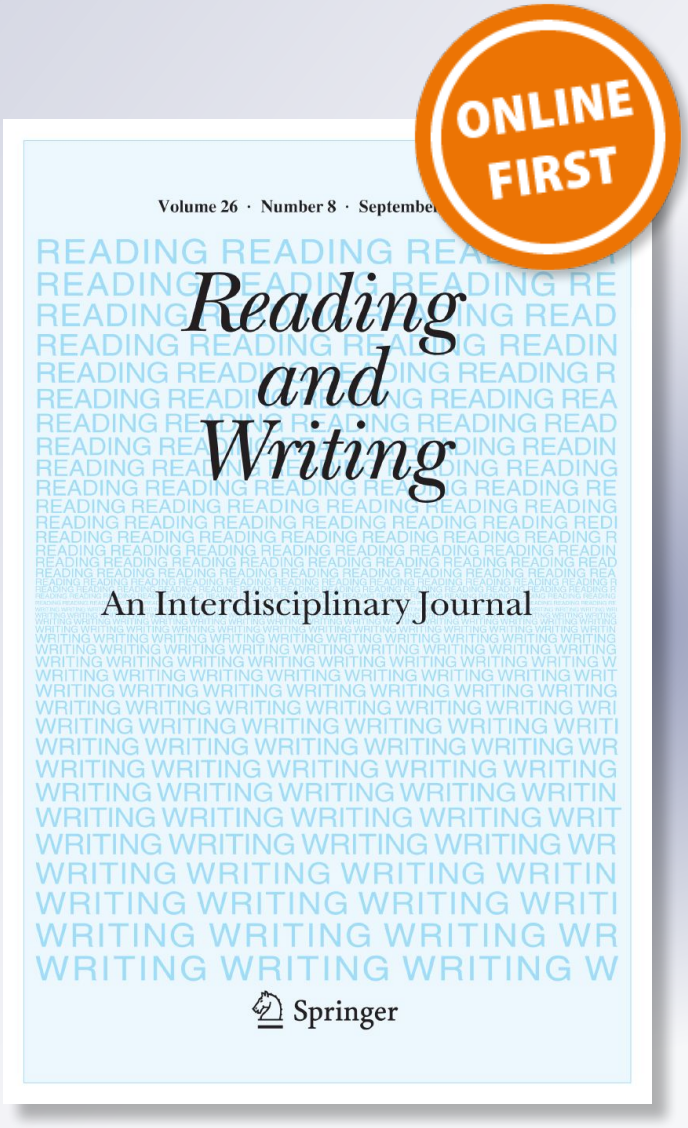
The relationship of teacher ratings of executive functions to emergent literacy in Head Start

Stephen R. Hooper, Lara-Jeane C. Costa, Melissa B. Green, Stephanie R. Catlett, Alexandra Barker, Edmund Fernandez, et al.

Reading and Writing
An Interdisciplinary Journal

ISSN 0922-4777

Read Writ
DOI 10.1007/s11145-019-09992-1



Springer

Reading and Writing
https://doi.org/10.1007/s11145-019-09992-1

The relationship of teacher ratings of executive functions to emergent literacy in Head Start

Stephen R. Hooper, et al. ***[full author details at the end of the article]***

Abstract
The purpose of this study was to investigate the concurrent relationships between selected teacher-rated executive function (EF) and a comprehensive array of emergent literacy skills in preschool children after adjusting for targeted covariates including at-risk status. The sample comprised 114 three-year-olds who were attending Head Start preschool. The teacher-completed Behavior Rating Inventory of Executive Function-Preschool was used to generate three predictor variables: Inhibitory Self-Control, Flexibility, and Emergent Metacognition. The emergent literacy outcomes included the Teacher Ratings of Oral Language and Literacy Reading, Writing, and Language scales, Stanford Binet Intelligence Scale 5 Vocabulary Subtest, Test of Early Reading-3 Convention Subtest, and Print Knowledge and Phonological Awareness subtests from the Test of Preschool Early Literacy. Findings revealed that after controlling for selected covariates (age, gender, classroom) and at-risk status, when the three EF indices were included in the model the amount of variance significantly increased for all of the emergent literacy outcomes, with the total variance accounted for ranging from 32% (Phonological Awareness) to 59% (pre-Writing). Emergent Metacognition was a significant predictor for nearly every outcome except Phonological Awareness and Reading Conventions; Flexibility and Inhibitory Self-Control were significant predictors of Language. Significant interactions were present for at-risk status and teacher ratings of both Flexibility and Inhibitory on TERA-3 Conventions, but these findings appeared to be affected more by the not at-risk group than the at-risk group. Results reinforce the potential added importance of teacher ratings of EF, particularly with respect to the integrity of early developing EF, in the prediction of emergent literacy skills in young preschool children.

Keywords Emergent literacy · Executive functions · Teacher ratings · Preschool · Head Start

Published online: 16 November 2019

Introduction

Emergent literacy refers to the early skills necessary for the development of later reading and writing. The concept of emergent literacy usually is applied to children prior to their enrollment into kindergarten, and it has been extended downward to include one- and two-year old children (Teale & Sulzby, 1986), but it is important to note that it also has been used to describe the early literacy skills of children once they enter kindergarten (Freeman & Hatch, 1989). For this study, we will use this term to refer to preschool children prior to their entry into kindergarten. Further, there are components to emergent literacy that represent early precursors to the later development of formal reading and writing such as print knowledge, vocabulary, letter knowledge (i.e., names shapes, and sounds), and phonological awareness. To be clear, emergent literacy does not refer to formal reading and writing skills, as by far the majority of three-year-old and four-year-old children have not learned to read and write like their school-age peers, but rather to the foundational skills important to later reading and writing.

Preschool children who experience difficulties in emergent literacy are likely to be at increased risk for having poor school readiness skills (i.e., language and literacy, cognition and general knowledge, approaches to learning, physical well-being and motor development, and social-emotional development; Head Start, 2019), and subsequently entering elementary school without an adequate early literacy foundation (Lonigan, Burgess, & Anthony, 2000). Recognizing these early needs becomes critical for later learning and associated school success. With respect to early identification, it is important to note that many of the components of emergent literacy are highly dependent on cognitive development (Welsh, Nix, Blair, Bierman, & Nelson, 2010), including the development of executive functioning skills (Blair, 2002; Horowitz-Kraus, Schmitz, Hutton, & Schumacher, 2017).

Executive functions

Executive Function (EF) is a multidimensional construct that refers to the higher-level cognitive processes needed for goal-directed control of thoughts, behaviors, and emotions. The construct typically includes working memory, inhibition, cognitive flexibility, set-shifting, planning and problem solving, attention regulation, and emotional control (Bailey, Barnes, Park, Sokolovic, & Jones, 2018; Best & Miller, 2010; Escobar et al., 2018; Garon, Bryson, & Smith, 2008; Lonigan, Allan & Phillips, 2017; Miyake et al., 2000; Purpura, Schmitt, & Ganley, 2017). The emergence of the multiple components of EF has been associated with the development of the prefrontal cortex and its interactions with a variety of other brain regions (Best & Miller, 2010; Garon et al., 2008), with the development of EF beginning during infancy and continuing into young adulthood. This development manifests as a sequential unfolding of EF that will have a differential effect on learning and behavior over time (Anderson, 2002; Best & Miller, 2010).

For preschool children, there has been some debate over the number of EF components that exist, with some investigators citing a one factor model (Allan &

Lonigan, 2011; Wiebe et al., 2011; Willoughby, Blair, Wirth, & Greenberg, 2010) and other groups suggesting multiple dimensions (Garon et al., 2008). Regardless of the number of EF components, preschool studies to date have demonstrated a significant relationship between delayed and impaired early EF and emergent literacy skills in preschool children (McClelland et al., 2007; Poinitz, McClelland, Matthews, & Morrison, 2009), with this predictive relationship extending into the early elementary school years (Bull, Espy, & Wiebe, 2008; Willoughby, Wylie, & Little, 2019).

The relationship of executive functions to early learning

With respect to the relationship between early EF abilities and emergent literacy, a variety of concurrent and longitudinal studies have been conducted to date. With respect to concurrent studies, McClelland et al. (2007), Poinitz et al. (2009) examined the relationships between behavioral regulation (i.e., Head-Toes-Knees-Shoulders Task)—a task assessing attention, working memory, and inhibitory control—and emergent literacy in 310 four-year-old children. They found that their behavioral regulation task successfully predicted letter-word identification and early vocabulary skills, with the magnitude of these relationships being in the small to moderate range. Miller, Giesbrecht, Müller, McInerney, and Kerns (2013) examined the relationship between working memory, inhibitory control, and school readiness in their sample of 129 three- to five-year-old preschool children. They found that the children with strong working memory were at an advantage in learning early letter identification skills while in preschool. Further, they reported that inhibitory control did not contribute to letter identification in an independent manner. Constructing a battery of EF tasks, defined by both hot (i.e., affective) and cool (i.e., cognitive) types of EF tasks, Allan and Lonigan (2011) examined how these functions related to emergent literacy skills in 234 three- to five-year-old preschoolers. They found that both a one and two factor model of EF were significantly related to the emergent literacy skills of phonological awareness, print knowledge, and vocabulary, with the magnitude of the correlations ranging from small (vocabulary) to medium (phonological awareness and print knowledge) across both EF models. Willoughby, Kupersmidt, and Voegler-Lee (2012) provided a concurrent examination of EF and emergent literacy skills in nearly 800 four-year-old preschool children. Using the Preschool Self-Regulation Assessment (Smith-Donald, Raver, Hayes, & Richardson, 2007), a collection of direct assessments of EF, and measures of letter-word identification and sound awareness from the Woodcock-Johnson III Tests of Achievement, they found that the measures of inhibitory control were significantly associated with the early literacy tasks, with the magnitude of these relationships varying from small to medium after controlling for targeted covariates. From the current studies, it appears that EF has been linked to letter/word identification, vocabulary, phonological awareness, and print knowledge, with some sense that both working memory and inhibitory control have predictive value for emergent literacy skills.

