The Influence of Gesture and Early Language on the Emergence of Executive Function during Childhood

Laura Jean Kuhn

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Approved by:

Michael Willoughby
Kathleen Gallagher
Julie Ellison Justice
Jeffrey Greene
Lynne Vernon-Feagans
ABSTRACT

LAURA JEAN KUHN: The Influence of Gesture and Early Language on the Emergence of Executive Function during Childhood
(Under the direction of Lynne Vernon-Feagans, Ph.D.)

The current study examined the relations among children’s gestures, language, and EF across the first 4 years of life. The study was specifically interested in determining whether children’s gestures, representative of their early symbolic development, were related to their language skills and if these abilities were predictive of later EF capacities. Utilizing longitudinal data from the Family Life Project, the study used both specific and general models to examine relations between children’s gestures, language skills at 24 and 36 months, and in turn EF. The models depicted both naturalistic observations and standardized assessments of infants’ gestures at 15 months, and language skills at 24 and 36 months. The findings revealed that both observed (specific model) and standardized (general model) measures of children’s gestures, and language skills had a significant association with later EF. As predicted, the study found a mediated relation between children’s gestures and later EF abilities, expressed through their language skills. Thus, the findings provided evidence in support of several developmental theories (Marcovitch & Zelazo, 2009; Zelazo & Frye, 1998; Zelazo, et al., 2003) that have highlighted the importance of children’s language abilities in representing the conflict inherent to EF tasks.
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CHAPTER ONE

Introduction

The preschool years are marked by the excitement of children learning to communicate with others, regulate their emotions, and solve problems. This means children can begin to tell caregivers how they feel and what they want, they also learn to perform goal-oriented tasks like feeding and dressing themselves. In addition to this self-care, during preschool children learn to delay their immediate desires in order to follow the rules of their classrooms. This co-development of language skills and executive function (EF) abilities are hallmarks of early childhood. Executive function is defined as self-regulatory abilities that control the cognitive processes used to achieve goal-oriented problem solving (Isquith, Crawford, Espy, & Gioia, 2005). Researchers have long recognized the individual contributions of language (Cohen & Mendez, 2009; Gallagher, 1999; Howes, & Matheson, 1992) and EF (Carlson, Mandell, & Williams, 2004; Diamond, Barnett, Thomas, & Munro, 2007; Zelazo, Muller, Frye, & Marcovitch, 2003), and their similar developmental timelines (Best & Miller, 2010; Garon, Bryson, & Smith, 2008; Golinkoff & Hirsh-Pasek, 1990; Hoff, 2006; Reznick & Goldfield, 1992). Less is known about the relation between these cognitive abilities and a potential mechanism, symbolic representation, which may be driving their development.

Understanding Symbolic Representation in the Service of Other Cognitive Abilities
At 15 months of age children begin to use *symbolic representation* (Bates, Bretherton, Synder, Shore, & Volterra, 1980), which serves as the foundation for several cognitive processes that continue to develop throughout the preschool years. Symbolic representation is the ability to understand that symbols stand in for, or are used to reference, objects and ideas that are not physically present. This ability is a general cognitive process that contributes to the maturation of a diversity of skills, such as referential understanding, language, and working memory (Bates, 1979; Piaget, 1962; Werner & Kaplan, 1963). Several studies have suggested that symbolic representation is first observed through children’s use of communicative gestures (Bates, O’Connell, & Shore, 1987; Blake, 2000). This line of research indicates that the basis of symbolic representation occurs even before children are capable of productive speech. Perhaps the advances children make in symbolic representation, when they begin to use communicative gestures, are the mechanism driving later language development (Bates, et al., 1980; Blake, 2000) and higher order thinking. Indeed, past research has demonstrated that children’s gesturing predicts later vocabularies (Bates, et al., 1987; Bates, Thal, Whitesell, Fenson, & Oakes, 1989; Blake, 2000). Acredolo and Goodwyn (1990) have argued that gesture and spoken language begin as two separate systems that can only become integrated when children realize the relevance of symbols for communication.

However, children’s use of symbolic representation to advance language development is only one example of its importance. In general, children’s ability to use symbols is crucial for cognition because it allows for psychological distancing (Sigel, 1993). Psychological distance is an important skill because its development allows
children to achieve a greater level of mental abstraction through reflection. When using language, increases in abstraction are demonstrated through children’s application of rules to multiple word utterances. These language rules are necessary to express the relations between words. For example, to express ownership children will say *my bottle*. It is this ability to use symbols that represent the concepts of *bottle* and *mine* that may be foundational for children’s higher order cognitive skills such as, EF. Specifically, it has been suggested that symbolic representation via children’s reflection (Zelazo, et al., 2003) is a prerequisite for implementing the hierarchical rule structure that denotes EF ability.

**Associations between Preschoolers’ Language and EF Abilities**

Although the role of symbolic representation in the development of higher order cognitive skills is not well understood, a relation between language and EF has been established in the literature. A number of studies have documented the positive association between children’s language skills and performance on EF tasks (Fuhs & Day, 2010; Karbach & Kray, 2007; Kirkham, Cruess, & Diamond, 2003; Kray, Eber, & Karbach, 2008; Kray, Eber, & Lindenberger, 2003; Muller, Zelazo, Lurye, & Liebermann, 2008; Muller, Zelazo, Hood, Leone, & Rohrer, 2004). The development of language and early EF abilities are major cognitive milestones children achieve during the preschool years. To illustrate this co-occurrence, the average two-year-old has a vocabulary of 300 words (Fenson, Dale, Reznick, Bates, & Thal, 1994) and performs better on an EF sorting task when asked to use this limited vocabulary to verbally sort pictures, as opposed to physically sorting them (e.g., “Is this something you ride or something that can play music?”; Zelazo, Reznick, & Pinon, 1995). Further, select
studies show that when children use verbal labels their EF performance is improved (Garon & Moore, 2007; Kirkham, et al., 2003; Muller, Zelazo, & Imrisek, 2004). Yet, the particulars of how this relation between language and EF develops are unclear.

For instance, results contrary to the positive association between children’s expressive language and performance on EF tasks have also been found (Hughes, 1998a; Lang & Perner, 2002; Muller, et al., 2005; Perner, Kain, & Barchfeld, 2002). At a minimum, this work indicates that the association between language and EF is more nuanced than an additive relation. Demonstrating this complexity between children’s language skills and EF, several studies have found that the use of labels in an EF task can actually hinder children’s performance (Brace, Morton, & Munakata, 2006; Muller, et al., 2008; Yerys & Munakata, 2006). Researchers have suggested that some facility with language is required before children can use labels to scaffold their performance (Muller, et al., 2008; Yerys & Munakata, 2006); otherwise labels may actually impede performance on EF tasks.

Perhaps a more nuanced perspective on the co-development of children’s language and EF, one that focuses on symbolic representation, could illuminate the direction of the relations between them. A limitation common to the majority of the current literature is that measures of children’s language and EF are concurrent. Although these studies have been informative, this methodological design makes it impossible to determine the direction of the relation between language and EF. Theoretical work by Zelazo and his colleagues (Zelazo & Frye, 1998; Zelazo, et al., 2003) holds that the maturation of EF is dependent upon children’s ability to symbolically represent the conflicting conditions present in an EF task. This suggests that children may use language
to create the symbolic representation of these conditions, and thus could be foundational for EF abilities. Language allows for conscious reflection and increases children’s chances of responding correctly in an EF task (Marcovitch & Zelazo, 2009). In support of this notion, the two longitudinal studies that have examined language and EF found previous language ability does contribute to children’s later EF performance (Fuhs & Day, 2010; Hughes, 1998b). Yet, more research is needed to clarify this relation and to consider the possibility that communicative gestures, a precursor to spoken language (Iverson & Thelen, 1999; McNeill, 1992), may also be associated with later EF abilities.

**Identifying Precursors to EF through a Cognitive Developmental Framework**

Although the interplay between the co-development of language and EF is not well understood, an abundance of research has investigated EF and its correlates during early childhood. This interest is understandable given EF’s connection to important childhood outcomes, such as academic and social success (Blair & Peters, 2003; Qi & Kaiser, 2004; McLean & Hitch, 1999). Given the importance of EF for children’s development, it is surprising that its precursors have yet to be identified. There are several potential explanations for the hesitation in linking EF and children’s language abilities, both gestural and verbal. First, from a theoretical perspective; existing research has failed to identify a cognitive underpinning that is common to both the development of language and EF. I argue that symbolic representation may be this underlying mechanism and examine how it develops from (1) basic representation to (2) abstraction and then (3) rule use. This progression is observed via children’s gestures, vocabularies, and early multiple word utterances. Second, most studies have design issues making it difficult to determine the directionality of the relation between language and EF such as, (1) the use
of concurrent measurements and (2) standardized measures of communication that are limited to receptive language. These limitations will be addressed in the current study by examining the longitudinal relations between gestures, language, and EF between 15-and 48-months of age. Specifically, I propose an indirect relation between children’s gestures and EF abilities, by which the influence of gestures on EF is through language skills.

**Defining Executive Function**

Executive function is an umbrella term used to refer to the integration of several neurological subprocesses. In a review of the adult literature, Miyake and colleagues (2000) established the subprocesses of mental set shifting, working memory, and inhibitory control (inhibition of prepotent responses) as components, or factors, of a unified EF construct. *Set shifting* or *attention shifting* is the subprocess of shifting attention from one mental set to another. However, these subprocesses may look different in children than they do in adults; therefore, age appropriate measures are critical for defining the subprocesses. For children, measures of attention shifting assess the ability to shift focus from an initial association to a secondary one that is in conflict with the first association (Davidson, Amso, Anderson, & Diamond, 2006). The second subprocess is *working memory*. Children use working memory to hold information in short term memory for the modification of their behaviors in goal-oriented activities (Baddeley, 1992; Garon, et al., 2008). The final subprocess, *inhibitory control* is the ability to withhold a previously reinforced or automatic response (Garon, et al., 2008). For children, inhibitory control can be assessed in both simple and complex tasks. In simple inhibition tasks, children are required to suppress a dominant response.
inhibition tasks not only require the inhibition of a dominant response, but also a response to a secondary association over the initial dominant one (Garon, et al., 2008).

The differences among these subprocesses are not relevant during early childhood, because EF is not fully maturated and the more complex components (e.g., planning and the evaluation of solutions) are still undifferentiated (Friedman, Haberstick, Willcutt, Miyake, Young, et al., 2007; Friedman, Miyake, Young, DeFries, Corley, et al., 2008; Huizinga, Dolan, & van der Molen, 2006). The neural circuitry underlying EF also supports this undifferentiated conceptualization during the first years of life because of the lengthy development of the prefrontal cortex (Lenroot & Giedd, 2006). Therefore, this undifferentiated skill set, which eventually becomes adult EF, may best be understood as a group of cognitive skills used for the goal of solving problems (Zelazo, Carter, Reznick, & Frye, 1997).

Problem solving has generally been agreed upon as key to defining EF (Shallice & Burgess, 1996). The essential cognitive skills that children utilize to accomplish goals are the deployment and coordination of working memory, inhibitory control, and set shifting abilities. For example, almost every EF task requires children to hold instructions in their memory, make plans, and monitor their performances for errors, all with the goal of meeting the parameters of a specific task. This suggests that understanding the individual contributions of the subprocesses is not as valuable as understanding how they are deployed for the purpose of solving a singular problem. In accordance, the current study adopted an undifferentiated, single factor conceptualization of EF. Recent literature (Hughes, Ensor, Wilson, & Graham, 2010; Wiebe, Sheffield, Nelson, Clark, Chevalier, et al., 2011; Willoughby, Blair, Wirth, & Greenberg, 2010) has also supported this single
factor conceptualization, which manifests itself in observable actions taken by children to solve problems.

