HHS Public Access
Author manuscript
Dev Psychol. Author manuscript; available in PMC 2018 January 01.

Published in final edited form as:
Dev Psychol. 2017 January ; 53(1): 63–76. doi:10.1037/dev0000247.

Examining the Predictive Relations between Two Aspects of Self-Regulation and Growth in Preschool Children's Early Literacy Skills

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Abstract

There is strong evidence that self-regulatory processes are linked to early academic skills both concurrently and longitudinally. The majority of extant longitudinal studies, however, have been conducted using autoregressive techniques that may not accurately model change across time. The purpose of this study was to examine the unique associations between two components of self-regulation, attention and executive functioning (EF), and growth in early literacy skills over the preschool year using latent-growth-curve analysis. The sample included 1,082 preschool children (*M*-age = 55.0 months, *SD* = 3.73). Children completed measures of vocabulary, syntax, phonological awareness, print knowledge, cognitive ability, and self-regulation, and children's classroom teachers completed a behavior rating measure. To examine the independent relations of the self-regulatory skills and cognitive ability with children's initial early literacy skills and growth across the preschool year, growth models in which the intercept and slope were simultaneously regressed on each of the predictor variables were examined. Because of the significant relation between intercept and slope for most outcomes, slope was regressed on intercept in the models to allow a determination of direct and indirect effects of the predictors on growth in children's language and literacy skills across the preschool year. In general, both teacher-rated inattention and directly measured EF were uniquely associated with initial skills level; however, only teacher-rated inattention uniquely predicted growth in early literacy skills. These findings suggest that teacher-ratings of inattention may measure an aspect of self-regulation that is particularly associated with the acquisition of academic skills in early childhood.

Keywords

Preschool; Early Literacy; Self-Regulation; Inattention; Executive Function

An increasing number of studies have examined the relations between children's self-regulation and other important developmental outcomes, including socio-emotional behaviors and academic skills. The results of these studies indicate that self-regulation is associated with both socio-emotional and academic outcomes (e.g., Allan, Hume, Allan,

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Farrington, & Lonigan, 2014; Jacob & Parkinson, 2015; Schoemaker, Mulder, Deković, & Matthys, 2013). Self-regulation represents a variety of skills that involve the ability to regulate cognition, behavior, and emotion, and although a variety of definitions of self-regulation exist, most models of self-regulation include components intended to reflect the partially separable higher-order constructs of executive function (EF), attentional control, and effortful control (Blair, Ursache, Greenberg, Vernon-Feagans, et al., 2015). The development of self-regulation has been linked with the development of the prefrontal cortex and its function of activation and inhibition of other brain regions (e.g., Garon, Bryson, & Smith, 2008) as well as underlying hormonal systems associated with stress reactivity (e.g., Berry, Blair, Willoughby, Granger, et al., 2012). Well-developed self-regulation enables individuals to override more automatic or established responses, typically in the service of goal-directed behaviors. Among the most commonly studied areas of self-regulation in young children are processes associated with attention and components of EF; however, studies of these two dimensions of self-regulation tend to be reported in distinct literatures. In this study, we examined both dimensions.

Self-Regulation and Academic Skills

Findings of linkage between children's self-regulation and academic skills have led some to posit that children with better developed self-regulation are better equipped to handle the demands of early educational environments through behaviors such as attention, memory for rules, and sustained engagement (Blair & Raver, 2014). In fact, based in part on the relations between young children's self-regulation and their academic skills, some have suggested that modifications to the focus of early childhood instruction from academic skills to self-regulation would better serve children's longer term educational needs (e.g., Blair & Diamond, 2008; Diamond, 2010). To date, however, the majority of studies of preschool-age children have examined the linkage between one dimension of self-regulation (e.g., attention or EF) and either concurrent relations with children's academic skills (Allan & Lonigan, 2011; Sims & Lonigan, 2013) or predictive relations between self-regulation and later outcomes, controlling for scores on the outcome measure at an earlier point in time (i.e., autoregressive models; e.g., Fuhs, Farran, & Nesbitt, 2015; McClelland et al., 2007; Ponitz, McClelland, Matthews, & Morrison, 2009). Positive predictive relations between self-regulation and academic skills are typically interpreted as indicating that self-regulation influences growth in academic skills (e.g., McClelland et al., 2007; Welsh, Nix, Blair, Bierman, & Nelson, 2010). Although such analyses can identify associations between children's self-regulation and their academic skills, these analyses may misestimate the degree to which self-regulation is associated with growth in such skills (Rogosa, 1995; Rogosa, Brandt, & Zimowski, 1982). In this study, we used latent-growth-curve analyses to identify the associations between two dimensions of self-regulation and growth in a variety of early literacy skills across the preschool year.

