in the picture book task to communicate with caregivers, were coded. The gestures were selected based upon previous work by Rowe (2000) and the coding system has been described elsewhere (Abraham, Crais, Vernon-Feagans, & FLP Investigators, 2013). In the current analyses, only points (M = 2.80, SD = 4.15) and symbolic gestures (M = .28, SD = .96) were analyzed, because the picture book activity lent itself to pointing and there was a theoretical relevance from symbolic gestures. The transcript software Systematic Analysis of Language Transcripts (SALT; Miller & Chapman, 1985) was used to calculate frequencies for each type of gesture. On average, the inter-rater reliability for all gesture codes was acceptable (ICC= .90). Individual gesture reliability ranged from .74 to .99. Reliability was established by pairing each coder with a criterion coder and 60 transcripts were coded together.

Communicative Gestures: Parent Checklist at 15 months

Communication and Symbolic Behavior Scales Developmental Profile (CSBS; Wetherby & Prizant, 2002)—Communicative gestures were also measured using caregivers' report on the CSBS (Wetherby & Prizant, 2002). In the current analyses, only the Gestures subscale was used to capture children's gesture use and other subscales of communicative acts, like joint attention or oral language were excluded. Wetherby, Allen, Cleary, Kublin and Goldstein (2002) have examined the reliability and validity of the CSBS with a large sample of young children and found high reliability and validity.

Language Development: Standardized Measures at 2 and 3 years

***Preschool Language Scale 4th Edition* (PLS-4; Zimmerman, Steiner, & Pond, 2002)—**The PLS-4 is a norm-based measure of children's language skills, from birth to age 6. Only the expressive communication (EC) subscale of this assessment was administered. The EC subscale measured children's vocal development and social communication. Items

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administered at 2 years assessed rudimentary aspects of toddlers' expressive language, such as the ability to use vocalizations and gestures to request toys. Later items, administered at 3 years, required children to demonstrate a verbal understanding of language concepts, such as plural tense. Test-retest reliability for this age group has been found to be .82 for the EC subscale, and internal consistency estimates have been found to be .91 (Zimmerman et al., 2002).

Executive Function Tasks at 2 years

***Three boxes task* (Diamond, Prevor, Callendar, & Druin, 1997)—**Children were presented with three boxes of differing shape and color and were observed as the experimenter placed a sticker in each. The experimenter erected a barrier for five seconds while switching the location of the boxes, then removed the barrier and encouraged the child to find a sticker. The barrier and switching procedure was repeated until the child had retrieved all the stickers or made a total of 12 retrieval attempts. Number and location of attempts to retrieve the stickers were recorded.

***Snack delay task* (Murray & Kochanska, 2000)—**The experimenter placed a desirable snack (a cracker or small candy) underneath a transparent container and told the child to wait until she rang a bell before retrieving the snack. Four trials were completed: a 10-sec delay followed by 20-sec, 30-sec, and 45-sec delay trials. Children's responses were recorded as no wait = 0, partial wait = 1, and full wait = 2.

Executive Function Tasks at 4 years

Executive function was assessed with six tasks (administered in a fix order) that were specifically developed for young children. These tasks were designed to measure three dimensions of EF: working memory, inhibitory control, and attention shifting (Willoughby, Blair, Wirth, & Greenberg, 2010). The EF battery was developed from a theoretical perspective that supports an undifferentiated construct of EF in preschool aged children (Wiebe, Espy, & Charak, 2008). The child was tested using an open spiral bound flipbook and each task took approximately 5 minutes to administer. For each task, training and up to three practice trials were administered. The tasks were scored using Item response theory (IRT) models (for review see Willoughby, et al., 2012). This means the task scores can be interpreted on a z score metric, such that negative values indicate easy items, values near zero indicate average difficulty, and positive values indicate difficult items. Here, we provide an abbreviated description of each task.

