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EXECUTIVE FUNCTION AND EMERGENT LITERACY:

DIRECT AND MEDIATED PREDICTORS

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Abstract

Although recent research supports Executive Function (EF) as a predictor of Emergent Literacy, multiple questions remain. This study investigates how domain-specific EF skills relate to growth in Emergent Literacy over time; how Emergent Literacy predicts growth in Executive Function; and whether a child's behavioral engagement in the learning process (Approach to Learning) mediates the relationship between Executive Function and Emergent Literacy. Participants, initially Head Start students from both urban and rural Pennsylvania counties, were followed from the Fall of pre-Kindergarten through the Spring of first grade (N=164). Measures of EF (Backward Word Span, Dimensional Change Card Sort, Pencil Tapping), Approach to Learning, and multiple measures of Emergent Literacy were administered across time. Hypotheses were tested using path analysis models. These models provided consistent support for the hypothesis that Emergent Literacy predicts growth in EF and partial support for the hypothesis that EF predicts growth in Emergent Literacy. There was very limited evidence that Approach to Learning mediated the relationship between EF and Emergent Literacy. This study provides clear support for a transactional relationship between EF and Emergent Literacy, but the mechanism(s) creating this relationship remain open to further research.

TABLE OF CONTENTS

List of Tables

List of Figures

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With great love, there are always miracles
- Willa Sibert Cather

Introduction

From 65% to 75% of children diagnosed with reading disabilities in early grades continue to display reading difficulties throughout the remainder of their formal schooling, and while most schools have instituted programs to assist struggling readers, reading difficulties remain frustratingly stable (Scarborough, 2001). Low-income children are particularly at risk for reading difficulties (Farkas, 2000). One reason for this includes fewer opportunities to develop emergent literacy, the skills and knowledge that research has shown are the developmental precursors of literacy (Scarborough, 2001; Whitehurst & Lonigan, 1998). For example, low-income children have fewer conversations with adults, providing these children with fewer opportunities to improve their vocabulary and speech patterns. Low-income children may not have anyone to help them learn the sounds associated with individual letters. In addition to a lack of these literacy-promoting social interactions, many of these children lack adequate access to books and other print materials (Farkas, 2000). As might be expected, upon their entry to school, low-income students are already achieving less than their middle-income peers. This achievement gap continues to grow over time.

Compensatory education programs focusing on low-income students, such as Head Start, attempt to promote emergent literacy skills before children begin formal schooling. These programs often focus on teaching students additional literacy-related content and skills (e.g., knowing the names of letters) prior to the start of Kindergarten. And as highlighted above, low-income children do come to school in need of additional content knowledge. But researcher findings and teacher reports both indicate that more than a lack of content knowledge may be impeding the ability of low-income children to catch up to their middle-income peers (McClelland, Connor, Jewkes, Cameron, Farris, & Morrison, 2007; Scarborough, 2001).

Kindergarten teachers frequently report that the inability to sit still, follow directions, and work independently interferes with student success. A major review of the topic reported that 17% of all students struggled with these skills but that this number approached 50% in some classrooms (McClelland et al., 2007). Unfortunately, this situation does not necessarily ameliorate itself with time and continued development. Many first-graders also come to school unable to sit still, pay attention, and work independently (Farkas, 2000). If children come to school unable to successfully complete behavioral tasks such as sitting still and paying attention, they are at a significantly greater risk of negative outcomes, including poor academic achievement (Farkas, 2000). Thus, a deficit in emergent literacy skills might be compounded by an approach to learning in which these students fail to effectively engage in the learning process.

The executive function (EF) skills of attention control, inhibitory control, and working memory, may prove useful in understanding children's varying ability to acquire emergent literacy skills and effectively engage in the learning process. Prior research has found that EF skills in pre-Kindergarten are predictive of reading skills in Kindergarten (Blair & Razza, 2007; Bull, Espy, & Wiebe, 2008; Welsh, Nix, Blair, Bierman, & Nelson, in press). The behaviors that Kindergarten and first grade teachers find problematic appear to tap into EF skills; for example, an inability to focus or appropriately shift attention may reflect a child's limited attention control.

Considering how EF skills might impact emergent literacy development also raises the possibility that emergent literacy skills might impact the development of EF skills. Although there is no empirical research specifically testing the role of emergent literacy in the development of EF skills, multiple lines of reasoning indicate its plausibility. Oral and written language skills, which are both components of emergent literacy, are theorized to have contributed to the evolution of executive function in humans (Ardila, 2008). Neuroscience research reports that tasks pulling on oral language activate EF centers (Hernandez & Meschyan, 2006). Finally, emergent literacy tasks both draw upon and provide opportunities to practice and enhance EF skills. For example, learning to distinguish one letter from another (e.g. distinguishing a "b" from a "d") requires careful attention to detail and therefore could enhance attention control skills. In the same way, the act of reading itself provides opportunities to practice and enhance EF skills. For example, working memory is required as a child remembers a syllable already sounded out, while simultaneously working to sound out the second syllable in a word. Thus, reading itself provides a natural way for children to practice and thus build their EF skills, supporting the hypothesis that Emergent Literacy skills would influence the development of EF skills.

In this paper, I investigate the relationships among Executive Function skills, Emergent Literacy skills, and children's Approach to Learning in a longitudinal study of 164 students from the start of their pre-Kindergarten year in Head Start through first grade. I expect to find that EF skills will predict growth in Emergent Literacy skills across both Kindergarten and first grade. However, because the curriculum becomes more formalized in 1st grade, succeeding on first grade literacy tasks might rely on different EF skills than succeeding on the less-formalized Kindergarten tasks. Further, I expect to find that how a child engages with the learning process will mediate the relationship between one or more of the EF skills and the Emergent Literacy skills. Finally, I expect that Emergent Literacy skills will predict growth in EF skills.

Emergent Literacy

As recently as the 1980's, literacy was considered to begin with formal schooling (Scarborough, 2001; Whitehurst & Lonigan, 1998). It was rarely considered that children's experiences during their pre-school years might impact literacy, even though children began formal schooling with markedly different skill levels and abilities. Aiding struggling readers was a task left for educators once children reached Kindergarten (Scarborough, 2001).

The Emergent Literacy perspective, now widely accepted, argues against this constricted view of literacy as beginning only with formal schooling. Emergent literacy includes the skills and knowledge that are the developmental precursors of formal literacy (Lonigan et al., 1999; Whitehurst & Lonigan, 1998). These developmental precursors exist on a continuum beginning early in life. The Emergent Literacy perspective also emphasizes the interdependent development of reading, writing, and oral language skills. Development of these skills can occur in multiple forums, including through social interactions that involve reading, writing, and oral language (Whitehurst & Lonigan, 1998).

Emergent readers must master two groups of skills to convert printed text into meaningful information. The first group of skills is called variously Decoding, Word Recognition (Scarborough, 2001) or Inside-Out Processes (Whitehurst & Lonigan, 1998). This first group of skills focuses on the ability to understand words from the "inside-out", translating print into sounds and sounds into print. The second group of skills is called variously Language Comprehension (Scarborough, 2001) or Outside-In Processes (Whitehurst & Lonigan, 1998), and involves the use of context and other outside knowledge to enable the child to attach meaning to printed text. When considering how to measure Emergent Literacy skills, it is useful to hone in on the strongest predictors of later literacy within each of these skill domains. In a review of studies predicting first grade reading skills from Emergent Literacy skills at the start of Kindergarten, Scarborough (2001) found that the most predictive decoding skills were phonological awareness and print knowledge, and that the most predictive comprehension skills were expressive and receptive vocabulary and syntax.

Phonological awareness refers to children's ability to understand and manipulate the sound structure of oral language (Lonigan et al., 1999). Phonological awareness develops from larger sound structures to smaller ones: infants and toddlers learn to separate the stream of oral language into a sequence of distinct words, while older preschool children learn to decompose words into syllables, and eventually syllables into phonemes. A child's ability to detect these phoneme-level sounds is a key step towards formal literacy, allowing a child to begin to pair blocks of sound (phonemes) with their corresponding letters (graphemes). Additionally, once a child can recognize syllables and phonemes, the sounds can further be blended together or broken apart, aiding in the decoding of other words that utilize those same sounds.

The remaining components of phonological awareness are, as noted above, phonological memory and phonological access. Phonological memory refers to the child's ability to hold phoneme-based sounds in short-term memory; phonological memory has been shown to support the learning of new vocabulary (Gathercole, Hitch, Service, & Martin, 1997). Efficiency of phonological access refers to how quickly a child can retrieve phonological information. Decoding is an time-sensitive process; the faster children can retrieve phonological information (e.g. the name of the letter, the accompanying sound), the more efficiently they can decode words, resulting in an overall improvement in reading fluency (Bowers & Wolf, 1993).