In addition to the concurrent measurement studies, several studies have employed longitudinal methodology to examine the relationships between early EF and later

literacy skills. Using a large sample of preschool children, ages four to 5 years, Lonigan et al. (2017) found that teacher ratings of attention (i.e., attention behavior regulation) and the Head-Toes-Knees-Shoulders Task (i.e., inhibitory control and working memory) were significantly related to baseline emergent literacy skills, but growth in emergent literacy skills was predicted only by teacher ratings of inattention. This was somewhat in contrast to the concurrent findings by Miller et al. (2013) noted above where inhibitory control was not related to emergent literacy skills. Blair and Razza (2007) used both direct measures of EF in preschool and kindergarten, along with preschool teacher ratings of effortful control (Children's Behavior Questionnaire composite of Inhibitory Control, Attention, Approach, and Anger subscales) and examined their relationships with early reading readiness (i.e., phonemic awareness and letter knowledge) in a sample of 141 three to five year old children from low-income settings. They found that preschoolers' inhibitory control was distinctively related to later phonemic awareness and letter knowledge in kindergarten. These investigators also speculated that this component of EF may be an important ingredient for the development of automaticity in these early reading skills. Other studies have documented similar relationships between EF and emergent literacy. Willoughby et al. (2017), in a large sample of preschool children representing low socioeconomic status from the Family Life Project (n = 1121), demonstrated that children who showed a slowed rate of growth in EF across three to five years of age experienced poorer academic readiness in kindergarten. Specifically, moderate to large effect sizes were exhibited for several different academic outcomes in kindergarten including letter-word identification, picture vocabulary, and teacher ratings of basic academic skills. Not only did this study demonstrate the utility of early EF in predicting later early literacy skills, but it advocated for the use of routine measurement of EF as a strategy for early identification of later learning problems upon entry into kindergarten. These longitudinal studies showed the benefits of obtaining estimates of EF functions with respect to school readiness skills upon entry into kindergarten.

Longitudinal studies also have shown that EF are significant predictors of reading skills not only in preschool and kindergarten, but in the early elementary grades as well (Bull et al., 2008; Espy et al., 2004; Nesbitt, Farran, & Fuhs, 2015; Skibbe, Montroy, Bowles, & Morrison, 2019). For example, Bull et al. (2008) found that preschool children with strong EF skills had an advantage in school readiness, including reading, that was maintained throughout the first three years of elementary school. More recently, Skibbe et al. (2019) reported that the presence of intact behavioral self-regulation in early childhood related significantly to earlier development of both reading decoding and reading comprehension skills. Reading skill levels also remained higher through the second grade. These studies reinforce the importance of obtaining assessment of EF during the preschool years as one indicator of school readiness and later performance during elementary school.

Taken together, these concurrent and longitudinal studies provide evidence of the importance of various EFs to emergent literacy skills during preschool as well as to school readiness upon entrance into kindergarten and later school success in the early elementary years. Two meta-analyses of this literature also have documented

these relationships between EF and early literacy, with small to moderate associations being noted across studies (Allan, Hume, Allan, Farrington, & Lonigan, 2014; Jacob & Parkinson, 2015). Specifically, the EFs of working memory, inhibitory control, and self-regulation were significant predictors of these literacy-related functions.

These studies primarily demonstrate the importance of direct assessment of EF as one potential predictor of emergent literacy capabilities in the preschool population, but the use of teacher ratings has not been emphasized; and, in the few instances where teacher ratings were used, they reportedly did not perform as well as direct assessments of EF (Allan et al., 2014) or were not related to direct assessments of EF (Toplak, West, & Stanovich, 2013). In contrast, Lonigan et al. (2017) found that their preschool teacher ratings of inattention and related components of EF were not only important in identifying children at-risk for problems in emergent literacy, but that they were the only EF measure that was related to the change of emergent literacy skills over time. Additionally, Blair and Razza (2007) found that their use of a composite score from the Children's Behavior Questionnaire completed by teachers during preschool proved useful in predicting kindergarten early literacy functions. Lonigan et al. (2017) noted that using teacher ratings may be especially important to determining those who may be at-risk for later academic difficulties. Further, the use of well standardized and normed teacher ratings of EF would provide an efficient, non-intrusive strategy for obtaining estimates of EF in this sometimes difficult-to-test young population. The use of teacher ratings has the benefits of a cost-effective strategy for collecting reliable information on EF in a population of children that may present challenges for direct assessments of EF and other types of cognitive functions (e.g., short attention span, limited language, behavioral stamina). This study will address this gap in the literature by using a comprehensive teacher rating of EF to examine the relationships of targeted EFs and emergent literacy in three-year-old children from low socioeconomic backgrounds.

Current study

The primary purpose of this study was to investigate the concurrent relationships between selected EFs, as defined by teacher ratings of Inhibitory Self-Control, Flexibility, and Emergent Metacognition, and a comprehensive array of emergent literacy skills, as defined by measures assessing phonological awareness, reading conventions, print knowledge, language, and vocabulary in three-year old preschool children being served in a Head Start setting. The emergent literacy measures also included assessments of pre-reading and, importantly the often-neglected pre-writing skills. The primary research question addressed whether teacher ratings of EF significantly contributed to the prediction of emergent literacy skills for preschool children after adjusting for key sociodemographic covariates and at-risk status. Based largely on the literature using direct assessments of EF with preschool children to date, it was hypothesized that Inhibition/Self-Control and Emergent Metacognition would be significant contributors to print knowledge, phonological awareness, and pre-reading and pre-writing skills after adjusting for emergent literacy

risk status and targeted sociodemographic covariates. Additionally, it was suspected that there would be significant interactions between at-risk status and each of the EF variables in the prediction of emergent literacy skills in this young population. With respect to the interactions, it was suspected that the at-risk group would show worse teacher ratings of EF than the not at-risk group across the emergent literacy measures.

This study differs from most of the prior studies by using a comprehensive, well-normed teacher rating scale to obtain our EF estimates, employs an array of measures reflecting various aspects of emergent literacy—including both prereading and prewriting, and focuses exclusively on a three-year old sample. Findings from this study will add to the growing literature examining how early cognitive abilities, such as EF, are associated with emergent literacy skills, and they will expand upon the relative importance of using teacher ratings with respect to identifying children at-risk for challenges in early literacy. To date, studies examining EF and emergent literacy primarily have utilized direct assessment of EF, and relatively few studies have employed teacher ratings of EF (Blair & Razza, 2007; Lonigan et al., 2017). Additionally, few studies have examined pre-writing skills as a component of emergent literacy (Puranik & Lonigan, 2011, 2014), with the bulk of the studies focusing on pre-reading skills. The current study will address these gaps in the literature.

Methods

Participants

The sample comprised 114 three-year-old children (mean = 3.82 years, SD = 0.32) enrolled at 5 Head Start preschools and in 10 classrooms located across two neighboring counties including several mid-sized urban-suburban cities in the southeast—4 preschools with 8 classrooms in one county and 1 preschool with 2 classrooms in the other. Participants were 50% male and represented 64% Black, 5% White, and 6% Multiracial. About 24% were of Hispanic ethnicity. Approximately 91% of the families enrolled in the study had incomes at or below poverty with the median household income being $9137. The primary caregivers' highest levels of education were 23% more than high school (10% college degree, 13% some college or advanced training), and 48% high school graduate, and 29% less than high school. About 40% of the children were receiving some form of special education services (e.g., Speech therapy, Occupational Therapy, Physical Therapy) with the following disabilities reported: autism, speech impairment, language impairment, orthopedic impairment, and developmental delay. Table 1 provides descriptive characteristics of the sample.

Research staff and preschool teachers recruited participants at parent orientations prior to the beginning of school as well as during the first 4 weeks of the 2017–2018 school year. All 3-year-old children who were enrolled in the preschool were eligible for the study. In general, to be admitted to a Head Start Program, children and families must meet income requirements as determined by the U.S. Federal Poverty Guidelines. Additionally, children and families can be enrolled in Head Start if the

Table 1 Child and family descriptive characteristics

Variable	Total sample (N = 114) Mean (SD) or % (n)	At-risk group (n = 70) Mean (SD) or % (n)	Not at-risk group (n = 44) Mean (SD) or % (n)
County			
Orange	82% (94)	80% (56)	86% (38)
Durham	18% (20)	20% (14)	14% (6)
Family income	$9137 (9955)	$9831 (10,130)	$8000 (9692)
Missing	19	11	8
Caregiver education			
Less than high school	29% (27)	38% (22)	14% (5)
High school or GED	48% (45)	48% (28)	49% (17)
More than high school	23% (21)	14% (8)	37% (13)
Missing	21	12	9
Race/ethnicity			
Hispanic	24% (23)	29% (17)	17% (6)
Black	64% (61)	63% (37)	67% (24)
White	5% (5)	5% (3)	6% (2)
Multiracial	6% (6)	3% (2)	11% (4)
Missing	19	11	8
Child age at study entry (in months)	45.86 (3.85)	46.59 (3.66)	44.71 (3.92)
Missing	1	1	0
Child sex			
Male	50% (57)	59% (41)	36% (16)
Missing	0	0	0
Has individual education plan[a]			
Yes	40% (38)	47% (28)	28% (10)
No	60% (57)	53% (26)	72% (26)
Missing	19	11	8

[a]Disability conditions included developmental delay (n = 10), speech/language impairment (n = 7), Autism (n = 2), orthopedic impairment (n = 1), other/not specified impairments (n = 10)

child has a documented disability regardless of family income, is a foster child, is receiving Temporary Assistance for Needy Families (TANF), or is receiving Supplemental Security Income (SSI). In accordance with Institutional Review Board requirements, legal guardians signed a consent allowing their child to be included in this project.

