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Effects of Language on the Development of Executive Functions in Preschool Children

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ACCEPTANCE

This dissertation, EFFECTS OF LANGUAGE ON THE DEVELOPMENT OF EXECUTIVE FUNCTIONS IN PRESCHOOL CHILDREN, by GREER ALEXANDER EZRINE, was prepared under the direction of the candidate's Dissertation Advisory Committee. It is accepted by the committee members in partial fulfillment of the requirements for the degree Doctor of Philosophy in the College of Education, Georgia State University.

The Dissertation Advisory Committee and the student's Department Chair, as representatives of the faculty, certify that this dissertation has met all standards of excellence and scholarship as determined by the faculty. The Dean of the College of Education concurs.

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ABSTRACT

EFFECTS OF LANGUAGE ON THE DEVELOPMENT OF EXECUTIVE FUNCTIONS IN PRESCHOOL CHILDREN
by
Greer Alexander Ezrine

The purpose of this research was to investigate the relationship between language skills and the development of executive functions in a normative preschool population over a 3 year period. Hierarchical Linear Modeling (HLM) was used to examine models of individual change and correlates of change in the growth of 7 executive skills in a sample of 39 children ages 3 to 5. Results of the analyses revealed significant positive linear growth trajectories over time for 5 of the 7 executive skills measured ($p < .05$). Maturation alone accounted for a significant amount of variance in nonverbal working memory (Block Span, Stanford Binet-5th Edition (SB-5)) and problem solving skills (Tower, NEPSY). Growth in verbal working memory (Memory for Sentences, SB-5) was predicted uniquely by initial receptive vocabulary (Peabody Picture Vocabulary Test–3rd Edition) and oral language (Comprehensive Assessment of Spoken Language) skills, even after considering age. Language variables did not predict rate of change in the 6 other executive skills measured. Thus, the pattern of results extends previous cross-sectional research by documenting that executive skills grow systematically with age in individual children during the preschool period. Furthermore, results suggest that during the preschool years, language ability is an important predictor of growth in working memory for verbal information—a capacity associated both theoretically and empirically with the transition from other- to self-regulation in early childhood. Findings are discussed in relationship to the literature on school readiness and the development of self-regulation. Implications for future research and practice are also suggested.

EFFECTS OF LANGUAGE ON THE DEVELOPMENT OF EXECUTIVE FUNCTIONS IN PRESCHOOL CHILDREN

by

Greer Alexander Ezrine

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ABBREVIATIONS

ADHD	Attention Deficit Hyperactivity Disorder
ASD	Autistic Spectrum Disorder
CAS	Cognitive Assessment System
CASL	Comprehensive Assessment of Spoken Language
DCCS	Dimensional Change Card Sorting Task
EF	Executive Function
HLM	Hierarchical Linear Modeling
IQ	Intelligence Quotient
PPVT-III	Peabody Picture Vocabulary Test-Third Edition
SB-5	Stanford Binet Intelligence Scales-Fifth Edition
SOPT	Self-Ordered Pointing Task
WISC-III	Wechsler Intelligence Scale for Children-Third Edition

CHAPTER 1

DOES LANGUAGE INFLUENCE THE RELATIONSHIP BETWEEN SELF-REGULATION AND SCHOOL READINESS IN EARLY CHILDHOOD?

During the preschool period, young children make significant progress in their ability to control their behavior, emotions, and thought processes (Kopp, 1982). Flavell (1977) described this movement toward self-regulation as “one of the really central and significant cognitive-developmental hallmarks of the early childhood period” (p. 64). The development of self-regulation is associated with maturity and self-control, including the ability to comply with adult requests, to control behavior and emotions according to social and situational demands, to sustain attention, to delay gratification, and to direct and monitor thinking and problem solving (Bronson, 2000). While there continues to be debate about the definition and components of self-regulation in early childhood, there is general agreement among scholars that self-regulation is adaptive in nature and encompasses self-monitoring, self-evaluation, and behavioral adjustment (Bandura, 1986). Further, as previously disparate lines of research across the developmental sciences have begun to converge, there is a growing consensus that the development of self-regulation is dependent, to some extent, on maturational changes in prefrontal cortex, a region of the brain involved in executive functioning (Diamond, 2001).

A growing body of literature points to self-regulation as a primary mechanism driving ‘school readiness’, a term used to describe children’s preparedness to learn and perform in the classroom at school entry (Carlton & Winsler, 1999). This multidimensional construct encompasses both pre-academic skills and socio-emotional behaviors, including readiness to socialize with peers, follow directions, communicate effectively, and stay on task (Rimm-Kaufman, Pianta, & Cox, 2000). Self-regulation has also been linked to social-emotional competence (Kochanska, Murray, Jacques, Koenig & Vandegeest, 1996), appropriate behavioral control (Eisenberg, Fabes, & Losoya, 1997), and academic achievement (Duncan et al., 2007; McClelland et al., 2007). As well, researchers have documented the social and academic risks associated with inadequate self-regulatory skills in early childhood including peer rejection (Ladd, Birch, & Buhs, 1999) and lower levels of academic achievement (McClelland, Morrison, & Holmes, 2000).

While it is becoming increasingly clear that self-regulatory skills are critical for school readiness and optimal cognitive and social-emotional development, our understanding of the developmental pathways through which self-regulation influences academic and social outcomes remains unclear (NICHD Early Child Care Research Network, 2003). As suggested by Shonkoff and Phillips (2000), there is still much to learn about both normative and atypical patterns of regulatory development as well as the mechanisms that underlie the "successful navigation of the many challenges encountered en route to well-regulated behavior" (p. 122). Hence, researchers may ask, "What developmental processes or mechanisms might influence the relationship between self-regulation and school readiness?" Additionally, practitioners may ask, "What prerequisite or foundational skills, if any, do children need to develop adequate self-regulation in preschool and how can we help them develop those skills?"

In this paper, these questions will be addressed by asking whether relations between self-regulation and school readiness are influenced by individual differences in children's language ability. As such, this paper has two purposes. The first purpose is to review the major theoretical perspectives and empirical evidence across the developmental sciences suggesting that language influences the development of self-regulation in ontogeny. The second purpose is to examine the research and practical implications of a language-focused approach to investigating the relationship between self-regulation and school readiness in both typically developing and special populations. A review of relevant literature addressing these questions follows.

Purpose One: Review of Theory and Research

Theoretical Foundations Linking Language and Self-Regulation

Relations between language and thought have been of perennial interest to linguists, psychologists, and cognitive scientists (Nelson, 1996; Pinker, 1994; Vygotsky 1978). An important theorist in this regard is Vygotsky (1978) who proposed that all psychological functions originate in social interactions and that mental processes begin as culturally supported external activities ultimately internalized through the course of development. Notably, Vygotsky (1986) viewed the unique human capacity for language as a cultural tool that facilitates children's learning and allows for self-regulation of thought and behavior. He drew a clear distinction between basic psychological processes, such as perception, memory, and attention, which are shared by animals and are reflexive, and higher psychological processes, which include abstract thought and conscious behavior (Vocate, 1987). Voluntary in nature, these processes, including the ability to regulate one's own perceptions, memories, and behavior, allow humans to surpass the bounds of the immediate environment and sensory perceptions (Luria, 1982). Thus, through our unique linguistic representational systems, humans are able to perceive and manipulate objects and actions indirectly, without having to directly experience them. Hence, language allows for the formulation of conceptual generalizations and categories, the basis of concept formation and rational thought (Vygotsky, 1986). Additionally, language permits the transmission of information and knowledge to others across time, making it possible for humans to acquire the experience of previous generations and consider future possibilities (Luria, 1982).

Luria (1961) extended Vygotskian theory by applying neurophysiological mechanisms to the study of language and self-regulation. While Vygotsky focused on the role of social and cultural factors to explain the regulative function of language, Luria (1982) asserted a role for the frontal lobes, an area of the brain involved in the direction and control of motor movement. He posited a gradual, three-stage process in the power of speech to regulate behavior. Initially, children's motor acts are initiated by adult verbal commands on a social (i.e., interpsychological) plane of functioning. By focusing the child's attention to specific objects in the environment, the adult organizes and directs the child's actions with verbal instructions (e.g., "Where's the ball?" "Pick it up!"). At this stage, however, if there is a conflict between the semantic aspect and the impulsive aspect of speech, the impulsive aspect will dominate. For example, children younger than 3 will often become distracted by other, more salient, objects in the immediate environment when acting on a verbal directive (e.g., child will not pick up the ball when asked, but instead a more brightly colored block). During the second stage in the preschool period between the ages of 3 and 6, self-regulation of behavior begins to be realized through the child's expanded and externally vocalized (i.e., egocentric) speech. Children's verbalizations are purposeful, in that they serve to solicit help from others and to support rudimentary problem solving. Finally, egocentric speech gradually turns inward and converts to inner speech in the third stage, becoming a tool for intellectual activity and a method of organizing and regulating mental processes (Luria, 1982). In sum, Luria (1961) argued:

> This formation of internal speech, which is closely bound up with thought, leads to a new, specifically human, stage of development. The verbal analysis of the situation begins to play an important role in the establishment of new connections; the child orients himself to the given signals with the help of the rules he has verbally formulated for himself; this abstracting and generalizing function of speech mediates the stimuli acting upon the child and turns the process of elaboration of temporary connections into the complex, "highest-self-regulating system" (Luria, 1961, p. 96).

The Role of Language in Contemporary Theories of Executive Functions

Contemporary conversations about self-regulation and school readiness increasingly emphasize the importance of executive functions (Brock, Rimm-Kaufman, Nathanson, & Grimm, 2009). Indeed, Blair (2002) has proposed a neurodevelopmental approach to the study of school readiness suggesting that executive functions "underlie many of the behaviors and attributes that are associated with successful school adjustment" (p. 112). Although no firm consensus on a definition of executive functions has been established, they are thought to involve a number of interrelated skills necessary for independent, purposeful, and goal-directed activity (Anderson, 1998). Self-regulatory skills generally agreed to be subsumed under the executive functions umbrella include inhibition, working memory, selective attention, goal setting, planning and organizing, performance monitoring, and maintaining and shifting set (Anderson, 1998; Lezak, Howieson, & Loring, 2005).

In recent years, a number of empirical studies have demonstrated that executive functions can be measured in very young children using developmentally sensitive assessment methods (Carlson, 2005) and that the preschool years, in particular, are characterized by rapid changes in these abilities (Espy, Kaufmann, McDiarmid, & Glisky, 1999). Developmental studies have also documented progressive incremental growth in executive functions across childhood and adolescence, coinciding with growth spurts in prefrontal cortex and associated neural projections (Diamond, 2001, 2002). Neural imaging studies suggest that while prefrontal regions may play a critical role in orchestrating behavior, the integrity of the entire brain may be necessary for efficient executive functioning (Anderson, Anderson, Jacobs, & Smith, 2008). Cognitive processes, such as perception, memory, and language, rely on posterior brain areas and feed into anterior brain regions to sustain executive functions (Denckla, 1996). Hence, executive functions are inherently integrative in nature and therefore dependent upon the input and quality of information from other brain centers, like those responsible for language. Three of the prominent contemporary models of executive functions ascribing an important role to language are described here.

Neuropsychological Model of Executive Functions. According to Barkley (2001), "an executive act is any act toward oneself that functions to modify one's own behavior so as to change the future outcomes for that individual" (p. 4). Hence, executive functions are future-oriented behaviors directed at the self for the purpose of self-regulation. Grounded in an evolutionary perspective, Barkley's (1997a) model argues that self-regulation is instinctual and is employed in the service of our own self-interests. The model is comprised of an overarching behavioral inhibition system and four distinct, yet interactive, executive functions that control behavioral responses (e.g., nonverbal working memory, verbal working memory, affect/motivation regulation, and analysis/synthesis). Importantly, behavioral inhibition is thought to permit executive functioning by either inhibiting the initial prepotent response, interrupting an ineffective ongoing response, or providing interference control (i.e., resistance to distraction) (Barkley, 2001).

In Barkley's (1997a) model executive functions greatly facilitate adaptive functioning by allowing an individual to evaluate the event at hand, modify his or her eventual response, and improve the long-term future consequences related to that event. As such, executive functions allow for purposive, effortful, or intentional actions including the organization and planning of behavior across time and the delay of gratification. Additionally, Barkley (2001) posited that executive functions represent private, covert or internalized forms of behavior that emerge via a common process across development. Similar to Vygotskian (1978) notions of internalization, Barkley (1997a) proposed that executive functions originate as forms of behavior that are entirely public, observable, and directed toward others. With maturation, they become increasingly less observable to others and are directed toward the self as a means to control one's own behavior (Barkley, 2001). For example, egocentric speech becomes internalized over the course of early development, providing "an instrument of reflection and exploration and thereby permitting the individual to construct various hypothetical messages or responses before choosing one to emit" (Barkley, 1997a, p. 87).