Measuring phonological processing is often accomplished via the Blending and Elision Scales from the Test of Preschool Early Literacy (TOPEL; Lonigan, Wagner, Torgesen, & Rashotte, 2007; Bierman, Nix, Greenberg, Blair, & Domitrovich, 2008). The Blending Scale requires the child to put together two parts of a word, such as “b” plus “at,” and then point to the picture of the bat or say the word bat. The Elision Scale requires that, instead of putting together parts of a word, the child break the word apart. In this measure, the child might be asked to say “snowshoe” without “snow,” the correct response being “shoe.”

Print knowledge includes knowledge of the alphabet, including both upper- and lower-case letters. In addition, print knowledge includes understanding details about a book such as that it is read from left to right. Other details about books that fall under print knowledge include understanding that a book has a title and an author, and knowing where to locate that information. Together with phonological processing skills, print knowledge helps the child to decode words and groups of words, thus translating marks on a page into meaningful symbols and sounds.

Measuring print knowledge can be accomplished in a variety of ways. One method is to ask a child to name all the letters of the alphabet as they are presented in random order (Lonigan et al., 1999). Children might also be shown a book and rated on such things as their understanding of the left-to-right, front-to-back format. The Print Knowledge Scale of the TOPEL asks children to identify pictures of letters or words, and say the names of letters (TOPEL; Lonigan et al., 2007; Bierman et al., 2008).

Measures of oral language, both expressive and receptive, are also important predictors of reading success. In order to understand the meaning of the decoded words, the child must already comprehend the oral version of the word. Decoding a word a child comprehends orally allows the child to gain information and assign meaning to the text, a necessary skill for academic success.

Measuring children's oral language can be effectively accomplished with the Expressive One-Word Picture Vocabulary Test-Revised (EOWPVT-R, Brownell, 2000) and the Peabody Picture Vocabulary Test-Revised (PPVT-R, Williams & Wang, 1997). The EOWPVT-R measures a child's expressive oral language skills by showing the child pictures and asking the child to name them. Conversely, the PPVT-R measures a child's receptive language ability. In this test, the experimenter names an object or action and the child is asked to point to the corresponding photo.

Executive Function

The idea of EF gained prominence in the 1970's and 1980's as a construct describing the skills necessary for individuals to form goals, plan how to achieve these goals, and effectively follow plans toward successful accomplishment of goals (Jurado & Rosselli, 2007). There is a great deal of discussion in the field as to whether EF consists of one latent factor that explains all the differing skills that are considered part of EF, or whether EF skills are related, yet distinct, from each other (Bernstein & Waber, 2007; Fischer & Daley, 2007; Jurado & Rosselli, 2007). While this topic remains hotly debated, most researchers agree that EF incorporates at least the following components: attention focus and shifting; inhibitory control; and working memory. Additionally, as follows from the overall purpose of EF, these skills are expected to serve the purpose of planning goal- directed activities and carrying these plans to fruition (Bierman et al., 2008).

In this paper, I define EF as an overarching construct that includes the component functions of attention control, inhibitory control, and working memory. Attention control includes the ability to focus attention and the ability to shift attention as the task requires. Inhibitory control refers to the child's ability to inhibit a prepotent response and instead engage a subdominant response. Working memory refers to the child's capacity to keep information in mind and manipulate it. Finally, these component functions work together in service of the accomplishment of goal-directed activities.

EF skills appear to develop sequentially across childhood. The development of the distinct EF skills is intercorrelated but not homogenous (Altemeier, Abbott, & Berninger, 2008). The age at which each skill begins to develop varies, as does the trajectory of development and the age at which the skill is considered to have reached maturity (Jurado & Rosselli, 2007).

Attention Control. To complete a task, children must first learn to focus on a task, while inhibiting their responses to environmental or other stimuli that might distract them from successful completion of their task. They must also learn to flexibly shift that focus as necessary (Garon, Bryson, & Smith, 2008; Jurado & Rosselli, 2007). At what point do children demonstrate attention control? Some researchers point to children's successful completion of the A-not-B Task as evidence of attention control (Jurado & Rosselli, 2007). At 9 months, children will continually reach for a desired object in its initial or prior location (A), even though it clearly is now located in a different location (B). By 12 months, however, some children will successfully complete the task and reach for the object in the current location (B). This task requires children to shift their attention from A to B, demonstrating at least some level of attention control by the age of 12 months. After attention control emerges, researchers point to two major growth spurts: one at ages 3 and 4 years, during the preschool years (Garon et al., 2008); and a final large growth spurt around age 15 (Jurado & Rosselli, 2007).

Inhibitory Control. Inhibitory control, as shown by the ability to suppress a dominant response, begins to develop within the first year of a child's life. For example, 40% of the time 8-month olds were able to inhibit a rewarding behavior when told "don't" by their caregiver (Kochanska, Tjebkes, & Forman, 1998). This ability continues to increase over time, as shown by Carlson's (2005) study utilizing Mischel's classic Delay of Gratification paradigm. Children were shown two bowls, one containing two treats, and another containing ten treats. Children were told that the experimenter had to leave the room to do some work. If they waited for the experimenter to return (5 minutes), they could have the bowl with ten treats. However, if they got tired of waiting, they could ring the bell and receive the bowl with two treats. At three years of age, 64% of the children waited for the experimenter to return. By four years of age, 84% of the children were able to wait for the experimenter to return.

Working Memory. The early development of working memory is evidenced by infants' ability to hold information over a delay; specifically it is measured by how long an infant can hold a representation in mind. This skill is evident by six months of age, when infants can hold a representation in mind for a few seconds. At 12 months of age, infants can hold a representation in mind for more than 10 seconds (Garon et al., 2008). The more complex forms of working memory include the ability to mentally update and manipulate information. Most measures focus on children ages three years and above. Scores on measures of working memory typically increase from the ages of three to five. Measures capable of capturing increased levels of development (i.e. measures with higher ceilings), such as digit-word and object-spatial spans, show continued improvement throughout the elementary school years (Garon et al., 2008).

Measuring Executive Function Skill

Multiple methods of measuring EF skills exist, including both direct child test and observer-report measures. However, each of these measures is subject to one or more of the challenges inherent to measuring any EF skill. First, it is widely acknowledged that many EF measures tap into multiple components simultaneously, making it difficult to isolate the impact of a specific EF skill (Carlson, 2005). Another complaint is that some EF measures, now utilized with young children, have been adapted from adult measures without adequate consideration given to children's differing linguistic, motor, and other skills (Isquith, Crawford, Espy, & Gioia, 2005). Finally, many measures rely heavily on language. When task instructions are complex, children's language ability may be confounded with their performance on the EF task (Jurado & Rosselli, 2007).

Direct Child Test Measures of Executive Function

Attention Control: The Dimensional Change Card Sort (DCCS; Frye, Zelazo, & Palfai,1995) is a card sorting task that requires attention control in the form of attention shifting. This task includes cards that have both a shape and a color on each. The children are taught to sort the cards on one dimension initially, for example, by putting all the red cards in one pile and the blue in the other, regardless of whether the shape on the card is a circle or a square. They are then asked to shift attention by now putting all the cards with a square in one pile and all the cards with a circle on them in the other pile, disregarding the color dimension. While primarily considered an attention shifting task, DCCS also pulls on working memory (remembering the task instructions) and inhibitory control (inhibiting the prepotent response of continuing to sort per the previous practice).

Inhibitory Control. Inhibitory control is frequently measured through any of a number of versions of the Stroop Task. In a Stroop task, the child is asked to say something incongruous with, and most often also semantically linked to, the picture displayed. For example, in one version a child is shown four different pairs of pictures: a boy and a girl, daytime and nighttime, up and down, large and small (Diamantopoulou, Rydell, Thorell, & Bohlin, 2007). When children see the card with the girl, the correct response is boy; when they see the daytime card, the correct response is nighttime. This requires inhibition of the prepotent response (saying girl when they see a photo of a girl) and activation of a subdominant response (saying boy). Another common task for assessing inhibitory control is the peg (or pencil) tapping task (Diamond & Taylor, 1996). In this test, children are asked to tap a peg once when the experimenter taps it twice, and vice versa. As with DCCS, both the Stroop and peg tapping tasks also pull on working memory, as the child must be able to recall the instructions given.

Working Memory: Working memory can be measured through both verbal and non-verbal tasks. A common verbal measure is the Backward Word Span Task. In this task, children are read a list of words. They are then ask to repeat the words, but in the reverse order from which the words were read (Bierman et al., 2008). An example of a non-verbal working memory task involves delayed recall: researchers show children an airplane located at a particular location on a computer screen, then the children are given a distraction task, after which they are asked to recall the location of the airplane on the computer screen (Diamantopoulou et al., 2007).

Measuring Multiple EF Components: While the EF measures described above attempt to isolate a specific EF skill, "Touch Your Toes!" specifically includes multiple EF components (Cameron-Ponitz et al., 2008). Although designed as a tool for measuring behavioral regulation, the researchers' definition of behavioral regulation incorporates the main components of EF: attention control, inhibitory control, and working memory. Specifically, the measure is presented as a game in which children are told to do the opposite of what the experimenter asks them to do (either touch their head or touch their toes). The child must be able to pay attention and remember the task instructions, while simultaneously inhibiting the prepotent response by doing the opposite of the experimenter's instruction.