Measures

Participants were assessed in spaces provided by the Head Start preschools that they attended. Tasks were administered one-on-one by trained research assistants. Each measure was administered and scored according to standardized procedures as per the published test manuals. Several assessments required verbal responses by the

participants and were audio recorded for verification. Although some of the measures (e.g., TROLL) have scales labeled as "reading" and "writing," it is important to note that none of the participants were engaged in formal reading and writing at age three; but, rather, all of the measures were selected to reflect different aspects of emergent literacy and assessed purported precursors to formal reading and writing skills. All assessments were administered in English. Children who were English Language Learners or Dual Language Learners were spoken to in Spanish to build rapport and were explained the measures. Table 2 shows the means and standard deviations for each of the measures for the total sample as well as at-risk groupings. The study utilized teacher ratings for several of the measures and included the involvement of 10 different teachers representing the students from each of the 10 classrooms.

Table 2 Means and standard deviations on the predictor and outcomes measures

Variable	Total sample (N = 114) Mean (SD)	At-risk group (n = 70) Mean (SD)	Not at-risk group (n = 44) Mean (SD)
BRIEF-P			
Inhibitory self-control	52.93 (13.19)	54.41 (13.62)	50.57 (12.24)
Flexibility	50.04 (12.79)	51.90 (14.12)	47.09 (9.76)
Emergent metacognition	58.27 (13.97)	60.69 (14.30)	54.35 (12.62)
Missing	0	0	0
Stanford-Binet 5			
Vocabulary	6.99 (3.10)	6.10 (3.00)	8.36 (2.77)
Missing	2	2	0
TROLL			
Reading	23.12 (2.65)	21.52 (4.64)	25.73 (4.62)
Missing	6	3	3
Writing	9.07 (2.65)	8.53 (2.35)	10.00 (2.91)
Missing	6	2	4
Language	20.08 (6.00)	18.48 (5.54)	22.69 (5.86)
Missing	11	6	5
TERA-3			
Conventions	7.38 (1.39)	7.03 (1.28)	8.00 (1.37)
Missing	11	4	7
TOPEL			
Print knowledge	6.95 (7.25)	4.10 (3.95)	11.51 (8.88)
Missing	2	1	1
Phonological awareness	7.94 (4.89)	6.90 (4.21)	9.56 (5.45)
Missing	4	3	1

BRIEF-P scores are age-based T-scores with a mean = 50 and standard deviation = 10, higher scores reflect a more impaired performance. TERA-3 Conventions and Stanford-Binet 5 Vocabulary are age-based scaled scores with a mean = 10 and standard deviation = 3, higher scores reflect a more intact performance. The TROLL and TOPEL are presented in raw scores, higher scores reflect a more intact performance

Teacher ratings of executive functions

The *Behavior Rating Inventory of Executive Function–Preschool Version (*BRIEF-Preschool; Gioia, Espy, Isquith, 2003) is a rating scale that provides insight into EF behaviors that children aged 2–5 years regularly display based on teacher report. How the teachers responded to the 63 questions can indicate problems with various behaviors. The BRIEF-Preschool yields 5 clinical scales, 3 summary scores, and a Global Executive Composite (GEC). The clinical scales are Inhibit, Shift, Emotional Control, Working Memory, and Plan/Organize, and the summary indices are Inhibitory Self-Control Index (ability to direct actions, responses, emotions and behavior), Flexibility Index (ability to move among actions, responses, emotions and behavior), and Emergent Metacognition Index (ability to continue with ideas and activities, and create a problem-solving plan). The BRIEF-Preschool was completed for each participant by his or her teacher by January 2018 of the year. Teachers knew the child for an average of 21 weeks prior to completing the BRIEF-Preschool. Age-based T-scores were generated for all BRIEF-Preschool scales and indices; higher scores reflect more impaired performance. As reported in the test manual, Cronbach's alphas for the BRIEF-Preschool clinical scales, summary scales and GEC are very high for the teacher version (r = .90–.97). The internal structure of the BRIEF-P was examined with principal factor analysis revealing a three-factor model based on teacher data and accounted for 92% of the variance. Moderate correlations (.47–.61) were reported among the factors. For this study, and in line with the literature on EF in preschoolers (e.g., Garon et al., 2008) and EF across the life span (Best & Miller, 2010), we selected the BRIEF-P summary indices (i.e., Inhibitory Self-Control, Flexibility, Emergent Metacognition) as our primary indicators of EF. The BRIEF-P was completed by teachers for all 114 children.

Emergent literacy skills

We used four measures to assess the participants' emergent literacy skills and selected them based on their appropriateness for children aged 3–5. They are designed to capture emergent and early literacy including reading conventions, print knowledge, phonological awareness, oral language and oral vocabulary. All emergent literacy measures were administered to children throughout the fall of the school year.

The *Stanford Binet Intelligence Scales for Early Childhood—Fifth Edition* (SB-5; Roid, 2005) Abbreviated Battery examines nonverbal fluid reasoning and verbal crystallized knowledge. For this study, oral vocabulary was measured using the verbal knowledge subtest. This subtest requires children to use their verbal knowledge to identify parts of body (e.g., "Show me your mouth. Look at the picture. Point to the girl's (boy's) mouth."), identify physical objects (e.g., "Look at this toy. What is this?" correct response is duck), and define objects (e.g., Child looks at the written word and is asked, "What is a cup?" many correct responses). As reported in the manual, the internal-consistency coefficient for verbal knowledge was .88 for 3- and 4-year-olds. Criterion-related validity for preschool samples was found with a correlation of .73 between SB-5 Verbal Knowledge and the SB-5 (Roid, 2003) Verbal

Reasoning. For the SB-5, there were 112 participants who completed the Vocabulary Subtest.

The *Teacher Rating of Oral Language and Literacy* (TROLL; Dickinson McCabe, & Sprague, 2001) was completed by the participants' teachers to gain insight about the child's language and early literacy. The TROLL is a 25-item rating scale that asks questions using a Likert scale and multiple-choice questions. These items can be completed without any training and include: "Does this child recognize other names?" with response options of "No", "A couple (1 or 2)", "A few (3–5)", or "Several (6 or more);" and "How often does this child recognize his/her own first name in print?" with response options of "Never", "Rarely", "Sometimes", and "Often." The TROLL scores provide estimates of the skills related to literacy acquisition that include Reading, Writing, and Language scores. Age-adjusted raw scores are reported for each of the three scales of the TROLL, with higher scores reflecting a more intact performance. As reported in the test manual, internal consistency reliability for these subtests ranges from .77 to .92 for 3- to 5-year-olds, and data from the TROLL show moderate associations with children's scores on the *Peabody Picture Vocabulary Test* (.38–.47; Dunn & Dunn, 1997), and *Early Phonemic Awareness Profile* (.34–.47; Dickinson & Chaney, 1997). For the TROLL, there were 108 participants with teacher-completed forms.

The *Test of Early Reading Ability-Third Edition* (TERA-3; Reid, Hresko, & Hammill, 2001) examines the early development of pre-and early reading skills. For this study, we administered Subtest II: Conventions. This 21-item task assesses print conventions for emergent literacy such as book handling (e.g., Show me the two pictures that have the book right side up the way we need it to read), word orientation (e.g., Show me the writing), and capitalization (i.e., Point to the letter B and say, show me another b), as well as for early literacy such as text genre, punctuation, and spelling. Given the administration guidelines to discontinue testing when a ceiling of three consecutive incorrect responses is reached, none of the preschoolers in our sample were administered questions beyond 11 (i.e., items that assessed text genre, punctuation, spelling). Age-based scaled scores were used in the data analyses, with higher scores reflecting a more intact performance. As reported in the test manual, internal consistency coefficients ranged from .81 to .95 across ages. Moderate to high correlations were found between the TERA-3 and the *Stanford Achievement Test Series–9th edition* (Psychological Corporation, 1996) and the *Woodcock Reading Mastery-Revised NU* (Woodcock, 1998). For the TERA-3, there were 103 participants who completed the Conventions Subtest.

The *Test of Preschool Early Literacy* (TOPEL; Lonigan, Wagner, Torgesen, & Rashotte, 2007) examines emergent and early literacy in a comprehensive fashion. For this study, we administered the Print Knowledge and Phonological Awareness subtests. The Print Knowledge Subtest measures the participant's print concepts (e.g., "Which one can you read?"), letter discrimination ("Which one is I?"), letter-name identification ("What is the name of this letter?"), and letter-sound identification ("What sound does this letter make?"). The Phonological Awareness Subtest assesses word elision (e.g., say sunflower without flower) and blending (e.g., what is ca—p) abilities. Both abilities are assessed using questions that initially offer a picture response that is later removed for higher level questions;

thus, the child must provide an oral response for the higher-level questions. Each subtest is separated into item sets: Print Knowledge has three item sets with a total of 36 questions and Phonological Awareness has four item sets with a total of 27 questions. We followed administration guidelines to discontinue testing when a ceiling of three consecutive incorrect responses was reached within each set. Raw scores for our sample ranged from 0 to 34 for Print Knowledge and 0–25 for Phonological Awareness. Age-adjusted raw scores were used in the data analyses, with higher scores reflecting a more intact performance. As reported in the test manual, internal consistency reliability estimates for these subtests ranged from .86 to .96 for 3- to 5-year-olds. Concurrent validity estimates for the subtests ranged from .59 to .77. For the TOPEL, there were 112 participants who completed the Print Knowledge subtest and 110 participants who completed the Phonological Awareness Subtest.