Barkley (1997a) borrowed from Vygotskian (1986) theory in proposing that the development of internalized, self-directed speech supports the development of self-regulation. However, Barkley challenged the social and cultural origins of self-regulation by arguing that executive functions are a biological adaptation that evolved out of interpersonal competition within our species (Barkley, 2001). That is, the social environment sculpts rather than creates self-regulatory capacities (Bronson, 2000). According to Barkley (1997a), language supports a behavioral shift in early childhood from being externally guided to being "planned, organized, and regulated by internally represented information—a shift from reactive to purposive or intentional actions, and from context-dependent to self-determined (internally guided) behavior" (p. 91). Moreover, self-directed speech is theorized to permit self-questioning through language, thereby forming the basis of self-regulated learning and metacognition.

In sum, Barkley (1997a) emphasized the mediating role of language in the development of self-regulation:

> Self-directed speech is believed to provide a means for description and reflection by which the individual covertly labels, describes, and verbally contemplates the nature of an event or situation prior to responding to that event. Private speech also provides a means for self-questioning through language, creating an important source of problem-solving ability as well as a means of generating rules and plans (p. 175).

Working Memory Model. Baddeley and Hitch (1974) proposed a narrower conceptual model of executive functions focused on working memory, a specific executive domain. In this model, working memory is defined as “a limited capacity system allowing the temporary storage and manipulation of information necessary for such complex tasks as comprehension, learning, and reasoning” (Baddeley, 2000, p. 418). The working memory model consists of a limited capacity attentional control system (central executive) aided by two subsidiary systems, the ‘phonological loop’ and the ‘visuospatial sketchpad’ (Baddeley, 2000). While the phonological loop is assumed to temporarily hold and manipulate verbal and acoustic information, the visuospatial sketchpad is assumed to hold and manipulate visuo-spatial information. The functions of the central executive involve selective attention, switching attention, coordinating concurrent activities, and retrieval of information from long-term memory (Baddeley, 2000; Baddeley & Hitch, 1994).

Based on neuropsychological evidence, the working memory model was recently modified to include a fourth component, the ‘episodic buffer’ (Baddeley, 2000, 2002). The episodic buffer, which is controlled by the central executive, is proposed to provide temporary storage of integrated information from various sources, including the subsidiary systems (e.g., phonological loop and visuospatial sketchpad) and from long-term memory. Notably, Baddeley (2002) suggests that “the episodic buffer serves as a system not only for representing the environment and making it accessible to conscious awareness …but also for utilizing past experience to model the future” (p. 257). As such, the episodic buffer serves as a multimodal store capable of holding complex representations and is assumed to play an important role in learning by feeding information into and retrieving information from long-term memory.

The phonological loop has been proposed as both temporary storage for verbal information and a mechanism for subvocal rehearsal that is able to refresh decaying memory traces in the phonological store (Baddeley, 1986). Importantly, Baddeley, Gathercole, and Papagno (1998) suggested that the primary function of the phonological loop is to mediate language learning by providing temporary storage of novel speech input while more permanent memory representations are being constructed. In the case of written input of verbal material, Baddeley and his colleagues (1998) argued that visual information is also fed into the phonological store by means of self-directed speech. This position is based on neuropsychological evidence from patients with defective phonological loop function who have great difficulty learning new vocabulary (Baddeley et al., 1998). Further, evidence comes from studies linking children's phonological memory skills (e.g., nonword repetition accuracy) and new word learning, even when exposure to new words is controlled across subjects (Baddeley et al., 1998). Hence, it is proposed that the ability to learn new words is constrained by phonological loop capacity. The association between the phonological loop and long-term phonological learning has also been proposed to be bidirectional, such that, children's prior knowledge of the structure of individual words and of language more generally benefits immediate memory performance (Baddeley et al., 1998).

In sum, the working memory model of executive functions attributes an important role to language in the form of the phonological loop, which supports immediate memory and word learning and interacts, through the multimodal episodic buffer, with long-term memory (e.g., crystallized language and semantic knowledge). As Baddeley (2002) suggested, the capacity of the working memory system to interface with long-term memory would provide an important mechanism for self-directed speech to control behavior as proposed by Vygotskian (1986) theory.

Cognitive Complexity and Control (CCC) Theory. Zelazo and Frye (1997) expounded a conceptual framework to explain how executive processes operate in an integrative manner to solve problems and/or achieve a goal state. According to CCC theory, age-related changes in behavior control are due to changes in the acquisition of increasingly complex language-based rule systems that children can formulate and use when solving problems. In this model, complexity corresponds to the number of levels of embedded rules (e.g., condition-action ‘if-then’ statements) that the child can represent (Zelazo, Frye, & Rapus, 1996). Furthermore, developmental changes in complexity are dependent upon the extent to which children can reflect on their own subjective experiences (Müller, Jacques, Brocki, & Zelazo, 2009). According to CCC theory, therefore, executive failures are attributed to “lack of reflection on rules, not to lack of consciousness of rules per se” (Zelazo et al., 1996, p. 41). In other words, there is a well-documented dissociation in very young children between knowing rules and using them (Zelazo et al., 1996).

For example, a number of studies using the Dimensional Change Card Sorting Task (DCCS; Frye, Zelazo, & Palfai, 1995) have shown consistently that 3-year-olds can successfully use one pair of rules to sort cards (e.g., “If it’s a triangle it goes in this box; if it’s a circle in goes in that box”). However, when two different pairs of rules are put into conflict (color vs. shape), 3-year-olds persist in sorting cards according to the first rule pair (e.g., sort by shape) despite being told to switch to a new pair of rules (e.g., sort by color; "If it's blue put it here; if it's yellow put it there) (Zelazo et al., 1996). In contrast, 4- and 5-year-olds tend to have little difficulty switching immediately to the new pair of rules on post-switch trials.

According to CCC theory, language plays an essential role in the conscious control of behavior because it allows for the separation of the child from his or her immediate situation (Müller et al., 2009). That is, semantic descriptors can be maintained in working memory and reflected on by the child, making recursive consciousness possible. As such, "labeling subjective experience is the precondition, on this approach, for further reflection on subjective experience – it transforms what was subjective into an object of conscious consideration" (Müller et al., 2009, p. 57). Furthermore, verbalizations stored in working memory lead not only to consciousness of rules, but also to the ability of the child to "bring the right knowledge to bear on their behavior (and their inferences) at the right time in specific situations" (Müeller et al., 2009, p. 57). On the DCCS, therefore, 4- and 5-year-olds not only demonstrate knowledge of the pre- and post-switch rules (as 3-year-olds do), they can also *act* on them in the right situation by using self-directed speech (vocal or sub-vocal) to guide their behavior.

In sum, the contemporary theories of executive function described here all posit a role for language in the development of self-regulation. Whether discussed in the context of self-directed speech, the phonological loop, or sub-vocal rehearsal, these theories all suggest that language has the power to both inform and instruct behavior. First, language informs behavior by allowing the child to describe the situation at hand, reflect on it, and create new rules by which to guide behavior. Then, as language becomes turned on the self in the form of self-directed speech, children develop the capacity to use these verbalizations to actually control their cognitive and motor responses. Finally, while these contemporary theories emanate from a neuropsychological rather than sociocultural research tradition, they all incorporate the Vygotskian (1986) notion of internalization, placing language at the core of the movement from other- to self-regulation in early childhood.

Research Examining the Link Between Language and Self-Regulation

Other veins of research primarily from the field of developmental psychology have also explored the role of language in the development of self-regulation. For example, a number of empirical studies investigating self-directed speech, its social origins, and its relationship to task performance have shed light on how language influences self-regulation in both normal and atypical development.

Developmental Trajectories in Self-Directed Speech. Vygotsky's (1986) original proposition regarding the emergence of self-regulation in early childhood focused on merging preverbal thought and preintellectual language. This critical shift in development occurs during the preschool period when children begin to use language, not just as a tool for communication with others, but also as a cognitive instrument for guiding, planning, and regulating their own thoughts and behavior (Diaz & Berk, 1992). Vygotsky (1978) posited a three stage developmental progression from (a) pre-intellectual, purely social and communicative speech, in infancy; to (b) overt egocentric or private speech in the preschool period; to (c) internal dialogue, or covert inner speech, in later childhood when language becomes intellectual and thinking becomes verbal.

Evidence of this developmental process in language internalization comes primarily from research on children's overt speech directed to the self, often referred to in the neo-Vygotskian literature as 'private speech' (Winsler, Diaz, Atencio, McCarthy, & Chabay, 2000). Research with normally developing children has largely confirmed Vygotsky's (1978) original observations and hypotheses of a global developmental pattern in private speech (Winsler, 2009). In general, private speech has been found to increase in frequency during the preschool period, peaking between the ages of 4 to 6. Reducing in frequency during the elementary school years, private speech is then gradually replaced with more covert-forms of self-directed speech (e.g., whispers, inaudible muttering), and then eventually with silent inner verbal thought (Winsler, 2009).

Recently, Winsler and Naglieri (2003) extended previous private speech research, focused almost exclusively on early childhood, with their cross-sectional study of verbal strategy use in a large (N = 2,156) nationally representative sample of children and adolescents between 5 and 17. Overt and partially covert (whispers, muttering) private speech was observed and children's self-reported use of inner speech was coded during a standardized planning task from the Cognitive Assessment System (CAS; Naglieri & Das, 1997), an individually administered test of cognitive abilities. The self-regulatory demands were high due to the sequential planning and set switching demands of the task, which was based on the Trail-Making Task (Reitan, 1971), a widely used neuropsychological assessment of executive functions. Results showed clear support for the notion that private speech moves from more externalized forms of speech to more internalized forms as children get older. That is, overt private speech was common among 5-year-olds (43%) and declined linearly with age (10% for 17-year-olds). Moreover, the self-reported use of silent, inner speech was rare for the 5-year-olds (4.1%) and became common for the oldest age groups (33% for 16-year-olds and 28% for 17-year-olds). Importantly, the percentage of children and adolescents (60%) using some kind of verbal mediation (overt, partially covert, or covert) remained constant across the ages studied. Thus, it was the type of verbal strategy use rather than the simple presence of a verbal strategy that varied by age. Even among late adolescents, a considerable minority continued to use private speech to guide problem solving, which suggests that the use and internalization of speech extends well beyond early and middle childhood, as originally proposed by Vygotsky (1986). As argued by Winsler (2009), "the existence of overt self-talk in older individuals is simply the continued and periodic use of a strategy that was found to be important earlier in development" (p. 9).

Private Speech and Task Performance. In addition to the investigation of developmental trajectories in private speech, researchers have also explored the relation between private speech and task performance. A number of studies have demonstrated that, for both children and adults, overt private speech appears to peak during moments of initial task difficulty, gradually decreasing over time as the task is mastered or repeated (Berk & Spuhl, 1995; Duncan & Cheyne, 2001). Moreover, children have been found to be more likely to use private speech when (a) engaged in goal-directed, academic, or problem-solving activities, as compared to free play or other activities (Winsler & Diaz, 1995); (b) when the problem-solving task is neither too simple nor too difficult (Fernyhough & Fradley, 2005); and (c) when they are alone or with peers, as opposed to in the presence of an adult, who provides external control and direction or 'other-regulation' (Winsler, Carlton, & Barry, 2000). It appears, therefore, that private speech is maximized in problem-solving situations where executive control is required and there is little regulation provided by adults (Diaz, 1992). Finally, there is also evidence that private speech is associated with improved task performance in preschool children (Winsler, Diaz, & Montero, 1997) and that private speech becomes more systematic, strategic, and task relevant as children get older (Winsler et al., 2000).

Social Origins of Self-Regulation. Central to Vygotskian (1978) theory of cognitive development, is the socio-cultural context in which the child operates. This view suggests the development of rational thinking in the child is a gradual process of assimilation emanating from social interaction, such that:

> Every function in the child's cultural development appears twice: first, on the social level, and later, on the individual level; first, between people (interpsychological), and then inside the child (intrapsychological). This applies equally to voluntary attention, to logical memory, and to the formation of concepts. All the higher functions originate as actual relations between human individuals. (Vygotsky, 1978, p. 57)

With regard to self-regulation, it has been proposed that young children transition during the preschool years from relying on adult assistance in problem-solving to internalization of the skills necessary for independent problem-solving (Rogoff, Mistry, Goncu, & Mosier, 1993). Relevant to this process is a specific form of social interaction termed 'scaffolding', a term introduced by Wood, Bruner, and Ross (1976). When an adult scaffolds a task for a child, his or her level of assistance adjusts according to the child's level of mastery. This support involves modulating task difficulty by breaking down the task into manageable parts, focusing a child's attention to specific features, and organizing his or her verbal and physical responses (Wertsch, 1979).

Notably, during the preschool period when language skills are developing rapidly, adult scaffolding is more likely to involve complex verbal support (e.g., explanations, analogies, leading questions) to assist children in learning problem-solving strategies (Bridges, 1979). Indeed, a number of studies have examined the effects of verbal scaffolding on children's concurrent and subsequent task performance. For example, in their longitudinal study of verbal scaffolding and cognitive abilities, Smith, Landry, and Swank (2000) demonstrated that higher levels of maternal verbal input at age 3, regarding information about the association between objects, actions, and concepts, was predictive of higher levels of verbal and nonverbal cognitive skills at age 5. Moreover, Landry, Miller-Loncar, Smith, and Swank (2002) found, using structural equation modeling, that maternal verbal scaffolding at 3 years positively predicted later executive skills at age 6. Additionally, these researchers found that this path directly influenced children's language and nonverbal problem-solving skills at age 4, which suggests that verbal scaffolding may not only facilitate children's current developmental needs (e.g., level of attention, motor skills), but may also facilitate future executive skills by giving children instruction in how to use language to solve problems.