Observer-Ratings of Executive Function

Direct-child test measures of EF have existed since at least the 1980's, but these measures have a number of problems, including the need for specialized materials and substantial time to administer (Cameron-Ponitz et al., 2008), and the likelihood that requirements for fine motor skills confound children's motor abilities with their EF abilities (Cameron-Ponitz et al., 2008). Measures based on observer ratings have sometimes been used as an alternative, but observer-rated measures are particularly susceptible to study design issues, such as the lack of another rater to provide inter-rater reliability information. Additionally, observer ratings based on a single visit with a participant might not be representative of the child on a "typical day," but are subject to the vacillations of that day's circumstances. Nonetheless, researchers have adapted previous observer-rated measures and developed new observer-rated measures to attend to these problems.

One example is a study involving adaptations of the California Child Q-Sort (CCQ) and the Haan Q-Sort to assess participants' EF (Buckner, Mezzacappa, & Beardslee, 2003). Both instruments consist of cards listing either a behavioral or personality descriptor (CCQ) or a personality process related to coping methods (Haan Q-Sort). The experimenter places each card into one of nine piles that represent how much the descriptor characterizes the child, from extremely uncharacteristic to extremely characteristic. To measure EF, the researchers identified 8 items from the CCQ and 16 from the Haan Q-Sort that they believed would assess EF (e.g., "is attentive and able to concentrate," "is planful; thinks ahead," "inhibits his/her reactions for the time being when appropriate"). Internal consistencies for the respective EF item-sets were good, they were moderately strongly correlated with each other, and the overall measure of self-regulation was a significant predictor of children's resilience.

A weakness of this method is the reliance on the experimenter to accurately rate the child on the adapted Q-sort items. In this case, each rater had interviewed the participant multiple times over 2-3 years. Many studies will not have the benefit of this extended relationship between an individual experimenter and an individual participant. In addition, in this study, only one rated each child, allowing for no determination of inter-rater reliability. Finally, no information is presented as to how these adapted Q-Sort items correlate with direct child-test measures of EF. However, if this measure is reliable, the researchers would have created a relatively brief (24-item) measure that does not require the child's immediate presence, requires limited additional materials, and represents the child's overall EF abilities.

Approach to Learning

What might mediate the relationship between EF skills and Emergent Literacy? Work mentioned previously by Farkas (2000) and McClelland and colleagues (2007) points to the role of children's behavior in their academic outcomes. The concept of a child's Approach to Learning captures how children's behavior either helps them, or prevents them from, successfully engaging in learning tasks.

For example, one observer-rated measure focuses on a child's engagement with the learning process during a series of testing sessions (Smith-Donald, Raver, Hayes, & Richardson, 2007). Example items include: "pays attention to instructions and demonstrations," "sustains concentration; willing to try repetitive tasks," "can wait during and between tasks," and "careful, interested in accuracy." Each item is rated on a 4-point scale. This measure is similar to the Touch Your Toes task (Cameron-Ponitz et al., 2008) in that both measures focus on the integrated coordination of multiple EF skills, but the Approach to Learning task is distinct in relying on observer ratings of performance. It is similar to the adapted Q-sort measure described above in that both rely on an observer rating, but it is much narrower in its focus on behavior observed in a very restricted set of learning tasks.

In the context of the present study, the question is: do observer ratings of behavior suggesting successful integration of EF skills in the contexts of learning tasks mediate the association between mainly cognitive, lab-measured processes of EF skills and growth in emergent literacy skills? If so, it would suggest that EF skills may translate into specific behaviors that better allow a child to take advantage of the learning opportunities provided in the classroom.

Executive Function, Approach to Learning, and Emergent Literacy

Having discussed the three main constructs relevant to this study, the next question is if and how they relate to each other. First, what does theory have to say about potential relationships between these three constructs? Second, what does current empirical evidence - particularly data focused on low-income students - tell us?

Theory suggests that EF skills impact the development of emergent literacy. For example, researchers argue that poor inhibitory control might result in students perseverating on irrelevant phonological codes, instead of quickly suppressing them and moving on to efficiently access the desired, correct codes (Altemeier et al., 2008). This inability to suppress irrelevant phonological codes and move on to access the correct codes would slow the decoding process. Conversely, researchers argue that an efficient phonological memory (a construct very close to working memory) would result in more fluent decoding. Children whose phonological memories operate efficiently are able to hold individual phonemes in memory, with sufficient resources remaining to allow them to also focus on the decoding and comprehension tasks of reading (Lonigan et al., 2009).

Empirical evidence also supports links between Executive Function skills and Emergent Literacy skills. One set of findings, which will be built on in this paper, comes from researchers on the Head Start REDI study. Growth in a composite measure of EF skills during the pre-Kindergarten year uniquely predicted Kindergarten reading achievement, even after controlling for prior emergent literacy skills (Welsh et al., in press). In another sample of Head Start students, researchers found that inhibitory control at pre-Kindergarten predicted Phonemic Awareness and Letter Knowledge in Kindergarten. Attention shifting at pre-Kindergarten also predicted Phonemic Awareness in Kindergarten (Blair & Razza, 2007).

Two additional longitudinal studies follow children past the age of Kindergarten, strongly suggesting a continuing relationship between EF and Emergent Literacy skills. A longitudinal study from the UK followed students from pre-Kindergarten through age seven. The sample consisted of students from working to middle-class homes. Students who scored higher on inhibitory control in pre-Kindergarten had higher reading scores in Kindergarten, a relationship that was maintained through age 7. Attention control at pre-Kindergarten did not predict reading achievement across time, but it was correlated with reading achievement at each individual time point (Bull et al., 2008). In a longitudinal study following two somewhat older cohorts of students (cohort 1 from grades 1-4, cohort 2 from grades 3-6), inhibitory control uniquely predicted word reading at each grade level (Altemeier et al., 2008). What that relationship looks like in low-income and minority students in the U.S., however, is difficult to generalize from these studies due to variations in sample characteristics, measures used, and study designs.

In considering the possibility that emergent literacy is predictive of EF skills, there is a distinct lack of specific empirical investigation on the topic. However, if we consider the comprehension and decoding skill components of EL, we can see several ways in which oral language might impact the development of EF skills. First, most broadly, work in anthropology and the communication sciences argues that the development of oral language led to the development of Executive Function in humans (Ardila, 2008). Second and more narrowly, researchers investigating the role of SES in child outcomes found that language mediated the relationship between SES and both attention control and inhibitory control (Noble, McCandliss, & Farah, 2007). Third, zooming in all the way to the level of neuroscience, researchers find that certain oral language tasks also activated EF centers (Hernandez & Meschyan, 2006). Emergent Literacy skills may also foster the development of EF skills by requiring the practice of EF skills in the very act of decoding print. For example, "sounding out" a word requires sustained attentional control (systematic left-to-right eye movement), working memory (keeping initial phonemes in memory as later ones are encountered) and inhibitory control (inhibiting the "ssss" sound when the letter "s" is followed by an "h").

Finally, as discussed previously, it is important to understand how the lab-administered EF tasks connect to a child's actual Emergent Literacy outcomes. A strong contender for a mediator between EF and Emergent Literacy is a child's Approach to Learning, that is, how the child's behaviors contribute to his or her ability to engage in learning in the classroom. Both theory and empirical evidence support the role of children's classroom behaviors, such as the behavioral regulation of attention and time on task, as predictors of academic success. These behaviors are considered just as predictive of school success as measures of intelligence (Blair, 2002). While the literature strongly suggests that a child's Approach to Learning will be predictive of Emergent Literacy skills, it is less clear if EF skills will predict a child's Approach to Learning and thus support Approach to Learning as a mediator between EF skills and Emergent Literacy skills.

Present Study

This paper builds on two previous reports of findings from the Head Start REDI study. In one of these reports, researchers compared gains on EF measures in the intervention versus control groups across the pre-Kindergarten year (Bierman et al., 2008). In a second report, researchers tested a composite measure of EF as a predictor of early literacy and numeracy skills for the control group from the Fall of pre-Kindergarten through the Spring of Kindergarten (Welsh et al., in press). The present analyses extend those previous findings in three ways. First, I break down the larger EF composite utilized in previous analyses into the domain-specific processes of attention control, inhibitory control, and working memory. I hypothesize that each will predict growth in emergent literacy across pre-Kindergarten, Kindergarten, and first grade. Second, I test the role of emergent literacy as a predictor of growth in the domain-specific EF skills across the pre-Kindergarten and Kindergarten years. Third, I test whether approaches to learning mediates the associations between attention control, inhibitory control, and working memory and growth in emergent literacy.