The *Working Memory Span (WMS)* task required children to name and hold two pieces of information in mind simultaneously (i.e., naming an animal and color in a series of "houses"). Then, children had to activate one piece of information (i.e., recall the animal in each house), while overcoming interference from the other piece of information (i.e., the color in each house). Based on the work from Engle, Kane and colleagues (e.g., Kane & Engle, 2003), the task was scored by the number of colors or animals that children correctly recalled.

Pick the Picture (PTP) was adapted from a self-ordered pointing task (Cragg & Nation, 2007; Petrides & Milner, 1982) that assessed working memory. Children were shown an array of pictures that varied in location on a page and they were required to touch each individual picture in a series so that each picture “got a turn”. The task was scored by the number of series in which a unique picture was selected every time.

Silly Sounds Stroop (SSS) was derived from the Day-Night task developed by Gerstadt, Hong, and Diamond (1994) and assessed inhibitory control. Children were asked to make a bark sound when shown a picture of a cat and meow sound when shown a picture of a dog. The task was scored by the number of times children correctly paired the animal sound and picture.

Spatial Conflict Arrows (SCA) was similar to the Simon task used by Gerardi-Caulton (2000) and assessed inhibitory control. Children were presented a series of arrows pointing in alternating directions. While children respond to the initial set of items by touching a response card in the same position as the stimuli, the test items require a contra-lateral response. In other words, the stimulus is presented on the right side but pointing to the left and the correct response requires that the child touch the left side of his/her response card. In this way, the spatial location is no longer informative. The task was scored by the number of items children correctly responded based upon the direction of the arrows.

Animal Go No-Go (GNG) was a standard go no-go task (e.g., Durston, Thomas, Yang, Ulug, Zimmerman, & Casey, 2002). The task included varying numbers of go trials prior to each no-go trial, including, in standard order, 1-go, 3-go, 3-go, 5-go, 1-go, 1-go, and 3-go trials. No-go trials required inhibitory control. The task was scored by the number of items that children correctly responded or withheld responses.

Something’s the Same Game (STS) was derived from Jacques and Zelazo’s (2001) flexible item selection task. Children were required to shift their attention from an initial dimension of similarity to a new dimension of similarity. The task was scored by the number of items in which children correctly identified two unique similarities across three pictures.

Analytic Strategy

All research questions were addressed using structural equation models (SEM), where communicative gestures and EF were represented as latent variables (due to the availability of multiple indicators). Language and covariates were represented using manifest variables. Analyses proceeded in four steps. First, a measurement model was estimated to establish the magnitude of the unadjusted, bivariate associations between communicative gestures, language, and EF. Second, a SEM was estimated to test for direct and indirect effects of communicative gestures and language on later EF, adjusting for a number of potential confounds. Third, multiple groups SEM was estimated to test whether the set of direct and indirect effects in the total sample differed for children who resided in low and not-low income households. Initially, this involved simultaneously estimating the model for both groups. Subsequently, this model was re-estimated with the imposition of parameter constraints on paths relating the focal predictor variables (communicative gesture, language) to EF. Because these models were nested, a chi square difference test was used to test

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whether the imposition of constraints resulted in a significant decrement in model fit. Finally, alternative theories that may have also accounted for the development of EF were considered. All models were estimated using Mplus version 7 (Muthén & Muthén, 1998-2007), and took into account the complex sampling design (stratification, over-sampling of low income, in NC, and African American families). We used Hu and Bentler's (1999) recommendations (i.e., CFI > .95, RMSEA <= .05) as a guide for evaluating model fit, and chi square difference tests were performed using MLR adjustments (Satorra & Bentler, 2001).

Results

Sample Description

The current study used child variables assessed at the 15-month, 2-, 3-, and 4-year home visits. Families and children who participated in the 4-year assessment (N = 1,066) did not differ from those who did not participate in the assessment (N = 226) with respect to race, gender of the child, or being recruited in the low-income stratum. However, children of the families who participated in the 4-year assessment were more likely to reside in the state of Pennsylvania (34% vs. 42%, p = .03). Families and children who participated in the 3-year assessment (N = 1,123) did not differ from those who did not participate in the assessment (N = 169) with respect to state of residence, race of the child, or being recruited in the low-income stratum. However, children of the families who participated in the 3-year assessment were more likely to be female than children whose families did not participate (50% vs. 41%, $p < .05$).