Focused on an at-risk population, Winsler, Diaz, McCarthy, Atencio, and Chabay (1999) conducted a longitudinal study of the development of verbal self-regulation in 3- to 5-year-old children identified by their preschool teachers as evidencing behavior problems. Notably, patterns of mother-child interaction during collaborative problem-solving activities were different for behaviorally at-risk children compared to controls.

Mother-child interaction for the at-risk group was characterized by negativity, conflict, less praise, and less physical withdrawal over time, as compared to interactions involving the control group. To explain this finding, these researchers suggest that difficult to manage children may elicit negative and controlling patterns of parent-child interaction, which may reduce opportunities for appropriate scaffolding and verbally mediated joint problem-solving, ultimately constraining or delaying the development of self-regulation.

Links between Language and Self-Regulation in Special Populations

Language competence is widely believed to be an important mediator of both normal and atypical cognitive and behavioral development (Bronson, 2000; Nelson, 1996). Given the central role that self-regulation plays in behavioral adaptation, it is no surprise that various forms of psychopathology involve executive dysfunction (Pennington & Ozonoff, 1996). In particular, verbal self-regulatory deficits have been implicated in two developmental disorders, attention-deficit hyperactivity disorder (ADHD) (Barkley, 1997b) and autistic spectrum disorders (ASD) (Joseph, McGrath, & Tager-Flusberg, 2005).

Attention-Deficit Hyperactivity Disorder. As proposed in Barkley's (1997a) neuropsychological model of executive functions, a core deficit in ADHD is the delayed internalization of self-directed speech. As previously discussed, Barkley (1997a; 1997b) has argued that self-directed speech is a means for reflection, description, and self-questioning through language, thereby forming the basis for formulating rules, plans, and ultimately metacognition. Furthermore, as self-directed speech matures and becomes gradually internalized across development, behavior comes increasingly under its control. Indeed, a number of studies have demonstrated that unmedicated children with ADHD are delayed in their internalization of self-directed speech relative to controls (Winsler, 2009). For example, Berk and Potts' (1991) cross-sectional naturalistic observations of 6- to 12-year-old boys engaged in independent math seatwork found significant differences in the developmental patterns of private speech use in boys with ADHD compared to controls. Interestingly, boys with ADHD were not found to be impaired in their spontaneous production of private speech. Rather, boys with ADHD demonstrated a developmental lag in their internalization of private speech such that they engaged in more externalized, self-guiding, and less inaudible private speech than controls. Additionally, the more distractible boys with ADHD used the greatest quantity of externalized, task-relevant speech, yet such speech was effective in controlling behavior for only the least distractible boys with ADHD, for whom it was positively associated with attentiveness to task. Moreover, observation of a sub-sample of boys with ADHD who were tracked both on and off stimulant medication showed that medication was associated with the most mature internalized task-relevant speech, reduced motor restlessness, and focused attention to task. In sum, Berk and Potts (1991) argue that verbal self-regulation is less mature and less effective in the service of learning for unmedicated boys with ADHD. Moreover, they suggest that these findings provide support for reciprocal interaction between self-guiding private speech and behavior, such that the eventual internalization and regulatory power of private speech is critically dependent on an intact, maturely functioning attentional system.

Similarly, Winsler's (1998) study of parent-child interaction and scaffolding during joint problem-solving among 6- to 8-year-old boys with ADHD showed a delay in internalization of private speech compared to age-matched controls. Moreover, boys with

ADHD were found to be more off-task and noncompliant than control boys. In addition, their interactions with parents were characterized by more negative verbal control strategies, poorer quality scaffolding, and less withdrawal of adult control and assistance. In both the ADHD and control groups, withdrawal of adult control, good quality scaffolding, and lack of negative control were positively related to children's subsequent individual attention and task performance. Hence, Winsler argues that children's delay in the internalization of speech and resulting poor verbal self-regulation may be negatively influenced by both a dysfunctional attention system, as posited by Berk and Potts (1991), and the consequences of negative and controlling parent-child social interactions.

Autistic Spectrum Disorders. Autism is another developmental disorder that has been shown by a number of studies to involve a core executive deficit in verbal self-regulation (Hughes, 1996; Joseph, Steele, Meyer, & Tager-Flusberg, 2005; Russell, Jarrold, & Hood, 1999). For example, Russell et al. (1999) demonstrated that compared to matched controls, children with autism were selectively impaired on executive tasks that involve arbitrary, novel rules (e.g., 'rule-bound' task), but had little difficulty with non-rulebound executive tasks— those that involved holding information in mind and inhibition of a prepotent response, but do not contain 'if-then' rules. To explain these findings, these authors argue that children with autism have trouble specifically with using inner speech to guide behavior. That is, they are impaired in using verbal encoding and rehearsal strategies in the service of working memory.

Joseph et al. (2005) attempted to further specify the nature of the verbal self-regulation deficit evidenced by children with ASD by directly comparing their verbal and non-verbal working memory skills using a self-ordered pointing task (SOPT). Subjects, ages 5 to 14 years, were matched with controls based on age, IQ, and receptive and expressive vocabulary. In the SOPT, children were presented with an array of stimuli on a single sheet of paper. Each stimulus set was presented repeatedly, in a new spatial arrangement each time. The child's task was to point to a different picture on each presentation, with the goal of not touching the same picture more than once. In the verbal condition, the stimuli were pictures of concrete, nameable objects, whereas in the non-verbal condition, the stimuli were abstract and not easily named or encoded verbally. The results showed that children with ASD performed as well as controls on a verbal span task and the non-verbal SOPT. However, consistent with Russell et al.'s (1999) hypothesis that individuals with autism fail to use language in the service of self-monitoring, the ASD group performed significantly worse on the verbal SOPT. Overall, findings from this study suggest that children with autism do not exhibit language impairment per se, but rather exhibit a failure to use internal language in the service of self-regulation. Hence, in the context of Baddeley's (2000) working memory model of executive functions, the authors propose that it is not impairment in 'phonological loop' capacity that is relevant, but impairment of the 'central executive' aspect of working memory to use verbal mediation strategies to maintain and monitor goal-related information in working memory.

In another recent study, Whitehouse, Mayberry, and Durkin (2006) investigated the use of verbal mediation strategies in boys with autism and ability-matched controls using verbal encoding and recall tasks (e.g., pictures and words) and a task-switching paradigm. Researchers manipulated the extent to which stimuli could be encoded verbally and whether inner speech could be used during retrieval via articulatory suppression. The results demonstrated that children with autism did not benefit from a 'picture-superiority effect', the tendency to recall significantly more pictures than words. That is, unlike typically developing children, individuals with autism do not construct internal verbal codes for pictorial information during memory tasks to the same extent as controls. Moreover, while task performance of controls was disturbed when inner speech was blocked via articulatory suppression, this was not the case with the autistic group. The authors of this study suggest that these findings reflect a lack of inner speech in children with autism, a delay in the development of inner speech, or alternatively, a poor awareness of how to use inner speech.

In sum, the role of language in executive dysfunction has become of increasing interest to researchers who study developmental disorders. While impairments of language and executive functions have been found to coexist in a variety of disorders, studies profiling these abilities in children with ADHD and ASD, in particular, have advanced our understanding by identifying selective executive deficits in the area of verbal self-regulation in both disorders. Specifically, the delayed internalization of private speech in ADHD and the impairment of the executive (i.e., self-monitoring) aspects of the verbal working memory system in ASD have been the focus of recent studies. Future research will examine whether the co-occurrence of language and executive impairment in these disorders is due to common genetic factors (Chein & Fiez, 2001) or etiologically distinct deficits in language and in the verbal working memory system that interact across development (Joseph et al., 2005).

Purpose Two: Implications for Research and Practice

As evident from this review, a number of prominent classical and contemporary developmental theorists have ascribed an important role to language in the development of self-regulation (Baddeley, 1998; Barkley, 1997a; Luria, 1961; Vygotsky, 1978; Zelazo, 2004). While these theories differ in their emphasis of either the sociocultural or neuropsychological origins of self-regulation, they all assert that self-directed speech plays a transformative role, facilitating the move from other-regulation to self-regulation in early childhood. The central premise being that the use of language in self-directed speech renders children capable of voluntary, purposeful behavior in that it becomes a tool for guiding, planning, and regulating thoughts and behavior (Diaz & Berk, 1992). Additionally, studies of self-directed or private speech, emanating primarily from neo-Vygotskian research in the sociocultural tradition, have provided empirical evidence supporting a link between language and self-regulation in both children and adolescents. These studies have shed light on the multitude of factors that contribute to the development of self-regulation in normal and atypical populations, including task conditions (e.g., level of difficulty, adult direction) and social context (e.g., quality of verbal scaffolding, patterns of parent-child interaction). Taken together, the literature reviewed here suggests that the development of self-regulatory skills is not just a result of maturation, but rather, is a dynamic process shaped by a complex interplay between physiological processes, environmental influences, and the child's own socialization experiences (Bodrova and Leong, 2006).

Implications for Future Research

At the beginning of this paper, the following question was asked: "What developmental processes or mechanisms might influence the relationship between self-regulation and school readiness?" Based on the theory and research presented in this paper, it is suggested that examining individual differences in children's language skills might yield benefits for researchers interested in investigating the developmental pathways through which self-regulation influences school readiness. Of particular importance may be the transformative process of speech internalization originally posited by Vygotsky (1986).

This view is consistent with Blair's (2002) assertion that the study of individual differences in children's capacity for self-regulation may be a particularly fruitful way to advance school readiness research. Goals of future research, therefore, should be to more fully capture the complexity of the developmental pathways through which self-regulation influences school readiness. In particular, examining the effects of language on these pathways using sophisticated analyses may yield important insights. For example, studies using path analysis or structural equation modeling could help to clarify whether language exerts a mediating or moderating effect on the relationship between self-regulation and school readiness. Additionally, future studies should go beyond the use of language as a control variable and examine the relations between different aspects of language (e.g., semantics, syntax, pragmatics), different language-based abilities (e.g., verbal working memory), and different aspects of self-regulation (e.g., cognitive, emotional, behavioral). Furthermore, as current research findings are largely based on cross-sectional studies, longitudinal studies may provide additional insights into the developmental trajectories of self-regulatory skills over time. Specifically, growth curve analysis may be helpful in explaining how individual characteristics, such as a child's level of speech internalization or phonological loop capacity, affects the initial status and rate of growth of self-regulatory skills during the preschool years and beyond (Singer & Willett, 2003).

Practical Implications

The second question posed at the beginning of this article was: "What prerequisite or foundational skills, if any, do children need to develop adequate self-regulation in early childhood and how can we help them develop those skills?" Based on the literature reviewed in this paper, educators and clinicians who are interested in fostering self-regulatory skills in young children should consider a language-focused approach to inform the design and development of early intervention programs. It appears from the private speech research reviewed in this paper that socialization experiences are vital to the development of self-regulatory skills. Indeed, intervention approaches that actively teach self-regulation skills by modeling the use of language as a tool for thinking and encourage children to engage in verbally mediated joint problem solving with peers and adults have been shown to improve cognitive self-regulation in at-risk preschool children (Diamond, Barnett, Thomas, & Munro, 2007). Moreover, Landry et al. (2002) have shown that parent-child interactions in the form of scaffolded instruction (e.g, hints, prompts, and other verbal supports) at age 3 predicted high scores on problem-solving skills at age 6. Other language-focused techniques that may also support self-regulatory development in both typical and atypical populations might include in-vivo labeling of teacher and child actions, the encouragement of task-relevant overt self-talk, and scaffolded instruction to assist children in using private speech during problem-solving tasks (Bodrova & Leong, 2007; Deniz, 2009).

Bodrova and Leong (2007) recommend a number of instructional strategies to support the use of private speech for self-regulation in preschoolers. In their Tools of the Mind curriculum, Bodrova and Leong recommend that teachers label rules and standards for behavior using simple and specific language. For example, instead of using commands like, “stop it” or “don’t do that”, adults should model the language the child should be using to regulate his or her behavior such as, “Don’t run with scissors because they are sharp. If you fall you could hurt yourself.” Additionally, it is suggested that teachers make explicit to children the relationship between speech and its effect on the behavior of others. For example, games can be played that involve the adult and child taking turns telling each other what to do and then doing it. This method helps establish the relationship between giving commands and obeying them. Finally, Bodrova and Leong recommend enriching make-believe play by using language extensively to label props, explain character actions, and imitate the speech of others.

To summarize, a number of language-based instructional strategies may support the development of self-regulation in young children. In general, it appears from the research reviewed here that the use of self-directed speech should be encouraged and monitored in preschool classrooms. Adults should model the use of language for problem solving and engage in verbal scaffolding when opportunities are presented during play and skill-based tasks. Likewise, as children gain proficiency in using self-directed speech, adult regulation should be gradually withdrawn giving children the opportunity to practice self-regulation. Whether working with typically developing children or atypical populations, language-based strategies may be useful to promote the development of self-regulated learning and school readiness.