Methods

This longitudinal study focused on 164 children who, from the start of pre-Kindergarten through the end of first grade, served as the control group in the Head Start REDI project (Bierman et al., 2008). These children received the usual-practice Head Start curriculum, rather than the enhanced curriculum received by children in the intervention group. After pre-Kindergarten, both the control and intervention groups entered non-REDI related Kindergarten and first grade classrooms.

These 164 children were recruited from 22 Head Start classrooms in three Pennsylvania counties. To recruit participants, brochures were sent to parents of children expected to begin Kindergarten the following year. Overall, 86% of eligible children received permission and underwent assessment at the Fall of pre-Kindergarten (M_{age} = 53.88 months, SD = 3.6).

Individual and family demographic information were collected, including family income, mother's education, child's ethnicity and sex, and with whom the child lived. All families had incomes at or below the threshold necessary for participation in Head Start. Of these, 68% had incomes below the national poverty level. 33% of the mothers had not completed high school, and 46% graduated from high school or had completed an equivalency exam. 19% had completed some technical training, and only 2% had a college degree. Participants represented multiple ethnicities (14% Latino American, 30% African American, 56% European Americans), and 57% were female. 40% of the participants lived in a two-parent household, 43% lived with their mothers, and 7% lived with either relatives or as foster children.

Procedures

Measures were collected at four time points: 1) fall of the pre-Kindergarten year, 2) spring of the pre-Kindergarten year, 3) spring of the Kindergarten year, and 4) spring of the first grade year. Each child assessment consisted of two individual "pull-out" sessions from the child's regular Head Start or elementary school classroom. Each session was 30-45 minutes long. The two-session format provided two advantages. First, a session as long as the two combined would likely overtax the students, particularly the younger ones. Second, each assistant rated the child's behavior after each pull-out session was complete, allowing for greater reliability because observer-rated behaviors could be averaged across the two sessions.

Child assessments were performed by trained research assistants. Research assistants were trained to administer the measures during a 3-day workshop. Each assistant was observed by a supervisor while completing a minimum of two assessments. The supervisor provided the assistant detailed feedback following the assessments. Monitoring of each assistant continued throughout all data collection periods to ensure consistent adherence to the research protocol.

Measures

EF (Dimensional Change Card Sort, Peg/Pencil Tapping, and Backward Word Span) measures were collected at both pre-Kindergarten time points, as well as at the spring of Kindergarten year. Approach to Learning was collected at all four time points. Emergent Literacy measures were collected at all four time points. Due to children's increasing emergent literacy skills, two groups of developmentally appropriate measures were used to form the composite. During the two pre-Kindergarten time points, the Emergent Literacy composite consisted of the Print Knowledge, Blending, and Elision scales of the Test of Preschool Early Literacy (TOPEL; Lonigan et al., 2007). At the Kindergarten and first grade time points, the Emergent Literacy composite consisted of the Sight Word Efficiency and Phonemic Decoding Efficiency scales from the Test of Word Reading Efficiency (TOWRE; Torgesen et al., 1999), and the Letter-Word Identification and Story Recall subtests from the Woodcock Johnson III (Woodcock, McGrew, & Mather, 2001).

Executive Function Measures

Attention control was assessed via the Dimensional Change Card Sort task (Frye et al., 1995). This task used cards with pictures of blue rabbits, red rabbits, blue boats, and red boats. Children first sorted 12 cards either by color (blue versus red), or by the item depicted (rabbits versus boats). For the final 6 cards, children were asked to sort by the other dimension. The child's score consisted of one point for each of the final 6 cards which the child sorted correctly. This task primarily captures the child's ability to shift attention, but also tapped into the child's inhibitory control (inhibiting the impulse to sort in the previous manner) and working memory (remembering the instructions to sort by the new dimension). This task is considered appropriate for our sample as administered in both pre-Kindergarten and Kindergarten (Carlson, 2005).

Inhibitory control was assessed via the Peg/Pencil Tapping Task (Diamond and Taylor, 1996). In this task, children watched the experimenter tap a peg on a table either one or two times. Children were then supposed to tap their pegs the opposite number of times from the experimenter; that is, if the experimenter tapped her peg once, the child was to tap twice, and vice-versa. The child's score equated to one point for each correct one or two-tap response, for a possible total score of 16. This task primarily measured children's inhibitory control, as it required inhibiting the prepotent response of imitating the experimenter. However, completion of the task also required worked memory, as children had to keep in mind the experimenter's instructions.

Working memory was assessed using the Backward Word Span measure. In this task, the child was asked to listen to a list of words and then repeat those words in reverse order. Children received a score of 0 if they could not do the task; 1 if they could repeat two words in reverse order; and 2 if they could repeat more than two words. This task requires utilization of both components of working memory: storage of information (while listening to the words and trying to remember them), and mental manipulation of that information (while reversing the order of the words).

Approach to Learning

Approach to Learning was conceptualized as a child's engagement with learning tasks and goals. It was assessed using the 13-item Adapted Leiter-R Assessor Report (Smith-Donald et al., 2007; Roid and Miller, 1997). Immediately after each testing sessions, the experimenter completed the Leiter-R for the child. Items were rated on a 4-point scale. Items included: "paying attention to instructions and demonstrations," "willingness to try repetitive tasks," and "sustains concentration" ($\alpha = .93$). Scores from the two testing sessions were averaged at each time point.

Emergent Literacy

In both pre-Kindergarten assessments, decoding skills were measured with three scales from the Test of Preschool Early Literacy (TOPEL; Lonigan et al., 2007. Phonological awareness was measured with the Blending and Elision scales. The Blending Scale requires the child to put together two parts of a word, such as "b" plus "at," and then point to the picture of the bat or say the word bat. The Elision Scale requires that, instead of putting together parts of a word, the child break the word apart. In this measure, the child might be asked to say "snowshoe" without "snow," the correct response being "shoe." Print knowledge was tested with the Print Knowledge scale, in which children are asked to identify pictures of named letters and to name pictured letters.

In Kindergarten and first grade, word-level decoding skills were assessed with three tests. The Phonemic Decoding Efficiency and Sight Word Efficiency scales from the Test of Word Reading Efficiency (TOWRE; Torgesen et al., 1999) measure a child's ability to quickly and accurately pronounce printed words (Torgesen et al., 1999). Children are given 45 seconds to read words (Sight Word Efficiency) or phonetically regular non-words (Phonemic Decoding Efficiency) from a list as quickly as possible. This measure assesses a child's ability to rapidly read common words and to fluently apply phonetic decoding skills. The Woodcock-Johnson Letter-Word Identification subtest (Woodcock et al., 2001) focuses entirely on word-reading accuracy rather than speed: children sound out words, moving presented in a flip-book that moves from easier words to harder ones. A correctly pronounced word is scored as 1; an incorrectly pronounced word is scored as 0.

In Kindergarten and first grade, oral language skills were assessed with the Woodcock-Johnson Story Recall subtest (Woodcock et al., 2001). Children listen to an audio recording of a story. After the audio recording is finished, the experimenter says "tell me the story." Children receive 1 point for each element of the story they correctly recall. The Story Recall subtest tests not only the child's narrative recall, but also tests the child's receptive and expressive oral language skills.

Composite measures of emergent literacy. To account for children's continued development of emergent literacy skills, the composite scores for emergent literacy were computed differently in pre-Kindergarten than in Kindergarten and first grade. At the Fall and Spring of pre-Kindergarten, Emergent Literacy was measured by averaging students' standardized z-scores on the Blending, Elision, and Print Knowledge measures

(TOPEL; Lonigan et al, 2007). At the Kindergarten and first grade time points, emergent literacy was measured by averaging students' standardized z-scores on the Sight Word Efficiency and Phonemic Decoding Efficiency scales from the Test of Word Reading Efficiency (TOWRE; Torgesen et al., 1999), and the Letter-Word Identification and Story Recall subtests from the Woodcock Johnson III (Woodcock et al., 2001).

Results

Data Analysis Plan

First, I reviewed the data to identify any abnormalities that needed to be addressed prior to modeling, such as extremely non-normal distributions that may arise from either floor and ceiling effects in the Executive Function measures, a not infrequent result of administering the same measures repeatedly across a period of rapid developmental growth. Next, I examined the intercorrelations among the key measures to understand how the domain-specific measures of Executive Function correlated with each other at each time point, how the three main "sets" of variables correlated with each other at each time point, and the stability of each of the variables across each time point.

I then used a series of path models to test my hypotheses. Each model accounted for baseline intercorrelations and stability over time, so that cross-lag coefficients could be interpreted as predicting change in the dependent variable. The first path model tested the hypothesis that the domain specific components of Executive Functions at each time point would predict growth in Emergent Literacy Skills at the subsequent time point. The second path model tested the hypothesis that Emergent Literacy skills at each time point would predict growth in the domain specific components of Executive Function skills at the subsequent time point. Using a chi-square difference test, I then compared these two models to see which model yielded a better fit to the data.