**Correlates of Executive Function**

Executive function in early childhood is an important area of study because it plays a vital role in multiple domains of development, including theory of mind (Hughes, 1998; McEvoy, Rogers, & Pennington, 1993), social-emotional development (Carlson, et al., 2004; Hughes & Enson, 2007), and academic achievement (Bull & Scerif, 2001; Diamond, et al., 2007; Espy, Bull, Martin, & Stroup, 2006). In fact, EF has shown to be more relevant for school readiness than children’s intelligence quotient (IQ) (Blair & Razaa, 2007). During early childhood there is a particular interest in children’s ability to make a successful transition to school, and it is not surprising that preschoolers’ ability to regulate their emotions and focus attention helps to determine their level of school readiness (Blair, 2002). For example, children’s inability to follow directions was the most frequently rated behavior problem by teachers (Rimm-Kaufman, Pianta, & Cox, 2000). Preschoolers’ ability to regulate their behavior was also predictive of grade school literacy, vocabulary, and math achievement (McClelland, Cameron, Connor, Farris, Jewkes, et al., 2007). Likewise, Blair and Razza (2007) found that preschool and kindergarten students’ self-regulation, as measured by performance on EF tasks, accounted for significant differences in mathematics and letter knowledge. Overall, early EF abilities continue to predict children’s math and reading achievement throughout the primary school years (Gathercole, Pickering, Knight, & Stegmann, 2004).

In addition to academic performance, EF is also associated with children’s brain development, specifically in the *prefrontal cortex (PFC)*. The PFC is responsible for
transforming thoughts into actions and meeting internal goals (Miller & Cohen, 2001); meeting goals is a defining component of EF. For adults who have sustained PFC damage, there is a significant impairment to performance on tasks that measure top-down processing (Cohen & Servan-Schreiber, 1992; Luciana & Nelson, 1998). In order to successfully complete a top-down EF task, one must be capable of following contrasting or embedded rules (e.g., inhibiting a dominate response or demonstrating rule flexibility).

Not as much is known about PFC damage in children. Studies that have examined children’s PFC development typically use behavioral measures with reliable neural correlates. These studies have shown a consistent association between the age-related development of the PFC and improved performance on EF tasks (Casey, Trainor, Orendi, Schubert, Nystrom, et al., 1997; Luciana & Nelson, 1998; Posner & Rothbart, 1998). This relation between EF abilities and the maturation of the PFC confirms the need for an ability to represent the conditions of a problem before being able to plan the actions for solving that problem.

The Development of Executive Function

As suggested by its relation to early brain development, the antecedents of EF can be traced back into infancy. The A-not-B paradigm is a frequently used measure to assess EF-like abilities during infancy. This task requires infants to search for a hidden object in multiple locations. Diamond (1985; Diamond, Cruttenden, & Neiderman, 1994) has suggested that successful performance on this task requires some components of EF. The most common type of error made by infants, between the ages of 8-and 12-months, is a perseveration on the first hiding location (Diamond, 1990; Marcovitch & Zelazo, 1999). However, older infants no longer committed this preservative error (Marcovitch &
This achievement to override an innate response, in the A-not-B paradigm, demonstrates that the growth in EF abilities occurs throughout infancy.

Upon reaching the preschool years, EF undergoes rapid developmental change (Carlson & Moses, 2001; Sabbagh, Xu, Carlson, Moses, & Lee, 2006), and this growth is illustrated by children’s performance on the Dimensional Change Card Sort (DCCS). In the DCCS, children are presented with a series of cards that have colored pictures, such as a red flower. Children are asked to sort the cards according to two conflicting rules, when the sort “rule” is to sort by color the red flower card goes in the red tray. In later trials, the sort “rule” will switch and children will need to sort by shape rather than color. Three-and four-year-olds typically perseverate on the initial sort rule, but this perseveration decreased with age (Carlson, 2005; Zelazo, et al., 2003). Meanwhile, five-year-olds easily switched between the two set of conflicting rules (Frye, Zelazo, & Palfai, 1995). The DCCS is frequently manipulated to lessen the demands of the task. For example, in a no conflict version four-year-olds lost the advantage they had over three-year-olds in the DCCS (Zelazo, et al., 2003). These differences in children’s performance highlight the incremental changes in EF ability between the ages of three and five years.

As demonstrated by research with the DCCS, much attention has been paid to changes in children’s EF abilities over the preschool years (for review see Best & Miller, 2010). Further, a developmental timeline for the maturation of the subprocesses associated with EF has been established (Carlson, 2005; Carlson & Moses, 2001; Luciana & Nelson, 1998; Luciana, Gunnar, Davis, Nelson, Donzella, et al., 2005; Sabbagh, et al., 2006). However, despite the numerous measures of EF for preschoolers, we still know relatively little about precursors to EF. That is, what prior maturational experiences make
it possible for EF to emerge and develop quickly between the ages of three and five years? Answers to this question can be gleaned from theories of EF development.

Theories of EF Development

Cognitive Complexity and Control Theory

Zelazo and colleagues’ Cognitive Complexity and Control theory (CCC theory; Zelazo & Frye, 1998; Zelazo, et al., 2003) is the guiding framework for the current study’s examination into a common underpinning influencing the development of children’s language and EF. To understand how the CCC theory operates, a conceptual view of EF that contains four distinct phases must be adapted. In the first phase, a mental representation of the problem is created; in phase two, children evaluate potential solutions or devise a plan; in phase three, children execute their plan; and finally, in phase four the plan is evaluated for errors or success (Zelazo, et al., 1997; Zelazo & Frye, 1998). The CCC theory assumes that children’s plans or actions are based upon their mental representation of rules needed to solve the problem (Zelazo, Frye, & Rapus, 1996), and it is language that helps children to construct these representations.

According to the CCC theory, children’s language plays a foundational role in the development of EF because it allows for reflection on the contradictory rules of a problem, and the distance to evaluate potential solutions. For example, children may use self-directed speech to represent the appropriate conditions under which taking an action to solve a problem is appropriate (e.g., “This is a red flower and we are playing the color games; therefore, I should put the card in the red tray”). Zelazo (1999) argues that children’s decisions to take specific actions are dependent upon their ability to use labels to create a conscious representation of a problem. Zelazo and Frye (1998) explain,
“When children acquire the ability to reflect on the rules they represent, they become able to consider them in contradistinction to other rules and embed them under higher order rules” (p.122). In other words, language is a prerequisite for children to represent rules and the potential conflict between them. The current examples have examined situations where children use language to simultaneously scaffold their performance on an EF task. Since the current study is interested in precursors to EF, it is also necessary to understand how EF develops before children have the ability to use speech for scaffolding their performance.

Hierarchical Competing Systems Model

To understand how language may be used to bolster EF performance before children are capable of self-directed speech, I turn to the Hierarchical Competing Systems Model (HCSM; Marcovitch & Zelazo, 2009). The HCSM was proposed to specifically explain the emergence of early EF. This model is not in competition with the CCC theory, but rather augments it by providing a framework for understanding EF in younger children. The HCSM highlights the inter-connections between associative learning, conscious reflection, and language acquisition during first two years of life. The model proposes children’s early cognition processes arise from a habit system, based solely on infants’ previous experiences, but then transforms into a representational system that allows for conscious reflection. The HCSM suggests that 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). Specifically, children have a greater likelihood of overriding a prepotent response (i.e. moving to the representational system) when reflection occurs. This pivotal activation of the representational system
occurs when children have the ability to verbally label or represent the conditions of a problem.

**Integrating the CCC Theory and the HCSM**

Similar developmental changes have been suggested by the CCC theory. For example, Zelazo and his colleagues theorize that EF evolves as children’s maturation allows for increased awareness in applying rules and complexity in planning. That is, there are developmental changes in children’s abilities to apply rules. Similar to the progression proposed by the HCSM, Zelazo (1999) has demonstrated that two-year-olds can only use a single excitatory rule, where three-year-olds begin to use pairs of rules, and five-year-olds can differentiate between pairs of embedded rules. Over the course of early childhood, transitions in EF occur when children gain representation skills, which allow for more complex rule use. The HCSM suggests that it is language that allows children to move away from a habit system to this type of representational system.

A review of these developmental theories highlight two possible components of children’s cognition that are necessary for understanding how EF abilities emerge into a problem solving, representational rule system. The first component is symbol use. As Zelazo (1999) explains, children need to be capable of representing or labeling a condition before they have the capacity to act upon it. Likewise, Marcovitch and Zelazo (2009) highlight that it is the ability to create psychological distance that makes it possible for children to override prepotent responses. Often it is use of a symbol that allows children to create this type of psychological distance (Carlson, Davis, & Leach, 2005). The second component is rule use. As children begin to label the conditions of a problem, the only way for them to resolve conflict or express relationships between
conditions is to establish rules (Zelazo & Frye, 1998). Both symbol and rule use may have their roots in language and are part of a larger common cognitive underpinning known as symbolic representation. Children demonstrate growth in symbolic representation through their use of gestures, building of vocabularies, and creation of multiple word utterances.

**Symbolic Representation through Gesture**

It has been argued that children demonstrate their understanding of symbols beginning at 10 months of age (Bates, et al., 1976; Folven & Bonvillian, 1991). This early understanding is first established through manual gestures, and by 15 months children are beginning to understand symbolic representation (Bates, et al., 1980). Children’s achievement of symbolic representation is crucial for understanding how gestures are related to other cognitive abilities, such as EF. Bates (1976) proposes that early gestures are children’s initial attempts to communicate with caregivers. Most often, these early gestures are classified as being from one of two common categories: deictic or symbolic. **Deictic gestures** are typically comprised of three different types of context specific gestures (i.e., pointing, giving, and showing). These deictic gestures are often used to draw a caregiver’s attention to a particular object with the intent of communicating a want or desire (Bates, et al., 1987). While these deictic gestures clearly demonstrate communicative intent on behalf of the toddler, these gestures are not symbolic because they are only understandable if produced in the presence of the particular object or referent.

Although not symbolic in nature, deictic gestures are still essential for children’s early language development. For example, Bates and colleagues (1987) contend that
children initially produce giving and showing gestures to elicit attention. But, quickly children begin to use communicative pointing to gain and maintain their caregivers’ attention to a particular referent. This type of communicative pointing is pivotal to language development because it demonstrates children’s first clear attempt at reference (Bates, et al., 1987; McNeill, 1992). This type of early pointing is an example of referential understanding and highlights the uniqueness of points, because its purpose is to both identify an object and bring it to the attention of another person. Arguably, this type of referential pointing is essential for language in that it lays the foundation by which symbolic representation is acquired (Bates & Elman, 2000). When children use communicative pointing it is intuitive for caregivers to respond with a label for that object (Goldin-Meadow, Goodrich, Sauer & Iverson, 2007), and this process highlights how children’s gestures can become representative of an object.

**Symbolic Gestures**

Symbolic representation is best demonstrated by children when they begin to use the second category of early gestures, *symbolic gestures*. Symbolic gestures are both communicative and representational, but unlike deictic gestures they are differentiated from their original context and can be used without the presence of an object (Acredolo & Goodwyn, 1990). An example of a symbolic gesture is when children place their pinky finger and thumb to the side of their head to pretend to talk on the telephone. Using this type of gesture to represent an object, which is not present, is an important developmental milestone because it indicates that the child has acquired an understanding of symbolic representation (i.e., that a gesture can *stand for* or *represent* a referent). This representational understanding is only demonstrated when the symbolic gesture is
decontextualized from the referent and used across a variety of situations (Blake, 2000). Thus, children’s progression from early non-symbolic giving and showing gestures, to pointing, and then symbolic gestures, reflects growth in children’s symbolic representation (Bates, et al., 1980). While children’s deictic gestures, such as communicative points, may illicit labels from a caregiver, there is a clear developmental transition when children themselves begin to produce symbolic gestures.