Conclusions

In recent years, self-regulation has emerged as a critical area of focus for policy makers, researchers, and practitioners interested in the development and education of young children (Shonkoff & Phillips, 2000). In educational settings, children who do not meet age-appropriate expectations for behavioral, emotional, and/or cognitive self-control generate concern. Expulsion of young children with self-regulatory deficits from preschool programs is increasing at alarming rates (Gilliam & Shahar, 2006) and the rate of special education referral for children with behavior and attention problems is on the rise (Goldstein & Naglieri, 2008). Moreover, it appears that early childhood educators are growing increasingly frustrated by the numbers of children exhibiting dysregulated behavior in the classroom (Bodrova & Leong, 2006). For example, in a large, nationally representative sample of kindergarten teachers, 46% reported that a majority of the children in their class exhibited problems with self-regulation, including following directions and working independently (Rimm-Kaufman et al., 2000). These findings suggest that many children are arriving at school without the basic regulatory competencies needed to be successful and that teachers are concerned with the capacity of these children to learn (Blair, 2002).

Furthermore, as children advance in school, there is an implicit expectation of increasing independence and self-generated, albeit externally reinforced, productivity (Denckla, 1996). Even in elementary school, students must rely heavily on efficient self-regulatory skills to complete long-term projects, write lengthy assignments, and take open-ended tests (Meltzer, Pollica, & Barzillai, 2007). Nonetheless, these skills are rarely systematically taught, as classroom instruction tends to focus on content rather than executive strategies such as planning, organizing, prioritizing, and monitoring progress. As a result, many students underachieve in school, not because of impaired intellectual performance or domain-specific information processing deficits, but because they struggle with the executive requirements necessary for academic success (Meltzer et al., 2007).

As argued by Shonkoff and Phillips (2000), “the growth of self-regulation is a cornerstone of early childhood development that cuts across all domains of behavior” (p. 26). While a growing body of literature has demonstrated that self-regulation has been shown to be a key component of school readiness, however, relatively little is known about its developmental precursors, as few studies have addressed this question directly (NICHD Early Child Care Research Network, 2003). To foster children’s development of self-regulation in the preschool years, knowledge of the developmental processes that are predictive of future academic and social outcomes is crucial. As other researchers have argued, an important next step in the study of school readiness is a focus on the influence of children’s characteristics on the development of self-regulation (Blair, 2002). As the evidence presented in this paper suggests, a better understanding of the interaction between language and self-regulatory skills in early childhood may yield insights about the developmental pathways through which self-regulation influences important outcomes in early childhood. In sum, by better understanding how language may influence the interplay among biological, developmental, and environmental factors in the development of self-regulation, not only will theoretical models be strengthened, but recommendations for early intervention will be better informed and more targeted.

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CHAPTER 2

EFFECTS OF LANGUAGE ON THE DEVELOPMENT OF EXECUTIVE FUNCTIONS IN PRESCHOOL CHILDREN

Executive function (EF) is a neuropsychological term referring to the self-directed actions that individuals use to regulate their behavior, emotions, and cognitive processing (Barkley, 2001). In short, EFs are "those types of actions we perform to ourselves so as to accomplish self-control, goal-directed behavior, and the maximization of future outcomes" (Barkley, 1997, p. 57). In recent years, there has been increasing interest in the study of EF development in young children due to the implication of executive dysfunction in a range of developmental disorders, including attention deficit hyperactivity disorder (ADHD) and autistic spectrum disorders (ASD) (Pennington & Ozonoff, 1996). Interest in the normative development of EF has also heightened as numerous studies have demonstrated links between EF and important childhood outcomes including emotional and social competence (Kochanska, Murray, Jacques, Koenig, & Vandegeest, 1996), appropriate behavioral control (Eisenberg, Fabes, & Losoya, 1997), social understanding (theory of mind) (Perner & Lang, 1999), successful school adjustment (Blair, 2002; Bodrova & Leong, 2006), and academic achievement (Bull & Scerif, 2001; Duncan et al., 2007; McClelland, Cameron, Connor, Farris, Jewkes, & Morrison, 2007).

While the frontal lobes were previously thought to be functionally silent in infancy and early childhood (Golden, 1981), recent developmental studies have challenged this view. Coinciding with growth spurts in prefrontal cortex and associated neural projections and neurotransmitter systems, progressive incremental growth in EF has been documented across childhood and adolescence (Diamond, 2001, 2002). Moreover, advances in the creation of developmentally sensitive assessment techniques (Carlson, 2005) have documented that the preschool years, in particular, represent a period characterized by rapid changes in the growth of executive abilities (Espy, Kaufmann, McDiarmid, & Glisky, 1999).

Although there is not currently widespread agreement on a comprehensive model of EF, a number of studies have provided converging evidence regarding the self-regulatory skills that fall under the EF umbrella (Anderson, 2008). In general, unitary models attributing EF to a 'central executive' and 'supervisory system' have given way to fractionated models based on evidence of distinct, but interrelated control systems (Lehto, Juujärvi, Kooistra, & Pulkkinen, 2003; Miyake, Friedman, Emerson, Witzki, & Howerter, 2000; Stuss & Alexander, 2000). For example, recent investigations using latent variable analyses have identified inhibition, cognitive flexibility (set-shifting), and working memory as related, yet separable, dimensions of executive functioning in both children and adults (Lehto et al., 2003; Miyake et al., 2000). Moreover, factor analytic studies of children and adolescents have identified problem solving, planning, and speeded responding (fluency) as specific aspects of EF (Levin et al., 1991; Welsh, Pennington, & Groisser, 1991).

Rationale for Current Study

Much progress has been made in recent years to identify dimensions of EF (Lehto et al., 2003; Miyake et al., 2000) and to explicate developmental trajectories of component skills across the lifespan (Espy, 1997; Levin et al., 1991; Smidts, Jacobs, & Anderson, 2004; Welsh et al., 1991). However, much of the research on EF development has used cross-sectional designs, and thus, current understanding of patterns of change, including individual differences in the rate of growth and specific staging of EF developmental trajectories, is limited. Furthermore, while theoretically relevant variables have been identified that may be predictive of EF development (e.g., language; Denckla, 1996), these variables have not yet been studied longitudinally. Rather, in most studies to date, verbal ability has been used as a control variable and not investigated in relation to EF in its own right (Müller, Jacques, Brocki, & Zelazo, 2009).

Language has been ascribed an important role in the development of EF by a number of prominent classical and contemporary theorists (Baddeley, Gathercole, & Papagno, 1998; Barkley, 1997; Luria, 1961; Vygotsky, 1986; Zelazo, 2004). In particular, self-directed speech has been asserted as playing a transformative role in the development of EF in early childhood, facilitating the move from external regulation to internal or self-regulation (Barkley, 2001). The central premise is that the development of internalized, self-directed speech may serve to enhance the process of self-regulation, providing a form of self-guidance and direction by facilitating problem solving (Vygotsky, 1978). Thus, language becomes internalized over the course of early development, providing "an instrument of reflection and exploration and thereby permitting the individual to construct various hypothetical messages or responses before choosing one to emit"

(Barkley, 1997, p. 87). In short, language is turned on the self as a means to control one's own behavior (Barkley, 2001).

Carlson and Beck (2009) have asserted that advancement of developmental research requires a shift from "description to explanation, from questions of "what" and "when" to "*how*" EF develops" (p. 164). An important step in this direction would be to investigate the development of executive functions longitudinally in individual children. While recent studies have documented the effects of contextual variables on EF development in groups of children (Berk & Spuhl, 1995; Landry, Miller-Loncar, Smith, & Swank, 2002), studies examining the effects of individual characteristics on EF development have not yet been carried out. Hence, a major limitation of the current body of literature concerning the development of EF is methodological. At present, what we know about EF development is largely based on cross sectional research (Anderson, Anderson, Jacobs, & Smith, 2008).

Questions regarding developmental change can only be answered with longitudinal research designs. However, few published studies of EF development are truly longitudinal in that they rely upon cross-sectional or two-wave designs. Observed differences in groups evidenced in these studies may be due, in large or small part, to differences in individual characteristics, not to differences in development (Willett, Singer, & Martin, 1998). Longitudinal studies with at least three waves of data are required to answer research questions about systematic changes in development over time (Singer and Willett, 2003). Using hierarchical linear modeling (HLM), questions about systemic changes in outcome variables that change over time, such as performance on executive tasks, can be answered. Likewise, assessments can be made about whether different individuals manifest different developmental trajectories. Moreover, HLM allows for the prediction of differences in patterns of individual change based on individual characteristics and other contextual variables (Singer & Willett, 2003).

The purpose of the present study was to investigate the relationship between language skills and the development of executive functions in a normative preschool population over time. Data used in this study come from the Preschool Executive Functions Project, a three-year longitudinal study of language, executive, and visual-motor abilities in children ages 3 to 5 years. In particular, the following research questions are asked:

1. To what extent do executive skills change over time during the preschool period? (3 - 5 years)
2. How do individuals vary in their rate of change?
3. How do language skills explain differences in rate of change?

It is hypothesized that executive skills will increase over time and that their rate of growth will vary systematically with age. Secondly, it is expected that individuals will differ significantly in their rate of growth in executive skills, even after age is considered. Lastly, language ability is hypothesized to predict differences in the growth rate of executive skills, with higher levels of language ability relating to faster rates of increase.

Method

Participants

The sample was composed of 39 preschool children who, upon entry into the study, ranged in age from 3 years 0 months to 5 years 8 months (M_{age} = 3 years 9 months, SD_{age} = 5.14 months). Children were recruited via informed parental consent from two child development centers associated with Georgia State University. There were 16 girls (41%) and 23 boys (59%) in the sample. The racial make-up of the sample was 44% Caucasian, 41% African American, 3% Asian, and 12% Biracial/Other. Breakdown of the sample by marital status of the participants' parents was 79% married and 21% unmarried. Mean parent maternal education level of the sample was 18.3 years (*SD* = 2.45 years). Mean parent paternal education level was 16.9 years (*SD* = 2.94 years). All of the children in the sample were English speaking. English was the primary language spoken in the home of 95% of the sample, 5% of the sample was bilingual. Other languages reportedly spoken in the home included German, Chinese, and Malay. Parental report of handedness was 64% right-handed, 15% left-handed, 10% ambidextrous or not sure, and 10% not reported. All children were typically developing; that is, no child included in the study had any known developmental delay or neurological disorder evidenced by parental report.

Language Measures

Two individually administered, norm-referenced measures of language ability were selected to assess each child's initial receptive and expressive language skills. The measures were chosen due to their wide use in school, clinical, and research settings. Both measures were appropriate for use with preschool children and required no reading or writing.

Receptive Vocabulary (VOC). The Peabody Picture Vocabulary Test, Third Edition (PPVT-III: Dunn & Dunn, 1997) was used to measure initial receptive vocabulary. Children are asked to select the picture (out of an array of 4 pictures) that best describes the meaning of the stimulus word. The child may respond with either a verbal or nonverbal (i.e., pointing) response. The PPVT-III is an appropriate measure of receptive vocabulary for English speaking individuals between the ages of 2 years, 6 months and 90+ years of age. The normative sample included 2,725 persons selected to match the data of the 1994 US Census. The sample was stratified within each age group by gender, race/ethnicity, geographic region, and socioeconomic status. Internal consistency (Cronbach's alpha) for the 25 standardized age groups ranged from .92 and .98 with a median reliability of .95 for both forms. The split-half reliabilities for the 25 age groups ranged from .86 to .97, with a median of .94 for both forms. The alternate forms reliabilities range from .86 to .96 with a median correlation of .94. Concurrent validity correlations of the PPVT-III with scores of the Wechsler Intelligence Scale for Children, Third Edition (WISC-III) range from .82 and .92 for the verbal, performance, and full scale IQ scales.

Oral Language (OLA). The Comprehensive Assessment of Spoken Language (CASL: Carrow-Woolfolk, 1999) was selected to measure initial oral language skills. The CASL is an appropriate assessment of spoken language for English speakers ages 3 through 21 years. The CASL is composed of 15 subtests measuring comprehension, retrieval, and expression skills in four language categories including lexical/semantic, syntactic, supralinguistic, and pragmatic. A Core Composite *(OLA)* score provides a global measure of oral language based on a group of selected tests that are representative of all the language skills and categories. The CASL was normed on a nationwide standardization sample of 1,700 individuals, stratified to match 1994 US Census data on gender, race/ethnicity, region, and mother's educational level. Internal reliabilities for the CASL subtests, using the Rasch split-half method, range from .64 to .94, with most being in the .80s and .90s. Test-retest reliabilities for the CASL subtests range from .65 to .95. Five criterion-related validity studies were carried out during standardization of the CASL. Correlations of the CASL Core Composite and Index scores with the PPVT-III, corrected for the variability of the norm group, range from .71 to .85. Descriptions of the subtests of the CASL are as follows:

1. *Basic Concepts* measures comprehension of perceptual and conceptual words. The examiner reads a sentence aloud while the child looks at four pictures. The child is then asked to point to the picture or part of the picture that represents the correct response.
2. *Antonyms* measures word retrieval and knowledge of opposites. The examiner says a stimulus word. The child must then respond orally with a single word that means the opposite of the stimulus word.
3. *Syntax Construction* measures the grammatical correctness of oral expressions. The examiner reads the stimulus item while the examinee looks at a picture. The child must respond with a word, phrase, or sentence that is grammatically and semantically appropriate.
4. *Paragraph Comprehension* measures comprehension of syntactic structures. The examiner reads a stimulus paragraph twice then reads a series of items relating to the paragraph while the child looks at a set of pictures for each item. The child must respond by pointing to or giving the item number of the correct response.
5. *Pragmatic Judgment* measures the child's knowledge and use of appropriate language. The examiner reads a situation that represents some aspect of

everyday life that requires communication or a pragmatic judgment on the part of the child. The child must respond with the appropriate thing to say or do in the situation.