Finally, I used a third path model to test the hypothesis that children's engagement in the learning process (Approach to Learning) would mediate the relationship between EF and Emergent Literacy. I tested this hypothesis for each EF skill. Mediation exists when the relationship between Executive Function and Emergent Literacy skills is reduced by the inclusion of a potential mediator. According to Cole and Maxwell (2003), this situation exists when the product $AB \neq 0$, where A represents the path coefficient between the independent variable (EF) and the mediator, and B represents the path coefficient between the mediator and the dependent variable (emergent literacy). The product $AB \neq 0$ is considered both necessary and sufficient evidence of mediation.

Distributions of Measures to be Modeled

Descriptive statistics for each measure, at each time point, are presented in Table 1. Three EF measures presented unusually high skewness: Backward Word Span at the Fall of pre-Kindergarten; Dimensional Change Card Sort at the Spring of Kindergarten; and Pencil Tapping at the Spring of Kindergarten. In cases where skewness is unusually high, log or root transformations may normalize the data. A log transformation resulted in a slightly reduced skewness in Backward Word Span at the Fall of pre-Kindergarten from 2.8 to 2.5. However, a root transformation on the two variables exhibiting a negative skewness only increased the absolute skewness (e.g., for Dimensional Change Card Sort,a root transformation increased skewness from -2.6 to -3.0; for Pencil Tapping, a root transformation increased skewness from -3.1 to -4.5. Because neither log nor root transformations provided substantial reductions in skewness, analyses proceeded with the data in its original state.

To further understand the overall characteristics of the data to be modeled, I examined the distributions of each Executive Function measure across time. Preschool children are in a period of rapid developmental growth in regards to EF skills, and other studies have shown consistently increasing performance on the same EF measures from the ages of three to six years (Carlson, 2005), raising the possibility of either floor or ceiling effects. The box plots for the three EF measures are shown in Figure 1. With DCCS, the median score at in the Fall of pre-K was four on a scale ranging from zero to six, but the median score increased to the ceiling of six at the Spring of pre-K, with over 75% of children scoring at the ceiling in the spring of Kindergarten. In the case of Pencil Tapping, the median score at at Fall pre-K was slightly below 10 on a scale from 0 to 20 and increased to approximately 15 by Spring pre-K. By the spring of Kindergarten, the median score moved only slightly higher, but the variance of the scores decreased as very few children obtained very low scores. Finally, Backward Word Span displays a clear floor effect at the Fall of pre-Kindergarten: over 75% of children could not complete the task successfully. At the Spring of pre-Kindergarten, the median score increased to one, although at least 25% of children still scored at the floor. By the Spring of Kindergarten, over 75% of children scored at the median score of one.

Intercorrelations Among Variables to be Modeled

Intercorrelations between the variables are presented in Table 2. Looking at the domain-specific EF measures, we can see that their intercorrelations are between r = .23 and r = .24 at the Fall of pre-Kindergarten, and between r = .32 and r = .34 at the Spring of pre-Kindergarten, all $p < .01$. At Kindergarten, however, the intercorrelations drop to between .11 and .18. While the intercorrelations between Backward Word Span and Dimensional Change Card Sort remain significant at the $p < .05$ level, the correlation between Pencil Tapping and Dimensional Change ($r = .11$) is not significant. This may be because both Pencil Tapping and Dimensional Change Card Sort were suffering from ceiling effects by Kindergarten.

The Emergent Literacy skills also present an interesting pattern of correlations with the other variables in the dataset. In the Fall and Spring of pre-Kindergarten, the correlations between Emergent Literacy skills and AL and EF skills range between $r = .39$ and $r = .50$, all $p < .01$. However, in Kindergarten the correlations spread across a wider range and in some cases decrease below significance, $r = .11$ to $r = .38$, where r is statistically significant ($p < .05$) only when equal to or greater than .16.

Finally, we can examine the stability correlations for each measure. The Executive Function variables all show statistically reliable stability correlations that decrease in magnitude over time. For example, for Backward Word Span, $r_{12} = .42$, $r_{23} = .25$, both $p < .01$. Both DCCS and Pencil Tapping follow a similar pattern. Approach to Learning demonstrates a similar pattern of decreasing stability correlations, $r_{12} = .50$, $p < .01$; $r_{23} = .17$, $p < .05$. The same pattern of decreasing stability correlations also existed for emergent literacy, $r_{12} = .62$, $r_{23} = .40$, both $p < .01$.

Hypothesis 1: Executive Functions Predict Growth in Emergent Literacy

Hypothesis one was tested with the path model illustrated in Figure 1. The model accounts for the significant baseline associations between the measures of EF and emergent literacy ($\beta = .44$ to $\beta = .48$) so that each path from a measure of EF to emergent literacy can be interpreted as the unique role of that measure of EF in predicting growth in emergent literacy. Attention control (DCCS) at the Fall of pre-Kindergarten significantly predicted growth in Emergent Literacy skills during pre-Kindergarten ($\beta = .18$, $p < .01$), but it did not predict growth in Emergent Literacy skills across either of the two subsequent time intervals. Inhibitory Control (Pencil Tapping) significantly predicted growth in Emergent Literacy skills from the Fall of pre-Kindergarten to the Spring of pre-Kindergarten ($\beta = .21$, $p < .01$), and from the Spring of pre-Kindergarten to the Spring of Kindergarten ($\beta = .14$, $p < .05$), but not from the Spring of Kindergarten to the Spring of first grade. Finally, working memory (Backward Word Span) was not predictive of growth in Emergent Literacy skills during pre-Kindergarten, but it did predict growth in Emergent Literacy skills from the Spring of pre-Kindergarten to the Spring of Kindergarten ($\beta = .29$, $p < .001$); and from the Spring of Kindergarten to the Spring of first grade ($\beta = .18$, $p < .01$). Thus, we can see that each domain specific component of Executive Function was uniquely predictive of Emergent Literacy skills, although at varying time points.

The tested model deviated significantly from the observed data, $\chi^2(54) = 153.6$, $p < .001$. This is not surprising given the complexity of the model. The Root Mean Square of Approximation (RMSEA) considers model fit in light of the complexity of the model. For this model, RMSEA = .11. An RMSEA above .10 is considered to be a poor fit

(Chen, Curran, Bollen, Kirby, & Paxton, 2008). Thus, overall, this model is not considered to be a good fit for the data.

Hypothesis Two: Emergent Literacy Predicts Growth in Executive Function

Hypothesis two was tested with the path model illustrated in Figure 2. This model was the same as the previous one except for the addition of the six pathways linking emergent literacy to subsequent measures of Executive Function skills. Emergent literacy at the Fall of pre-Kindergarten predicted growth at the Spring of pre-Kindergarten in attention control ($\beta = .21$, $p < .01$), inhibitory control ($\beta = .26$, $p < .001$), and working memory ($\beta = .36$, $p < .001$). Emergent Literacy at the Spring of pre-Kindergarten predicted growth at the Spring of Kindergarten in attention control ($\beta = .20$, $p = .01$), inhibitory control ($\beta = .34$, $p < .001$), and working memory ($\beta = .35$, $p < .001$).

As with the first model, this model deviated significantly from the observed data, $\chi^2(48) = 78.2$, $p < .01$. Because model 1 was nested within model 2, it is possible to use a chi-square difference test to evaluate the relative fit of the two models. In this case, $\Delta\chi^2(6) = 75.4$, $p < .001$, indicating that the second model does a significantly better job of fitting the data than the first model. Moreover, for model 2, RMSEA = .06, which is below the level of .08 considered to indicate a good fit (Chen et al., 2008).

Hypothesis 3: Approach to Learning Mediates the Relationship between Executive Function and Emergent Literacy Skills

Hypothesis three was tested with two parallel path models, each representing one set of time points. As noted above, mediation is evident when the relationship between EF skills and Emergent Literacy skills is reduced by the inclusion of a potential mediator (in this case, Approach to Learning), as tested by the equation $AB \neq 0$, where A is the path coefficient between a measure of EF and Approach to Learning, and B is the path coefficient between the Approach to Learning and emergent literacy. In the first path model, illustrated in Figure 4, we tested whether Approach to Learning at the spring of pre-Kindergarten served as a mediator between EF skills at the Fall of pre-Kindergarten and Emergent Literacy skills at the spring of Kindergarten. In the second path model, we tested this same hypothesis, but progressed to the subsequent time period for all variables.

In the Fall of pre-Kindergarten, attention control was the only EF measure to significantly predict growth in Approach to Learning at the Spring of pre-Kindergarten ($\beta_A = .21$, $p < .01$). Approach to Learning is a significant predictor of growth in Emergent Literacy skills between the Fall of pre-Kindergarten and the Spring of Kindergarten ($\beta_B = .22$, $p < .01$). The chi-square for this model = 2.38 (2 df), p = .304, suggests that the data do not differ significantly from our predicted model. The RMSEA = .034. Thus this model is considered to be a good fit for the data. Thus support for the hypothesis that Approach to Learning mediates the relationship between EF skills and Emergent Literacy is supported only in the case of the EF skill of attention control (DCCS).