**Vocabulary: Moving from Basic Representation to Abstraction**

The referential nature of these more advanced gestures emphasizes the representational progression from children’s manual gestures to spoken labels, because of the link between a symbolic gesture and a word. On average, three months after children first produced a symbolic gesture they spoke the corresponding word for that object (Goodwyn & Acredolo, 1993). Blake (2000) argues that there is indeed a common underpinning driving the development of both spoken words and manual symbolic gestures. She theorizes that this mechanism is mental or symbolic representation. For example, Goldin-Meadow and colleagues (2007) have found approximately 75% of children’s early vocabulary occurred first in gestural form. These findings highlight not only the association between children’s gestures and later vocabulary, but also the possibility for the maturation of symbolic representational to explicate this association.

Children’s use of symbolic gestures and the building of a lexicon follow a similar maturational process. Children’s first words are often initially rigid or context specific, which means children only use new words in a particular context (Barrett, 1995; Caselli, Bates, Casadio, & Fenson, 1995). This use of words indicates children have mastered a basic representation but have yet to move to abstraction, where a word can be used across
a variety of contexts. For example, children may use the word “car” to refer to a particular toy car, but they do not yet generalize the word “car” to their families’ automobile. With experience children become more advanced and learn to decontextualize the word “car” across many contexts, including their families’ automobiles (Barrett, 1995; Caselli, et al., 1995). This process of using increasingly advanced or abstract representation is similar for the development of both symbolic gestures and spoken words. Just as children must learn that a telephone gesture can be used to communicate about a toy phone or Mommy’s cell phone, they must also learn that the word “telephone” can stand in for its referent across a variety of contexts (Golinkoff, Mervis, & Hirsh-Pasek, 1994). Children’s communicative progression from gestures to a spoken lexicon suggests that once they have the ability to understand and use symbols, words quickly follow. This ability to use symbols in an increasingly abstract fashion marks the transition into the next phase of development in symbolic representation.

Children’s development of symbolic understanding is arguably the largest influence on children’s rapid lexicon development (Acredolo & Goodwyn, 1990; Bates, et al., 1980; Blake, 2000). The decontextualization of a word, or the symbolic mapping of a word onto an object, may initially be slow for children but as they develop a lexicon it becomes rapid. In a longitudinal study, Nelson and colleagues (1973) found an increase in lexicons for children who had a larger portion of general labels, rather than specific, among their 50 first words. General labels refer to basic-level objects like dog, ball, or house. This category of words stands in contrast to specific-level labels such as, Spot or Sarah. Nelson’s findings (1973) suggest that with experience some children learn words
based upon their level of category membership (e.g., a new label is more likely to be “dog” than “Shar Pei”). That is, children develop a hierarchy and initially demonstrate a preference for new words contained within the category of basic-level (Hall & Waxman, 1993; Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976). Perhaps as children build their vocabularies, general labels indicate a greater level of symbolic representation than specific words. To illustrate how basic-level labels may reflect more complex symbolic representation, I return to the previous example of a toddler’s use of the word “car.” Once the general label “car” is decontextualized, children will apply the label correctly and incorrectly to refer to buses, trucks, cars, and toy cars. Over time, more experienced language partners will clarify incorrect uses of “car” and provide new words such as “semi”, “tractor”, and “motorcycle.” This example demonstrates how a general word at a basic-level of representation may assist children with increasing their lexicon. This entire process demonstrates how children advance from referential (but not yet symbolic) pointing, to symbolic gestures, to spoken words, which are unmistakably symbolic.

**Syntax: Rule Use**

Around 18 to 20 months of age, children experience another language milestone, using *two-word combinations*. At this age, children are comfortable using symbols but the use of word combinations marks an understanding about the order of words and the relations between them. The rules that govern how language is organized and operates are called *syntax* (Hoff, 2005). Children initially use syntax in the form of *grammar*, or word order, to express relationships. The advent of syntax is significant because it demonstrates children’s ability to use a symbolic based rule system. When combining words, children are not only using words as symbols but also applying rules in the form
of grammar to them. Once these rules have been mastered, children can even use syntax to determine the meanings of new words (Gelman & Taylor, 1984; Gelman & Markman, 1986). Children’s first two-word combinations are predictable and typically are classified by several common forms (Brown, 1973). Examples of the relations expressed in two-word combinations include an agent plus an action, such as Mommy drive, or a possessor plus a possession, as in my blanket. These common forms suggest that children are learning patterns or simple rules necessary for expressing relations between two-word phrases. When combining two words, children are symbolically representing them into the appropriate category (i.e., agent vs. action) or pattern. For example, when using word combinations, children must represent Mommy into the category of an agent and drive into the category of an action. This simple representation of a word into a specific category marks a significant advance in children’s ability to use symbols, because the rules can now be applied to entire categories of words.

Advances in children’s symbolic representation continue as their ability to combine words moves beyond Brown’s common patterns. With increased language experience, children learn to represent words in broad grammatical categories, such as noun and verb (Gelman & Markman, 1986). Once children have represented a new word into the appropriate category, specific syntax can be applied to that word. This means children now have the capacity to discern how a noun or verb will operate in a word combination without ever having heard that word before (Landau & Gleitman, 1985). When children use syntax in this way it marks a significant new ability to represent a system of rules and apply them across a variety of situations. This knowledge of a new word as a noun or a verb is different from Brown’s simple word combinations because
children can no longer rely upon memorized patterns. Rather, children are learning and applying a system of rules to novel language situations.

With the demands of learning such complicated syntax, it is surprising that children make few grammatical errors. However, the occasional overgeneralization of a rule does occur (Hoff, 2005). Interestingly, even when children commit grammatical errors they are typically mistakes that still provide evidence for the development of symbolic representation. Common errors include applying a familiar rule to a new word with an irregular plural or past tense form, such as gooses instead of geese or goed instead of went. These types of mistakes suggest that children are not simply repeating words they have heard before (on the contrary, children most likely have never heard the word goed), but rather are learning and grappling with the complexities of syntax. Meaning, children have learned a general rule (e.g., to make a plural add “s”) and are comfortable applying that rule to all sorts of words. Indeed, children’s errors can most likely be attributed to the application of a well-understood rule to a novel situation (Hoff, 2005). By the time children are committing mistakes of overgeneralization, they are not only familiar with thinking about words as symbols that belong to specific category, but also with using an entire system of rules the govern how words are used and combined.

**Language Development and Emerging Executive Function**

How children learn to communicate is a complex process that involves many stages from gestures, to first words, to multiple word phrases composed of nouns, adjectives, and verbs. However, symbolic representation stands out as a common underpinning for language acquisition (Bates, et al., 1980; Blake, 2000) and the building of EF skills (Muller, Jacques, Brocki, & Zelazo, 2009). This is because the development
of both requires children to use symbols and referents. Understanding of symbolic representation is demonstrated by children’s use of symbols, which begins as the representation of an object (as a gesture or single word) that applies only to a specific context or requires the presence of that object. As symbolic representation matures, children become capable of decontextualizing symbolic gestures or words across a variety of contexts. This transition is significant because it signifies children’s understanding of language as a system of symbols. After children learn how to abstract words (i.e., apply them across multiple contexts), they begin to use rules in the form of syntax to express relationships between words. Children’s use of syntax is remarkable because it indicates an ability to use symbols within the context of a complex rule system.

Children’s acquisition of syntax can be constructed as a forerunner to Zelazo’s representations of rules (Zelazo & Frye, 1998), which determines performance in EF tasks. Although the rules of language may be more simplistic than the hierarchical rule structure that denote EF ability, children’s use of syntax to determine the definition of words shows problem-solving skills and an ability to generalize conventions. By the time children are assessed with EF tasks, their ability to use rules has become more sophisticated. Thus, the rules children apply in EF tasks are more complicated than basic syntax because they are imbedded. It may be the ability to use symbols, or the maturation of symbolic representation, that makes it possible for children to mentally construct the complicated imbedded rule structure required by EF tasks. Communication, in the forms of gestures, vocabularies, and syntax may be the foundational skills needed for later EF because they are children’s first opportunity to use symbols. The CCC theory (Zelazo & Frye, 1998; Zelazo, et al., 2003) and the HCSM (Marcovitch & Zelazo, 2009) suggest,
although do not explicitly state, that the development of EF is dependent upon the maturation of symbolic representation. The goal of the current study is to test the proposed relation between children’s gestures, language, and emerging EF. According to theories put forth by Zelazo and Marcovitch, this relation is not only positive but also directional, such that language should predict later EF.

The Current Study

The goal of the current study was to examine the relations between children’s gestures, language, and later executive function guided by the developmental framework proposed in the CCC theory (Zelazo & Frye, 1998; Zelazo, et al., 2003) and the HCSM (Marcovitch & Zelazo, 2009). These theories emphasize the role of language in children’s capacity to represent rules and the conditions of a problem, but do not identify the mechanism bringing about these changes. With the development of language, children become capable of using symbols and this cognitive milestone allows them to reflect upon the conditions of a problem, and then modify their behaviors to find a solution to that problem. This process highlights a role for symbolic representation to be the mechanism influencing the development of language and EF. Although the current literature has established a relation between children’s expressive language and EF (Fuhs & Day, 2010; Karbach & Kray, 2007; Kirkham, et al., 2003; Kray, et al., 2008; Kray, et al., 2004; Muller, et al., 2004), the direction of this relation is not well understood (Brace, et al., 2006; Muller, et al., 2008; Yerys & Munakata, 2006). The current study explored the possibility that children’s language predicted later EF abilities through the use of longitudinal data. Moreover, research has yet to examine the influence of children’s preverbal language, such as gestures, on EF development. The current study examined
this issue by including children’s gestures in a model predicting later EF abilities. The study examined a number of specific research questions. At the most basic level, (1) Do children’s gestures at 15 months directly influence their performance on an EF task at 48 months? Further, (2) Do children’s vocabularies at 24 months and (3) their syntax at 36 months directly influence their performance on an EF task? And finally, (4) Is this relation between children’s gestures and EF performance best understood through indirect effects of vocabulary and/or syntax? (5) If the indirect relation is through both, are children’s gestures related to their vocabularies, which in turn relates to their syntax, and then EF performance? Finally, the current study also explored (6) If group membership, according to gender, race, or state of residence, affected the nature of the relations between children’s gestures, language, and EF?

These questions were considered through two different types of data. A methodology common in many studies with young children is the use of standardized assessments, typically completed by caregivers, to measure children’s abilities. Following suit, the current study used standardized assessments of children’s gestures and language abilities. While rigorous in their creation, standardized assessments typically provide a global measure of children’s abilities. The richness of this dataset also allowed for the research questions to be considered in a second more nuanced way. The same relations were explored with naturalistic observations of children’s gestures and language drawn from a picture book task. Therefore, to most completely address the current research questions two parallel models, utilizing different methods of measurement, were used. The first set of analyses utilized the more nuanced measures from the observed picture
book task, while the second set of analyses relied upon the more global standardized assessments.
CHAPTER TWO

Methods

Sample and Design

The Family Life Project (FLP) was designed to study families who lived in two of four major geographical areas of high child rural poverty (Dill, 1999). 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. Complex sampling procedures were used to recruit a representative sample of 1,292 families at the time of the birth of the child enrolled in the study. Low-income families in both states and African American families in NC were over-sampled. However, African American families were not over sampled in PA, as the target communities were at least 95% non-African American. Families were designated as low income if they reported household income less than 200% the poverty rate, use of social services requiring a similar income requirement (e.g., food stamps, WIC, Medicaid), or had less than a high school education.