Both the PPVT-III and CASL were administered in accordance with the standardized published instructions. Additionally, both measures were scored in a standard fashion as outlined in the administration manual of each test.

Executive Function Measures

For this study, EF measures were chosen based upon their established use in clinical and/or research settings, developmental appropriateness, and availability. At the present time, very few norm-referenced standardized measures of EF are available for use with preschool aged children.

NEPSY Subtests. One such measure, the NEPSY (Korkman, Kirk, & Kemp, 1998) is a standardized and norm-referenced instrument designed to assess neuropsychological development in preschool and school-aged children. The NEPSY standardization sample was comprised of 1,000 children ranging in age from 3 to 12 years. The sample was stratified to match 1995 US Census data based on age, gender, race/ethnicity, geographic region, and parent education. Reliability studies indicate moderate to high internal consistency or stability of NEPSY subtest scores, ranging from .50 to .91. Validity studies with clinical and non-clinical populations exhibit evidence for convergent and discriminant validity. Correlations between NEPSY Domain Scores and WISC-III IQ scores range from .20 to .62.

Three subtests from the NEPSY (Visual Attention, Statue, and Tower) were chosen for this study because they are appropriate for assessment of EF in preschoolers.

For children in the 3- to 5-year-old range, test-retest reliability coefficients range from .68 to .76 for the Visual Attention subtest, .48 to .50 for the Statue subtest, and .89 for the Tower subtest (Korkman et al., 1998). They are described here:

1. *Visual Attention (VAT)* measures the speed and accuracy with which a child is able to focus selectively on and maintain attention to visual targets within an array. The child is asked to scan an array of pictures and mark the targets as quickly and accurately as possible.
2. *Statue (STA)* measures motor persistence and inhibition. The child is asked to maintain a body position with eyes closed during a 75-second period and to inhibit the impulse to respond (i.e., body movement, vocalization, opening eyes) to distractors.
3. *Tower (TOW)* measures nonverbal planning and problem solving abilities. The child is asked to move three colored balls to a target position on three pegs in a prescribed number of moves. There are also rules to which the child must adhere on this timed task (e.g., only one ball can be moved at a time; balls must remain on the pegs when they are not being moved).

Binet Subtests. The Stanford Binet Intelligence Scales, Fifth Edition (SB-5: Roid, 2003) is another standardized, norm-referenced measure appropriate for use with very young children. Normative data for the SB-5 were gathered from 4,800 individuals between the ages of 2 and 85+ years. The normative sample matches the 2000 US Census, stratified by gender, race/ethnicity, geographic region, and socioeconomic status. Reliabilities for SB-5 scores range from .84 to .89 across all age groups. A number of studies provide evidence for concurrent and criterion validity. For this study, the SB-5

Memory for Sentences, Last word subtest was chosen to measure verbal working memory and the Block Span subtest was chosen to measure nonverbal working memory. They are described here:

1. *Verbal Working Memory (VWM).* The Memory for Sentences, Last Word subtest is a measure of short-term and working memory for verbal information. The examiner reads a sentence and asks the child to repeat the sentence verbatim. On more difficult items, the examiner reads brief questions and the child must respond with the last word in each question.
2. *Nonverbal Working Memory (NWM).* The Block Span subtest is a measure of short-term and working memory for visual-spatial information. The examiner taps blocks in a sequence. The child is asked to recall the sequence of block taps and to respond by sorting the sequence into those taps occurring in the yellow row versus those occurring in the red row.

Experimental Measures. Finally, two experimental measures, the Dimensional Change Card Sorting Task (DCCS; Frye, Zelazo, & Palfai, 1995), and the Cat-Dog, based on the Day-Night task (Gerstadt, Hong, & Diamond, 1994), were chosen due to their wide use in developmental studies of EF. Descriptions of these experimental measures are provided here:

1. *Cat-Dog Task (CAD).* This stroop-like inhibition task is based on Gerstadt et al.'s (1994) Day-Night task. This experimental task measures the child's ability to act according to remembered instructions and to inhibit a prepotent response. The examiner trains the child to say 'cat' whenever a picture of a dog is shown and to say 'dog' whenever a picture of a cat is shown. After the

initial training, the child's responses are recorded on a series of sixteen stimulus cards.

2. *Dimensional Change Card Sort (DCS).* This experimental task is based on Kirkham, Cruess, and Diamond's (2003) version of Frye et al.'s (1995) DCCS task. The task measures the child's ability to switch categorical sorting dimensions (e.g., color, shape) based upon specified rules. After initial training, the child is asked to sort cards by a series of rules, which are changed after every 6 cards. The child must keep the current rule set in mind, sort by that rule, then switch sets a total of 4 times (i.e., sort by color, then shape without interfering color, then shape with interfering color, finally color).

All executive function measures, with the exception of the experimental tasks *(CAD, DCS)*, were administered in accordance with the standardized published instructions. Additionally, all published measures were scored in a standard fashion as outlined in the administration manual of each test.

A summary of language and EF measures are found in Table 1.

Table 1

Language and Executive Function Variables

Skill Domain	Variable	Test
Language		
Receptive Vocabulary	VOC	PPVT-III
Oral Language	OLA	CASL Core Composite
Executive Function		
Verbal Working Memory	VWM	SB-5 (Memory for Sentences)
Nonverbal Working Memory	NWM	SB-5 (Block Span)
Visual Attention	VAT	NEPSY (Visual Attention)
Motor Inhibition	STA	NEPSY (Statue)
Cognitive Inhibition	CAD	Cat-Dog
Problem Solving	TOW	NEPSY (Tower)
Cognitive Flexibility	DCS	Dimensional Card Sort

Procedure

Six testing waves were conducted biannually beginning in Spring 2007. Each wave of testing occurred over the course of the academic semester. Upon entry to the study, children's initial language and executive skills were assessed. On subsequent testing waves, executive skills were reassessed in order to measure change in these abilities over time. Based upon the date of the child's entry into the study and subsequent departure of some children, due to aging out or leaving the preschool program, the number of measurement occasions (i.e., number of times the child was assessed) varied by child, as shown in Table 2.

Table 2

Measurement Occasions

Measurement Occasions	n	Percentage
3	25	64.1
4	7	17.9
5	7	17.9

Children were tested individually at the daycare center in a quiet room by a trained graduate student examiner. Each assessment session occurred in the morning, lasting between 30 and 45 minutes. Both the language and EF batteries used a fixed task order designed to maintain the child's maximal interest over the course of the assessment session.

Analysis

Hierarchical linear modeling (HLM) was used to examine how executive skills change over time and how language ability is associated with the rate of change in executive skills. HLM is an appropriate statistical method to analyze change processes in longitudinal studies, where multiple measurements are nested within individuals (Singer & Willett, 2003). Conceptually, HLM allows for the simultaneous measurement of change over time in a behavior of interest (e.g., executive skills) at both the individual (within-person) and group (between-person) level (DeLucia & Pitts, 2005). Advantages of using HLM in longitudinal data analyses include flexibility in the number and spacing of measurement occasions across individuals and the use of person level characteristics to explain variability (Willett et al., 1998).

HLM Models. The Level-1 (within-person) model resembles an ordinary least squares (OLS) regression model. It describes individual growth rates and can include time-varying predictor variables (e.g., age). In the Level-2 (between-person) model, the individual parameter estimates from the Level-1 model (e.g., intercept and slope) are treated as outcomes. The Level-2 model explains variation in growth between individuals and can include time-invariant predictors (e.g., gender).

A linear, rather than curvilinear, growth model was employed for this study due to the relatively small number of measurement occasions (e.g., up to 5 time points per individual). Growth modeling using HLM requires a minimum of three measurement occasions (Singer & Willett, 2003). At the present time, there is a limited number of researchers proposing sample size recommendations for HLM growth modeling and the complexity of the models for which they exist is still low. Most analytical estimations as well as most Monte Carlo simulation studies focus on linear growth models without Level-2 predictors. Just recently, Zhang and Wang (2009) published a set of SAS macros that allow researchers to estimate power for such models. Hedeker, Gibbons, and Waternaux (1999) indicate that adequate power to detect a growth effect can be achieved for medium effect sizes and four measurement occasions with 21 participants. Unfortunately, they do not offer sample sizes for three measurements per participants and their calculations also do not account for independent Level-1 errors, i.e. no autocorrelation or compact symmetry. In sum, researchers (Raudenbush & Liu, 2000;

Zhang & Wang, 2009) acknowledge that there is great need for sample size recommendations for more complex models such as the ones used in this study.

Analysis began by fitting unconditional models (i.e., no predictors other than time were introduced) to describe individual growth rates for each of the seven executive skills measured (VWM, NWM, VAT, STA, TOW, CAD, and DCS). Unconditional models allow for the specification of an individual growth equation and baseline statistics for evaluating subsequent Level-2 models (Raudenbush & Bryk, 2002). As such, executive skills (EF) exhibited by child *i* on occasion *t* is expressed as a linear function of age in months (AGE):

Level 1: $EF_{ti} = \pi_{0i} + \pi_{1i}\,(AGE - 36) + e_{ti}$

Level 2: $\pi_{0i} = \beta_{00} + r_{0i}$

$\pi_{1i} = \beta_{10} + r_{1i}$

where EF_{ti} is the performance for child *i* at time t; π_{0i} is child *i*'s intercept parameter, which is the expected score for child *i* when age equals 36 months; π_{1i} is the slope of the line relating EF to age for child *i* (as such, π_{1i} describes the rate of change in performance when age equals 36 months); and e_{ti} is random error. In the Level-2 model, the population-level estimates (i.e., β_{00} and β_{10}) are 'fixed effects' in that they are assumed to be constant for all individuals in the sample. The Level-2 residuals (r_{0i} and r_{1i}) are 'random effects', that are deviations of individuals from the mean growth curve.

To summarize, the combined unconditional model is:

$$EF_{ti} = \beta_{00} + \beta_{10}\,(AGE - 36) + r_{0i} + r_{1i}\,(AGE - 36) + e_{ti}$$

where β_{00} represents the mean across individuals of the individual EF score when age equals 0 and β_{10} is the mean across individuals of the individual linear growth rate.

To simplify interpretation, the predictor used to represent time (e.g., age in months) was re-centered at 3 years (i.e., 36 months), the youngest age at which data were collected. Centering is accomplished by simple subtraction, thereby shifting each score by the same amount. Hence, the fitted intercept will estimate the child's executive skills at age 36 months, rather than at age 0, an age that precedes the onset of data collection and one at which a child's executive skills can hardly be measured. Centering the temporal predictor (AGE) serves only to improve interpretability of the intercept and has no effect on the interpretation of each individual's slope (i.e., rate of change per month) (Singer & Willett, 2003).

Next, separate conditional models were run for each of the seven executive skills assessed to explain differences in individual growth rates. As such, initial language skills (VOC, OLA) were included as additional time-invariant predictors in the Level-2 model:

Level 1: $EF_{ti} = \pi_{0i} + \pi_{1i} (AGE\text{-}36)_{ti} + e_{ti}$

Level 2: $\pi_{0i} = \beta_{00} + r_{0i}$

$\pi_{1i} = \beta_{10} + \beta_{11} (VOC) + \beta_{12} (OLA) + r_{1i}$

The combined model is described here:

$$EF_{ti} = \beta_{00} + \beta_{10} (AGE\text{-}36)_{ti} + \beta_{11} (VOC)(AGE\text{-}36)_{ti} + \beta_{12} (OLA)(AGE\text{-}36)_{ti} + r_{0i} + r_{1i} (AGE\text{-}36)_{ti} + e_{ti}$$

This conditional HLM model hypothesizes that each EF skill can be predicted partially by the age of the child. Furthermore, the rate of change in EF can also be predicted by the child's initial language ability.

Results

Results will be presented by executive skill. For each executive skill, the first and second research questions are addressed by the results of the unconditional models. The third research question is addressed by the results of the conditional models. A summary of how the various findings address all three of the research questions will be indicated in the discussion section of this paper.

Descriptive statistics for each child's first measurement occasion are presented in Table 3. The correlations among the variables at the first measurement occasion are presented in Table 4. Growth trajectories of executive skills as a function of age are shown in Figures 1 through 7. Prior to running the HLM models, the distributional properties of the measures were examined. The distribution of scores for DCS was negatively skewed (skewness = -1.042) and suggested a ceiling effect, with almost half of the sample (48.7%) achieving a perfect score. To reduce extreme skewness, therefore, DCS scores were dummy coded 0 or 1 (individuals with more than 18 points, the score threshold beyond which switching is evidenced, were scored a 1, those who were equal to or less than 18 points were scored a 0).