Attention and academic skills

One aspect of self-regulation that has been linked with academic outcomes is children's attention. For example, Duncan et al. (2007) reported that measures of attention significantly and uniquely predicted school-age children's reading and math outcomes across multiple

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large-scale data sets. In fact, there is a substantial body of evidence that problems of attention are associated with the academic development of adults (e.g., Samuelsson, Lundberg, & Herkner, 2004), adolescents (e.g., Willcutt & Pennington, 2000), and elementary school-age children (e.g., Willcutt, Pennington, & DeFries, 2000), based on parent and teacher ratings, or direct assessments. Despite variability of instructional activities in different preschool settings, a growing body of evidence indicates that problems of attention also are associated with preschool-age children's developing academic skills. For example, Lonigan et al. (1999) reported that teacher ratings of inattention were negatively correlated with preschool children's emergent literacy skills. Sims and Lonigan (2013) reported that both teacher-rated inattention and omission errors on a continuous performance task uniquely predicted preschool children's concurrent phonological awareness and print knowledge skills. In a longitudinal study of children's developing emergent literacy skills, Walcott, Scheemaker, and Bielski (2010) reported that teacher-rated inattention of preschoolers significantly predicted kindergarten children's phonological awareness and letter knowledge, after controlling for emergent literacy skills in preschool. Problems of attention also are associated with children's developing mathematics skills (e.g., Sims, Purpura, & Lonigan, 2016).

Executive function and academic skills

A second aspect of self-regulation, EF, also has been linked to academic skill development during both the preschool and the early elementary years (Allan & Lonigan, 2011; Blair & Razza, 2007; Blair et al., 2015; Brock, Rimm-Kaufman, Nathanson, & Grimm, 2009; Willoughby, Kupersmidt, & Voegler-Lee, 2012). EF is typically defined as regulatory cognitive processes that are an integral component of effortful thought and action (Carlson, 2005). Although several dimensional models of EF have been proposed (e.g., Barkley, 2001; Duncan & Owen, 2000), factor analytic methods have uncovered at least three common dimensions in adolescents and adults: working memory, inhibitory control, and shifting (Lehto, Juujärvi, Kooistra, & Pulkkinen, 2003; Miyake et al., 2000). Working memory represents the updating or active use of information held in memory. Inhibitory control represents the ability to suppress or override a predisposed or learned response, and shifting represents the ability to alternate between sets of stimulus-response rules.

Much of the work relating EF to young children's academic outcomes has focused on inhibitory control; however, unlike results of studies with adolescents or adults, studies of the structure of EF among preschool children typically report that EF is unidimensional (e.g., Wiebe et al., 2011; Willoughby, Blair, Wirth, & Greenberg, 2010), indicating either that the development of EF has not progressed sufficiently to allow distinct components to emerge or that measures used with young children assess multiple dimensions of EF simultaneously. McClelland and colleagues (e.g., McClelland et al., 2007; Ponitz et al., 2009) developed a direct assessment of young children's self-regulation, the Head-Toes-Knees-Shoulders (HTKS) task, that they argued draws on multiple EFs, including working memory and inhibitory control.

In a longitudinal study of 310 preschoolers who were assessed on a variety of academic skills in both the fall and the spring of their preschool year, McClelland et al. (2007)

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reported that HTKS scores uniquely predicted spring scores on language, literacy, and math measures after controlling for scores on the same measure in the fall. In a related study, Ponitz et al. (2009) reported that the fall HTKS scores of 343 kindergarten children uniquely predicted their spring language, literacy, and math scores; however, when fall scores on the academic measures were included in the models, fall HTKS scores only uniquely predicted the spring math scores.

Using more traditional measures of EF, including measures of inhibitory control, working memory, and shifting, Fuhs, Nesbitt, Farran, and Dong (2014) reported that their EF factor accounted for changes between fall and spring of the preschool year in mathematics, language, and literacy domains, and for changes between spring of preschool and spring of kindergarten in mathematics and language domains in a series of cross-lagged path analyses of 562 4-year-old children studied longitudinally from the start of their preschool year to the end of their kindergarten year. Similarly, Fuhs et al. (2015) reported that an EF factor comprised of measures of inhibitory control, working memory, and shifting as well as a teacher-report of self-regulation uniquely predicted spring language, literacy, and mathematics scores after controlling for the corresponding fall score in a sample of 719 preschool children.