At both sites, recruitment occurred seven days a week over the 12 month recruitment period spanning September 15, 2003 through September 14, 2004, using a standardized script and screening protocol. The coverage rate was over 90% for all births that occurred in these counties in that 1-year period. In PA, families were recruited in person from three hospitals. These three hospitals represented a weighted probability
sample (hospitals were sampled proportional to size within county) of seven total
hospitals that delivered babies in the three target PA counties. Hospitals in PA were
sampled because the number of babies born in all seven target hospitals exceeded the
number needed for purposes of the design. In NC, families were recruited in person and
by phone. In-person recruitment occurred in all three of the hospitals that delivered
babies in target counties. Phone recruitment occurred for families who resided in target
counties but delivered in non-target county hospitals. These families were located
through systematic searches of the birth records located in the courthouses of nearby
counties.

In total, FLP recruiters identified 5,471 (59% NC, 41% PA) women who gave
birth during the recruitment period, 72% of which were eligible for the study. Eligibility
criteria included residency in target counties, English as the primary language spoken in
the home, and no intent to move from the area in the next three years. Of the 2,691
eligible families, 1,571 (58%) families were selected to participate with the sampling
proportions that were continually updated by a data center. Of those families selected to
participate, 1,292 (82%) families completed a home visit at 2 months of child age, at
which point they were formally enrolled in the study. Of this final enrollment number,
521 were African-American families of low-income and living in NC, 168 were of low-
income not African-American, and 86 families were not low-income, not African-
American living in NC. In PA, 344 families were of any race, low-income and 175 were
of any race, not low-income.

The current study only used child language variables from assessments with
primary caregivers. A primary caregiver was defined as the individual who was most
responsible for the care (i.e., bathing, feeding) of the child enrolled in the study. In the 15 month sample, 97.17% of primary caregivers were the biological mother of the child. Other typical primary caregivers included the maternal grandmother or aunt of the child. The current study used child variables assessed at the 15, 24, 36, and 48 month home visits. Families and children who participated in the 36 month visit ($n = 1,123$) did not differ from those who did not participate in this visit ($n = 169$) 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 36 month visit were more likely to be female than children whose families did not participate ($50\%$ vs. $41\%, p < .05$). Families and children who participated in the 48 month home visit ($n = 1,066$) did not differ from those who did not participate in this visit ($n = 226$) 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 48 month visit were more likely to reside in the state of Pennsylvania ($34\%$ vs. $42\%, p = .03$).

**Procedures**

Data presented here were collected during two and a half hour home visits, when children were 15, 24, 36, and 48 months of age. Two separate visits were conducted when children were 24 and 36 months of age, usually within two weeks of each other. Only one home visit was conducted when children were 15 and 48 months of age. Home visits were conducted by two research assistants (RAs), who simultaneously collected a variety of data from interviews and questionnaires given to caregivers, caregiver-child interactions and child-based tasks. The majority of the child assessments during the home visits were completed at a small portable table with the children sitting across from the
RA in a convenient location within the home. At the beginning of each home visit, RAs interviewed caregivers about their education, income, number of people living in the home, and other relevant demographic measures to characterize the background information about the families.

Child language variables were drawn from a 10 minute wordless picture book activity that was filmed through a DVD video recorder for later coding and transcription of the verbal interaction between the primary caregiver and the child. Primary caregivers were asked to sit in a comfortable chair or on the couch with their children and given the picture book. A wireless microphone was either attached to the child or caregiver. Research assistants instructed the caregivers to go through the book with their children, try not to whisper, and to signal when they were finished with the story. If the caregivers did not signal they were finished by 10 minutes, the task was terminated. At 15 months, the wordless picture book *No, David* (Shannon, 1998) was used. At 24 months, the modified picture books were *Just a Thunderstorm* and *The New Baby* (Mayer, 1993; 1983). Finally, at 36 months the picture books *Frog on His Own* (Mayer, 1973) and *A Boy, a Dog, a Frog and a Friend* (Mayer & Mayer, 1971) were used. Caregivers were given time to familiarize themselves with the story before beginning the activity.

The EF assessment occurred at the 48 month home visit. The assessment consisted of a battery of EF tasks (Willoughby, et al., 2010) administered at a table with the child sitting across from the RA. Children were presented with stimuli in the format of an open spiral bound flipbook, each page measuring 8 inches by 14 inches, allowing for stimuli on one page and administration text on the other. One RA was responsible for administering EF tasks (in a fixed order) to children, including keeping them engaged and
making decisions about how frequently to take breaks. A second RA was responsible for recording children’s responses to each task into a laptop computer. Neither RA was responsible for evaluating the accuracy of children’s responses. Computerized scoring, which took place when data for the entire visit were processed, was used to evaluate the accuracy of child responses to each task. This scored, item-level data formed the basis of psychometric analyses included herein. Cumulatively, EF assessments took approximately 45 minutes to complete.

Measures

**Demographic Variables.** From the home visit interviews, the following demographic control variables were derived: state of residence (NC = 0, PA = 1), race (White = 0, African-American = 1), and gender (female = 0, male = 1).

**Income-to-needs Ratio.** At each home visit, primary caregivers were asked to provide detailed information about all household income. Household annual income was comprised of the mothers’ reported annual income, the fathers’ reported annual income, annualized contributions of all other people included in the household and all other sources of income including unemployment insurance, worker’s compensation, social security retirement, other pension, cash income from welfare, child support, interest/dividend income, rental income, alimony, regular help from relatives, and regular help from friends. This annual total income figure was then divided by the federal poverty threshold for a family of that particular size and composition for that year (thresholds vary based on number of adults and children), 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 not. In the
current analyses, averages of the income-to-needs ratios from the 15 to 48 months home visits were used.

**Caregiver Education.** Parent education was derived from the home interview at the 15 month visit. During this interview, primary caregivers reported the highest level of education that they had obtained as of the date of the interview. Possible values ranged from 0 to 22, where 0 to 11 reflect the last grade that the primary caregiver completed, 12 reflects the receipt of a GED, 13 the receipt of a GED and some additional training, 14 a high school degree, and 15 reflects that the parent completed high school and additional training. Caregivers who completed some college (but no degree), received an associate’s degree, and received a four year college degree were given values of 16, 17, and 18, respectively. Values of 19 indicate that the parent completed some post college education, 20 a Masters degree, 21 a professional degree, and 22 a Ph.D.

**Bayley Scale of Infant Development.** The Bayley Scale of Infant Development (BSID-II; Bayley, 1993) was administered at 15 months of age to assess infant’s cognitive abilities. The BSID-II is a widely used standardized measure, with norm-referenced standard scores ($M = 100, SD = 15$), assessing children’s cognitive development from birth to age two. The reliability coefficients of the BSID-II have been established as ranging from .78 at 10 months to .93 at 27 months, with a standardized sample (Bayley, 1993). In a study of 175 children, the test-retest reliability of the BSID-II has also been found to be stable over time, with a correlation of .83 found between 1 and 12 months, and a correlation of .91 found between 24 and 36 months (Bayley, 1993). In the current analyses, the Mental Development Index (MDI) scale was used as an indicator of children’s cognitive skills.
**Covariates.** A standard set of covariates were used in all analyses. The variables included in the covariate set were the household’s INR, the primary caregiver’s level of education, and the child’s MDI. Poverty status (Hart & Risley, 1995; Heath, 1983; Hoff, 2006; Hoff & Tian, 2005; Lawrence & Shipley, 1996; Snow, 1976; Vernon-Feagans, 1996), and maternal education (Dollaghan, Campbell, Paradise, Feldman, Janosky, et al., 1999) have each been identified as important correlates of children’s language and to a lesser extent EF (Noble, McCandliss, & Farah, 2007; Noble, Norman, & Farah, 2005; Mezzacappa, 2004; Rhoades, Greenberg, Lanza, & Blair, 2011). In order to rule out alternative explanations for the hypothesized associations, children’s scores from the Bayley Scale of Infant Development were also included as a control variable. Specifically, paths were estimated from all control variables to the endogenous latent EF variable.

**Child Gestures.** From the 15 month picture book activity, children’s gestures were coded. Only children’s gestures intended to communicate with primary caregivers were coded. Research assistants were trained to observe child gestures and to enter them into the SALT transcript. These gestures typically referred to objects, or people in the story, or to the surrounding environment (e.g., pointing to the boy), depicted actions (e.g., moving arms to indicate swimming), or communicated common sentiments (e.g., nodding head for “yes”). The SALT software calculated a frequency for each type of gesture. At 15 months 86.16 % of children’s gestures were deictic or dependent upon context for meaning (e.g., point or give) in nature, while 8.59 % were symbolic gestures (e.g., using an imaginary telephone to call someone). The least frequently occurring
gestures were conventional gestures (e.g., shrugging ones shoulders, indicating yes by head nodding, or no by head shaking), which accounted for 5.25 % of total gestures.

*Communication and symbolic behavior scales.* Child communication skills at 15 months were measured using Infant-Toddler Checklist from the Communication and Symbolic Behavior Scales Developmental Profile (CSBS; Wetherby & Prizant, 2002), a screening and assessment tool. The CSBS was designed to be used with children from 6 to 24 months and can be utilized independently of the other components on the checklist. Caregivers completed the CSBS, rating their children in seven areas: Emotion and Eye Gaze, Communication, Gestures, Sounds, Words, Understanding, and Object Use. Results were summarized from all seven raw scores. Normative data for the CSBS is presented in 1-month intervals and is based on 1,891 children from culturally diverse groups. Total standard scores were based on a mean of 100 and a standard deviation on 15. Only the Gestures subscale was used in the current analyses.

Wetherby, Allen, Cleary, Kublin and Goldstein (2002) have reported the reliability of the CSBS to be stable over time. Their research has found that there were no significant differences in the retest scores in the components of the checklist over an interval of approximately 4 months. Internal reliability for the CSBS total communication score in this sample was .67.

**Child Language.** The software Systematic Analysis of Language Transcripts (SALT; Miller & Chapman, 1985) was used to transcribe all DVDs of the picture book activity. Transcription began after the RA had given the book to the caregiver and completed reading the instructions. Transcription ended when the caregiver signaled the end of the activity or at 10 minutes. All language directed to the child during the session
was transcribed by highly-trained graduate students. Transcribers underwent an extensive training process conducted by a senior graduate student who spent 1 year learning SALT conventions and developing a training manual. The training process involved transcribing 20 training transcripts that were then reviewed by a senior graduate student. As an ongoing check, this review process continued regularly with all transcribers periodically transcribing the same DVD and then discussing discrepancies at bi-weekly research meetings to ensure consistency in transcription.

Two measures of children’s language were derived from the transcripts at 24 and 36 months of age. Language was transcribed at the unit of an utterance, or at a sequence of words followed by a pause or a change in speaker turn. Onomatopoeic sounds (e.g., vroom) and evaluative sounds (e.g., uhhuh) were also transcribed as words. Omitted and unintelligible words were not included. Children’s number of different word roots (NDW), a measure of children’s vocabulary used at 24 months, and mean length utterance (MLU), a measure of children’s syntax used at 36 months, were calculated using the SALT software. The NDW, or measure of vocabulary, was determined by calculating the number of unique free morphemes over the entire transcript. Variations in the same word were not counted as separate root words. For example, “run” and “running” were considered the same root word. The NDW represents the number of different words used by children during an interaction with their primary caregiver and represents an overall lexical diversity (vocabulary) during the picture book activity at 24 months. The MLU, or measure of early syntax, is a general measure of complexity of utterances used by children. It was calculated by dividing the total number of utterances by the total number of morphemes (smallest meaningful unit of language). This average
length of children’s utterances, which is highly related to the complexity of their utterances used during the picture book activity, was the syntax measure used at 36 months.