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 norm-referenced assessments of language and cognitive abilities: Bayley MDI (M = 95.9, SD = 10.8) at 15 months, PLS-4 expressive communication at age 2 (M = 100.5, SD = 14.9) and 3 years (M = 98.0, SD = 15.7). On average, families reported an mean income-to-needs ratio (INR) of 1.9 (SD = 1.7), 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.

The correlations among all indicators are also presented in Table 1. Three points are noteworthy. First, the individual EF tasks at age 4 years were moderately correlated with measures of children's language (rs = .17 to .37) and weakly correlated with measures of communicative gestures (rs = .00 to .11). Second, the individual EF tasks at age 2 years were weakly to moderated correlated with language measures (rs = −.03 to .35) and with the individual EF tasks at 4 years (rs= −.04 to .24). Third, the language measures at ages 2 and 3 years were substantially correlated with each other (r = .57), and somewhat correlated with the communicative gesture variables (rs = .08 to .25).

Measurement Model

A measurement model was estimated to evaluate the bivariate correlations among the focal predictors (communicative gesture at 15 months, language at 2 and 3 years, and EF at 4 years). The measurement model fit the data well; χ^2 (40, *N*= 1117) = 60.30, *p* = .02, CFI = .98, RMSEA = .02. All of the factor loadings for the communicative gesture and EF latent variables were significant, as was the latent variances, which indicated inter-individual differences for these constructs. Individual differences in communicative gesture and language were positively inter-correlated from the ages 15 months through 3 years, and all three assessments were positively correlated with EF at age 4 years ($r/\phi >= .41$, $ps < .01$; see Table 2). That is, there were moderate to strong correlations for the latent communicative gesture with language at ages 2 years ($r = .49$) and 3 years ($r = .54$), as well as with latent EF at 4 years ($r = .41$). Further, 2 year language ($r = .53$) and 3 year language ($r = .64$) were also significantly correlated with latent EF.

Children's Communicative Gestures and Language Predicts 4 year EF

A SEM model was estimated to determine whether children's communicative gestures and language development were prospectively associated with later EF abilities after adjustment for potential confounder variables including primary caregivers' educational achievement, household INR, and children's early cognitive ability, as measured by the Bayley. As depicted in Figure 1, the structural model fit the data well; χ^2 (61, *N* = 1117) = 102.38, $p < .01$, CFI = .97, RMSEA= .03. Although communicative gestures were not directly related to EF ($\beta = -.04$, $p = .75$), they were directly related to language at 2 years ($\beta = .49$, $p = .00$) and 3 years ($\beta = .35$, $p= .00$). Moreover, communicative gestures were indirectly related to later EF through language at ages 2 and 3 years. Specifically, all paths were significant and the indirect effects of communicative gestures on EF were through language at ages 2 years ($\beta_{\text{gesture 2yr EF}} = .08$, $p = .01$), 3 years ($\beta_{\text{gesture 3yr EF}}= .14$, $p= .01$) and 2 and 3 years ($\beta_{\text{gesture 2yr 3yr EF}} = .08$, $p = .01$). Hence, the positive bivariate association between communicative gestures at 15 months and EF at age 4 years was entirely mediated through the effects of intervening language.

Language at age 2 years was directly related to language at age 3 years ($\beta = .41$, $p = .01$) and EF at age 4 years ($\beta =.17$, $p=.01$). Moreover, there was an indirect effect of 2-year language on EF expressed through 3-year language ($\beta_{\text{2yr 3yr EF}} = .17$, $p = .01$). Language at age 3 years was directly related to EF at age 4 years ($\beta = .41$, $p = .01$). Collectively, communicative gesture, language and covariates explained half of the variance ($R^2 = .50$, $p = .01$) in latent EF.