Covariates

The study included key demographic covariates including chronological age and gender, potential confounders for detecting relationships between EF and emergent literacy (Willoughby et al., 2012). Additionally, given the clustering of children within the five centers and ten classrooms, we used fixed-effect models to control for classroom effects in all analyses (Stapleton, McNeish, & Yang, 2016). Socioeconomic status, as defined by income status, and race/ethnicity were not included in the analyses as over 90% of the sample met federal poverty criteria as per one of the major entrance requirements into Head Start programs and over 70% of the sample represented a minority grouping.

Grouping variable for emergent literacy risk status

To assess emergent literacy at-risk status, we used *The Get Ready to Read!-Revised* (GRTR-R; Whitehurst & Lonigan, 2009). The GRTR-R is an early literacy screening tool used to measure preschoolers' print knowledge and phonological awareness. It consists of 25 items which take less than 10-min to administer. In the Fall of 2017, each child was asked to respond to each question by pointing to one of four pictures presented. Questions include, "Which one is car?", "Find the letter R.", "Find the one that shows how to write two words.", and "These pictures are: bed, cow, car, snake. Find scar without *sss*." Previously reported internal consistency reliability for the GRTR-R was .88. Wilson and Lonigan (2009) suggested that the GRTR-R is better than the *Individual Growth and Development Indicators* (McConnell, 2002) as a screener of the three emergent literacy skills measured by the TOPEL, which is a comprehensive diagnostic tool. We used the age-based performance level provided in the manual for the raw scores to assign each child to one of two groups: (1) children at-risk for emergent literacy difficulties (bottom quartile for chronological age) and (2) children not at-risk.

Data analysis

To address the targeted research question, we employed hierarchical regression models to test and describe relations between teacher-rated BRIEF-Preschool T-scores and the emergent literacy measures: TROLL Reading, Writing, and Language T-scores; TERA-3 Conventions scaled score; TOPEL Print Knowledge and Phonological Awareness raw scores; and SB-5 Vocabulary scaled score. As described above, the BRIEF-Preschool teacher ratings consist of five clinical scales, three summary indices, and an overall summary score. Given the high correlations among these scales, we focused on the BRIEF Summary Index scores as predictors of each of the emergent literacy outcomes.

Targeted variables were entered into the model in steps. Step 1 contained covariates only (Classroom indicators, gender, child age at outcome assessment); Step 2 included Risk Group as well as covariates; Step 3 added BRIEF-P Summary Index scores to the covariates and Risk Group status; and Step 4 added interactions between Risk Group and BRIEF-P summary indices to the covariates, Risk Group, and BRIEF Summary Index main effect terms. This strategy allows the independent, incremental contributions of each set of variables to be statistically assessed through incremental R^2 (ΔR^2) values and their associated F-tests. Once a final model was determined, examination of the F-tests allowed the "dominant" or most important BRIEF-P Summary Index predictors within the final model to be empirically determined.

Identification of the final model was made by sequentially comparing the Step 4 model (with interaction terms) to the Step 3 model (without interaction terms); and retaining the Step 4 model as the final model if the incremental R^2 was significant. If not significant, the Step 3 model (with BRIEF summary index main effects) was compared to the Step 2 model (without BRIEF summary index main effects); retaining the Step3 model if significant. Although it did not occur in these analyses, subsequent tests would have compared the Step 2 model (with risk status) versus the Step 1 model (with only covariates). Following the principle of marginality articulated by Nelder (1994) and others (e.g., Maxwell & Delaney, 2004), we do not report parameter estimates in the final models for interaction terms when they were found to be statistically non-significant because they are likely to distort interpretation of main effects in the resulting models.

Preliminary analyses did not find any dependencies (i.e., non-significant intraclass correlations) resulting from the clustering of children within the five centers and ten classrooms, thus fixed effect models were used to control for classroom effects in all analyses (Stapleton et al., 2016). Besides controlling for classroom effects, all models also adjusted for gender and chronological age at time of assessment. Gender was covaried given the significant differences between the two groups ($p < .05$), and age was included as a covariate given the wide range (3-0 to 3-11) for inclusion in the study. To address the impact of at-risk status on the relationship between EF and emergent literacy, emergent literacy at-risk status was included as a main effect term. Effect sizes for all terms in the final models were calculated using partial eta squared.

Results

Table 2 shows the means and standard deviations for the BRIEF-P summary indices and the emergent literacy measures for the total sample and each of the groups. As can be seen, most of the standard scores were within the low average to average range for both groups. In preparation for the hierarchical regression models, all measures were correlated to determine their appropriateness for inclusion in the regression. As can be seen in Table 3, the intercorrelations for the entire sample (N = 114) expectedly ranged from small (r = −.02) to large (r = −.85), with the largest correlations expectedly occurring for variables within specific tests (e.g., BRIEF Indices, TROLL scales). The correlations for variables across measures were generally small, but ranged widely from − .02 to − .51; thus, suggesting minimal issues of collinearity. The magnitude and pattern of correlations were remarkably similar for the at-risk and not at-risk subsamples. None of the correlations were deemed high enough to eliminate any of our emergent literacy outcomes; consequently, all targeted emergent literacy variables remained in the analyses.

Using hierarchical regression analysis, variables were entered into the model in steps. As noted above, Step 1 contained covariates only (Classroom indicators, gender, child age at outcome assessment); Step 2 included at-risk status as well as covariates; Step 3 added the three BRIEF-P Summary Index scores to the covariates and at-risk status; and Step 4 added the at-risk status X BRIEF-P Summary Index interactions to the covariates, at-risk status, and BRIEF Summary Index main effect terms. This strategy allows the independent contributions of each set of variables to be statistically assessed through incremental R^2 (ΔR^2) values and their associated t-tests. Results are presented by outcome variable, with a focus on findings showing the most significant incremental gain from the main effects (Step 2 or Step 3) or any interactions (Step 4) when present.

SB-5 Vocabulary

The hierarchical regression for the oral vocabulary measure of emergent literacy, SB-5 Vocabulary, revealed that at Step 1 the covariates were significant contributors ($p < .004$) as was at-risk status at Step 2 ($p < .002$), with a significant increase in variance accounted for going from about 23 to 30%. Introducing the BRIEF-P summary indices at Step 3 significantly increased the change in R^2 by 6% to a total of about 35% of the SB-5 Vocabulary variance, $F(3, 95) = 2.67$, $p < .05$. With all variables entered in Step 3, results showed chronological age ($p < .05$), at-risk status ($p < .05$), and the BRIEF-P Summary Index of Emergent Metacognition to be significant predictors of SB-5 Vocabulary. Effect sizes for these significant predictors were small in magnitude. When the interactions between Risk Status and BRIEF-P summary indices were added to the model in Step 4, no interactions were noted.

Table 3 Pearson correlations between measures used in the hierarchical regression for total sample of preschoolers (N = 114)

Measure	BRIEF ISC	BRIEF Fl	BRIEF EM	SB5 Vocabulary	TROLL Reading	TROLL Writing	TROLL Language	TERA-3 Convention	TOPEL Print Knowledge	TOPEL Phonological Awareness
BRIEF ISC	1.0									
BRIEF Fl	.85	1.0								
BRIEF EM	.74	.72	1.0							
SB5 Vocabulary	−.06	−.14	−.12	1.0						
TROLL Reading	−.27	−.26	−.42	.50	1.0					
TROLL Writing	−.29	−.32	−.40	.19	.52	1.0				
TROLL Language	−.26	−.38	−.51	.44	.78	.61	1.0			
TERA-3 Convention	−.07	−.02	−.09	.37	.39	.19	.20	1.0		
TOPEL Print Knowledge	−.15	−.10	−.23	.12	.34	.13	.21	.42	1.0	
TOPEL Phonological Awareness	−.19	−.13	−.17	.30	.35	.21	.39	.27	.46	1.0

BRIEF ISI Behavior Rating Inventory for Executive Functions Inhibitory Self-Control Index, *BRIEF FI* Behavior Rating Inventory for Executive Functions Flexibility Index, *BRIEF EM* Behavior Rating Inventory Emergent Metacognition Index, *SB5 Vocab.* Stanford-Binet 5 Vocabulary Subtest, *TROLL* Teacher Rating of Oral Language and Literacy, *TERA-3* Test of Early Reading Ability, *TOPEL* Test of Preschool Early Literacy

TROLL

Reading

As can be seen in Table 4, Step 3 produced the most significant gains in the model. Specifically, the hierarchical regression revealed that at Step 1 the covariates contributed significantly to TROLL Reading ($p < .0002$) as did at-risk status at Step 2 ($p < .0001$), with a significant increase in variance accounted for from about 30 to 41%. Introducing the BRIEF-P summary indices at Step 3 significantly increased the change in R^2 by 14% to a total of about 55% of the TROLL Reading variance, $F(3, 91) = 9.54$, $p < .0001$. With all variables entered into the model in Step 3, results showed chronological age ($p < .05$), at-risk status ($p < .05$), and BRIEF-P Emergent Metacognition ($p < .001$) to be significant predictors of TROLL Reading. Effect sizes for these significant predictors were small to medium in magnitude. When the interactions between at-risk status and BRIEF-P summary indices were added to the model in Step 4, no interactions were noted.

Writing

The hierarchical regression revealed that at Step 1 the covariates contributed significantly to TROLL Writing ($p < .0001$) as did at-risk status at Step 2 ($p < .009$), with the variance accounted for moving from about 46 to 50%. Introducing the BRIEF-P summary indices at Step 3 significantly increased the R^2 by 10% to a total of about 59% of the TROLL Reading variance, $F(3, 91) = 7.35$, $p < .0002$. With all of the variables entered into the model in Step 3, results showed the covariates of male gender ($p < .001$) and chronological age ($p < .01$), and the main effects of at-risk status ($p < .05$) and BRIEF-P Emergent Metacognition ($p < .001$) to be significant predictors of TROLL Writing. Effect sizes for these significant predictors were small to medium in magnitude. When the interactions between at-risk status and BRIEF-P summary indices were added to the model in Step 4, no interactions were noted.