Table 3

Descriptive Statistics at First Measurement Occasion

Variable	Mean	SD	Min	Max
Age (months)	45.00	5.14	36	56
Language Skills				
VOC	102.03	13.45	66	127
OLA	102.44	14.35	59	128
Executive Skills				
VWM	9.64	3.12	0	15
NWM	8.85	3.57	0	14
DCS	21.72	2.95	14	24
VAT	10.28	2.26	4	13
STA	16.54	6.70	0	29
CAD	10.87	4.32	2	16
TOW	2.79	1.32	0	5

Note. Scores reported are raw scores except for VOC, OLA, and VAT (standard scores); VOC = PPVT-3; OLA = CASL Core Composite; VAT = Visual Attention subtest of NEPSY.

Table 4

Correlations Among Variables at First Measurement Occasion

Measure	1	2	3	4	5	6	7	8	9	10
1.Age	1.0									
2.VOC[1]	-.04	1.0								
3. OLA[1]	.03	.77**	1.0							
4. VWM	.39*	.41**	.48**	1.0						
5. NWM	.39*	.23	.33*	.52**	1.0					
6. DCS	.41**	.09	.21	.26	.30	1.0				
7. VAT[2]	-.07	.19	.40*	.28	.35*	.19	1.0			
8. STA	.54**	.09	.11	.49**	.61**	.31	.16	1.0		
9. CAD	.31	.15	.27	.44**	.45**	.25	.20	.24	1.0	
10. TOW	.40*	.44**	.36*	.40*	.53**	.44**	.09	.44**	.25	1.0

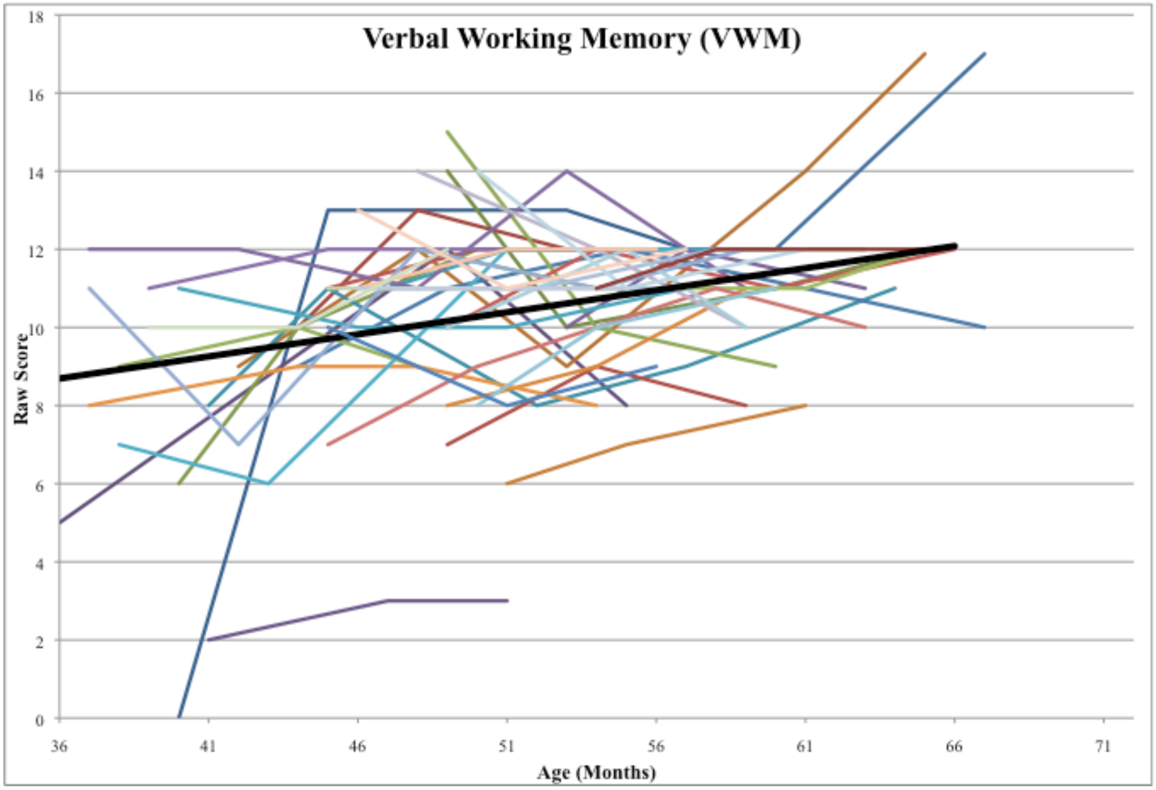
[1] Standard Scores (M = 100, SD = 15) [2]Standard Scores (M = 10, SD = 3)
Note. VOC = Vocabulary; OLA = CASL Core Composite; VWM = Verbal Working Memory; NWM = Nonverbal Working Memory; DCS = Dimensional Card Sort; VAT = Visual Attention; STA = Statue; CAD = Cat-Dog Task; TOW = Tower.
*p < .05. **p < .01.

Verbal Working Memory (VWM)

Unconditional growth models. The unconditional growth model (Model 2) for VWM revealed a significant positive linear growth trajectory over time, such that at 36 months the average VWM score across individuals was 8.691 (see Table 4). Age was a statistically significant predictor of VWM. As age increased by 1 month, VWM increased, on average, by 0.113 points. Even after age was considered, significant variation in children's individual intercepts and slopes remained. Thus, children differed in both their initial status and growth rates of VWM.

Figure 1

Verbal Working Memory Growth Trajectories



Conditional growth models. Inter-individual variation in rate of growth for VWM was also examined to determine if slope related systematically to children's initial language ability. In Model 3, VOC was found to be a significant predictor of rate of change in VWM. In Model 4, OLA was also found to be a significant predictor of slope in VWM. In the complete conditional model (Model 5), both VOC and OLA were examined simultaneously. In combination with OLA, VOC was no longer a significant predictor of slope in VWM. However, OLA remained a unique and significant predictor of rate of change in VWM. There is still a significant amount of unexplained variance in the rate of growth in VWM, even after considering age and language predictors.

Therefore, factors other than those measured in the models here also contribute to the growth of VWM.

Table 5

Results of the Unconditional and Conditional Models for VWM

Parameter	Model 1	Model 2	Model 3	Model 4	Model 5
			Fixed Effects		
Intercept	10.443 (0.293)	8.691 (0.634)	8.760 (0.631)	8.809 (0.614)	8.772 (0.608)
Level 1 (time)					
Age		0.113* (0.0314)	-0.147 (0.0912)	-0.282* (0.075)	-0.230* (0.0759)
Level 2 (child)					
VOC			0.00254* (0.000835)		-0.00170 (0.00107)
OLA				0.00384* (0.000651)	0.00503* (0.00105)
			Random parameters		
Level 2					
Intercept (τ_{00})	2.177*	8.600*	8.508*	8.159*	7.928*
Age (τ_{11})		0.015*	0.019*	0.0198*	0.0176*
Level 1					
Intercept (σ^2)	2.017	2.822	2.819	2.779	2.809

Note. Standard errors are in parentheses. No statistical significance results were available for the level-2 intercept variances.
* $p < .05$.

Nonverbal Working Memory (NWM)

Unconditional growth models. Model 2 revealed a significant positive linear growth trajectory over time, such that at 36 months the average NWM score across individuals was 6.911 points. Age was a statistically significant predictor of NWM; such that, as age increased by one month, NWM increased, on average, by 0.229 points. Rate of growth in NWM was explained sufficiently by maturation. Hence, children differed in their initial status, rather than their rate of growth in NWM.

Figure 2

Nonverbal Working Memory Growth Trajectories

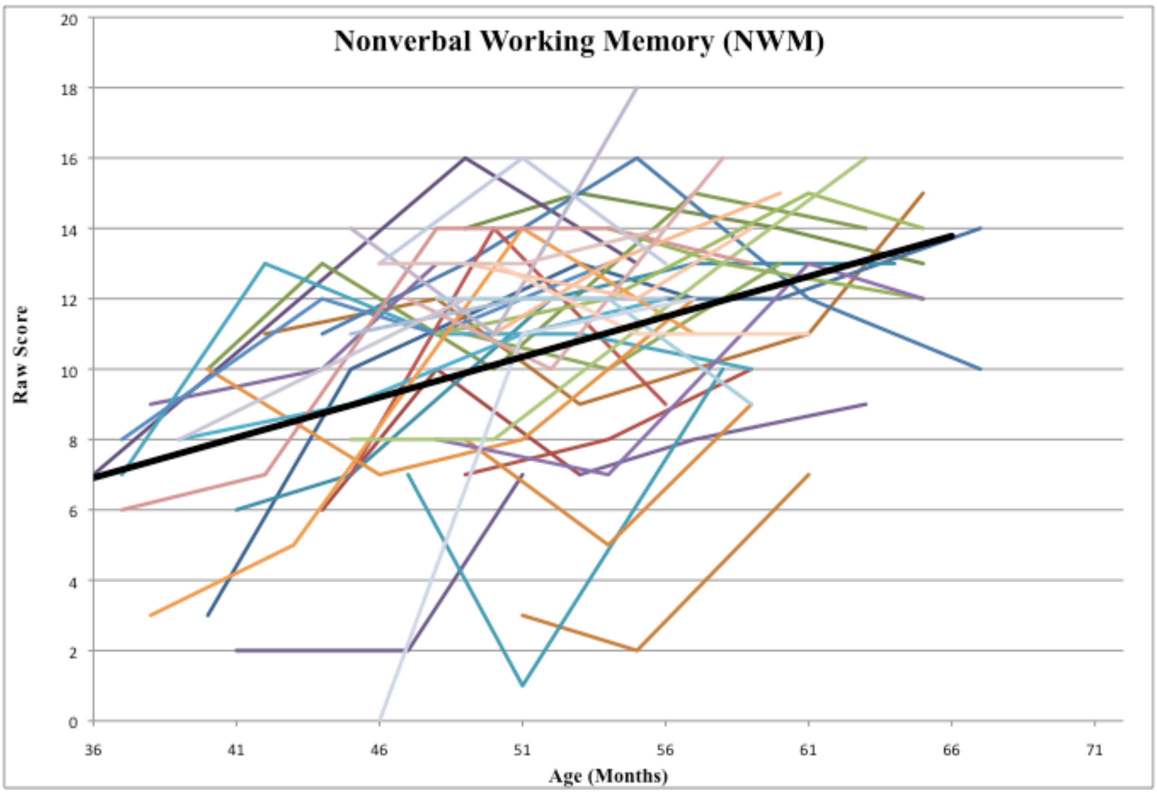


Table 6

Results of the Unconditional Models for NWM

Parameter	Model 1	Model 2
	Fixed Effects	
Intercept	10.569 (0.393)	6.911 (0.772)
Level 1 (time)		
Age		0.229* (0.0338)
Level 2 (child)		
VOC		
OLA		
	Random Parameters	
Level 2		
Intercept (τ_{00})	3.631*	11.632
Age (τ_{11})		0.00695
Level 1		
Intercept (σ^2)	8.292	5.143

Note. Standard errors are in parentheses.
* $p < .05$.

Visual Attention (VAT)

Unconditional growth models. Model 2 did not reveal a significant linear growth trajectory in VAT. Thus, age was not a significant predictor of VAT. The average VAT score across individuals at 36 months was 10.547 points. As age increased by 1 month, VAT increased, on average, by 0.032 points. Standardization of scores for this measure likely resulted in a loss of variability and contributed to the lack of significance for the unconditional model. It was necessary to use standard scores because the published stimulus materials for this task change at 60 months, making raw scores incomparable across relevant age ranges. Children were found to differ in their initial status on this task as significant variation remained in the individual intercept parameter after accounting for age.