Multiple Groups: Low vs. Not-Low Income Groups

The next models tested whether the relations among children's communicative gestures, language and EF were equivalent across income groups. Two income groups were created by using a family's average INR from 15 months to 3 years. The low income group was defined as having an average INR of 2.0 or lower (*N* = 762), an INR of 2.0 is commonly used to index poor and near poor families. While, the not-low income group was defined as having an average INR greater than 2.0 (*N* = 343). First, a baseline model was estimated with all structural paths allowed to be free across low and not-low income groups. As shown

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in Figure 2, the model fit the data well; χ^2 (122, *N* = 1105) = 157.35, *p* = .02, CFI= .97, RMSEA= .02. Across income groups, there was not a significant direct relation between children's communicative gestures and EF. However, there were significant relations between communicative gestures and EF mediated by children's 2- and 3-year language. The amount variance explained in latent EF was also approximately equal for low income (R^2 = .43) and not-low income groups (R^2 = .50). The model was then re-estimated imposing equality constraints on all of the regression coefficients that linked language variables to each other and to EF across the two income groups. This model also fit the data well; χ^2 (128, *N*= 1105) =171.39, *p* = .01, CFI = .96, RMSEA = .03. However, the chi square difference test revealed that the model which imposed cross-group equality constraints resulted in worse model fit; χ^2 (6) = 12.45, *p* = .05. This was unexpected given that the general pattern of associations between language and later EF appeared to be comparable across income groups. A series of models were re-estimated imposing equality constraints on each regression coefficient, one at a time, to determine which path(s) might be significantly different across the two income groups. The only path that resulted in a significant difference was the path between language at age 2 years and EF; χ^2 (1) = 11.47, *p* =.01. This path was not significant (b = −.00, β = −.06, *p* = .58) for the not-low income group; however, it was significant for the low income group (b = .01, β = .27, *p* = .01). Although there was a difference in one individual path, the general pattern of relations between gestures, language and EF was similar across the two income groups.

Alternative Explanations to Communicative Gestures EF Model

We attributed the effects of communicative gestures as foundational for early language and subsequent EF. However, EF is also emerging early in life. Moreover, we may be misattributing effects to children's gesture use that are better characterized by parenting practices and language use that is indicative of caregivers' engagement. Here we test those possibilities by including two additional predictors. We considered an alternative model that included measures of EF at age 2 years and quality of parenting at age 15 months. This model also fit the data well; χ^2 (75, *N* = 1117) =154.55, *p* = .01, CFI = .95, RMSEA = .03. The relation between communicative gestures and EF, expressed through language skills, held even after controlling for parenting at age 15 months. The mediated relation through 2- and 3-year language was not impacted by the inclusion of EF at age 2 years. In fact, in this alternative model, the direct relation between age 2 years EF and age 4 years EF (β = −.05, *p* = .16) was not significant. There was, however, a significant indirect effect from age 2 year EF, expressed through 3-year language on EF at 4 years ($\beta_{2yr\ EF\ 3yr\ EF}$ = .03, *p* = .01). The additions of sensitive parenting and EF at age 2 years did not have meaningful impact on the relation between communicative gestures and EF, expressed through language.

Discussion

The purpose of the current study was to determine whether individual differences in children's early communicative gestures prospectively predicted language development and EF during early childhood. To explore this question, we analyzed longitudinal data from a diverse population using multiple indicators of gesture use (15 months), language development (2 & 3 years), and EF skills (2 & 4 years). The findings revealed that individual differences in communicative gestures at age 15 months predicted language development at ages 2 and 3 years, which in turn predicted EF skills at age 4 years. These interrelations were all positive, demonstrating that infants who used more gestures had better language and EF skills between the ages of 2 and 4 years. While the link between children's gesture use and language abilities has been well established (Acredolo & Goodwyn, 1990; Bates, et al., 1987; Iverson & Goldin-Meadow, 2005), these results demonstrate that individual differences in gesture use also forecast EF. It is important to note that these predictive associations were evident even after controlling for potential child (early general cognitive ability & EF), maternal (education & observed parenting), and household (INR) confounders.