Language

As with the other two TROLL subscales, Table 4 shows that the model in Step 3 produced the most significant predictive gains for TROLL Language. Hierarchical regression revealed that at Step 1 the covariates contributed significantly to TROLL Language ($p < .003$) as did at-risk status at Step 2 ($p < .001$), with a significant increase in variance accounted for going from about 25 to 33%. Introducing the BRIEF-P summary indices at Step 3 significantly increased the change in R^2 by 17% to a total of about 50% of the TROLL Writing variance, $F(3, 86) = 9.88$, $p < .0001$. With all variables entered into the model in Step 3, results showed chronological age ($p < .05$), at-risk status ($p < .05$), and all three BRIEF-P summary indices to be significant predictors of TROLL Reading. Effect sizes for these significant predictors were small to medium in magnitude. When the interactions between at-risk status and BRIEF-P summary indices were added to the model in Step 4, no interactions were noted.

Table 4 Hierarchical regression models and model comparisons relating emergent literacy outcomes to covariates, risk status, and BRIEF-P summary indices

Steps	SB-5 Vocabulary	TROLL Reading	TROLL Writing	TROLL Language
Step 1: Covariates only	$R^2 = .23$; $F(11,100) = 2.71$; $p \leq .004$	$R^2 = .30$; $F(11,96) = 3.79$; $p \leq .0002$	$R^2 = .46$; $F(11,96) = 7.37$; $p \leq .0001$	$R^2 = .25$; $F(11,91) = 2.76$; $p \leq .003$
Step 2: Step 1 terms + risk status	$R^2 = .30$; $\Delta R^2 = .07$; $F(1,99) = 9.65$; $p \leq .002$	$R^2 = .41$; $\Delta R^2 = .11$; $F(1,95) = 17.31$; $p \leq .0001$	$R^2 = .50$; $\Delta R^2 = .04$; $F(1,95) = 7.15$; $p \leq .008$	$R^2 = .33$; $\Delta R^2 = .08$; $F(1,90) = 10.39$; $p \leq .001$
Step 3: Step 2 terms + BRIEF summary indices	$R^2 = .35$; $\Delta R^2 = .06$; $F(3,95) = 2.67$; $p \leq .05$	$R^2 = .55$; $\Delta R^2 = .14$; $F(3,91) = 9.54$; $p \leq .0001$	$R^2 = .59$; $\Delta R^2 = .10$; $F(3,91) = 7.35$; $p \leq .0002$	$R^2 = .50$; $\Delta R^2 = .17$; $F(3,86) = 9.88$; $p \leq .0001$
Step 4: Step 3 terms + risk status by summary index interactions	$R^2 = .37$; $\Delta R^2 = .02$; $F(3,92) = .97$; $p \leq .41$	$R^2 = .55$; $\Delta R^2 = .003$; $F(3,88) = .17$; $p \leq .91$	$R^2 = .60$; $\Delta R^2 = .01$; $F(3,88) = .74$; $p \leq .53$	$R^2 = .52$; $\Delta R^2 = .02$; $F(3,83) = 1.07$; $p \leq .37$
Final model parameter estimates and effect sizes	SB-5 Vocabulary Step 3 $\hat{b}(SE_{\hat{b}})$ ES	TROLL Reading Step 3 $\hat{b}(SE_{\hat{b}})$ ES	TROLL Writing Step 3 $\hat{b}(SE_{\hat{b}})$ ES	TROLL Language Step 3 $\hat{b}(SE_{\hat{b}})$ ES
Intercept	21.73 (3.98)***	23.59 (5.63)***	5.89 (2.83)*	19.82 (7.30)**
Classroom[a]	$F(9,95) = 2.46$* $\eta_p^2 = .15$	$F(9,91) = 5.41$*** $\eta_p^2 = .24$	$F(9,91) = 7.80$*** $\eta_p^2 = .31$	$F(9,86) = 1.83^{\dagger}$ $\eta_p^2 = .10$
Male	−.55 (.54) $\eta_p^2 = .01$	−1.24 (.75) $\eta_p^2 = .01$	−1.55 (.37)*** $\eta_p^2 = .08$	−2.47 (.97)* $\eta_p^2 = .04$
Age	−.18 (.08)* $\eta_p^2 = .04$	.22 (.11)* $\eta_p^2 = .02$	.15 (.05)** $\eta_p^2 = .03$	.26 (.14)† $\eta_p^2 = .02$
At-risk	−1.45 (.59)* $\eta_p^2 = .04$	−2.59 (.82)** $\eta_p^2 = .051$	−.87 (.41)* $\eta_p^2 = .02$	−2.23 (1.08)* $\eta_p^2 = .03$
Inhibitory self-control	.03 (.05) $\eta_p^2 = .003$	.07 (.06) $\eta_p^2 = .01$	.03 (.03) $\eta_p^2 = .01$	.25 (.08)** $\eta_p^2 = 06$
Flexibility	−.03 (.05) $\eta_p^2 = .002$	−.004 (.06) $\eta_p^2 = 0.00$	.004 (.03) $\eta_p^2 = .00$	−.17 (.08)* $\eta_p^2 = 03$
Emergent metacognition	−.07 (.04)* $\eta_p^2 = .03$	−.23 (.05)*** $\eta_p^2 = .11$	−.09 (.03)*** $\eta_p^2 = .06$	−.28 (.06)*** $\eta_p^2 = 11$

Table 4 (continued)

Steps	TERA-3 Conventions	TOPEL Print Knowledge	TOPEL Phonological Awareness
Step 1: Covariates only	$R^2 = .15$; $F(11,91) = 1.42$; $p \leq .17$	$R^2 = .10$; $F(11,100) = 1.03$; $p \leq .43$	$R^2 = .14$; $F(11,98) = 1.46$; $p \leq .15$
Step 2: Step 1 terms + Risk Status	$R^2 = .22$; $\Delta R^2 = .07$; $F(1,90) = 8.52$; $p \leq .004$	$R^2 = .35$; $\Delta R^2 = .25$; $F(1,99) = 38.61$; $p \leq .0001$	$R^2 = .23$; $\Delta R^2 = .09$; $F(1,97) = 11.20$; $p \leq .001$
Step 3: Step 2 terms + BRIEF Summary Indices	$R^2 = .26$; $\Delta R^2 = .04$; $F(3,87) = 1.50$; $p \leq .22$	$R^2 = .42$; $\Delta R^2 = .07$; $F(3,95) = 3.89$; $p \leq .01$	$R^2 = .32$; $\Delta R^2 = .09$; $F(3,93) = 4.11$; $p \leq .008$
Step 4: Step 3 terms + Risk Status by Summary Index Interactions	$R^2 = .34$; $\Delta R^2 = .08$; $F(3,84) = 3.59$; $p \leq .01$	$R^2 = .43$; $\Delta R^2 = .003$; $F(3,92) = .14$; $p \leq .93$	$R^2 = .33$; $\Delta R^2 = .01$; $F(3,90) = .42$; $p \leq .74$
Final model parameter estimates and effect sizes	TERA-3 Conventions Step 4 $\hat{b}(SE_{\hat{b}})$ ES	TOPEL Print Knowledge Step 3 $\hat{b}(SE_{\hat{b}})$ ES	TOPEL Phonological Awareness Step 3 $\hat{b}(SE_{\hat{b}})$ ES
Intercept	11.74 (2.31)***	15.97 (9.24)†	7.96 (6.75)*
Classroom[a]	$F(9,84) = 1.19$ $\eta_p^2 = .08$	$F(9,95) = 2.25$* $\eta_p^2 = .12$	$F(9,93) = 2.22$* $\eta_p^2 = .15$
Male	−.12 (.27) $\eta_p^2 = .002$	.52 (1.19) $\eta_p^2 = .001$	−1.97 (.87)* $\eta_p^2 = .04$
Age	−.08 (.04)† $\eta_p^2 = .03$	.08 (.18) $\eta_p^2 = .001$	.26 (.13)* $\eta_p^2 = .03$
At-risk	−.10 (1.37) $\eta_p^2 = < .0001$	−7.16 (1.32)*** $\eta_p^2 = .18$	−2.78 (.96)** $\eta_p^2 = .06$
Inhibitory self-control (ISCI)	−.11 (.03)* $\eta_p^2 = .03$	−.08 (.10) $\eta_p^2 = .004$	−.05 (.07) $\eta_p^2 = .004$
Flexibility (FI)	.10 (.04)* $\eta_p^2 = .03$	.16 (.10) $\eta_p^2 = .02$	.02 (.07) $\eta_p^2 = .0008$
Emergent metacognition (EMI)	.02 (.03) $\eta_p^2 = .002$	−.20 (.08)* $\eta_p^2 = .04$	−.10 (.06) $\eta_p^2 = .02$

Table 4 (continued)

Final model parameter estimates and effect sizes	TERA-3 Conventions Step 4 $\hat{b}(SE_{\hat{b}})$ ES	TOPEL Print Knowledge Step 3 $\hat{b}(SE_{\hat{b}})$ ES	TOPEL Phonological Awareness Step 3 $\hat{b}(SE_{\hat{b}})$ ES
At-risk by ISCI	.14 (.04)** $\eta_p^2 = .08$		
At-risk by FI	−.10 (.05)* $\eta_p^2 = .03$		
At-risk by EMI	−.05 (.03)† $\eta_p^2 = .03$		