Across the subsequent time periods, there was no support for the mediation hypothesis. None of the measures of of executive function predicted growth in approach to learning. Therefore, even though Approach to Learning did predict Emergent Literacy Skills ($\beta = .17$, $p < .05$), there is insufficient evidence to meet the criteria for mediation.

Discussion

Results support the hypothesis that specific dimensions of executive functioning uniquely predict growth in Emergent Literacy skills from pre-Kindergarten through first grade, and that, in a more novel finding, Emergent Literacy skills predict growth in Executive Function skills even more strongly over this same period. There was only weak support for the hypothesis that the relation between EF skills and Emergent Literacy is mediated by a child's Approach to Learning. What is the broader importance of each of these findings? How do they each speak to our understanding of theory? What implications do these findings have for researchers? How do these results increase our understanding of how children develop into successful readers, as well as how they develop into individuals able to harness the Executive Function skills necessary for academic success and other positive outcomes?

Executive Function and Growth in Emergent Literacy

Prior research has supported the connection between Executive Function skills and Emergent Literacy (Altemeier et al, 2008; Blair & Razza, 2007; Bull et al., 2008; Welsh et al, in press). This study furthered that understanding by looking at a unique combination of the role of domain-specific components of EF, in a low-SES population, across the longer time period of pre-Kindergarten through first grade. The findings extended prior work by demonstrating that all three EF skills predicted growth in Emergent Literacy at various time points.

The question arises, however, as to why different EF skills predict Emergent Literacy skills at different time points. For example, the measure of working memory (Backward Word Span) does not predict Emergent Literacy skills across the pre-

Kindergarten year. However, it ascends to become the strongest predictor out of all the EF skills across both the Kindergarten and the first-grade year. Conversely, the measure of inhibitory control (Pencil Tapping) is the strongest predictor of Emergent Literacy skills across the pre-Kindergarten year, but becomes a non-significant predictor in predicting from Kindergarten to first grade.

It is no surprise that EF skills emerge at different times and develop at different rates, although there is disagreement regarding the sequential order of emergence and the timing of the development of EF skills (Jurado & Rosselli, 2007; Welsh et al., 1991). It is generally agreed that the preschool and early elementary years are a time of rapid EF development. We might expect to see some correspondence between the rise of EF skills and their relationship to the development of Emergent Literacy, as skills that have yet to arise to any great degree could hardly be expected to strongly influence the development of other constructs. This explanation fits with the present data in the case of Inhibitory Control, believed by Jurado & Rosselli (2007) to be the first EF skill to emerge. As mentioned above, the measure of inhibitory control (Pencil Tapping) is the strongest predictor of Emergent Literacy across the preschool year. It then decreases as a predictor across the Kindergarten year, and is no longer a significant predictor across the first grade year.

Another possibility is that our measures of Executive Function are not doing an ideal job of capturing children's true levels of working memory, inhibitory control, and attention control. Referring to Figure 1, there is a clear floor effect for working memory at the first time point – the task which did the worst as a predictor across the pre-Kindergarten year. Inhibitory control, as captured by Pencil Tapping, suffered a ceiling effect at the last time point measured, and was an insignificant predictor at that time point. A strong case could be made that the floor and ceiling effects of these measures prevent us from accurately capturing the relationship between these EF skills and Emergent Literacy.

Future research could clarify these issues by working towards a consensus regarding the patterns of developmental change in the domain-specific EF skills, and their role as predictors of Emergent Literacy skills. Are we capturing legitimate patterns in the data which deserve further examination and explanation, that is, various EF skills rising and falling in their strength as predictors of Emergent Literacy? If so, what mechanisms might account for the varying relationships between specific EF skills and Emergent Literacy? How, for example, might the changing requirements of Emergent Literacy tasks influence this relationship? Finally, are the various strengths of specific EF skills as predictors at different time points impacted by our current measurement techniques?

Emergent Literacy and Growth in Executive Function

This finding is perhaps the most intriguing because I could not locate any other empirical studies testing the same effect. Moreover, the finding is stronger than anticipated. EF skills predicted growth in emergent literacy with β-weights ranging from .09 to .28 across the pre-Kindergarten and Kindergarten years, with only 5 of 9 of these pathways reaching statistical significance. In contrast, emergent literacy predicted growth in EF more strongly (β-weights ranging from .20 to .36) and more consistently, with all of 6 potential pathways reaching statistical significance. Several lines of reasoning – including some specific to children from low SES homes, as were our participants - converge to support a linkage between comprehension skills and decoding skills and the development of Executive Function.

Researchers have investigated the role of SES in the development of comprehension-focused oral language skills and executive functioning (Noble et al., 2007). Reasoning that children from low SES homes are subject to a higher number of environmental risk factors than their counterparts from middle income homes, researchers hypothesized that such children might show deficits in brain systems subject to extended postnatal development. The specific areas they identified as at risk were those responsible for the development of language and of executive functioning. Results supported their hypotheses that these children would suffer delays in the areas of language and executive functioning. Children from low SES homes, in comparison to children from middle income homes, performed a full standard deviation lower on language skills, and a half a standard deviation lower on executive functioning. Researchers then conducted a follow-up study with first-grade students from a more representative range of SES, and found that language abilities mediated the relationship between SES and measures of attention control and inhibitory control. These studies support the idea that language is a driving force - perhaps even the driving force - behind the finding that Emergent Literacy predicts growth in Executive Function, but *how* Emergent Literacy (and its language component) acts on EF remains unanswered.

From a very different line of inquiry into the connection between language and executive function, Ardila (2008) conceptualizes the existence of two different types of Executive Function: metacognitive and emotional/motivational. Metacognitive EF, he argues, are the skills necessary for successful completion of higher-order capabilities such as goal-directed planning and problem solving. Metacognitive EF specifically includes working memory. Emotional/motivational EF might be seen as operating on a "lower" level, focusing on utilizing cognitive resources in service of obtaining our personal desires, often within a social milieu that imposes restrictions on what is considered appropriate behavior. Emotional/motivational EF includes inhibitory control. Metacognitive EF is evident only in humans, while emotional/motivational EF has been observed in primates. Why would only humans demonstrate Metacognitive EF? Ardila theorizes that it was the uniquely human development of oral language that allowed them to plan and execute goal-directed activities. Further, oral language allows for the transmission of knowledge across generations, further supporting ways of thinking about situations that would allow for greater success in the overarching purposes of EF such as problem solving and the setting and achieving of goals. Ardila's work reinforces the view that, as shown in our data, there is a connection between the development of oral language and the subsequent development of EF skills. However, two issues make it challenging to link Ardila's work to our findings. First, it is difficult to take Ardila's broad perspective – thinking about the development of oral language and EF across millennia – and apply it to the development of these same skills across the extremely brief period of a childhood. Second, our data showed Emergent Literacy predicting both metacognitive EF (working memory) and emotional/motivational EF (inhibitory control). While he does not argue against oral language aiding in the further development of emotional/motivational EF, our data do not reflect a clear distinction wherein Emergent Literacy is only predictive of metacognitive EF. Again, we are left with reasons to think that the finding of Emergent Literacy as a predictor of EF is at least partly driven by oral language, but the mechanisms by which this might be achieved remain unclear.

Another possibility is that emergent literacy activities involving the mastery and practice of decoding skills provide opportunities to reinforce and enhance executive function skills. For example, keeping track of the sequence of sounds in a spoken word requires focused attention and working memory; as do the processes of reading and writing using phonetic decoding skills. Future research could focus on clarifying whether the comprehension or decoding aspects of emergent literacy -- or both -- contribute to growth in EF skills.

Approach to Learning Mediates the Relationship between Executive Function and Emergent Literacy Skills

Research findings and teacher reports have highlighted specific behaviors as interfering with children's ability to engage in the learning process (Farkas, 2000; McClelland et al, 2007). Among the problematic behaviors reported were inabilities to sit still, follow directions, and pay attention. These problematic behaviors map quite readily onto the EF skills of inhibitory control and attention control. The final EF skill of working memory would also be implicated, as it would allow the child to recall the directions to be followed. I expected that the better developed a child's EF skills, the better the child would be able to engage in the learning opportunities presented (as measured by Approach to Learning), and the greater the resulting growth in Emergent Literacy skills. However, this hypothesis received only weak, partial support. Approach to Learning mediated the relationship between attention control and growth in Emergent Literacy across the prekindergarten year, but Approach to Learning did not mediate the relationship between any of the other EF skills and emergent literacy across the pre-Kindergarten year, nor did it mediate the relationship between any of the EF skills (including attention control) and emergent literacy across the Kindergarten year.