*Preschool Language Scale.* The Preschool Language Scale Fourth Edition (PLS-4; Zimmerman, Steiner, & Pond, 2002) was administered by RAs during the 24 and 36 month home visits. The PLS-4 is a norm-based measure of children’s language skills, from birth to age 6. The PLS-4 yields two subscale measures, auditory comprehension and expressive communication. Only the expressive communication subscale was administered in the FLP. This subscale measured how well children communicated with others. Infant and toddler items assessed rudimentary aspects of expressive language, such as the ability to make sounds of pleasure, and later involved items that required the child to verbally demonstrate a comprehension of language concepts, such as plural tense. Test-retest reliability of expressive language for this age group has been found to be .82 and internal consistency estimates have been found to be .91 (Zimmerman, et al., 2002).

**Executive Function Battery.** A battery composed of five tasks was used to index children’s executive functioning at 48 months. Item response theory (IRT) models were applied to each task for the purpose of establishing difficulty and discrimination parameters (for review see Willoughby, Blair, Wirth, & Greenberg, 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. Willoughby and colleagues (2010) have previously established that a single factor model fits the task scores best and that the battery successfully measures a wide range of children’s EF ability levels.
**Working Memory Span (WM).** This task is based upon principles described by Engle, Kane and collaborators (e.g., Conway, Kane, Bunting, Hambrick, Wilhelm, et al., 2005). In this task, children are presented with a line drawing of an animal figure above which is colored dot. Both the animal and the colored dot are located within the outline of a house. After establishing that the child knows both colors and animals in a pretest phase, the examiner asks the child to name the animal and then to name the color. The examiner then turns the page which only shows the outline of the house from the previous page. The examiner then asks the child which animal was/lived in the house. The task requires children to perform the operation of naming and holding in mind two pieces of information simultaneously and to activate the animal name while overcoming interference occurring from naming the color. Children received one 1-house trial, two 2-house, two 3-house, and two 4-house trials.

**Spatial Conflict Arrows (SCA).** The SCA is a Simon task, similar to that used by Gerardi-Caulton (2000), is intended to assess inhibitory control. A response card, which has two side-by-side black circles that are referred to as “buttons,” is placed in front of the child. The RA turns pages that depict either a left pointing or right pointing arrow. The child is instructed to touch the left most button with his/her left hand when the arrow points to the left and to touch the right most button with his/her right hand when the arrow points to the right. Across the first 8 trials, arrows are depicted centrally (in the center of the page). These items provide an opportunity to teach the child the task (i.e., to touch the left button when you see left pointing arrows and the right button when you see right pointing arrows). For items 9-22, left and right pointing arrows are depicted laterally, with left pointing arrows always appearing on the left side of the flip book page.
left arrows appear “above” the left button) and right pointing arrows always appearing on the right side of the flip book page (right arrows appear “above” the right button). These items build a prepotency to touch the response card based on the location of the stimuli. For items 23-35, left and right pointing arrows begin to be depicted contra-laterally, with left pointing arrows usually (though not exclusively) appearing on the right side of the flip book page (“above” the right button of the response card) and right pointing appears appearing on the left side of the flip book page (“above” the left button of the response card). Items presented contra-laterally require inhibitory control from the previously established pre-potent response in order to be answered correctly (spatial location is no longer informative).

**Something’s the Same (STS).** This task, which was modeled on the Flexible Item Selection Task developed by Jacques and Zelazo (2001), is intended to assess attention shifting. In the version of the task developed for flipbook administration, children are first presented with a page on which there are two line drawn items that are similar in terms of shape, size or color. The examiner draws the child’s attention to the dimension along which the items are similar, stating “See, here are two pictures. These pictures are the same, they are both (cats, blue, big, etc.)”. The examiner then flips a page which presents the same two items again, to the right of which is a dashed vertical line and a picture of a third item. The new third item is similar to one of the first two items along a second dimension that is different from the similarity of the first two items. For example, if the first two items were similar in terms of shape, the third item would be similar to one of the first two items in terms of either size or color. When presenting the new, third item to the child the examiner states to the child, “See, here is a new picture. The new
picture is the same as one of these two pictures. Show me which of these two pictures is the same as this new picture.” This task is preceded by a pretest in which children demonstrate knowledge of color, shape, and size.

**Silly Sounds Stroop (SSS).** This task, which was modeled after the Day-Night task by Gerstadt and colleagues (1994), is intended to assess inhibitory control of a pre-potent response. In this task children are instructed to make the sound of a dog when shown a line drawing of a cat, and to make the sound of a cat when shown a line drawing of a dog. Following a pretest phase, children are presented with 18 trials (pages) involving a line drawing of a dog and cat in random order. Due to a high degree of local dependence, only the first animal on each page is used for purposes of scoring.

**Animal Go No-Go (GNG).** This is a standard go no-go task (e.g., Durston, Thomas, Yang, Uluğ, Zimmerman, et al., 2002) that is intended to assess inhibitory motor control. Children are presented with a large button that makes a “clicking” sound when it is pressed. Children are instructed to click their button every time that they see an animal except when that animal is a pig. The examiner flips pages at a rate of one page per two seconds, with each page depicting a line drawing of 1 of 7 possible animals. The task presents 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.

**Latent Variables.** The analyses were conducted using two latent variables, one representing children’s gesture use at 15-months-of-age and the second representing children’s EF ability at 48-months-of-age. The Gestures latent variable was comprised of four indicators: counts of children’s points, nods, shakes, and symbolic gestures used during the picture book task. The EF latent variable was comprised of five indicators
from the EF battery. These indicators were working memory, silly sound stroop, go no-
go, spatial conflict arrows, and something’s the same. Both latent variables were scaled
by setting the first factor loadings to 1.0. For Gesture, the scaling variable was point
because this was the most frequently occurring gesture during the picture book task. For
EF, the scaling variable was the working memory task because conceptually working
memory is consistently viewed as a primary component of these abilities.
Analytic Strategy

Structural equation modeling (SEM) methods were used to test all research questions; the models were estimated using Mplus version 5.0 (Muthen & Muthen, 2007). The Mplus software can accommodate the complex sampling design used by the FLP, including individual survey weights associated with the oversampling of low-income and African-American participants and stratification on income and race. All SEM models were estimated using a robust maximum likelihood (MLR) estimator and missing data was managed with full information maximum likelihood (FIML) methods (Arbuckle, 1996). The adequacy of model fit was determined using the likelihood ratio test (i.e., model chi square). Two fit indices were also used to determined model, the root mean-squared error of approximation (RMSEA) and the comparative fit index (CFI). The CFI was a useful tool for evaluating model fit given the FLP’s sample size, and the likelihood ratio test tendency to reach significance with even small model misspecifications in large samples (MacCallum, 1990). Guided by the work of Hu and Bentler (1999), RMSEA values below .05 and comparative fit indices with values above .95 indicated good fit.

Specific and General Models. Analyses were conducted in two different sets, or parallel models. The first set of analyses, used observed measures of children’s gestures (multiple indicators were combined to form a latent variable), vocabulary (number of different words), and syntax (mean length utterance) from a picture book task and represented the specific model. The second set of analyses, used standardized assessments of children’s gestures (communication and symbolic behavior scales), early (24 month PLS-4), and later (36 month PLS-4) language and represented the general model. The
general model only refers to early and later language because the global nature of standardized assessments does not provide specific information about children’s vocabularies or syntax. Both models used a latent variable of EF as the outcome variable. The results from these two models informed research questions one through five.

All models were estimated using survey weights, and Figure 1 represents the specific paths associated with the research questions in the specific model. To answer the first research question, a direct path between gesture and EF was estimated. Path A represents the direct relation between gesture and EF. To answer questions two and three, direct paths between vocabulary and EF, and syntax and EF were estimated. Illustrating the second and third questions, paths C and F represent the direct effects of vocabulary and syntax on EF. Since it was predicted that the effects of gesture on EF would occur indirectly, through vocabulary or syntax, the indirect effects were estimated using maximum likelihood. To answer question four, an indirect path from gesture to EF through vocabulary was estimated. This indirect effect is represented by paths B+C. Second, the indirect path from gesture to EF through syntax is represented by paths E+F. To answer question five, indirect paths from gesture to EF through vocabulary and then syntax were estimated. This indirect effect is represented by paths B+D+F.

**Multiple Group Models.** A secondary issue was whether any of the hypothesized relations between children’s gestures, language skills, and EF differed as a function of gender, race, or state of residence. An exploratory set of multiple group analyses were performed to answer question six. This strategy capitalized on the representative nature of the FLP sample. Further, some literature has supported mean level differences between girls and boys (Bauer, Goldfield, & Reznick, 2002; Bornstein, Hahn, & Haynes, 2004;
Fenson, et al., 1994; Fenson, Pethick, Renda, Cox, Dale, et al., 2000), or White and African-American children (Hart & Risley, 1995; Pungello, Iruka, Dotterer, Mills-Koonce, & Reznick, 2009) in language variables, such as the diversity and complexity of vocabulary. Other language research has indicated that girls begin gesturing (Chipman & Hampson, 2007) and speaking (Bavin, Prior, Reilly, Bretherton, Williams, et al., 2008; Kern, 2007; Sansavini, Bello, Guarini, Savini, & Caselli, et al., 2010) before boys. It is possible that with this earlier onset of language skills girls’ development of EF is different from boys. Less is known about group differences in EF, but work has indicated that boys have greater EF abilities in early childhood (Wiebe, Espy, & Charak, 2008; Willoughby & Blair, in press). Additionally, a study also using the FLP sample, has found race differences in EF performance (Rhoades, et al., 2011).

The multiple group analyses proceeded in three stages. The goal of the first stage was to establish that the latent variables operated similarly across groups by applying tests of measurement invariance. This was accomplished by using a series of increasingly restrictive CFA models. Following the recommendations of Meredith (1993), the Gesture and EF latent variables were constrained from weak to strong factorial invariance. The first step in this process was to estimate a model with configural invariance. In the configural model, identical paths were estimated but both factor loadings and intercepts were allowed to vary across groups. In these multiple group analyses point and working memory were no longer set as the scaling indicators of Gesture and EF, respective. Rather, for identification purposes, the latent means were fixed to 0 and the latent variances were set to 1.0 in the female, White, and NC reference groups.
In the second stage, a model was estimated with weak factorial invariance (Horn & McArdle, 1992), which required that the indicators of the latent variables were equivalent across groups. Finally, in the third stage strong factorial invariance was established by constraining the intercepts of the indicators to be equal across groups (Vandenberg & Lance, 2000). The advantage of strong factorial invariance is that it establishes both the regression weights and the intercept terms of the factors to be invariant across groups (Widaman & Reise, 1997). Models with equality constraints across groups are nested, which permits the use of a chi square difference test to evaluate if applying the constraints resulted in a significant decrement in model fit. This test has the sensitivity to determine the impact of small incremental changes on model fit, and if statistically significant suggests that there was a decrement in model fit by applying constraints. If the chi-square test was not statistically significant the more parsimonious model (i.e., with constraints) was retained. In the current analyses, all chi square differences tests were performed using MLR adjustments (Satorra & Bentler, 2001).