Covariates: Classroom (10 classrooms), Child Sex (0 = F, 1 = M), and Child Age

Risk status: 0 = not at high risk, 1 = high risk

BRIEF summary indices: inhibitory self-control, flexibility, emergent metacognition

Unless otherwise noted, all statistical tests of individual parameter estimates are reported as *t* tests $\left(t = \hat{b}/SE_{\hat{b}}\right)$, which are equivalent to 1-df F-tests

$^{\dagger}p \leq .10$; $^{*}p \leq .05$; $^{**}p \leq .01$; $^{***}p \leq .001$; effect size (ES) = partial eta-square (η_p^2)

[a]Since there are 10 classrooms, the joint test of classroom effects has 9 df, so it is reported as a 9-df F-test. Also, since fixed effects of classrooms were included solely to control for effects of classroom contexts, their parameter estimates are not reported in detail. They are available upon request

TERA-3 Conventions

While the main effects of Inhibitory Self-Control and Flexibility were significant predictors of TERA-3 Conventions after controlling for the covariates and at-risk status, the results for Step 4 revealed two significant at-risk status by BRIEF-P Summary Index interactions, which relegated findings to examination of the Step 4 model. As can be seen in Table 4, Step 4 showed that the additional of the BRIEF-P summary indices accounted for about 34% of the TERA-3 Conventions variance, $F(3, 84) = 3.59$, $p < .01$. Specifically, Step 4 showed that the at-risk status by BRIEF-P Inhibitory Self-Control Index interaction, $F(1, 84) = 10.26$, $p < .001$, and the at-risk by Flexibility Index interaction, $F(1, 84) = 3.38$, $p < .05$, to be significant predictors of TERA-3 Conventions.

Figure 1 illustrates the significant interaction between at-risk status and Inhibitory Self-Control. Despite the statistical significance of this interaction, the nature of this finding is unclear and appears to be driven by the apparently worse teacher ratings aligning with lower TERA-3 Conventions for the not-at-risk Group rather than the at-risk group which was relatively unchanged performance with worsening teacher ratings of EF.

Figure 2 depicts the significant interaction between at-risk status and Flexibility. Here, as with Fig. 1, the pattern of performance on the TERA-3 Conventions subtest appears relatively unchanged for the at-risk group; however, in contrast to Fig. 1, the significant interaction appears to be driven by the unusual findings of the not at-risk

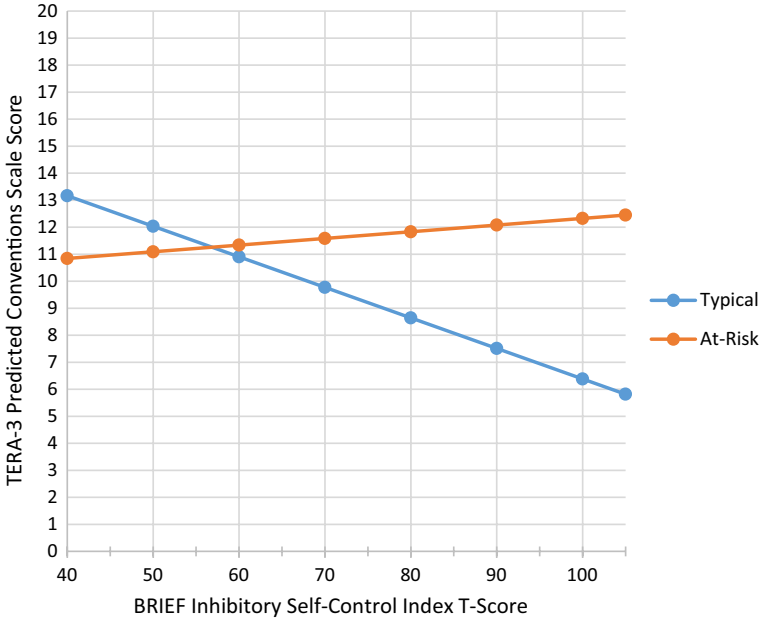


Fig. 1 At-risk status by BRIEF-P Inhibitory Self-Control Index (ISCI) for TERA-3 Conventions ($p < .001$)

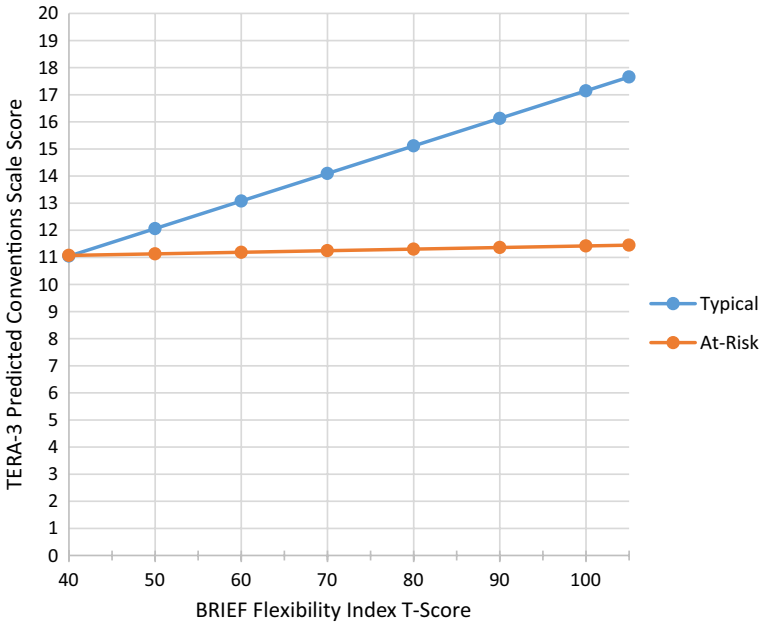


Fig. 2 At-risk status by BRIEF-P Flexibility Index (FI) for TERA-3 Conventions ($p < .05$)

group receiving more impaired Flexibility teacher ratings with increasing reading convention skills.

The at-risk status by Emergent Metacognition interaction approached significance, $F(1, 84) = 3.28$, $p < .07$, but did meet the $p < .05$ criterion.

TOPEL

Print Knowledge

For the TOPEL, Table 4 shows that the model in Step 3 produced the most significant predictive gains for Print Knowledge. Hierarchical regression revealed that at Step 1 the covariates did not contribute significantly to TOPEL Print Knowledge ($p < .43$), but that there was a significant increase in the amount of variance accounted for when at-risk status was included in the model at Step 2 ($p < .0001$), with an increase in variance from 10% at Step 1 to 35% at Step 3. Introducing the BRIEF-P summary indices at Step 3 further increased the change in R^2 by 7% to a total of about 42% of the TOPEL Print Knowledge variance, $F(3, 95) = 3.89$, $p < .01$. With all variables entered into the model in Step 3, results showed at-risk status ($p < .001$), and BRIEF-P Emergent Metacognition to be significant predictors of TOPEL Print Knowledge. Effect sizes for these significant predictors ranged from small for Emergent Metacognition to large for at-risk status. When the interactions

between at-risk status and BRIEF-P summary indices were added to the model in Step 4, no interactions were noted.

Phonological Awareness

For TOPEL Phonological Awareness, Table 4 shows that the model in Step 3 produced the most significant predictive gains via the hierarchical regression. Step 1 revealed that the covariates did not contribute significantly to TOPEL Phonological Awareness, but the amount of variance significantly increased in Step 2 from 14 to 23% when at-risk status was added to the model ($p < .001$). When the BRIEF-P summary indices were added to the model in Step 3, there was a change in R^2 by another 9% to a total of about 32% of the TOPEL Phonological Awareness Subtest, $F(3, 93) = 4.11$, $p < .008$. At Step 3, results showed male gender ($p < .05$), chronological age ($p < .05$), and at-risk status ($p < .01$) to be significant predictors of TOPEL Phonological Awareness; however, none of the BRIEF-P summary indices were significant. Effect sizes for these significant predictors were small to medium in magnitude. When the interactions between at-risk status and BRIEF-P summary indices were added to the model in Step 4, no interactions were noted.

Discussion

The primary purpose of this study was to investigate the concurrent relationships between selected EFs, as defined by teacher ratings of Inhibitory/Self-Control, Flexibility, and Emergent Metacognition, and a comprehensive array of emergent literacy skills, as defined by measures assessing phonological awareness, reading conventions, print knowledge, language, and vocabulary in three-year-old preschool children being served in a Head Start setting. This study also provided estimates of both pre-reading and pre-writing skills, the latter an often mentioned, but neglected component in the study of emergent literacy. The primary research question addressed whether teacher ratings of EF significantly contributed to the prediction of these emergent literacy skills after adjusting for key sociodemographic covariates and at-risk status.

Do preschool teacher ratings of EF predict emergent literacy skills?

The EF predictor models, which included the sociodemographic covariates and at-risk status, accounted for large amounts of variance with respect to the emergent literacy outcomes. These variances ranged from 32% for print knowledge to 59% for (pre)writing. Based on the available literature, it was hypothesized that Inhibitory Self-Control and Emergent Metacognition would be significant contributors to print knowledge, phonological awareness, pre-reading, and pre-writing skills after adjusting for emergent literacy risk status and targeted sociodemographic covariates. As suspected, findings revealed that teacher ratings of the BRIEF-P Emergent Metacognition added significant predictive value to most

of the emergent literacy outcome except phonological awareness and reading conventions: i.e., Vocabulary, (pre)reading, (pre)writing, language, print knowledge. In contrast, Inhibitory Self-Control was not as predictive of the emergent literacy outcomes, adding significant value only to Language. A similar result was demonstrated for Flexibility. This differential pattern of results was similar to those obtained by Miller et al. (2013) who showed working memory to be a stronger predictor of letter identification than inhibitory control, and with Willoughby et al. (2019) who demonstrated the importance of both working memory and flexibility in the preschool years to the later development of reading skills in elementary school. For all of the current findings, the small to medium effect sizes observed were generally congruent with the those demonstrated across the literature.