The findings revealed that the positive association between early gesture use and later EF was mediated entirely by intervening language development. In spite of this, the relation between language and EF, with the inclusion of EF at 2 years, was more complicated. Children's 2-year language and EF were interrelated and both independently predicted language skills at age 3 years. However, children's EF skills at age 2 years did *not* predict their later EF, only children's language skills at ages 2 and 3 years prospectively predicted EF at age 4 years. Thus, the relation between children's EF skills at ages 2 and 4 years was completely mediated by 3-year language.

Considering these complex and dynamic associations, one interpretation of these findings is that children's gesture use is an early indicator of the cognitive abilities that later manifest themselves as EF. As such, the cognitive abilities (i.e., joint attention, referential attention, and symbolic understanding) demonstrated by children's use of gestures may be relevant for understanding the developing connection between later-emerging language and EF. Children's symbolic understanding may be particularly relevant, given that it has been previously described as a mechanism common to both gesture use (Blake, 2000) and vocabulary development (Bates, et al., 1979). It is possible that the representational skills that children develop through the use of symbolic gestures, later transitions into word learning for verbal communication, and then into the ability to manage multiple representations (de Villiers & Pyers, 2002) or conflicts (Zelazo & Frye, 1998), which is a skill essential for EF. At a minimum, a conservative interpretation of our findings is that gestures can be used to index language and language can be used to index EF.

However, an alternative and we think stronger interpretation of these findings is that children's early gesture use predicts language development, which ultimately allows children to think in more complex ways and to reflect upon information in different ways that support the emergence of EF. In this interpretation, it is not only that there are cognitive abilities common to gesture, language and EF, but rather that gesture supports language development, which in turn is foundational for the emergence of EF. Support for this alternative interpretation is provided by our findings indicating that a portion of the variance in EF at age 4 years is accounted for by communicative gestures and earlier language development, even after controlling for children's early general cognitive abilities. Our work supports the notion that early indictors of EF can be found in preceding preverbal and verbal communication skills. Specifically, children's communicative gestures are not only a means to improve performance during a cognitively-demanding task (O'Neill & Miller, 2012), but also the foundation by which language (Özçaliskan & Goldin-Meadow, 2005) and EF skills develop.

The possibility of a causal relation between language and EF, with language underlying EF, has also been suggested by Zelazo and colleagues (Marcovitch & Zelazo, 2009; Zelazo & Frye, 1998; Zelazo, et al., 2003). This notion is predicated on the idea that children must have the words to mentally represent the conditions of a problem before being able to create the hierarchical rule structure needed to solve that problem. Perhaps it is the growth in children's representational skills as they transition from using symbolic gestures, to building a vocabulary, and then to gaining proficiency with multiple-word phrases that influences the emergence of EF. For example, as children learn to distinguish the word "cat" from the word "dog", while simultaneously understanding that both labels belong under the category of animal, they are demonstrating the ability to organize symbols in a hierarchical manner (Hall & Waxman, 1993). Further, as children develop more advanced language skills by learning to apply morphological rules about word endings and syntactic rules that dictate word order (Rowe & Goldin-Meadow, 2008), they are gaining experience with rule use (Gelman & Markman, 1985). This understanding of rules, derived from the use of language, may translate to an enhanced ability to organize information. The ability to hierarchically organize information is needed for the cognitive process involved in EF like attention shifting and inhibitory control (Zelazo & Frye, 1998; Zelazo, et al., 2003). The specific mechanism by which a causal relation between language and EF occurs warrants further study.

Implications

The current findings indicate that there is a downstream effect of language, beginning with precursors to language like communicative gestures, on EF. This has implications for various types of research dealing with children's early cognitive development. For instance, research that examines brain development in relation EF may also need to consider regions of brain related to language and gesture. In one study, Moreno and colleagues (2011) found that a music intervention could improve both children's language and EF skills. Interestingly, through event-related potentials (ERP) procedures, the authors established that gains in preschoolers' verbal intelligence were positively associated with changes in functional brain plasticity during an EF task (Moreno, Bialystok, Barac, Schellenberg, Cepeda, & Chau, 2011). This work emphasizes that early brain development related to language acquisition may be a neural correlate of EF.