Self-regulation and literacy versus math skills

Although studies support linkages between children's self-regulation and both their literacy and their math skills, there is evidence that the linkage is stronger for math skills than it is for literacy skills. With respect to concurrent relations, Allan et al. (2014) reported that children's inhibitory control was more strongly associated with math outcomes ($r = .34$) than it was with literacy outcomes ($r = .25$) in their meta-analysis of the relation of inhibitory control and preschool and kindergarten children's academic skills, With respect to longitudinal relations, Blair et al. (2015) reported that EF (a composite of six tasks), a direct measure of effortful control, and a composite of two subscales of the Children's Behavior Questionnaire intended to measure effortful control (i.e., Attention Focusing and Inhibitory Control subscales) completed by parents and kindergarten teachers predicted growth in scores on the Applied Problems subtest but not the Letter-Word Identification subtest of the Woodcock-Johnson Test of Achievement in growth models for 1,099 children followed from preschool to second grade, controlling for other covariates in the models.

Blair et al. (2015) proposed that the reasons for stronger relations between components of self-regulation with math versus reading-related skills might be due to the nature of the cognitive activity required to perform the task. They suggested that many math tasks involved active processing of information or the application of reasoning-based skills and, hence, may require flexible shifting of attention, inhibition of responses, and working memory. In contrast, they suggested some reading-related tasks simply involve accessing knowledge (e.g., letter names, letter sounds, sight words), which does not require self-regulation; however, they suggested that other reading-related tasks that involve more than knowledge access, like reading comprehension, would be expected to be associated with self-regulation.

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Self-Regulation and Early Literacy Skills

Young children's early literacy skills predict later decoding and reading comprehension skills in elementary school (Lonigan, Burgess, & Anthony, 2000; Storch & Whitehurst, 2002). Children who display deficits in these skills prior to formal education often continue to struggle throughout elementary school and beyond (e.g., Juel, 1988; Lonigan & Shanahan, 2010). Thus, understanding the potentially malleable factors that may contribute to the development of early literacy skills is critical to efforts to promote academic success. Whereas there are studies of the relations between self-regulatory processes and reading-related skills with preschool children, the majority of these studies have either focused on concurrent relations between self-regulation and reading-related skills (e.g., Allan & Lonigan, 2011) or focused on longitudinal relations between self-regulation and conventional aspects of reading (e.g., Fuhs et al., 2014, 2015; McClelland et al., 2007). Most preschool children do not yet possess measurable conventional literacy skills (e.g., decoding, reading comprehension), but, prior to the development of conventional literacy, it is possible to measure the developmental precursors of these skills (i.e., emergent or early literacy skills; e.g., Whitehurst & Lonigan, 1998). In this study, we focused on the development of early literacy skills across children's preschool year.

Components of early literacy

Whitehurst and Lonigan (1998) defined emergent literacy skills as the developmental precursors to conventional forms of reading and writing, and identified early skills with connections to later reading and writing skills. Early literacy skills can be divided into those that are primarily associated with later word-decoding, including print knowledge (i.e., understanding print conventions, letter-name and letter-sound knowledge) and phonological processing abilities (i.e., phonological awareness, phonological memory, phonological access to lexical store), and those that are primarily associated with later reading comprehension, including components of oral language (i.e., vocabulary, syntax). Whereas skills in these code-related and meaning-related domains are correlated during development, they are differentially predictive of different aspects of later conventional literacy skills (Lonigan, Schatschneider, & Westberg, 2008a), and they are responsive to different types of instructional activities (e.g., Lonigan, Purpura, Wilson, Walker, & Clancy-Menchetti, 2013; Lonigan, Schatschneider, & Westberg, 2008b), indicating modularity of the skills.

Nature of early literacy skills and possible influence of self-regulation

Based on the proposal by Blair et al. (2015) concerning the nature of tasks that should be associated with self-regulation, it would be expected that some early literacy skills would be more strongly related to self-regulation than others. Specifically, meaning-related skills and phonological processing skills should be more strongly associated with self-regulation than are print knowledge skills. Theories of reading comprehension posit a significant role of working memory (Kintsch, 1988; van Dijk & Kintsch, 1983), a component of EF. Meaning-related skills such as vocabulary and syntax, which are related to later reading comprehension, require various levels of integration and inhibition. For instance, to comprehend both written and spoken language, current information needs to be integrated with information in long-term memory, and comprehension often requires making inferences

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across recent material or between recent material and other knowledge. Given the complexities involved, it might be expected that vocabulary would be less associated with self-regulation than is syntax (e.g., Verhagen & Leseman, 2016), as most vocabulary measures involve simple recall of words or associations of words with pictures. Phonological awareness, the core phonological processing ability associated with word-decoding, involves manipulating the sound structure of words independent of their meaning. Therefore, to perform phonological awareness tasks successfully, children need to inhibit responses based on word meanings. In contrast, most print knowledge tasks represent recall of names or sounds associated with letters, which does not require much active cognitive processing. In this study, we examined the association of self-regulation with each of these different components of early literacy skills.