Additionally, it was suspected that there would be significant interactions between at-risk status and each of the EF variables in the prediction of emergent literacy skills across all of the measures in this young population. In contrast to our expectations, though, this was uncovered for only the TERA-3 Conventions subtest. Here, two of the three EF variables (Inhibitory Self-Control and Flexibility) significantly interacted with at-risk status; however,, the nature of the interactions were unusual. For the at-risk status by Inhibitory Self-Control Index for (Reading) Conventions interaction, the expected pattern for the not-at-risk group (i.e., poorer inhibitory/self-control with poorer pre-reading conventions) was evident, while the opposite pattern was noted for the at-risk by Flexibility interaction. Further, for both interactions, the performance on the Conventions subtests for the at-risk group did not change with increasingly poorer teacher ratings of Inhibitory Self-Control or Flexibility. Reasons for these findings are unclear and perhaps reflect some aspect of teacher expectancies for the preschoolers in the not-at-risk group versus those in the at-risk group; however, this was not observed on the other measures.

While there has been an increase in the number of well executed studies examining the relationship between EF, variously defined, and emergent/early literacy skills, relatively few studies have examined at-risk status in emergent literacy with respect to the predictive value of teacher ratings of EF (Blair & Razza, 2007; Lonigan et al., 2017). Additionally, there is some mixed findings with respect to the value of teacher ratings of EF in the early identification of preschool children at-risk for later literacy problems (Allan et al., 2014; Lonigan et al., 2017). From a concurrent perspective, our findings suggest the added predictive value from teacher ratings of EF for nearly all emergent literacy outcomes, although this appeared to be related largely to the Emergent Metacognition Index. The Emergent Metacognition Index on the BRIEF-P comprises items assessing working memory, planning, and organization, EFs that are likely related to the acquisition and execution of emergent literacy skills. Consequently, this would be consistent with findings in the literature showing the importance of working memory to emergent literacy skills (Allan & Lonigan, 2011; McClelland et al., 2007; Miller et al., 2013; Poinitz et al., 2009), as well as with studies where such measures were included in a larger omnibus single factor of EF (Allan & Lonigan, 2011). In addition, Emergent Metacognition also was predictive of (pre)writing skills. As noted earlier, much of the work in emergent literacy has focused on emergent reading-related skills, and the current findings with

teacher ratings reflect the importance of selected EFs for emergent writing-related skills as well.

In contrast, we did not find a similar pattern for our teacher rating of Inhibitory Self-Control. The available literature has consistently pointed to the importance of inhibitory control as a significant predictor of emergent literacy skills, whether a direct assessment of EF was used (McClelland et al., 2007; Lonigan et al., 2017) or a teacher rating scale (Blair & Razza, 2007; Lonigan et al., 2017), but our findings suggested a predictive relationship only with the TROLL Language Scale. Further, this was not the most significant single EF predictor of language functions with Emergent Metacognition being the strongest predictor of the three EF indices. While this finding was not necessarily inconsistent with the available literature, as it was predictive of general language skills (which might subsume many of the emergent literacy skills), it does suggest a more limited relationship of inhibitory control with specific emergent literacy skills than what has been presented in the literature to date.

Finally, it is important to note that not one of the EF indices was significantly predictive of phonological awareness. Many of the studies to date showed direct assessments of working memory and inhibitory control, and teacher ratings of self-regulation to be associated with phonological awareness (Allan & Lonigan, 2011; Blair & Razza, 2007; Smith-Donald et al., 2007). In the current study, while the model including the BRIEF-P indices was significant, none of the summary indices was significant. This may be indicative of the relative dissociation of teacher ratings of EFs with phonological awareness, but it also could be related to the lack of sensitivity of teacher ratings to such skills at this developmental time period (Allan et al., 2014).

Limitations

The current study maintains a number of strengths, particularly with respect to the use of standardized measurement of both EF and emergent literacy, the examination of an array of emergent literacy skills (e.g., vocabulary, print knowledge, phonological awareness, pre-reading, pre-writing, etc.), and an adequate sample size. Further, in accordance with Willoughby et al. (2012), we included several key covariates in our hierarchical regression in order to minimize the impact of specific confounders in the findings (e.g., age, gender, at-risk status). Nonetheless, there are several limitations that require mention.

First, our measure of EF was, by design, a teacher rating scale. While we have discussed the importance of using teacher ratings and observations for very young children versus direct assessments earlier in the paper, we also are aware that it is possible that the significant relationships that were uncovered between the targeted EFs and emergent literacy skills may have been secondary to general teacher perceptions and biases with respect to how they viewed the children in their classrooms; thus, our findings may reflect these biases more so than any indicators of specific relationships between EF and emergent literacy. Relatedly, it is possible that a different pattern of findings would emerge with direct assessments of EF, although our

findings did mirror some of the available findings in the literature regardless of the assessment strategies employed.

Second, we are cognizant that different results might occur if we employed a different measure for determining at-risk status, particularly with respect to its relationship with our emergent literacy measures as well as possible interactions with the EF variables. In this regard, we examined the correlations for the GRTR-R with all emergent literacy measures included in the study. In general, the correlations between the GRTR-R with the other literacy measures ranged from .25 for the Vocabulary measure to .59 for the TOEPEL; consequently, we are confident that the GRTR-R performed well as our screening tool, but are mindful that another screening measure may have produced a different pattern of findings.

Third, our study was conducted with a sample of Head Start preschool children, a sample that, by definition, will limit the generalizability of our findings to children from the lower socioeconomic strata. Care should be used when generalizing our results to other types of preschool settings.

Finally, while we did uncover significantly large amounts of variance in the various relationships between the EF models and emergent literacy, there also may be other variables that would be equally, if not more important in these equations. For example, while we included key covariates in the study (i.e., chronological age, gender, risk status, classroom), it is recognized that there may be a wide range of other potential contributors (e.g., parent involvement, classroom climate) to emergent literacy outcomes (Heath et al., 2014), and it will be important for future studies to consider inclusion of such variables.

Conclusions

Executive functions appear to be an important set of abilities to be included with other cognitive abilities, family factors, and appropriate early childhood curricula in the assessment of very young children with respect to their evolving emergent literacy skills. This may be particularly true for very young children who are at-risk for literacy difficulties. This study has provided additional support to the literature with respect to the importance of EF to emergent literacy skills for three-year-old preschool children, and it has added to this literature by demonstrating the capabilities of teachers to provide these observations via teacher ratings in a significant fashion. Results from this study demonstrate the utility of using teacher ratings of selected EFs for predicting a wide array of emergent literacy skills, even after controlling for other potential confounders—including at-risk status for emergent literacy problems. Further, this study has suggested that such ratings may be useful for both prediction of both pre-reading and pre-writing along with other emergent literacy skills. The added predictive value of these early teacher ratings for formal school entry into kindergarten and early elementary school remains to be seen. A number of investigators (e.g., Bull et al., 2008; Espy et al., 2004; Fuhs, Farran, & Nesbitt, 2015; Lonigan et al., 2017) have demonstrated the utility of obtaining various measures of EF in preschool to later learning in the formal school setting, with some using teacher ratings of self-regulation (Lonigan et al., 2017), but it remains

to be seen if our findings will carry over into the formal school setting. The use of preschool teacher ratings provides a time and cost-effective assessment mechanism for assessing the integrity of EF in very young children, and the concurrent relationship of these ratings with emergent literacy skills is encouraging, perhaps providing another pathway for interventions for those with EF deficits (Blair & Raver, 2016; Diamond & Ling, 2016; Weiland & Yoshikawa, 2013).

Acknowledgements This project was supported by funding awarded to Dr. Hooper from the Institute for Education Science, U.S. Department of Education (#R305A170529).

References

Allan, N. P., Hume, L. E., Allan, D. M., Farrington, A. L., & Lonigan, C. J. (2014). Relations between inhibitory control and the development of academic skills in preschool and kindergarten: A meta-analysis. *Developmental Psychology, 50,* 2368–2379.

Allan, N. P., & Lonigan, C. J. (2011). Examining the dimensionality of effortful control in preschool children and its relation to academic and socioemotional indicators. *Developmental Psychology, 47,* 905–915.

Anderson, P. (2002). Assessment and development of executive function (EF) during childhood. *Child Neuropsychology, 2,* 71–82.

Bailey, R., Barnes, S. P., Park, C., Sokolovic, N., & Jones, S. M. (2018). *Executive function mapping project measures compendium: A resource for selecting measures related to executive function and other regulation-related skills in early childhood.* OPRE Report #2018-59, Washington, DC: Office of Planning, Research and Evaluation, Administration for Children and Families, U.S. Department of Health and Human Services.

Best, J. R., & Miller, P. H. (2010). A developmental perspective on executive function. *Child Development, 81,* 1641–1660.

Blair, C. (2002). School readiness: Integrating cognition and emotion in a neurobiological conceptualization of children's functioning at school entry. *American Psychologist, 57*(2), 111–127.

Blair, C., & Raver, C. (2016). Poverty, stress, and brain development: New directions for prevention and intervention. *Academic Pediatrics, 16,* S30–S36.

Blair, C., & Razza, R. P. (2007). Relating effortful control, executive function, and false belief understanding to emerging math and literacy ability in kindergarten. *Child Development, 78,* 647–663.

Bull, R., Espy, K. A., & Wiebe, S. A. (2008). Short-term memory, working memory, and executive functioning in preschoolers: Longitudinal predictors of mathematical achievement at age 7 years. *Developmental Neuropsychology, 33,* 205–228.

Diamond, A., & Ling, D. S. (2016). Conclusions about interventions, programs, and approaches for improving executive functions that appear justified and those that, despite much hype, do no. *Developmental Cognitive Neuroscience, 18,* 34–48.