Next, after establishing measurement equivalence, it was tested whether the standardized paths between gesture, language, and EF were different. This was accomplished by estimating two sub models, the general and specific, with the objective of establishing structural invariance across groups. First, a model was estimated with no constraints on the structural paths. Then, an omnibus test of structural invariance was performed, because there were no a priori hypotheses about the relations between specific variables. Again, these models were nested making the chi square difference test appropriate for determining whether there was a decrement in model fit by applying the structural constraints.
CHAPTER THREE

Results

Sample Description

A summary of unweighted descriptive statistics for the variables used in the current study are presented in Table 1. The children in this study came from families with a mean income-to-needs ratio of 1.9 ($SD=1.6$), and their primary caregivers had a mean education level of 14.6 ($SD=2.8$). This indicated that the average family had a household income that met basic needs, but were closer to working poor than solidly in the middleclass. On average, primary caregivers had some schooling beyond high school but not a college degree. On standardized assessments of language and mental abilities, children in this study performed at about average. The average child had a PLS-4 score of 100.4 ($SD=15.1$) at 24 months and a slightly lower score of 97.9 ($SD=15.9$) at 36 months. The mean score on the MDI at 15 months was 96.3 ($SD=10.7$). Secondary analyses were also conducted with multiple groups, information about the means based upon gender, race, and state of residence are presented in Tables 2-4.

A review of the descriptive statistics for the variables used in the models is presented. A total of 17 variables were used between the two primary models. Table 1 provides the unweighted correlations between these variables. The correlations among the gesture variables (point, nod, shake, gesture, CSBS) ranged weak to moderate (.01 to .18), suggesting a latent construct was appropriate. The correlations among the EF tasks
(WM, SSS, GNG, STS, SCA) also ranged from weak to moderate (.08 to .28), again suggesting the potential for a latent construct. The EF tasks were moderately correlated with measures of children’s language (NDW, MLU, PLS), correlations ranged from .07 to .34, and weakly correlated with measures of gestures (correlations ranged from .11 to -.04). Language measures were moderately correlated with each other, the correlations ranged from .17 to .56. The gesture indicators were moderately correlated with children’s language measures, the correlations ranged from .25 to .01. These correlations highlighted the potential for associations between measures of children’s gestures, language skills, and EF, but certainly did not provide overwhelming evidence. All variables, with the exception of the gesture indicators, were moderately correlated with the control variables of primary caregiver education level, children’s mental abilities, and income-to-needs ratios.

**Measurement Model**

As can be seen in Figure 2, a model with the latent variables Gestures and EF fit the data well, $\chi^2 (47, N=1185) = 78.00, p<.01$, CFI=96, RMSEA=.02. There was a significant positive association between children’s 15 month Gestures and 48 month EF. All of the standardized factor estimates were significant for the latent variable Gestures. The standardized factor loadings ranged from low (.12 for nod) to moderate (.51, for gesture) for Gestures. The latent variance was also significant, indicating interindividual differences on point, nod, shake, and gesture. The $R^2$ values for the individual indicators were highly discrepant, with an indicator explaining anywhere from 2% to 26% of the variance. For the latent EF variable, all of the standardized factor estimates were significant. The factor loadings for the latent variable EF were moderate, ranging from
.33 (silly sound stroop) to .51 (something’s the same). The latent variance was also
significant, indicating interindividual differences on working memory, silly sound stroop,
go no-go, spatial conflict arrows, and something’s the same. The R² values for the
individual indicators were discrepant, with an indicator explaining anywhere from 11% to
23% of the variance. For both latent variables, the standardized residual variances of the
indicators were significant, estimates ranged from .74 (something’s the same) to .99
(nod). Finally, the standardized path from Gestures to EF was significant (β=.19, p=.04).

Research Question One: Do Children’s Gestures at 15 months Directly Influence
their Performance on an EF Task at 48 months?

The results from the specific model are presented in Figure 3. The overall model fit the data well, χ² (61, N=1194) =93.50, p=.00, CFI=.95, RMSEA=.02. To answer question one, using the observed measures from the picture book task, children’s gestures did not directly predict later EF abilities (β=-.05, p=.59). As can be seen in Figure 4, the overall general model also fit the data well, χ² (29, N=1194) =52.13, p=.01, CFI=.98, RMSEA=.03. When addressing question one, with standardized measures, a significant direct influence of gestures on EF (β=.00, p=.98) was not found. The finding was the same in both models; neither standardized nor observed measures of children’s gestures directly predicted later EF abilities, when in the presence of other language variables.

Research Question Two: Do Children’s Vocabularies/Language at 24 months
Directly Influence their Performance on an EF Task at 48 months?

To answer question two a direct path was estimated from children’s vocabulary/language at 24 months to their later EF, in both the general and specific models. When addressing this question with the specific model, a significant positive
association between vocabulary and EF was found ($\beta=.12, p=.04$). This meant that larger vocabularies at 24 months were associated with greater EF abilities at 48 months. In the general model, there was also a significant positive association between early language and EF ($\beta=.18, p=.00$). This indicated that those children with better language at 24 months also had greater EF scores at 48 months. Both models supported the predictive relation of children’s 24 month language on later EF abilities.

**Research Question Three: Do Children’s Syntax/Language at 36 months Directly Influence their Performance on an EF Task at 48 months?**

To answer question three a direct path was estimated from children’s syntax to their later EF, in both the general and specific models. In the specific model, a significant positive direct association between syntax and EF ($\beta=.11, p=.04$) was found. This indicated that children with longer utterances (syntax) at 36 months also had greater EF scores. In the general model, a significant positive direct association between language at 36 months and EF ($\beta=.35, p=.00$) was found. Children with higher language scores at 36 months also had higher EF scores. Both models provided support for the direct predictive relation of children’s 36 month language on later EF abilities.

**Research Question Four: Is the Indirect Relation between Children’s Gestures and Later EF Performance Through their 24 month Vocabularies/Language or 36 month Syntax/Language?**

To answer question four two indirect or mediated paths were estimated with both the general and specific models. The first indirect path was from children’s gestures to EF mediated by their vocabulary/language at 24 months. The second indirect path was from children’s gestures to EF mediated by their syntax/language at 36 months. In the
specific model, a significant positive indirect association through children’s vocabulary 
($\beta_{\text{gesture vocab}} = .01, p = .05$) was found. Thus, children who gestured more at 15 months had 
larger vocabularies at 24 months, and in turn higher EF scores at 48 months. However, a 
significant indirect association through children’s syntax was not found ($\beta_{\text{gesture syntax}} = .00, 
p = .38$). These results suggested that the relation between Gestures and EF was only 
mediated by children’s vocabulary. In the general model, a significant positive indirect 
association was found through children’s early language at 24 months ($\beta_{\text{gesture early}} = .04, 
p = .01$). Thus, children who gestured more at 15 months had higher language scores at 24 
months and in turn higher EF scores at 48 months. A significant positive indirect 
association through later language at 36 months ($\beta_{\text{gesture later}} = .05, p = .00$) was also found in 
the general model. This indicated that children who gestured more at 15 months had 
higher language scores at 36 months and in turn higher EF scores at 48 months. These 
results suggested that the relation between gestures and EF was mediated by children’s 
language at both 24 and 36 months. The general and specific models provided mixed 
support for the indirect influences, through children’s language at 24 and 36 month, 
explaining the relation between gestures and later EF. Although these indirect 
associations were small, given the difficulty of detecting fully mediated models with 
longitudinal data, the results are still worth noting.

**Research Question Five: Is the Indirect Relation between Children’s Gestures and 
Later EF Performance through Both 24 month Vocabularies/Language and 36 
month Syntax/Language?**

Finally, to answer question five an indirect path was estimated from children’s 
gestures at 15 months to later EF through their vocabulary/language at 24 months, and
then syntax/language at 36 months, in both the general and specific models. In the specific model, a significant mediated path from 15 month gesture to 48 month EF through both 24 month vocabulary and 36 month syntax was not found ($\beta_{\text{gesture vocab syntax}}=.00, p=.10$). However, in the general model a significant positive indirect association of 15 month gesture on 24 month language and then later 36 month language, which in turn predicted EF ($\beta_{\text{gesture early later}}=.05, p=.00$) was found. Children who gestured more at 15 months had higher language scores at 24 months, and in turn these children also had better later language at 36 months, and better EF scores at 48 months. Although it was a small indirect association, the results suggested that the relation between gestures and EF was mediated first by 24 month language and then by 36 month language.

**Research Question Six: Multiple Group Models**

In order to understand if the general and specific models fit equally well for different groups, such as gender (female, male), race (White, African-American), and state (NC, PA) a series of invariance tests were performed. In the multiple group approach a model is estimated for the two groups simultaneously. The results are reported by the separate group analyses (i.e., gender, race, and state). Within these groups’ results tests of measurement invariance are reported first, followed by model structural invariance tests.

**Gender Models**

**Measurement Invariance.** The measurement invariance results are presented in Table 5. Due to the exploratory nature of the current multiple group analyses, models with fit statistics below the previous established standard are reported. Therefore, these results should be interpreted with caution because lower fit statistic standards suggest that
the models may not be accurately characterizing the data across groups. The first model, which imposed configural invariance on Gesture and EF across gender fit the data somewhat well, $\chi^2 (49, N=1168) = 71.51, p = .02$, CFI=.90, RMSEA=.03, and this model was used as the baseline model. Next, the model was reestimated imposing weak measurement invariance, $\chi^2 (56, N=1168) = 91.12, p = .00$, CFI=.85, RMSEA=.03. A chi square difference test revealed a significant decrement in model fit, $\chi^2 (7) = 14.84, p = .04$. An inspection of the parameter estimates across gender suggested that factor loading for go no-go was different for males and females. The factor loadings for was lower for females ($\lambda_{females} = .17$, $\lambda_{males} = .96$). The model was then reestimated allowing the factor loading for go no-go to differ across groups, $\chi^2 (55, N=1168) = 66.91, p = .13$, CFI=.95, RMSEA=.02. This partial weak invariance model was not statistically different from the baseline model, $\chi^2 (6) = 3.19, p = .78$, but was more parsimonious. Finally, a model informing strong measurement invariance was estimated, $\chi^2 (61, N=1168) = 91.87, p = .01$, CFI=.87, RMSEA=.03. A chi square difference test revealed a significant decrement in model fit, $\chi^2 (6) = 19.74, p = .00$. An inspection of the parameter estimates across gender suggested that factor intercepts for go no-go, shake, and spatial conflict arrows were different for males and females. This partial strong model was then reestimated, this time allowing the factor intercepts for go no-go, shake, and spatial conflict arrows to differ across groups, $\chi^2 (58, N=1168) = 71.63, p = .11$, CFI=.94, RMSEA=.02. These steps were taken one at a time but a non-significant chi square was not achieved until all three intercepts were freed.

**Structural Invariance.** The purpose of examining structural invariance was to determine whether the relations among children’s gestures, language, and EF were
equivalent across gender. The results of these structural invariance models are presented in Table 5. The baseline model was estimated with all structural paths allowed to be free across males and females, imposing constraints from the measurement invariance tests. This resulted in a model with reasonable fit, $\chi^2 (119, N=1168) =174.28, p<.001, \text{CFI}=.92, \text{RMSEA}=.03$. The model was reestimated imposing equality constraints on the six regression coefficients relating to vocabulary, syntax, and EF across gender, $\chi^2 (125, N=1168) =175.48, p=.00, \text{CFI}=.92, \text{RMSEA}=.03$. A chi square difference test did not revealed a significant difference, $\chi^2 (6) = 3.85, p =.70$. This finding indicated that the relations between children’s gestures, vocabulary, syntax and later EF performance were not different as a function of gender.