A possible explanation for this finding is a lack of generalization from the laboratory measure we used for Approach to Learning and the child's behavior in the classroom. This measure consisted of an observer rating a child's learning-oriented behaviors after administering a 30-45 minute battery of tests. However, these tests were administered in a one-to-one, adult-to-child ratio. There were no peers to interrupt or divert attention from the tasks at hand. These conditions are quite different from conditions in a traditional classroom. This hypothesis should be further explored with an in-class rating of the child's Approach to Learning, whether by independent observers or teacher report.

To conclude, this current work reinforces prior research indicating the influence of Executive Function on the development of Emergent Literacy, extending the findings previously available on low-SES preschool participants by documenting the unique predictive role of three distinct dimensions of EF and extending analyses across three school years. It raises important questions as to whether the developmentally-varying predictive strength of specific EF skills are robust patterns indicating something important about developmental changes in the importance of different EF skills, whether they are remnants of limited measurement tools, or some combination thereof. Further, this work brings to the fore the finding emergent literacy is a stronger predictor of growth in Executive Function skills, although this finding has not been previously explicitly investigated. Either oral language comprehension skills or decoding skills could be driving this finding, but multiple questions remain. What is the mechanism by which emergent literacy is impacting the development of Executive Function skills? Is that mechanism the same for each of the domain-specific EF skills, or does it differ by skill or even across development? Finally, what is the mechanism by which these Executive Function skills are translated into Emergent Literacy outcomes? The mediation argument may have fallen short due to using a lab-based measure of approach to learning that failed to sufficiently generalize to the classroom environment.

Clarifying the associations among executive functioning, approach to learning and emergent literacy could play an important role in understanding developmental patterns of early school achievement, particularly among low-SES children. Despite efforts to assist young students with reading difficulties, from 65% to 75% of them will continue to struggle with reading throughout the remainder of their schooling (Scarborough, 2001). The persistence of reading difficulties emphasizes the need to expand the scope of our understanding beyond just improving students' literacy related content knowledge and skills. It is important to explore what and how additional developmental processes may contribute to early school achievement.

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APPENDIX

TABLES AND FIGURES

Table 1
Descriptive statistics for measures of executive functioning, approaches to learning and emergent literacy

	N	Min	Max	Mean	SD	Skewness
Pre-K Fall						
1. Backward Word Span	161	0.00	2.00	0.18	0.50	2.79
2. Dimensional Change Card Sort	159	0.00	6.00	3.21	2.71	-0.15
3. Pencil Tapping	151	0.00	17.00	9.06	6.02	-0.31
4. Approach to Learning	161	1.50	4.00	3.35	0.48	-1.00
5. Emergent Literacy	161	-1.38	2.24	0.00	0.71	0.61
Pre-K Spring						
6. Backward Word Span	157	0.00	2.00	0.46	0.64	1.07
7. Dimensional Change Card Sort	158	0.00	6.00	3.78	2.68	-0.55
8. Pencil Tapping	151	0.00	17.00	12.50	5.22	-1.33
9. Approach to Learning	158	1.50	4.00	3.38	0.49	-1.26
10. Emergent Literacy	158	-1.85	1.72	0.00	0.77	0.11
Kindergarten						
11. Backward Word Span	157	0.00	2.00	0.97	0.66	0.04
12. Dimensional Change Card Sort	157	0.00	6.00	5.38	1.47	-2.63
13. Pencil Tapping	145	0.00	16.00	14.45	2.64	-3.09
14. Approach to Learning	157	1.54	4.00	3.56	0.38	-1.69
15. Emergent Literacy	157	-1.53	2.51	-0.02	0.75	0.51
First Grade						
16. Approach to Learning	156	1.54	4.00	3.59	0.43	-2.00
17. Emergent Literacy	156	-1.99	2.27	-0.01	0.82	0.06

Table 2

Intercorrelations among measures of executive functioning, approaches to learning and emergent literacy

	1	2	3	4	5		6	7	8	9	10		11	12	13	14	15		16	17
Pre-K Fall																				
1 BWS	1.00																			
2 DCCS	.24	1.00																		
3 PT	.34	.23	1.00																	
4 AL	.21	.25	.40	1.00																
5 EL	.47	.44	.50	.40	1.00															
Pre-K Spring																				
6 BWS	.42	.24	.36	.18	.48		1.00													
7 DCCS	.17	.44	.31	.19	.36		.32	1.00												
8 PT	.26	.37	.51	.33	.45		.33	.34	1.00											
9 AL	.29	.34	.31	.50	.39		.36	.20	.46	1.00										
10 EL	.40	.43	.46	.31	.62		.48	.39	.48	.49	1.00									
Kindergarten																				
11 BWS	.20	.32	.28	.14	.34		.25	.21	.41	.28	.40		1.00							
12 DCCS	.03	.24	.15	.10	.20		.07	.19	.14	.12	.25		.16	1.00						
13 PT	.14	.25	.17	.16	.27		.25	.33	.30	.36	.40		.18	.11	1.00					
14 AL	.05	.29	.15	.26	.19		.07	.04	.20	.37	.26		.07	.03	.31	1.00				
15 EL	.24	.31	.27	.22	.44		.48	.34	.38	.39	.51		.26	.11	.38	.26	1.00			
First Grade																				
16 AL	.05	.19	.08	.17	.19		.16	.06	.13	.36	.16		.03	-.02	.27	.34	.23		1.00	
17 EL	.14	.25	.20	.15	.40		.43	.36	.37	.40	.48		.35	.15	.34	.25	.71		.35	1.00

Executive Function: Backward Word Span (BWS), Dimensional Change Card Sort (DCCS), Pencil Tapping (PT); Approach to Learning (AL); Emergent Literacy (EL)