Figure 3

Visual Attention Growth Trajectories

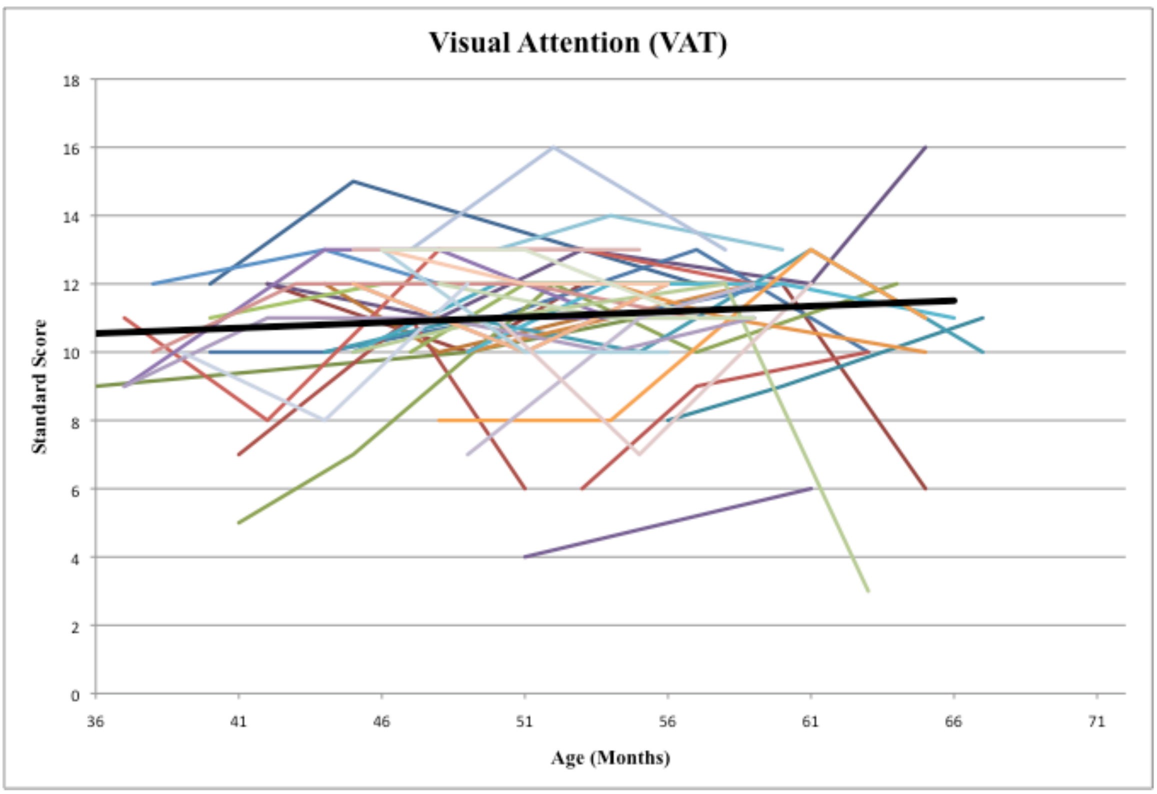


Table 7

Results of the Unconditional Models for VAT

Parameter	Model 1	Model 2
	Fixed Effects	
Intercept	11.032 (0.210)	10.547 (0.481)
Level 1 (time)		
Age		0.032 (0.0260)
Level 2 (child)		
VOC		
OLA		
	Random Parameters	
Level 2		
Intercept (τ_{00})	0.770*	3.029*
Age (τ_{11})		0.0619
Level 1		
Intercept (σ^2)	3.172	2.710

Note. Standard errors are in parentheses.
* $p < .05$.

Motor Inhibition (STA)

Unconditional growth models. Model 2 revealed a significant linear growth trajectory over time, such that at 36 months the average STA score across individuals was 12.670 points. Age was a significant predictor of STA. As age increased by 1 month, STA increased, on average by 0.424 points. Even after age was considered, significant variation remained in individual intercepts and slopes. Thus, children differed across both initial status and rate of growth.

Conditional growth models. Inter-individual variation in rate of growth in STA was not systematically related to children's initial language ability. In the conditional models, neither VOC nor OLA were found to be a significant predictor of rate of growth in STA individually or simultaneously.

Figure 4

Motor Inhibition Growth Trajectories

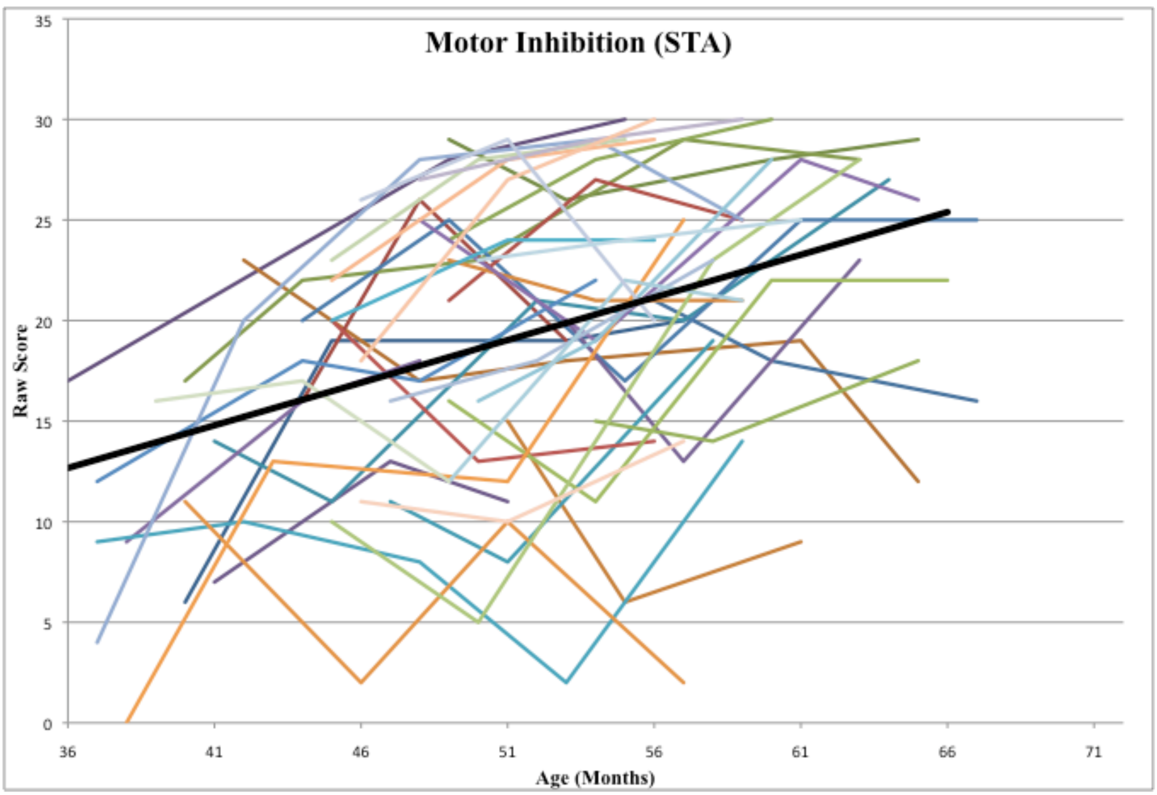


Table 8

Results of the Unconditional and Conditional Models for STA

Parameter	Model 1	Model 2	Model 3	Model 4	Model 5
			Fixed Effects		
Intercept	19.172 (0.885)	12.670 (1.342)	12.666 (1.342)	12.668 (1.341)	16.212.6643 (1.342)
Level 1 (time)					
Age		0.424* (0.0739)	0.364 (0.375)	0.204 (0.359)	0.279 (0.394)
Level 2 (child)					
VOC			0.000591 (0.00363)		-0.00297 (0.00586)
OLA				0.00216 (0.00344)	0.00438 (0.00558)
			Random parameters		
Level 2					
Intercept (τ_{00})	22.115*	31.590*	31.429*	31.294*	31.422*
Age (τ_{11})		0.0780*	0.0804*	0.0822*	0.0857*
Level 1					
Intercept (σ^2)	28.903	15.325	15.341	15.337	15.269

Note. Standard errors are in parentheses. No statistical significance results were available for the level-2 intercept variances.
* $p < .05$.

Cognitive Inhibition (CAD)

Unconditional growth models. Model 2 revealed a significant linear growth trajectory over time, such that at 36 months the average CAD score across individuals was 8.837 points. Age was a significant predictor of CAD. As age increased by 1 month, CAD increased, on average by 0.218 points. Significant variation remained in individual intercepts and slopes after accounting for age. Thus, children differed in both their initial status and rate of growth on this task.

Conditional growth models. Interindividual variation in rate of growth for this task was found to relate systematically to children's initial language ability. In the conditional models, neither VOC nor OLA were found to be a significant predictor of rate of growth in CAD either individually or simultaneously.

Figure 5

Cognitive Inhibition Growth Trajectories

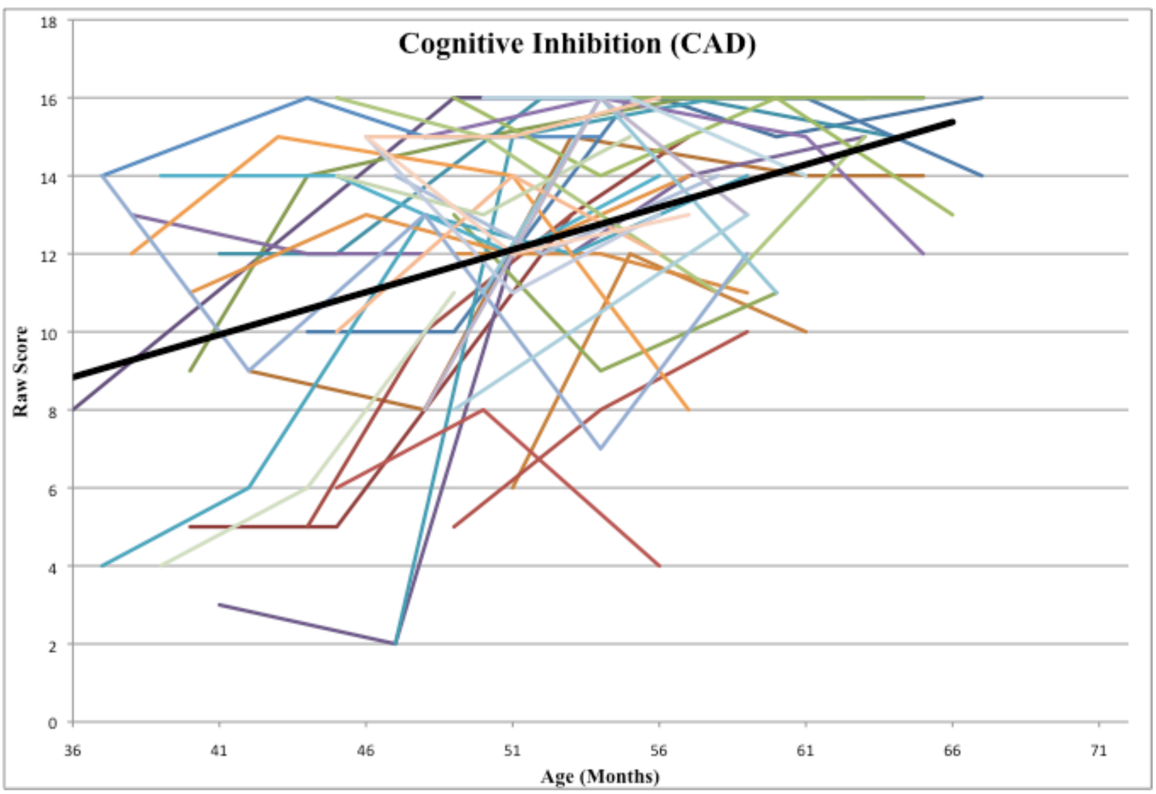


Table 9

Results of the Unconditional and Conditional Models for CAD

Parameter	Model 1	Model 2	Model 3	Model 4	Model 5
			Fixed Effects		
Intercept	12.211 (0.401)	8.837 (0.972)	8.878 (0.978)	8.901 (0.970)	8.924 (0.966)
Level 1 (time)					
Age		0.218* (0.0467)	0.103 (0.126)	0.0214 (0.122)	0.0414 (0.132)
Level 2 (child)					
VOC			0.00111 (0.00113)		-0.00112 (0.00191)
OLA				0.00189 (0.00109)	0.00280 (0.00186)
			Random parameters		
Level 2					
Intercept (τ_{00})	3.220*	20.379*	20.724*	20.249*	19.884*
Age (τ_{11})		0.0339*	0.0365*	0.0379*	0.0381*
Level 1					
Intercept (σ^2)	10.53	6.949	6.917	6.899	6.856

Note. Standard errors are in parentheses. No statistical significance results were available for the level-2 intercept variances.
* $p < .05$.

Problem-Solving (TOW)

Unconditional growth models. The unconditional growth model (Model 2) revealed a significant linear growth trajectory over time, such that at 36 months (intercept) the average TOW score across individuals was 1.993. Age was a significant predictor of TOW. As age increased by 1 month, TOW increased, on average by 0.1261 points. After age was considered, there was no significant variation in individual intercepts and slopes. Thus, maturation explained both initial status and rate of change.