Potential Mechanisms for the Influence of Self-Regulation on Growth of Academic Skills

Given the robust association between self-regulation and academic skills, research is needed to clarify the nature of the relation between these important areas of child development and to specify the mechanisms that underlie this relation. One possible mechanism is that higher self-regulation is associated with the development of complex reasoning abilities that require flexibility, inhibition, and attentional control, and this development occurs independent of instruction. Another possible mechanism is that self-regulation affects the developmental yield that children receive from instruction. Better self-regulation may allow children to take more advantage of the instruction they receive in school. That is, when provided with appropriate instructional activities, children with higher levels of self-regulation may be better able to attend to the instruction, remain on task for longer periods, filter extraneous information, integrate novel information with existing knowledge, maintain a higher level of motivation, and increase the probability of positive interactions with teachers and peers (Blair, & Raver, 2015; Garon et al., 2008; Loe & Felman, 2007; Ursache, Blair, & Raver, 2012). In other words, children’s self-regulation should moderate the effect of instruction and, conversely, instruction should moderate the effect of self-regulation such that stronger effects of self-regulation should be evident with higher levels of instructional frequency, quality, or both. To examine this possible mechanism by which self-regulation may influence the development of early literacy skills, we conducted analyses to examine whether the influence of EF and attention on growth in early literacy skills was different across preschools with varying amounts of direct instructional activities.

Current Study

The purpose of this study was to examine the linkages between two components of self-regulation, EF and attention, and the development of different components of early literacy skills over the course of the preschool year using latent-growth-curve modeling. Because the development of self-regulation is associated with both age and general cognitive abilities (Garon et al., 2008), we examined the relations between EF and attention and children’s early literacy skills controlling for these two variables. Given the robust relations between self-regulation and academic skills in previous concurrent and longitudinal studies, it was

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hypothesized that self-regulation would be associated both with initial early literacy skills and with growth in early literacy skills over the preschool year; however, we anticipated that self-regulation would be more strongly associated with measures of early literacy skills that require more active cognitive processing (i.e., syntax, phonological awareness, early meaning-making efforts from print) than with those that primarily involved knowledge retrieval (i.e., vocabulary, letter knowledge). Because direct-measures and informant ratings of self-regulatory skills are typically only modestly correlated (Toplak, West, & Stanovich, 2013), it was expected that each measure would be uniquely associated with early literacy skills. We also expected that the relations between self-regulation and early literacy skills would be stronger for children who attended preschools with a higher frequency and quality of instruction.

Method

Participants

Children were recruited for this study in three cohorts across three successive school years. Children were recruited from 43 different preschools that were either part of the local school district's Title I preschool program ($n = 21$) or were private fee-for-service preschools serving the same community ($n = 22$). Children were recruited from 30 of these preschools in Year 1 (14 Title I, 16 private), 36 of these preschools in Year 2 (21 Title I, 15 private), and 31 of the preschools in Year 3 (18 Title I, 13 private).

The larger project for this study focused on children with higher than average risk for later reading difficulties. Because of the admissions requirements, all children from the Title I preschools whose parents returned consents were eligible for inclusion in the study if they did not meet any of the exclusionary criteria. In contrast, the private preschools had an open enrollment policy, and comparison of children across type of center in Year 1 indicated that children from the private centers had substantially higher scores at preschool entry than children from the Title I preschools. Therefore, in Years 2 and 3, children from the private preschool were screened using the 25-item Revised Get Ready to Read! screening tool (R-GRTR; Lonigan & Wilson, 2008) and were excluded if their scores were 21 or higher (> ~80th percentile). Across both types of centers, children were excluded if there was evidence of severe developmental, neurological, or sensory impairment, based on observation of the child or teacher report.