In the general model, the baseline model was estimated with structural paths allowed to vary across gender. This resulted in a model with good fit, $\chi^2 (55, N=1168) =69.86, p=.09, \text{CFI}=.99, \text{RMSEA}=.02$. The model was reestimated imposing equality constraints on the six regression coefficients relating to early and later language, and EF across gender, $\chi^2 (61, N=1168) =80.46, p=.05, \text{CFI}=.98, \text{RMSEA}=.02$. A chi square difference test did not revealed a significant difference in model fit, $\chi^2 (6) = 10.23, p=.12$. This finding indicated that the relations between children’s gestures, early and later language, and EF performance were not different as a function of gender.

**State Models**

**Measurement Invariance.** The purpose of examining measurement invariance was to determine whether the measurement properties of the latent variables Gesture and EF were the same for children living in NC or PA. The results of these measurement invariance models are presented in Table 5. The model imposing configural invariance on
gesture and EF across gender fit the data reasonable well, $\chi^2(49, N=1170) = 51.04, p=.39$, CFI=.99, RMSEA=.01, and this model was used as the baseline model. Next, the model was reestimated imposing weak measurement invariance, $\chi^2(56, N=1170) = 55.13, p=.51$, CFI=1.00, RMSEA=.00. A chi square difference test did not reveal a significant decrement in model fit, $\chi^2(7) = 5.60, p = .59$, but was more parsimonious. Finally, a model informing strong measurement invariance was estimated, $\chi^2(62, N=1170) = 80.19, p=.06$, CFI=.91, RMSEA=.02. A chi square difference test revealed a significant decrement in model fit, $\chi^2(6) = 20.12, p = .00$. An inspection of the parameter estimates across state suggested that factor intercepts for something’s the same, and gest were different for children living in NC and PA. This partial strong model was then reestimated, allowing the factor intercepts for something’s the same, and gest to differ across groups, $\chi^2(60, N=1170) = 61.91, p=.41$, CFI=.99, RMSEA=.01. These steps were taken one at a time but a non-significant chi square was not achieved until both intercepts were freed.

**Structural Invariance.** The baseline model was estimated with all structural paths allowed to vary across NC and PA. In the specific model, this resulted in a model with reasonable fit, $\chi^2(119, N=1170) = 156.32, p=.01$, CFI=.94, RMSEA=.02. The model was then reestimated imposing equality constraints on the six regression coefficients relating to vocabulary, syntax, and EF across state of residence, $\chi^2(125, N=1170) = 154.00, p=.04$, CFI=.96, RMSEA=.02. A chi square difference test did not reveal a significant difference, $\chi^2(6) = 2.12, p = .91$. This finding indicated that the relations between children’s gestures, vocabulary, syntax and later EF performance were not different as a function of residence.
In the general model, the baseline model was estimated with structural paths allowed to vary across state of residence. This resulted in a model with good fit, $\chi^2 (55, \ N=1170) = 63.90, p=.19, \text{CFI}= .99, \text{RMSEA}= .02$. The model was reestimated imposing equality constraints on the six regression coefficients relating to early and later language, and EF across state $\chi^2 (61, \ N=1168) = 69.22, p=.22, \text{CFI}= .99, \text{RMSEA}= .02$. A chi square difference test did not revealed a significant difference in model fit, $\chi^2 (6) = 6.00, p=.42$. This finding indicated that the relations between children’s gestures, early and later language, and EF performance were not different as a function of their state of residence.

**Race Models**

**Measurement Invariance.** Although the identical methods were used to estimate the multiple group models by race the configural model would not converge. Several steps were taken to assist the software with finding a solution. First, the number of iterations was increased. Second, start values for all factor loadings and factor intercepts were provided. Finally, different scaling indicators were tried for the EF latent variable. This inability to estimate the latent variables across both race groups suggested that the indicators did not represent the same latent constructs of Gestures and EF for White and African-American children. For instance, Gestures may have a different factor structure for White children than African-American children, or the individual indicators such as *point* may have radically different variability between the groups. In general, it appeared that Gestures and EF operated differently as a function of race.
CHAPTER FOUR

Discussion

The current study examined the relations among children’s gestures, language, and EF across the first 4 years of life. The study was specifically interested in determining whether children’s gestures, representative of their early symbolic development, were related to their language skills and if these abilities were predictive of later EF. Utilizing longitudinal data from the Family Life Project, the study used both specific and general models to examine relations between children’s gestures, language skills at 24 and 36 months, and in turn EF. The models depicted both naturalistic observations and standardized assessments of infants’ gestures at 15 months, and language skills at 24 and 36 months. The findings revealed that both observed (specific model) and standardized (general model) measures of children’s gestures, and language skills had a significant association with later EF. Thus, the findings provided evidence in support of several developmental theories (Marcovitch & Zelazo, 2009; Zelazo & Frye, 1998; Zelazo, et al., 2003) that highlight the importance of children’s language abilities in representing the conflict inherent to EF tasks. To illustrate how this relation may operate, consider children’s performance on the EF task of spatial conflict. First, children must symbolically represent the concepts of left and right. Then, children must apply these representations within a rule structure that determines what action is appropriate based
upon if the arrow is pointing to the left or right, even if there is a left-right conflict between the location of the arrow and the direction it is pointing.

More precisely, the main contribution of this study was the examination of the direct relation between children’s gestures and EF abilities, coupled with the mediated relations through language. Although, there was not a significant direct association between children’s gestures and EF abilities, the findings from the observed measures (specific model) analyses indicated, as predicted, that children’s vocabularies and syntax had a direct association with later EF abilities. Further, a meaningful mediated relation was found for children’s gestures on later EF abilities through vocabulary. The findings from the standardized measures (general model) analyses were, as predicted, that children’s early and later language also had a direct association with later EF abilities. Mediated relations were also found. Children’s gestures had an indirect association with EF through early language, which in turn influenced later language.

In general, this study provided evidence for the maturation of symbolic representation (as demonstrated by children’s use of gestures, building of vocabulary and syntax) as foundational for EF abilities developing over the preschool years. For example, while a direct association between vocabulary, syntax, and later EF emerged, a significant mediated relation between children’s early gesture and their vocabulary was also found to predict EF. These findings provided support for the prospective taken by Zelazo and colleagues in the CCC theory (Zelazo & Frye, 1998; Zelazo, et al., 2003) and the HCSM (Marcovitch & Zelazo, 2009). Both theories suggest that children need to have the ability to mentally represent or label the conditions of a problem before being able to select the correct behavior to solve that problem. The current findings lend
support to this symbolic based foundation of EF with evidence provided from children’s language development. Specifically, the current study found that the relation between children’s gestures and EF was fully mediated by their later language skills. This finding offers support for considering growth in children’s ability to use symbols, as they transition from gestures, to single words, and then multiple words utterances, as influencing EF. Thus, it is symbolic representation that undergirds children’s development from gesture use to vocabulary building (Blake, 2000), and may in turn predict later EF.

Three key findings, which support the maturation of symbolic representation as an influence on EF development, are reviewed. First, the longitudinal findings that provided support for the mediated relations among gesture, language, and EF over 15, 24, 36, and 48 months are reviewed. Second, the insights gained from an examination of the nuances in language development with general and specific measures are reviewed. And third, the advantage of considering children’s gestures as the starting point for symbolic representation, the process that undergirds EF abilities, is argued.

**Longitudinal Findings**

This study uniquely contributed to the literature by examining the development of EF with longitudinal data. While previous studies have provided information about the relation between language and EF (Carlson, Moses, & Claxton, 2004; Hongwanishkul, Happaney, Lee, & Zelazo, 2005; Lang & Perner, 2002); the use of concurrent measures prevented the directionality of this relation to be determined. The current study sought to determine if children’s prior gestures and language skills predicted EF.
The current study did not find children’s gestures to be directly predictive of their later EF performance. However, there was a direct association between both children’s vocabulary and syntax with later EF. When using the general model of standardized measures, caregivers’ reports of children’s gestures at 15 months predicted early language at 24 months and then later language at 36 months, which in turn predicted EF at 48 months. These findings offered support for using longitudinal data to gain new insights into the developmental EF, and its associations with gestures and language. Indeed, the current study found that two of children’s language skills (e.g., vocabulary and syntax), as well as global language on standardized assessments, were predictive of later EF. Only a handful of other studies (Fuhs & Day, 2010; Hughes, 1998b) have clarified the direction of the relation between language and EF, and thus far the research is in agreement. Children’s early language skills are predictive of later EF abilities.

Another contribution of this study was the exploration of mediated relations between children’s gestures and EF longitudinally. The design of this study strengthened the claim that gestures had an influence on EF through later language skills because the same children were assessed at multiple times. When using either observed or standardized measures, significant mediated relations were found. Specifically, the study found a mediated relation between gesture and EF through children’s early language at 24 months. Additionally, a significant mediated relation was found between children’s gesture and EF through later language at 36 months. In other words, the influence of children’s gestures on EF abilities was exerted through either early or later language. A mediated relation was also found to exist between gesture and EF through early and then later language skills. This relation suggested that there was a downstream effect of
gestures on EF that changed over time. The downstream effect is one by which gesture first exerted its influence on EF through children’s early, and then later language. This indicated that changes in children’s language skills between 24 and 36 months were associated with later EF abilities. This finding lends support to an underlying mechanism that is expressed through language and changes over time, but remains associated with children’s EF abilities.

**General and Specific Language Measures**

Another limitation in previous work is the use of only standardized language measures (Fuhs & Day, 2010; Karbach & Kray, 2007; Kirkham, et al., 2003; Kray, et al., 2008; Kray, et al., 2004; Muller, et al., 2004). Although these studies do provide insight into the relation between language and EF, they do not address whether specific aspects of children’s language are more or less predictive of later EF abilities. To understand the nuanced relations among children’s gestures, vocabularies, and syntax in the prediction of EF abilities a more precise method of measurement was needed. Thus, the second unique contribution of this study was the inclusion of naturalistic observations of children’s gestures, vocabularies, and syntax. In order to fully investigate the contribution of symbolic representation on children’s EF, specific measures of language that illustrated its maturation were needed. For example, having an explicit measure of syntax allowed for the specific contribution from the ‘rule use’ aspect of language to be examined. Further, when multiple measures of specific language skills are used the independent contributions from these measures can be considered (i.e., vocabulary vs. syntax). This study confirmed that use of specific measures of children’s language provided new insights into precursors of EF.
Overall, this study found that both observed and standardized measures of children’s gestures and language were significant predictors of later EF abilities. This indicated that regardless of the source of data, naturalistic observation or standardized assessment, the direction of the relations between gestures, language, and EF were the same. The unique insight gained from the inclusion of naturalistic observations of children’s language came from the mediated relations. Specifically, the observed measures analyses highlighted the role of vocabulary in understanding how children’s gestures predicted later EF. For example, there was a significant mediated relation between gesture and EF through children’s vocabulary. However, there was not a significant indirect relation through children’s syntax. This finding was different from the standardized assessments where there was a significant mediated relation through children’s later language. Additionally, the observed measures analyses failed to support a second mediated relation through vocabulary, and then syntax. This indicated that gains in children’s language skills between vocabulary and syntax were not influential on later EF abilities.