Figure 6

Problem Solving Growth Trajectories

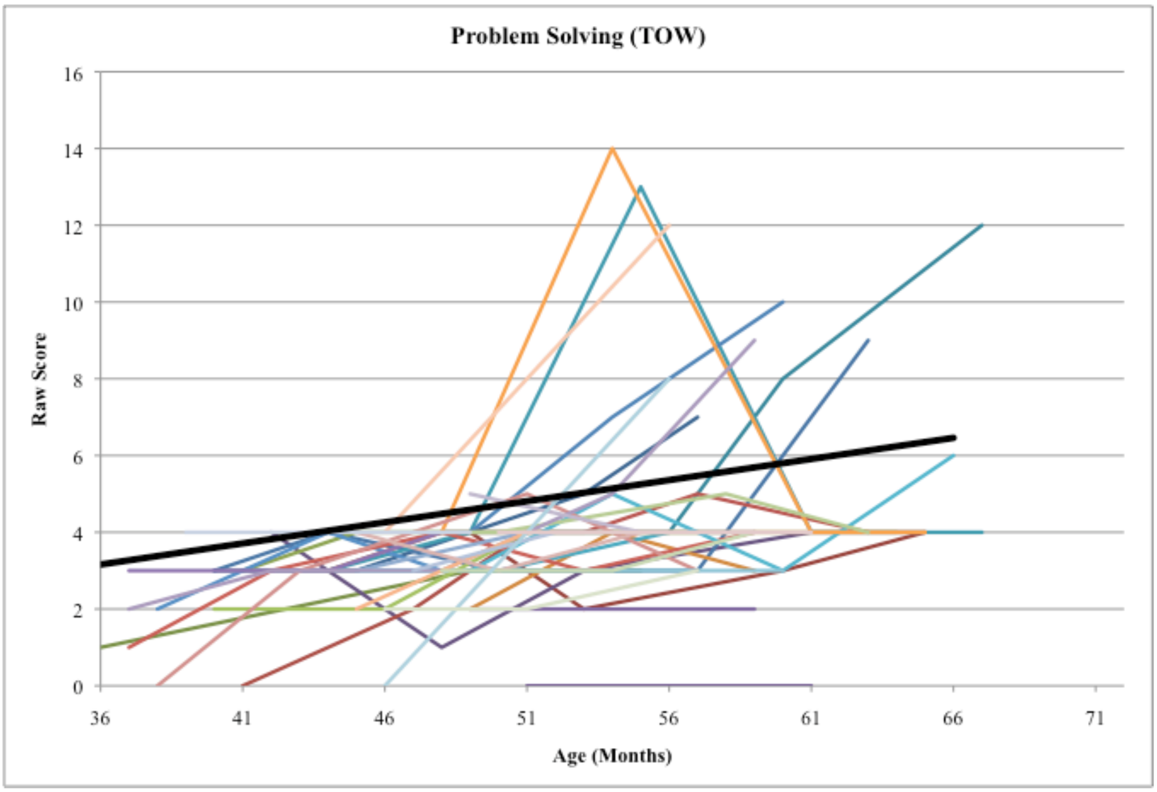


Table 10

Results of the Unconditional Models for TOW

Parameter	Model 1	Model 2
	Fixed Effects	
Intercept	3.961 (0.217)	3.16 (0.27)
Level 1 (time)		
Age		0.11* (0.03)
Level 2 (child)		
VOC		
OLA		
	Random Parameters	
Level 2		
Intercept (τ_{00})	0.658*	0.282
Age (τ_{11})		0.00705
Level 1		
Intercept (σ^2)	4.109	2.985

Note. Standard errors are in parentheses.
* $p < .05$.

Cognitive Flexibility (DCS)

Unconditional Growth Model. As previously mentioned, dummy coding scores for DCS was necessary to reduce extreme negative skewness. As a result, a binary outcome model was employed for this measure. Results showed no unexplained variance in the rate of change (Model 1). Children were found to differ only in their initial status on this task.

Figure 7

Cognitive Flexibility Growth Trajectories

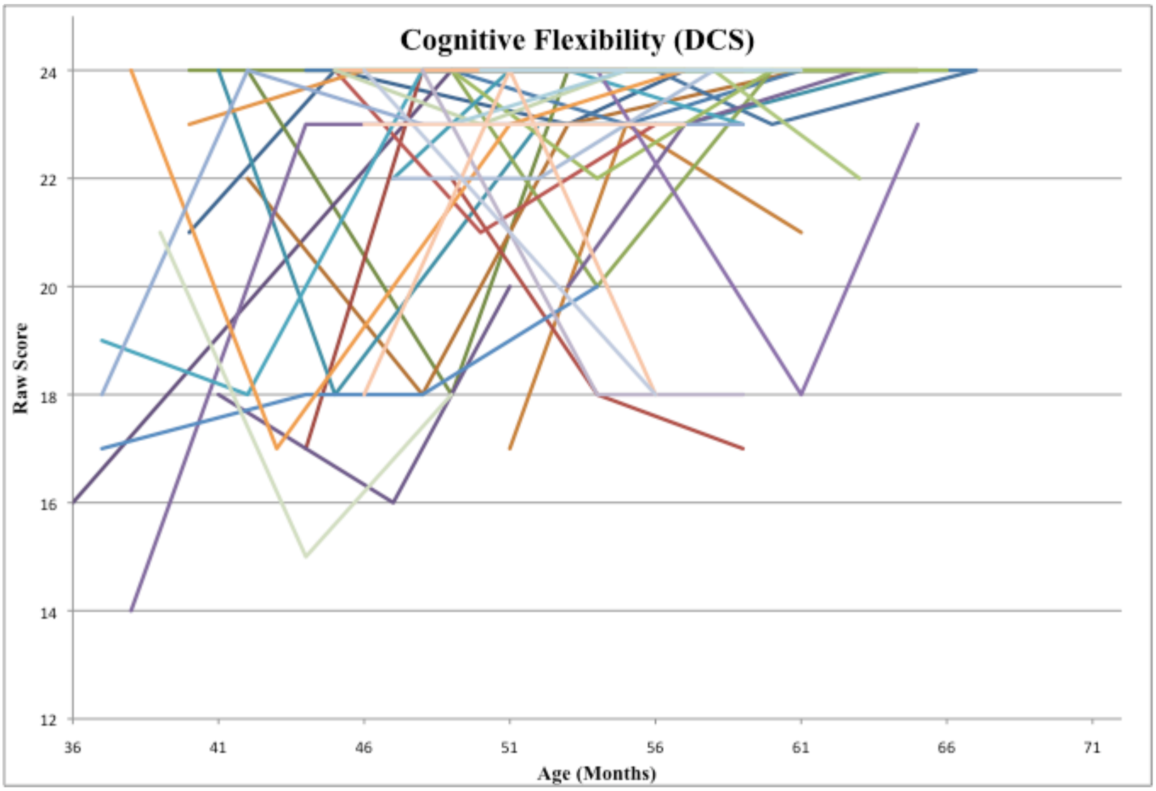


Table 11

Results of Unconditional Model for DCS

Parameter	Model 1
Intercept	1.533 (0.253) [4.634]
Level 1 (time)	
Age	
Level 2 (child)	
VOC	
OLA	
Level 2	
Intercept (τ_{00})	0.520
Age (τ_{11})	

Note. Standard errors are in parentheses. Odds ratios are in brackets.

Discussion

The present study was conducted to gain a better understanding of how executive skills change over time during the preschool period. The study of the growth trajectories of individuals was expected to yield additional insight into the development of executive functions beyond what is known based on group and cross-sectional data. Executive skills were expected to increase systematically with age and children were expected to vary in their growth rates, even after accounting for age. Additionally, initial language ability was investigated as a predictor of change in executive skills. Specifically, initial language ability was hypothesized to predict differences in the growth rate of executive skills with better language skills relating to faster rates of increase. Analyses were conducted separately by executive skill using HLM-6 statistical software.

The first research question sought to examine the extent to which executive skills changed in individual children during the preschool period. Results of the analyses revealed significant positive linear growth trajectories over time for five of the seven executive skills measured (all but visual attention (VAT) and cognitive flexibility (DCS)). Thus, the present study extends previous cross-sectional research by documenting that executive skills grow systematically with age in individual children during the preschool period. Lack of significant findings regarding age as a predictor of visual attention (VAT) and cognitive flexibility (DCS) may be explained by a loss of variability related to the need to standardize scores for VAT and dummy code scores for DCS.

The purpose of the second and third research questions was to investigate how individuals varied in their rate of change on the seven executive tasks measured and to explore to what extent, if any, initial language ability explained differences in rate of change. Results showed that even after considering age, a significant amount of variance in rate of change was still unaccounted for in three (VWM, STA, and CAD) of the seven executive skills measured. Thus, age alone accounted for a significant proportion of the variance in nonverbal working memory (NWM) and problem solving (TOW). In other words, growth in both of these skills across the preschool period is best explained as a maturational process.

For three executive skills (VWM, STA, CAD), significant variance in slope was still unaccounted for after considering age. Thus, conditional models were used to examine language as a predictor of rate of growth. Examined separately, both initial receptive vocabulary (VOC) and oral language skill (OLA) were found to be significant predictors of rate of growth in verbal working memory, even after considering age. Furthermore, when these variables were examined simultaneously, OLA remained a significant predictor in rate of growth of VWM. Neither language predictor explained a significant proportion of the variance in rate of growth for motor inhibition (STA) or cognitive inhibition (CAD). For all three executive skills (VWM, STA, CAD) for which conditional models were employed, significant variance in the rate of change remained even after considering both age and initial language ability. Thus, future research should consider other untested predictors to account for the remaining unexplained variance in rate of growth for these three tasks.

There were several limitations in the present study that may have contributed to the limited findings and can inform future research. Small sample size limited statistical power to detect effects and the limited number of measurement occasions necessitated a linear rather than curvilinear analysis. Likewise, as previously mentioned, the need to standardize scores for VAT and dummy code scores for DCS likely contributed to the lack of significant findings regarding age as a predictor of change for these executive skills. As argued by Willett and colleagues (1998), the process of standardization makes score variance equal across age and sacrifices underlying individual differences in growth. Currently, the scarcity of EF measures validated for use in young children makes selection of tasks appropriate for growth curve analysis difficult.

Despite these limitations, the present study provided insights into the pattern of development of EF in early childhood by using longitudinal analysis to investigate developmental trajectories of emerging executive functions. At present, the extant literature pertains to changes across populations at different times rather than changes within individuals across age. Direct investigations of changes in executive functions in individual children across age are rare, as are investigations of the sources of individual change. Results suggest that language skills may be more strongly associated with growth in some executive skills than others. This may be due to the type of underlying skill being measured or simply to the nature of the individual task, such as the type of stimuli or length and/or complexity of verbal instructions. For example, on the two tasks for which age clearly predicted outcome (NWM and TOW), children were asked to manipulate objects (blocks and wooden balls respectively) and hold in memory a spatial pattern. On both of those tasks, visuospatial memory span may have been more important to growth in performance than language ability. Growth in children's 'visuospatial sketchpad' capacity, as described by Baddeley and Hitch (1994), has been found to be largely dependent on maturation of visual processing centers in the right hemisphere (Barkley, 1997). Likewise, the use of visuo-spatial stimuli, which are less amenable to verbal encoding than conceptual stimuli (Pickering, Gathercole, Hall, & Lloyd, 2001), may help to explain these results.

Interestingly, the one executive skill (verbal working memory) for which initial language ability was found to be a significant predictor of rate of growth, has been linked both theoretically and empirically with the transition from other- to self-regulation in early childhood. That is, the Memory for Sentences Task (SB-5; Roid, 2003) is a measure of working memory for verbal information which is analogous to 'phonological loop' capacity as described by Baddeley and Hitch (1994). Baddeley, Gathercole, and Papagno

(1998) have demonstrated that across early and middle childhood, vocabulary knowledge is strongly associated with 'phonological loop' capacity. That is, children who perform well on verbal working memory tasks also have good vocabulary knowledge. As suggested by Barkley (1997), children's use of self-directed speech in service of self-regulation is partially dependent on the capacity to retain verbal rules in working memory. Thus, future studies should explore whether language ability, as measured here, exerts an indirect effect on the development of other executive skills by directly influencing the growth of verbal working memory span.

In sum, findings from this study suggest that future research should consider a broader array of predictors of growth in executive functions beyond the language measures used here. For example, future studies could explore other language variables (e.g., verbal self-instruction or level of private speech observed during task performance) or background variables (e.g., gender, socioeconomic status) to investigate whether individual characteristics, environmental or demographic factors systematically influence the rate of growth in executive functions development. At present, studies examining gender differences in executive function are inconsistent, with some studies showing differences in performance favoring girls and others favoring boys (Carlson, 2005). A longitudinal study that examines the influence of gender on the rate of change in executive skills over time could help to clarify this literature. Likewise, recent studies examining the relationship between socioeconomic status (e.g., parental education, occupation, and income) and executive function performance in young children have shown that lower-income children have disproportionately poor executive skills (Noble, Norman, & Farah, 2005; Noble, McCandliss, & Farah, 2007). While language ability (e.g., receptive vocabulary) has been found to statistically mediate the relationship between socioeconomic status and executive function in a sample of urban African-American kindergarteners (Nobel et al., 2005), longitudinal studies examining the relationship between language, socioeconomic status, and executive function have not been carried out.

Finally, although not addressed specifically in this study, results also indicate that children differ in their initial status on many of the executive skills measured. This finding suggests that future research should investigate factors that influence not just growth in executive skills, but also initial status in these abilities at the beginning of the preschool period.

Conclusion

Results from this study add to a growing body of research demonstrating the importance of the preschool years for EF development. Importantly, this study extends cross-sectional findings by employing longitudinal methods to the study of EF development. Specifically, the results of this study document that between the ages of 3 and 5 years, growth in many executive skills varies systematically with age. This study also demonstrates that during this period of development, maturation adequately explains growth trajectories for some executive skills (nonverbal working memory and problem solving) and not others (verbal working memory, motor inhibition, and cognitive inhibition). For the executive skills in which children were found to differ in their rate of growth after accounting for age, initial language ability was found to predict rate of change in only one executive skill, verbal working memory. This may be due in part to the nature of the tasks chosen to measure executive function in this study. Nonetheless, findings from this study suggest that for a number of executive skills, children's individual growth trajectories differ in both initial status and rate of growth. Thus, future investigations should consider a broader array of contextual variables, such as gender and socioeconomic status, as predictors of change to uncover the various pathways along which EF development may occur. This approach will likely yield insights into how not only individual characteristics contribute to various pathways of EF development, but also how EF links to other important childhood outcomes.

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