A total of 1,082 children (611 from Title I preschools) were deemed eligible for the project and completed assessments at the initial assessment. These children ranged in age from 48 to 63 months ($M = 55.0$, $SD = 3.70$), and 55% of them were male. There were more boys than girls in the Title I preschool sample (60%) but not in the private preschool sample (48%), $\chi^2 = 15.45$, $df = 1$, $p < .001$) The sample was racially and ethnically diverse (i.e., 47.8% white, 41.8% black/African American, 3.4% bi-/multi-racial, 2.4% Asian, .3% Native American, 1.3% unknown, and 3.0% Latino/Hispanic). More of the children in the private preschools were white (74%) than were children in the Title I preschools (28%), $\chi^2 = 231.50$, $df = 1$, $p < .001$; conversely, more of the children in the Title I preschools were black/African American (61%) than were children in the private preschools (17%), $\chi^2 = 207.13$, $df = 1$, $p < .001$.

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Measures

Children completed multiple measures of overall cognitive ability, oral language, phonological awareness, and print knowledge. Additionally, children were administered a measure of EF, and children's classroom teachers completed a behavior-rating measure.

Cognitive abilities measures—The Block Design and Matrix Reasoning subtests of the Wechsler Preschool and Primary Scales of Intelligence, 3rd Edition (WPPSI; Weschler, 2002) were administered to children to obtain a measure of general cognitive abilities. On the Block Design subtest, children are required to replicate increasingly complex geometric patterns from either a picture or a model, with a limited amount of time for each pattern to be replicated. On the Matrix Reasoning subtest, children are required to identify the one stimulus, out of four, that completes the two-by-two matrix of stimuli. Both subtests have good reliability, and they have significant correlations both with the WPPSI Performance and Full Scale IQ scores.

Oral language measures—Receptive and expressive language measures from both the *Preschool Comprehensive Test of Phonological and Print Processing* (PCTOPPP; Lonigan, Wagner, Torgesen, & Rashotte, 2002) and the Clinical Evaluation of Language Fundamentals--*Preschool* (CELF-P; Wiig, Secord, & Semel, 1992) were administered to children. The PCTOPPP was the development version of the *Test of Preschool Early Literacy* (TOPEL; Lonigan, Wagner, Torgesen, & Rashotte, 2007), which is a nationally normed and standardized measure. The PCTOPPP includes a Receptive Vocabulary subtest and a Definitional Vocabulary subtest. On the Receptive Vocabulary subtest, children must select the one picture out of four that corresponds to a word spoken by the examiner. On the Definitional Vocabulary subtest, children must provide the name of a picture and then give a brief definition of the word (e.g., if shown a picture of a shovel, the child must say "shovel" and answer the question, "what is it used for?"). Both subtests have high internal consistency reliability (αs > .91) and correlate with other measures of oral language (e.g., *r*s = .47–.62).

Children completed five of the six subtests from the CELF-P. These subtests were used to create Receptive Language (i.e., Linguistic Concepts, Basic Concepts, and Sentence Structure subtests) and Expressive Language (Formulating Labels, and Word Structure subtests) subscale scores. Scores for the Recalling Sentences in Context subscale were estimated from the scale scores on other measures such that the standard Expressive Language score could be calculated. All subtests include basal and ceiling rules that were followed. Internal consistency reliability for children in this sample's age span range from .81 to .96 for the composite scores, and scales have good evidence of concurrent validity with other norm-referenced measures (Wiig et al., 1992).

Phonological awareness measures—The two phonological awareness subtests of the PCTOPPP were used in this study. The 21-item Blending subtest requires children to indicate the word that results from combining sounds spoken by the examiner. The subtest includes nine multiple-choice items and 12 free-response items that require blending words (e.g., "star" + "fish" = "starfish"), syllables (e.g., "spy" + "der" = "spider"), onset-rime (e.g., /h/ + "at" = "hat), or phonemes (e.g., /h/ + /ae/ + /t/ = "hat"). The 18-item Elision

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subtest requires children to indicate the word that results when a sound is removed from a word spoken by the examiner. The subtest includes nine multiple-choice and nine free-response items that require elision at the word (e.g., “seesaw” without “see” = “saw”), syllable (e.g., “dresser” without “er” = “dress”), or phoneme (e.g., “lamp” without /p/ = “lamb”) level. Both subtests have good internal consistency (i.e., αs = .85–.87 for this age range) and adequate validity correlations (i.e., *r*s > .53).