There were several plausible explanations for why the indirect relations between gesture and EF through syntax were not found with the observed measures. First, the language variables used in the observed measures analyses were extracted from a picture book task. The nature of the picture book task may not have been ideal for eliciting a large quantity of children’s gestures. For example, many of the picture book tasks were conducted with the child sitting on a caregiver’s lap. The physical location of the child and caregiver made it somewhat prohibitive for the pair to view each other’s gestures. Moreover, the measures of children’s vocabularies and syntax drawn from this task were
confounded with caregivers’ input. The amount and type of language used by primary caregivers’ likely influenced their children’s vocabularies and syntax. Second, these observed measures of vocabulary and syntax were not inclusive representations of children’s language skills, but rather nuanced indicators. The results of the current analyses suggested that this type of fine grain language measurement may not be powerful enough to detect indirect relations. Perhaps, this was because the amount of language provided by children during this picture book task was too small. Further, both vocabulary and syntax were drawn from the same task, administered at different time points. Perhaps an observed measure with a longer assessment period that captured language across multiple tasks would be more representative of children’s abilities.

Alternatively, it is possible that syntax is not as powerful of a predictor of children’s EF abilities as vocabulary. In support of this possibility, select literature has speculated that vocabulary (Marcovitch & Zelazo, 2009; Zelazo & Cunningham, 2006; Zelazo, et al., 1997) is the most appropriate precursor to EF abilities. Although Zelazo and colleagues’ (Zelazo & Frye, 1998; Zelazo, et al., 2003) definition of EF highlights the importance of rule use, the majority of studies examining the relation between language and EF have focused on children’s vocabularies (Hongwanishkul, et al., 2005; Lang & Perner, 2002; Muller, et al., 2005). The lack of research examining the relation between children’s syntax and EF is counter intuitive given that the development of syntax is one of children’s first opportunities to practice using rule structures. It is unclear if children’s syntax has simply been ignored because it is difficult to measure with standardized assessments, or if children’s vocabularies have a stronger association with EF. Children’s vocabularies, used as a maker of their ability to symbolically represent
ideas and label them, may be a more appropriate predictor of later EF abilities. Further research is needed to clarify these relations.

**Using Gestures to Consider Symbolic Representation in the Definition of EF**

Although theory has suggested that precursors to EF abilities lie in children’s language, a paltry amount of literature has examined children’s skills prior to the advent of spoken language. Specifically, the CCC theory (Zelazo & Frye, 1998; Zelazo, et al., 2003) cites the necessity for children to use language in labeling the conditions of a conflict and the rules that dictate the appropriate actions to resolve that conflict. When adopting this view, it is only a small leap to also consider children’s gestures as a precursor to EF abilities. Abundant research (Acredolo & Goodwyn, 1990; Bates, et al., 1989; Bates, et al., 1987; Iverson & Goldin-Meadow, 2005) has already established the link between children’s use of gestures and later language abilities. In particular, this literature has highlighted the importance of symbolic representation as a mechanism that drives advances in both children’s gesture use (Blake, 2000) and vocabulary (Bates, 1987; Bates, et al., 1989). Symbolic representation also plays a crucial role in children’s later syntax development (Rowe & Goldin-Meadow, 2008) through the construction of rules, which governs how words are put together (Gelman & Taylor, 1984; Gelman & Markman, 1985). When considering a mechanism that explains how children’s labels and rule use improves performance on EF tasks, as suggested by the CCC theory, symbolic representation is a logical choice. The maturation of symbolic representation is precisely the skill set that enables children to use symbols in reference to increasingly complex ideas or embedded rules.
The current study is one of the first to consider the contribution from gestures, as a precursor of language skills, on children’s EF. Overall, this study offered support for broadening the foundation of EF to include symbolic representation. Providing specific support, the study found that there were significant relations between children’s gestures and EF exerted through language development. For example, the ability for children’s vocabulary to predict later EF, either directly or indirectly, confirmed the predominate role of symbol use, as suggested by the CCC theory, in EF performance. That is, children need to have the capacity to represent or label the conditions of a problem before being able to solve it (Zelazo, 1999). It is this ability, to label an object, which can be traced backed to children’s early use of gestures (Bates, 2000; Iverson & Goldin-Meadow, 2005).

However, the findings of this study also offered some opposition for the role of symbolic representation in EF. For example, the lack of a predictive relation between gesture and EF through syntax did not support the role of rule use in children’s EF. This finding suggested that children’s ability to express the relation between the conditions of a problem (Zelazo & Frye, 1998) may not be as important for resolving the conflict as the ability to label the different conditions. Further, although efforts were made in this study, by capitalizing on observed language measures, it is possible that the distinction between vocabulary and syntax was unnecessary. It may be that early and later language are the only factors associated with EF, and more work is needed to clarify if the rule use aspect of symbolic representation is associated with EF. Irrespective of the indirect influences through vocabulary or syntax, the current study supported children’s gestures as a predictor of later EF abilities.
Generalizability across Groups

Finally, the use of multiple group analyses offered additional support for the relations between gestures, language, and EF. Regardless of group membership by gender or state of residence the theoretical model tracing the foundations of EF back to children’s gesture use was supported. This meant whether you were a boy or a girl, living in NC or PA the associations between gestures, language, and EF were the same. However, the nature of these relations could not be tested by race. Thus, it remains unclear if associations between gestures, language, and EF are the same for White and African-American children. Overall, these findings indicated that the current conceptualization of EF is a robust one that was invariant across a number of different groups.

Conclusions and Limitations

The current study was uniquely situated to address the direct and indirect associations between children’s gesture use on later EF abilities, over the preschool years. In particular, it examined gestures and early spoken language, markers of symbolic representation, as the foundation upon which children’s EF abilities were built. As expected, the study found that children’s gestures, through language skills, predicted later EF abilities. However, when using a specific model of observed measures it was children’s vocabulary, not syntax that predicted later EF abilities. When using a general model of standardized measures, a downstream effect was found, which supported the maturation of symbolic representation as foundational for EF abilities. Still, this relation was not confirmed with both models. These inconsistent associations between gestures, vocabulary, syntax, and EF suggest that additional research is needed to determine if one
aspect of language is more relevant, than the other, for EF development. Moreover, because a measure of EF was not obtained at 15 months the directionally of relation between language and EF cannot be stated with certainty. One way to clarify these associations would be to include early measures of EF and to use more comprehensive measure of children’s vocabularies and syntax. Perhaps, such a study would reach different conclusions or clarify the strength of the associations among these variables.

Most importantly, this study provided support for symbolic representation as a mechanism undergirding EF and for using children’s gestures as an entry point into these associations. This dissertation is one of the only known studies to show a predictive relation between children’s gestures use and later EF abilities. This has important implications for future interventions. If symbolic representation is accepted as foundational for building EF skills, interventions could be developed for much younger children. In fact, the identification of a deficit could occur as early as 15 months and early detection is advantage for treatment outcomes. Moreover, because symbolic representation is developing throughout the preschool years, interventions could be targeted for specific age groups. For example, when developing an intervention for two-year-olds it would be logical to intervene at the level vocabulary, rather than at the level of gesture use.

Several limitations of this study should be noted. First, although a few familial factors were controlled for, such as the income-to-needs ratio, it is important to consider the influence of a variety of exogenous factors on children’s development of cognitive abilities. Many exogenous factors such as, the neighborhood a family lives in or the school children attend, are crucial for the development of children’s EF abilities. The
current study only used factors within the child to predict later EF abilities. It would be foolish to interpret these findings without acknowledging several factors outside of the child also significantly contribute to children’s cognitive development. For example, the input from caregivers has a vast influence on children’s language development (for review see Hoff, 2006). Further, it has been established the mothers who gesture more have children who gesture more (Rowe & Goldin-Meadow, 2009). Less is known about how parents directly contribute to children’s burgeoning EF (Bernier, Carlson, & Whipple, 2010), but established pathways through gesture and language offer some insights. Future research should examine the influences of exogenous factors such as, daycare attendance or parenting practices, on children’s gestures, language, and EF development.

Finally, although this study attempted to use sophisticated measures of children’s gestures, language skills, and EF abilities, these measures could always be improved. For instance, new tasks that are developed for specifically measuring gestures, expressive vocabulary, and syntax might provide additional insights. Future studies may also show stronger associations among children’s gestures, syntax, and EF if alternative, more sensitive measures are used. In the current study, the use of latent constructs had some limitations. For example, the amount of variances accounted for by the latent variables Gestures and EF was relatively low. Although, previous studies with young children (Hughes, Ensor, Wilson, & Graham, 2010) have accounted for a similar amount of variance when using latent constructs to represent cognitive skills. This measurement issue may be explained by the relatively young age of the children in this study, and their rapid cognitive development over the preschool years. The latent variable limitations
were particularly evident in the multiple group analyses. The lack of convergence with
the race model suggested that the indicators for Gestures and EF may not have been
appropriate for African-American children. However, it is important to note that the
direct relations among gestures, language, and EF were the same regardless of child
gender and state of residence. Future studies should explore whether significant
differences exist in the ability for children’s gestures to predict later EF based on race, or
if different indicators are needed for African-American children.
Table 1. Intercorrelations Between Variables

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Note: WM=Working memory, SSS=Silly sound stroop, GNG=Go no-go, SC/A=Spatial conflict arrows, STS=Something’s the same, NDW=Number of different words, MLU=Mean length utterance, PLS=Preschool Language Scale, CSBS=Communication and Symbolic Behavior Scales, MDI=Mental Developmental Index, MED=Maternal education, INR=Average income-to-needs ratio
### Table 2. Intercorrelations Between Variables by Gender

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Means: Males = mean values for males, Females = mean values for females.

Note: WM = Working memory, SSS = Silly sound stroop, GNG = Go no-go, SCA = Spatial conflict arrows, STS = Something's the same, NDW = Number of different words, MLU = Mean length utterance, PLS = Preschool Language Scale, CSBS = Communication and Symbolic Behavior Scales, MDI = Mental Developmental Index, MED = Maternal education, INR = Average income-to-needs ratio.
### Table 3. Intercorrelations Between Variables by Race

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Note: WM = Working memory, SSS = Silly sound stroop, GNG = Go no-go, SCA = Spatial conflict arrows, STS = Something’s the same, NDW = Number of different words, MLU = Mean length utterance, PLS = Preschool Language Scale, CSBS = Communication and Symbolic Behavior Scales, MDI = Mental Developmental Index, MED = Maternal education, INR = Average income-to-needs
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Table 5. Results of Chi Square Difference

Model Constrained by Gender

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Nested Models

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Model Constrained by State

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<td>Standardized-Omnibus</td>
<td>69.22</td>
<td>61</td>
<td>.22</td>
<td>.99</td>
<td>.02</td>
</tr>
</tbody>
</table>
### Nested Models

<table>
<thead>
<tr>
<th>Model</th>
<th>$\Delta \chi^2$</th>
<th>$\Delta df$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model 2 vs. 1</td>
<td>2.12</td>
<td>6</td>
<td>=.91</td>
</tr>
<tr>
<td>Model 4 vs. 3</td>
<td>6.00</td>
<td>6</td>
<td>=.42</td>
</tr>
</tbody>
</table>

### Model Constraint by Race

<table>
<thead>
<tr>
<th>Model</th>
<th>Model Description</th>
<th>$\chi^2$</th>
<th>$df$</th>
<th>$p$</th>
<th>CFI</th>
<th>RMSEA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Configural Invariance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Model would not converge</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
Figure 1. Conceptual Model of Analyses
Figure 2. Measurement Model

χ²(47, N=1185)=78.00, p<.01,
CFI=.96, RMSEA=.02
Figure 3. Model of Observed Language Measures

χ²(61, N=1194)=93.50, p=.00, CFI=.95, RMSEA=.02
Figure 4. Model of Standardized Language Measures

χ²(29, N=1194)=52.13, p=.01, CFI=.98, RMSEA=.03
References