In addition to biological research, the current study also has implications for intervention research. Our findings highlighted the similarities in the process by which low and not-low income groups acquired EF. Other work has found that poverty has a negative impact on EF (Blair & Razza, 2007; Raver, Blair, & Willoughby, 2013), but that social contexts mediate this effect, specifically parental marital status, responsiveness and the quality of the home environment (Sarsour, Sheridan, Jutte, Nuru-Jeter, Hinshaw, & Boyce, 2011). There is extensive research suggesting that the relation between poverty and language is mediated by social contexts (Hoff, 2006; Huttenlocher, Vasilyeva, Cymerman, & Levine, 2002). Adding to this literature, our study suggests that there is an earlier window of opportunity for interventions focused on diminishing the effects of poverty. Other empirical research has already demonstrated that increasing children's gesture use improves language skills (McGregor, 2008). A similar intervention could be designed to help parents increase their children's gestures use, which in turn may improve later EF abilities.

Limitations and Future Directions

Although the current study has established novel longitudinal associations between gesture, language, and EF over the first 4 years, several important limitations must be noted. First, despite our inclusion of potential confounder variables, the passive longitudinal design undermined our ability to make strong statements regarding causal relationships between language and EF. Randomized controlled trials (RCTs) that provide interventions targeting early gesture use and/or language would provide stronger tests of these questions. In the absence of RCTs, the capitalization of natural experiments, for example examining children's proficiency in and age at which they acquire a second language (Bialystok, Craik, Grady, Chau, Ishii, Gunji, & Pantev, 2005), might also provide important insights into the role of early language development on later EF. Second, it is plausible that other early cognitive indicators contribute to the emergence of EF, including EF prior to age 2 years. A recent study has shown that reliable measures of EF skills can be assessed earlier (Bernier, Carlson, & Whipple, 2010). Third, the indicators of communicative gesture used in the current study might have been superior if drawn from a different type of task. For instance, the frequency of symbolic gesture use during the picture book activity was relatively low in the current study. This low rate of symbolic gesturing may be attributed to the fact that (1) picture book activities readily lend themselves to pointing as opposed to symbolic gesturing and (2) the emergence of symbolic gesturing does not typically occur until around age 18 months (Blake, 2000). As a result, future studies should investigate other early correlates of EF and alternative indicators of gestures.

Few studies have considered which early developmental processes may precede and potentially facilitate the normative acquisition of EF abilities in early childhood. This stands in stark contrast to the explosion of work focused on the early development and predictive validity of EF for school readiness. Thus far, only a small number of child characteristics have been explored in relation to EF, with temperament being the most prominent (Rueda, Posner, & Rothbart, 2005), as well as examinations of parenting and child stress physiology as influences on EF (Bernier et al., 2010; Vernon-Feagans et al., 2013). It is important to consider the various other factors that may also influence the development of EF. Early language skills and gestures are other examples of correlates that may enrich our understanding of the development of EF and provide an opportunity for intervention.

The current study makes an important contribution to our understanding how language may enable a certain type of thought that provides for the emergence of higher-order cognitive abilities, like EF. In particular, our findings revealed that infants' preverbal communication (i.e., gestures) contributes to the relation between language and EF in meaningful ways. While scholars will continue to debate how language influences cognitive abilities and seek to identify other precursors to EF, we are the first to provide evidence for the predictive capacities of language for EF.