Print knowledge measures—Children completed the Print Knowledge subtest of the PCTOPPP, which is a 36-item measure that includes both multiple-choice and free-response items that assess children’s understanding of what letters are (e.g., versus pictures or non-letter symbols), that print can be read, and both letter names and letter sounds. Internal consistency reliability of the subtest is high (αs = .94–.95 for this age group), and scores on the subtest are highly correlated with other measures of print knowledge and word decoding (*r*s = .40–.75). Children also completed the Alphabet, Conventions, and Meaning subtests of the *Test of Early Reading Ability, 3rd Edition* (TERA; Reid, Hresko, Hammill, 2001). The Alphabet subtest of the TERA measures children’s knowledge of the alphabet, sound-letter correspondence, and rudimentary word-decoding skills. The Conventions subtest of the TERA measures children’s knowledge of concepts about print (i.e., directionality of text, parts of books, basic punctuation). The Meaning subtest of the TERA measures children’s beginning understanding of print (e.g., environmental print, signs, simple words). The internal consistency reliabilities of the three TERA subtests are high (αs > .95), and they have good test-retest reliabilities (*r*s > .92).

Self-regulation measures—Children’s EF was assessed using the HTKS (McClelland et al., 2007; Ponitz et al., 2008). On this task, children must do the opposite of a command spoken by the examiner (e.g., if told “touch your head,” the child must touch her toes). After practice trials to explain the task to the child, 10 initial trials are completed with two commands (i.e., “touch your head,” “touch your toes”) alternating in a fixed order. In a second set of 10 trials, two new commands are added (i.e., “touch your knees,” “touch your shoulders” [correct responses are touching shoulders for “knees” command and touching knees for “shoulder” command]). Each trial was scored using a three-point scale. Correct responses received a score of 2. Self-corrects (i.e., child initially reached for the command location [e.g., head for “touch your head”] but ended up with correct response) received a score of 1, and incorrect responses received a score of 0. Consequently, the maximum possible score was 40. Internal consistency for the HTKS is high (α = .93 in this sample). Scores on the HTKS correlate with other direct measures of self-regulation (e.g., Allan & Lonigan, 2011).

Children’s classroom teachers completed the *Connors’ Teacher Rating Scale* (CTRS; Connors, 1989). In this study, a 44-item hybrid version of the CTRS was used. The hybrid version included the 28 items from the CTRS-Restandardized and the non-overlapping items from the original CTRS-Short Form (see Gerhardstein, Lonigan, Cukrowicz, & McGuffey, 2003 for more detail on this version). This version of the CTRS yields three factors when completed on preschool children: Inattention, Hyperactivity/Impulsivity, and Oppositional Behavior. Teachers rate each item on the CTRS using a four-point scale that ranges from 0

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(not at all) to 3 (frequently). Three items on the CTRS that are related to academic performance ("poor in spelling," "not reading up to par," "poor in arithmetic") do not load on any of the three factors with preschool children and were not included in any analyses. Only scores from the Inattention subscale (i.e., unit sum of all items from the Inattention factor) were used in this study. Complete CTRS ratings were obtained from teachers for 934 children (86% of sample).

Procedure

Prior to completion of any assessments, written informed consent/permission was obtained from children's parents or guardians. Approximately 60% of eligible children were consented. All assessments of children's language and literacy skills were administered to children three times during the preschool year (fall, winter, spring). Children completed the two subtests of the WPPSI in the fall only, and they completed the HTKS task in the fall and spring (only fall results are reported herein). Assessments were administered to children in a quiet area in children's preschools by research assistants who had received training in the administration of these assessment measures and who had demonstrated mastery of the tests in one-on-one test-out sessions with the project's assessment coordinator. Assessments within each time period were completed over three to four 20- to 30-minute sessions within a two-week period. During testing, children were given breaks if requested or if the examiner noticed fatigue or distraction. Order of test administration varied across children. Near the end of the fall assessment period, children's classroom teachers were asked to complete the behavior ratings of the children.

Observations of all classrooms included in this project were conducted three times each year using the Teacher Behavior Rating Scale (Landry, Crawford, Gunnewig, & Swank, 2000). Details of these observations are reported in the supplemental on-line materials (SOM). Results of these observations (see Table S1) indicated that there was a significantly higher frequency and/or quality of instructional activities occurring in the Title I preschools than in the private preschools.