For r >.16, p = < .05; For r > .21, p < .01

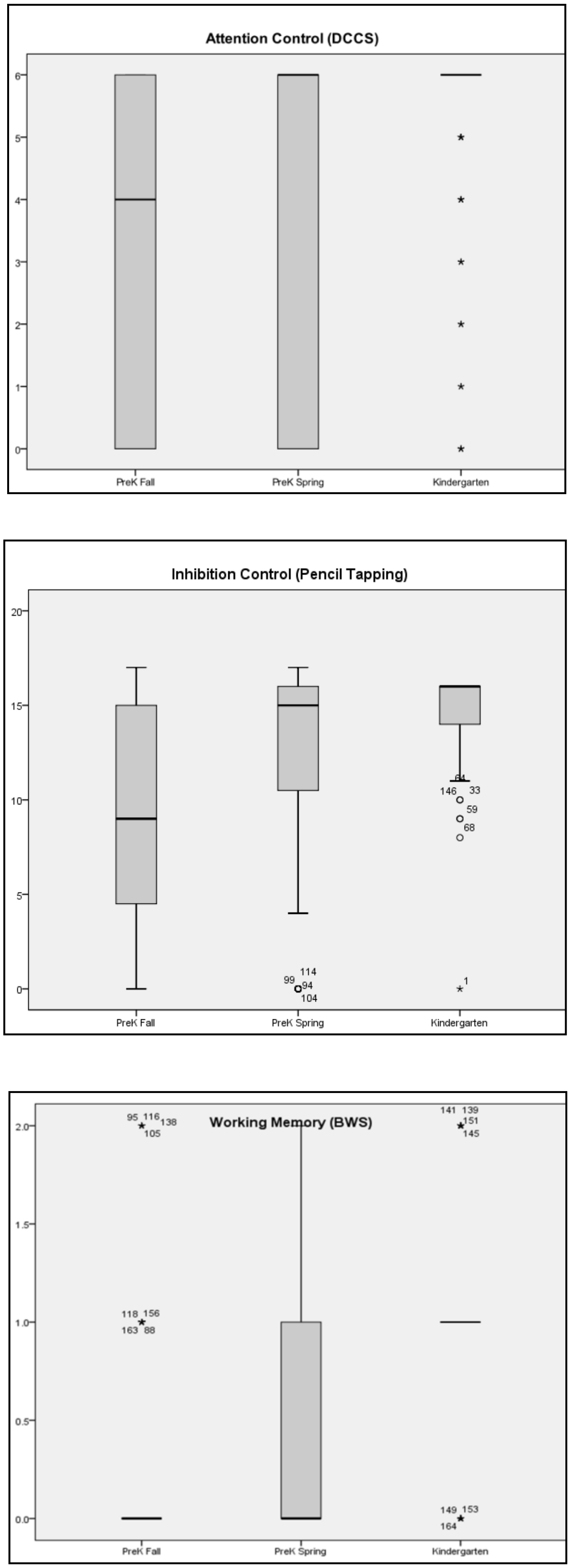

Figure 1. Box Plots for Each EF Measure

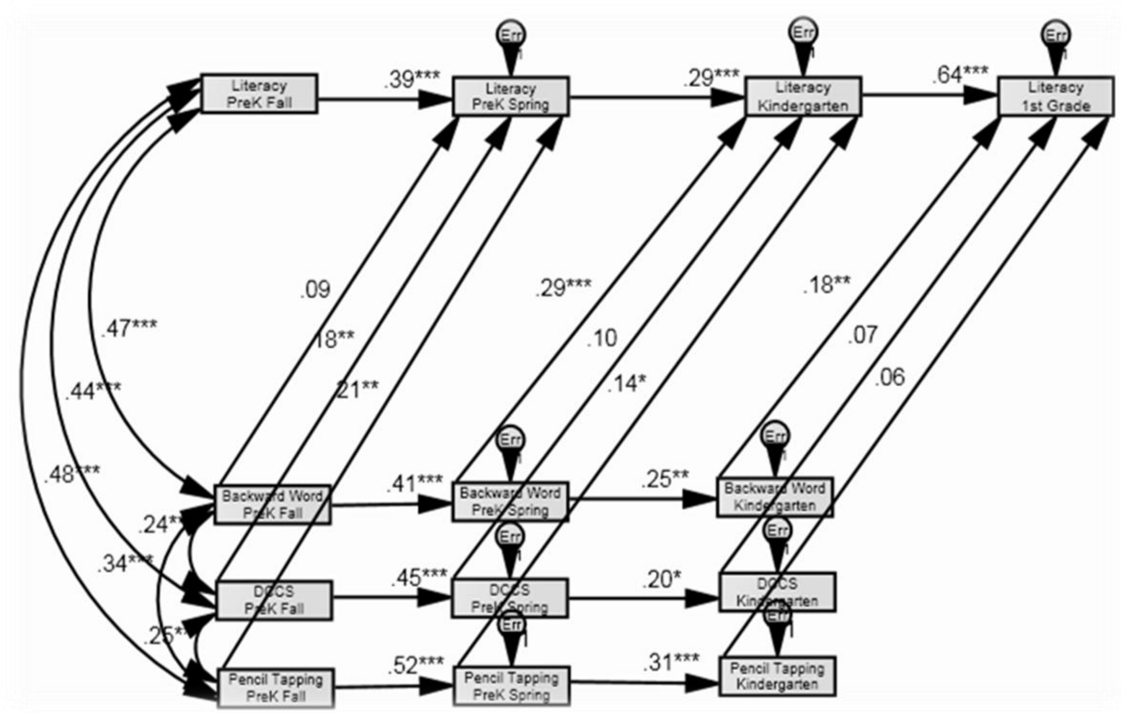

Figure 2. Executive Function Predicts Growth in Emergent Literacy

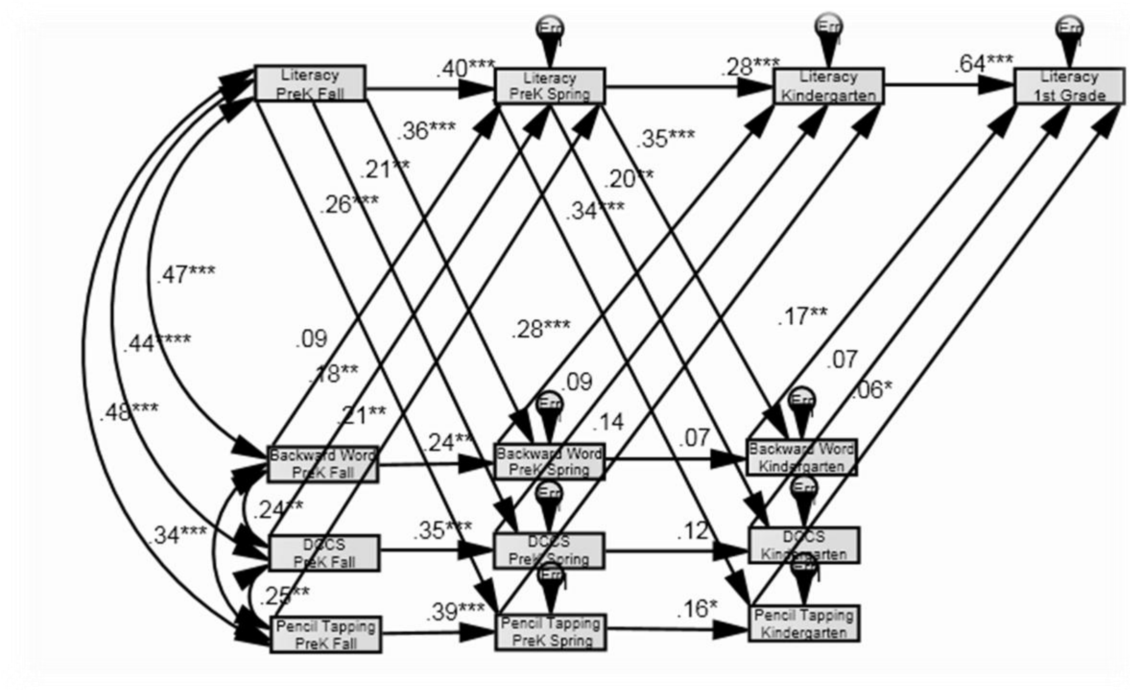

Figure 3. Emergent Literacy Predicts Growth in Executive Function

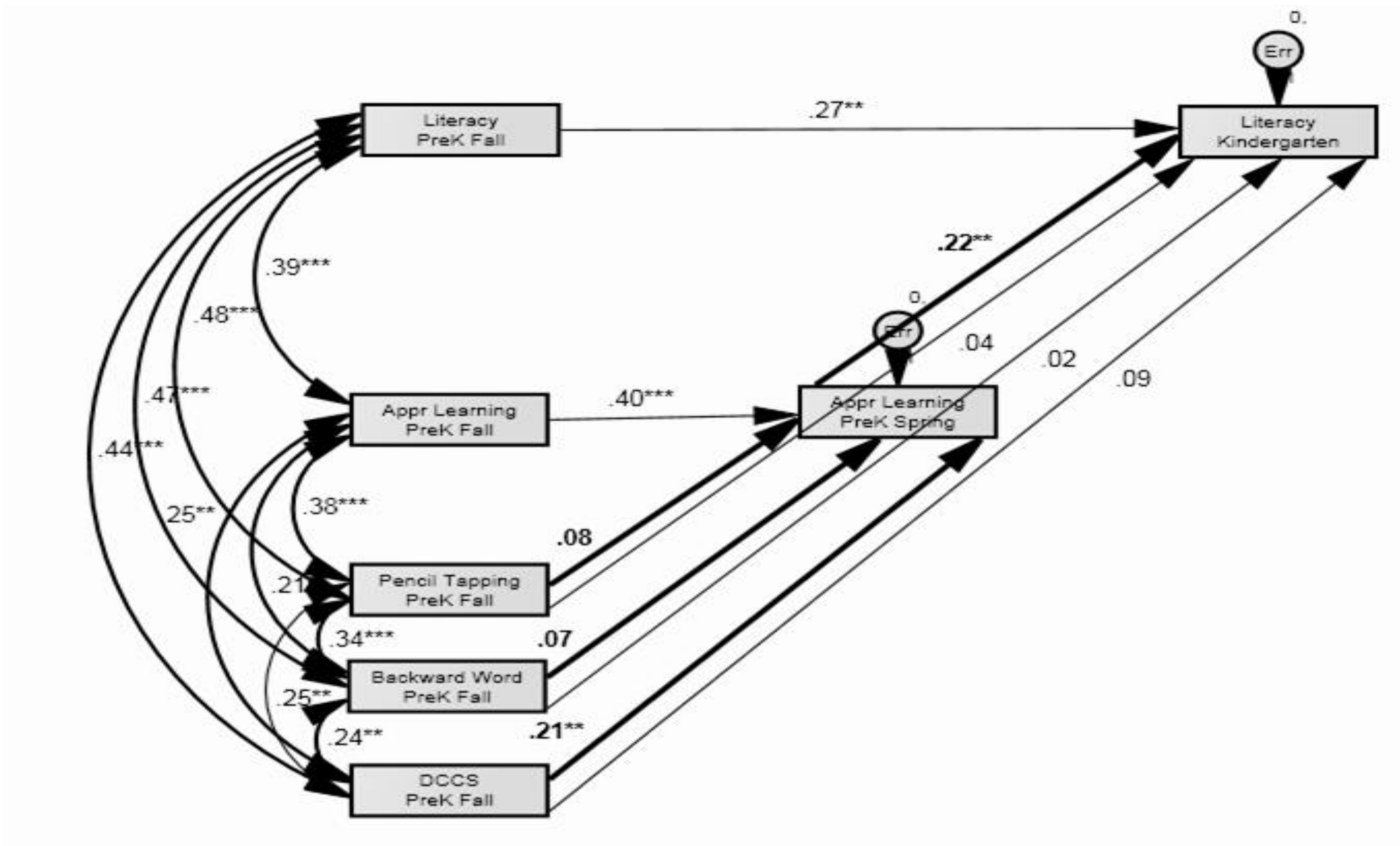

Figure 4. Approach to Learning Mediates Relationship between Executive Function Skills and Emergent Literacy Skills