Acknowledgments

Support for this research was provided by the National Institute of Child Health and Human Development grants R01 HD51502 and P01 HD39667, with co-funding from the National Institute on Drug Abuse. The Family Life Project (FLP) Phase I Key Investigators include: Lynne Vernon-Feagans, The University of North Carolina; Martha Cox, The University of North Carolina; Clancy Blair, The Pennsylvania State University; Peg Burchinal, The University of North Carolina; Linda Burton, Duke University; Keith Crnic, The Arizona State University; Ann Crouter, The Pennsylvania State University; Patricia Garrett-Peters, The University of North Carolina; Mark Greenberg, The Pennsylvania State University; Stephanie Lanza, The Pennsylvania State University; Roger Mills-Koonce, The University of North Carolina; Emily Werner, The Pennsylvania State University and Michael Willoughby, The University of North Carolina. We would also like to thank Kathleen Gallagher, Vrinda Kalia and the Wild Writing Group for their helpful comments on the manuscript.

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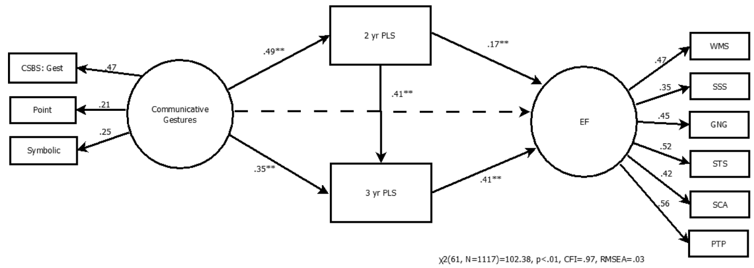

Figure 1.

Structural Model of Communicative Gestures Predicting EF

Note: Covariates of caregivers' educational achievement, household income-to-needs ratio, and children's early cognitive ability were included but not represented in the figure. WMS=Working memory span, SSS=Silly sound stroop, GNG=Go no-go, STS=Something's the same, SCA=Spatial conflict arrows, PTP=Pick the picture, PLS=Preschool Language Scale, CSBS=Communication and Symbolic Behavior Scales, EF = Executive Functioning

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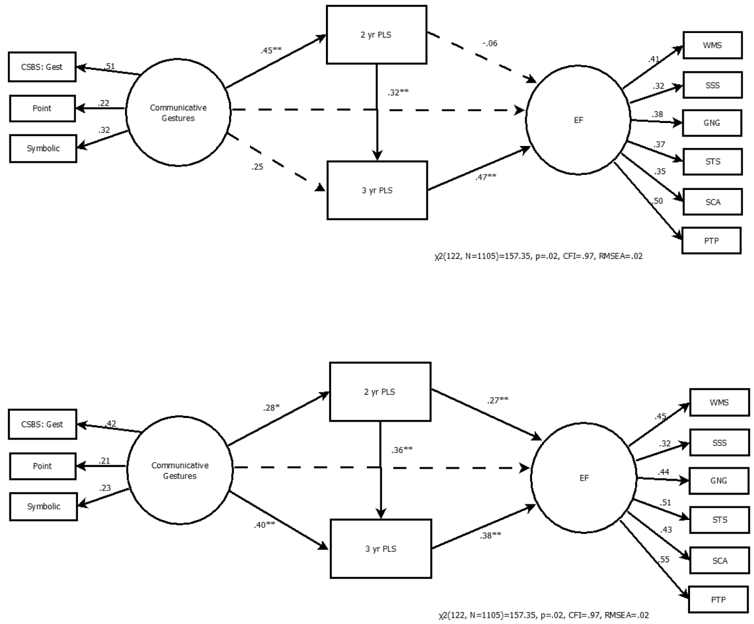

Figure 2.

Unconstrained model: Not-Low (Top) and Low-Income (Bottom) Group

Note: Covariates of caregivers' educational achievement and children's early cognitive ability were included but not represented in the figure. WMS=Working memory span, SSS=Silly sound stroop, GNG=Go no-go, STS=Something's the same, SCA=Spatial conflict arrows, PTP=Pick the picture, PLS=Preschool Language Scale, CSBS=Communication and Symbolic Behavior Scales, EF = Executive Functioning

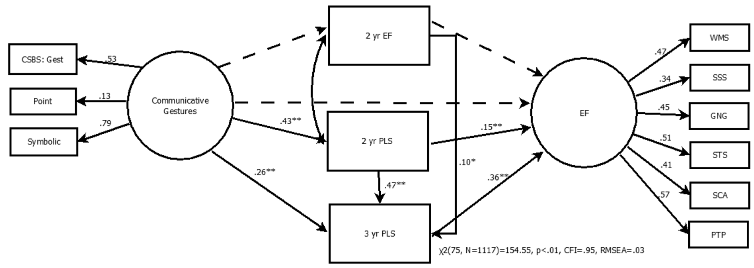

Figure 3.