Results

Descriptive Statistics

For descriptive purposes, standard scores for the subtests of the PCTOPPP were computed by re-ordering items into that of the TOPEL, applying TOPEL discontinuation rules, and using the tabled values for the TOPEL. As a group, children in the study scored in the average to low-average range on the measures of cognitive, language, and literacy abilities (see Table 1). Comparisons between children from the different types of preschools were made using mixed models that took into account the fact that children were nested within schools within years. As seen in Table 1, children in the Title I preschools were slightly older than children in the private preschools, and children in the Title I preschools scored significantly lower than did children in the private preschools on all standardized measures of cognitive, language, and literacy skills. Effect sizes for differences between children in the two types of preschools ranged from .36 to .94 based on Hedges g. Children in the Title I preschools also demonstrated lower levels of EF as measured by the HTKS and higher levels

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of teacher-rated inattention than did children in the private preschools. Examination of initial scores on all measures between children in the different cohorts using mixed models revealed just two significant differences (all other *p*s > .29). On the Block Design subtest of the WPPSI (scaled score), children in Cohort 2 ($M = 7.46$; $SD = 3.37$; $p < .001$) and Cohort 3 ($M = 7.76$; $SD = 2.93$; $p < .001$) had lower scores than did children in Cohort 1 ($M = 9.13$: $SD = 3.17$) but did not differ from each other ($p = .57$). On the HTKS (raw score), children in Cohort 3 ($M = 9.00$; $SD = 10.50$; $p = .001$) had lower scores than did children in Cohort 1 ($M = 13.39$; $SD = 12.22$) but not Cohort 2 ($M = 11.10$; $SD = 10.99$; $p = .09$), and Cohort 2 did not differ from Cohort 1 ($p = .10$).

Growth Models of Early Literacy Skills

Analyses of growth in children's language and literacy skills were conducted in Mplus 7.1 (Muthén & Muthén, 1998-2012) using raw scores on all measures (see Table S2 in SOM). Of the 1,082 children in the sample, 1014 (94% of sample) had test-score data for all three assessment periods. Of the 68 children with missing data, 16 (1.5% of sample) had data from the fall assessment period only, 47 (4% of sample) had data from the fall and winter assessment periods only, and 5 (.05% of sample) had data from the fall and spring assessment periods only. In all analyses, full information maximum likelihood estimation was used to account for missing data. The Yuan-Bentler scaled chi-square (Y-B χ^2) was used to account for nonnormality and nonindependence and to make adjustments to correct standard errors (Yuan & Bentler, 2000). The Y-B χ^2 and several fit indices were used to assess overall model fit. A nonsignificant Y-B χ^2 indicates that the overall test of model fit was acceptable. A comparative fit index (CFI) greater than or equal to .95 and root mean square error of approximation (RMSEA) below .08 also indicate acceptable overall model fit (e.g., Hu & Bentler, 1999). In all models, a sandwich estimator was used to account for the clustering of children in school and year.

In all models, the intercept was fixed at the initial (fall) assessment. Fit statistics and unstandardized parameters from the unconditional growth models are shown in Table 2 for all outcomes. With the exception of the model for the PCTOPPP Print Knowledge subtest, all models had adequate to excellent fits. Most models yielded a non-significant Y-B χ^2. All models had CFI of .98 or higher, and all but the model for PCTOPPP Print Knowledge had RMSEA of .08 or lower. A non-significant negative residual in the model for the PCTOPPP Print Knowledge subtest had to be fixed to 0, which reduced the absolute fit of the model.

Intercept parameters for all outcomes were significantly different from 0, and all intercept variances were statistically significant, indicating variability across children in scores at the start of the preschool year. Slope parameters for all outcomes were statistically significant, indicating that children's scores increased over the preschool year on all language and literacy variables. Slope variance for all outcomes except PCTOPPP Definitional Vocabulary, CELF Receptive Language, and TERA Meaning were statistically significant or marginally significant. When covariates were included, all slope variances except those for PCTOPPP Definitional Vocabulary and TERA Meaning were statistically significant or marginally significant, indicating that there was variability across children in rates of growth across the preschool year.

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Predictors of Initial Status and Growth in Early Literacy Skills

Zero-order relations—The next set of analyses was focused on the relations between the four predictor variables (i.e., age, cognitive ability, EF, inattention) and both the intercepts and slopes in the models. All predictor variables were grand-mean-centered prior to analyses. As seen in Table 3, six of 10 correlations between slope and intercept were statistically significant and negative. Scores for these measures grew slower over the course of the preschool year for children who started with higher scores than they did for children who started with lower scores. Intercepts and slopes were not significantly correlated for the other four measures.

All predictor variables were significantly correlated with model intercepts (see Table 3). Children with higher levels of cognitive ability, higher EF, and lower levels of inattention started the preschool year with higher scores on all of the measures. Children's ages were also significantly correlated with model intercepts. For all measures other than CELF Receptive and Expressive Language, older children started the preschool year with higher scores. For the two CELF outcomes, younger children were slightly more likely to have higher scores at the start of the preschool year than were older children.