Dickinson, D. K., & Chaney, C. (1997). *Early phonological awareness profile*. Newton, MA.: Education Development Center.

Dickinson, D. K., McCabe, A., & Sprague, K. (2001). *Teacher rating of oral language and literacy development*: *A research-based tool*. CIERA Report #3-016.

Dunn, L. M., & Dunn, L. M. (1997). *Peabody Picture Vocabulary test* (3rd ed.). Circle Pines, MN: American Guidance Service.

Escobar, J. P., Rosas-Díaz, R., Ceric, F., Aparicio, A., Arango, P., Arroyo, R., et al. (2018). The role of executive functions in the relation between socioeconomic level and the development of reading and math skills/El rol de las functiones ejecutivas en la relación entre el nivel socioeconómico y el desarrollo de habilidades lectoras y matemáticas. *Cultura y Educación, 30,* 368–392.

Espy, K. A., McDiarmid, M. M., Cwik, M. F., Stalets, M. M., Hamby, A., & Senn, T. E. (2004). The Contribution of executive functions to emergent mathematic skills in preschool children. *Developmental Neuropsychology, 26,* 465–486.

Freeman, E. B., & Hatch, J. A. (1989). Emergent literacy: Reconceptualizing kindergarten practice. *Childhood Education, 66,* 21–24.

Fuhs, M. W., Farran, D. C., & Nesbitt, K. T. (2015). Prekindergarten children's executive functioning skills and achievement gains: The utility of direct assessments and teacher ratings. *Journal of Educational Psychology, 107,* 207–221.

Garon, N., Byrson, S. E., & Smith, I. M. (2008). Executive function in preschoolers: A review using an integrative framework. *Psychological Bulletin, 134,* 31–60.

Gioia, G., Espy, K. A., & Isquith, P. K. (2003). *The Behavior Rating Inventory of Executive Function-Preschool Version*. Lutz, FL: PAR Inc.

Head Start Early Childhood Learning and Knowledge Center. (2019). *Head Start approach to school readiness*. Retrieved from https://eclkc.ohs.acf.hhs.gov/school-readiness/article/head-start-approach-school-readiness-overview#. Retrieved on November 5, 2019.

Heath, S. M., Bishop, D. V. M., Bloor, K. E., Boyle, G. L., Fletcher, J., Hogben, J. H., et al. (2014). A spotlight on preschool: The influence of family factors on children's early literacy skills. *PLoS ONE, 9,* 1–14.

Horowitz-Kraus, T., Schmitz, R., Hutton, J. S., & Schumacher, J. (2017). How to create a successful reader? Milestones in reading development from birth to adolescence. *Acta Paediatrica, 106,* 534–544.

Jacob, R., & Parkinson, J. (2015). The potential for school-based interventions that target executive function to improve academic achievement: A review. *Review of Educational Research, 85,* 512–552.

Lonigan, C. J., Allan, D. M., & Phillips, B. M. (2017). Examining the predictive relations between two aspects of self-regulation and growth in preschool children's early literacy skills. *Developmental Psychology, 53,* 63–76.

Lonigan, C. J., Burgess, S. R., & Anthony, J. L. (2000). Development of emergent literacy and early reading skills in preschool children: Evidence from a latent-variable longitudinal study. *Developmental Psychology, 36,* 596–613.

Lonigan, C. J., Wagner, R. K., Torgesen, J. K., & Rashotte, C. A. (2007). *Test of Preschool Early Literacy*. Austin, TX: Pro-Ed.

Maxwell, S. E., & Delaney, H. D. (2004). *Designing experiments and analyzing data: A model comparison perspective* (2nd ed.). Mahwah, NJ: Lawrence Erlbaum.

McClelland, M. M., Cameron, C. E., Connor, C. M., Farris, C. L., Jewkes, A. M., & Morrison, F. J. (2007). Links between behavioral regulation and preschoolers' literacy, vocabulary, and math skills. *Developmental Psychology, 43,* 947–949.

McConnell, S. R. (2002). *Individual growth and development indicators*. Minneapolis, MN: University of Minnesota.

Miller, M. R., Giesbrecht, G. F., Müller, U., McInerney, R. J., & Kerns, K. A. (2013). A latent variable approach to determining the structure of executive function in preschool children. *Journal of Cognition and Development, 13,* 395–423.

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex "frontal lobe" tasks: A latent variable analysis. *Cognitive Psychology, 41,* 49–100.

Nelder, J. A. (1994). The statistics of linear models: Back to basics. *Statistics and Computing, 4,* 221–234.

Nesbitt, K. T., Farran, D. C., & Fuhs, M. W. (2015). Executive function skills and academic achievement gains in prekindergarten: Contributions of learning-related behaviors. *Developmental Psychology, 51,* 865–878.

Poinitz, C. C., McClelland, M. M., Matthews, J. S., & Morrison, F. J. (2009). A structured observation of behavioral self-regulation and its contribution to kindergarten outcomes. *Developmental Psychology, 45,* 605–619.

Psychological Corporation. (1996). *Stanford Achievement Test Series* (9th ed.). San Antonio, TX: Harcourt Brace & Company, Educational Measurement.

Puranik, C. S., & Lonigan, C. J. (2011). From scribbles to scrabble: Preschool children's developing knowledge of written expression. *Reading and Writing: An Interdisciplinary Journal, 24,* 567–581.

Puranik, C. S., & Lonigan, C. J. (2014). Emergent writing in preschoolers: Preliminary evidence for a theoretical framework. *Reading Research Quarterly, 49,* 453–467.

Purpura, D. J., Schmitt, S. A., & Ganley, C. M. (2017). Foundations of mathematics and literacy: The role of executive functioning components. *Journal of Experimental Child Psychology, 153,* 15–34.

Reid, D. K., Hresko, W. P., & Hammill, D. D. (2001). *The Test of Early Reading Ability*. Austin, TX: Pro-Ed.

Roid, G. H. (2003). *Stanford Binet Intelligence Scales* (5th ed.). Austin, TX: Pro-Ed.
Roid, G. H. (2005). *Stanford Binet Intelligence Scales for Early Childhood* (5th ed.). Austin, TX: Pro-Ed.
Skibbe, L. E., Montroy, J. J., Bowles, R. P., & Morrison, F. J. (2019). Self-regulation and development of literacy and language achievement from preschool through second grade. *Early Childhood Research Quarterly, 46,* 240–251.
Smith-Donald, R., Raver, C. C., Hayes, T., & Richardson, B. (2007). Preliminary construct and concurrent validity of the Preschool Self-Regulation Assessment (PSRA) for field-based research. *Early Childhood Research Quarterly, 22,* 173–187.
Stapleton, L. M., McNeish, D. M., & Yang, J. S. (2016). Multilevel and single-level models for measured and latent variables when data are clustered. *Educational Psychologist, 51*(3–4), 317–330.
Teale, W. H., & Sulzby, E. (1986). *Emergent literacy: Writing and reading*. Norwood, NJ: Ablex.
Toplak, M. E., West, R. F., & Stanovich, K. E. (2013). Practitioner review: Do performance-based measures and ratings of executive function assess the same construct? *Journal of Child Psychology and Psychiatry, 54,* 131–143.
Weiland, C., & Yoshikawa, H. (2013). Impacts of a prekindergarten program on children's mathematics, language, literacy, executive function, and emotional skills. *Child Development, 84,* 2112–2130.
Welsh, J. A., Nix, R. L., Blair, C., Bierman, K. L., & Nelson, K. E. (2010). The development of cognitive skills and gains in academic school readiness for children from low-income families. *Journal of Educational Psychology, 102,* 43.
Whitehurst, G. J., & Lonigan, C. J. (2009). *Get ready to read-revised*. Washington, DC: Pearson Inc.
Wiebe, S. A., Sheffield, T., Nelson, J. M., Clark, C. A. C., Chevalier, N., & Espy, K. A. (2011). The structure of executive function in 3-year-olds. *Journal of Experimental Child Psychology, 108,* 436–452.
Willoughby, M. T., Blair, C. B., Wirth, R. J., & Greenberg, M. (2010). The measurement of executive function at age 3 years: Psychometric properties and criterion validity of a new battery of tasks. *Psychological Assessment, 22,* 306–317.
Willoughby, M. T., Kupersmidt, J. B., & Voegler-Lee, M. E. (2012). Is preschool executive function causally related to academic achievement? *Child Neuropsychology, 18,* 79–91.
Willoughby, M. T., Magnus, B., Vernon-Feagans, L., Blair, C. B., & the Family Life Project Investigators. (2017). Developmental delays in executive function from 3 to 5 years of age predict kindergarten academic readiness. *Journal of Learning Disabilities, 50,* 359–372.
Willoughby, M. T., Wylie, A. C., & Little, M. H. (2019). Testing longitudinal associations between executive function and academic achievement. *Developmental Psychology, 55,* 767–779.
Wilson, S. B., & Lonigan, C. J. (2009). An evaluation of two emergent literacy screening tools for preschool children. *Annals of Dyslexia, 59*(2), 115–131.
Woodcock, R. W. (1998). *Woodcock Reading Mastery—Revised NU*. Circle Pines, MN: American Guidance Service.

Affiliations

Stephen R. Hooper[1] · Lara-Jeane C. Costa[1] · Melissa B. Green[1] · Stephanie R. Catlett[1] · Alexandra Barker[1] · Edmund Fernandez[1] · Richard A. Faldowski[1]

✉ Stephen R. Hooper
Stephen_hooper@med.unc.edu

[1] Department of Allied Health Sciences, 1028 Bondurant Hall, School of Medicine, University of North Carolina-Chapel Hill, Chapel Hill, NC 27599, USA