Alternative Explanations Model

Note: Covariates of caregivers' educational achievement, household income-to-needs ratio, children's early cognitive ability, and sensitive parenting were included but not represented in the figure. WMS=Working memory span, SSS=Silly sound stroop, GNG=Go no-go, STS=Something's the same, SCA=Spatial conflict arrows, PTP=Pick the picture, PLS=Preschool Language Scale, CSBS=Communication and Symbolic Behavior Scales, EF = Executive Functioning

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Table 1

Intercorrelations Between Variables

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1. WMS	-																
2. SSS	.12	-															
3. GNG	.22	.20	-														
4. STS	.23	.19	.17	-													
5. SCA	.18	.08	.13	.28	-												
6. PTP	.27	.19	.29	.27	.23	-											
7. CSBS	.10	.06	.08	.11	.08	.10	-										
8. Point	-.01	.00	.01	.03	.03	.04	.07	-									
9. Gest	.08	.07	.04	.04	.04	.07	.06	.18	-								
10. 2yr PLS	.25	.17	.21	.32	.22	.26	.23	.09	.08	-							
11. 3yr PLS	.30	.18	.25	.35	.29	.36	.25	.11	.09	.57	-						
12. MDI	.26	.18	.23	.26	.20	.22	.25	.08	.14	.42	.44	-					
13. Edu	.24	.08	.07	.25	.18	.22	.06	.01	.07	.25	.37	.21	-				
14. INR	.19	.03	.12	.21	.19	.20	.08	.00	.02	.23	.37	.23	.55	-			
15. 15m Parent	.23	.06	.13	.21	.18	.18	.07	.03	.13	.19	.27	.22	.38	.33	-		
16. 2yr Boxes	−.14	−.04	−.04	−.10	−.09	−.11	−.09	−.03	−.06	−.06	−.12	−.09	−.07	−.07	−.06	-	
17. 2yr Snack	.13	.13	.12	.16	.09	.24	.11	.11	.09	.25	.35	.19	.18	.14	.19	−.11	-
Mean (SD)	−0.2 (.8)	−0.1 (.8)	−0.3 (.8)	0.01 (.7)	0.1 (.9)	−0.4 (.9)	8.1 (2.0)	2.8 (4.2)	.3 (1.0)	100.5 (15)	98.0 (15.8)	95.9 (10.7)	14.6 (2.8)	1.8 (1.4)	3.4 (.7)	.01 (1.5)	−.01 (.7)
Range	−1.7 – 1.84	−2.0 – 1.41	−2.0 – 0.85	−2.1 – 1.48	−1.7 – 1.71	−2.5 – 2.25	0-10	0-30	0-14	50 – 148	50 - 150	59 - 132	6 - 22	0-12.4	0-5	1-12	0-2

Note: WMS=Working memory span, SSS=Silly sound stroop, GNG=Go no-go, STS=Something's the same, SCA=Spatial conflict arrows, PTP=Pick the picture, PLS=Preschool Language Scale, CSBS=Communication and Symbolic Behavior Scales, MDI=Mental Developmental Index, Edu=Education, INR= Income-to-needs ratio, Parent=Sensitive parenting, Boxes=Six boxes, Snack=Snack delay

Table 2

Latent Correlations

	1	2	3	4
1. Communicative gestures (15 M)	-			
2. Language (2 year)	.49**	-		
3. Language (3 year)	.54**	.58**	-	
4. Executive function (4 year)	.41**	.53**	.64**	-

Note: M = months;

** = p < .01