There were fewer significant correlations between the predictors and slopes in the models (see Table 3), and the direction of the correlation varied by the outcome. Older children grew faster on the TERA Alphabet and Conventions subtests than did younger children, but younger children grew faster on the PCTOPPP Definitional Vocabulary and Print Knowledge subtests than did older children. For PCTOPPP Receptive and Definitional Vocabulary, children with lower cognitive ability, lower levels of EF, and higher levels of teacher-rated inattention grew at a faster rate over the preschool year than did children with higher cognitive ability, higher levels of EF, and lower levels of teacher-rated inattention. For TERA Alphabet and Conventions, children with higher cognitive ability, higher levels of EF, and lower levels of teacher-rated inattention grew at a faster rate during the preschool year than did children with lower cognitive ability, lower levels of EF, and higher levels of teacher-rated inattention. For CELF Receptive Language and PCTOPPP Print Knowledge, children with lower cognitive ability and higher levels of EF grew at a faster rate during the preschool year than did children with higher cognitive ability and lower levels of EF. Finally for CELF Expressive Language and PCTOPPP Elision, children with higher levels of teacher-rated inattention grew at a slower rate than did children with lower levels of teacher-rated inattention.

Multivariate relations—To examine the unique effects of the predictor variables on children's initial status and growth across the preschool year, structural models in which the intercept and slope were simultaneously regressed on the four predictor variables and slope was regressed on intercept were examined. The unique contributions of the four predictor variables to each of the outcomes are shown in Table 4 for language outcomes and Table 5 for code-related outcomes. Standardized parameters are shown in Tables 4 and 5 to allow comparison of the relative contributions of variables (i.e., comparisons in standard deviation units). Unstandardized parameter values are shown in Tables S3 and S4 in the SOM.

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For language outcomes, children's cognitive ability, HTKS scores and teacher-rated inattention were consistently and uniquely related to intercepts. Children with higher cognitive ability, higher EF, and less inattention started the preschool year with higher language skills on all four measures. Older children started the preschool year with lower language skills as measured by the CELF and slightly higher language skills as measured by the PCTOPPP. Teacher-rated inattention was significantly or marginally and uniquely associated with all slopes except PCTOPPP Receptive Vocabulary. Children rated as more inattentive by their teachers had slower growth on three of four language measures than did children rated as less inattentive by their teachers, and children who started the preschool year with higher levels of vocabulary grew less than did children who started the preschool year with lower levels of vocabulary.

For code-related outcomes, children's cognitive ability, HTKS scores, and teacher-rated inattention were consistently and uniquely related to intercepts. Children with higher cognitive ability, higher EF, and less inattention started the preschool year with higher phonological awareness and print knowledge. Older children scored higher than did younger children at the start of the preschool year on the PCTOPPP Print Knowledge and TERA Alphabet subtests. Teacher-rated inattention was significantly or marginally and uniquely related to growth on all phonological awareness and print knowledge outcomes. Additionally, both HTKS scores and children's cognitive abilities were significantly and uniquely associated with growth on PCTOPPP Elision and TERA Alphabet subtests. Scores on all code-related measures grew slower for children with higher levels of teacher-rated inattention than they did for children with lower levels of teacher-rated inattention, and growth for elision and alphabet skills was faster for children with higher cognitive ability and higher EF.

Sensitivity analyses—Between 0 and 22% of the sample scored within a few points of the ceiling on the measures at the end-of-year assessment, depending on the outcome measure. To evaluate the possibility that the pattern of relations may have been affected by ceiling effects on some measures, all models were re-evaluated treating the outcomes as censored variables. Results of these analyses are shown in Tables S5 and S6 in the SOM. Values for regression parameters were almost identical to those reported in Tables 4 and 5, indicating that the pattern of results was not the result of ceiling effects. Because of the possibility that some of the reported effects were due to classroom-level differences instead of child-level differences, all models also were re-evaluated after classroom-mean-centering all variables (i.e., a fixed-effects approach). Results of these analyses are shown in Table S7 and S8 in the SOM. Again, values for regression parameters were almost identical to those reported in Tables 4 and 5, indicating that the pattern of results was not the result of classroom-level effects. Finally, to rule out the possibility that some of the obtained effects were the result of SES-related variables or other child variables (i.e., sex, race) that influenced self-regulation and early literacy skills similarly, analyses were conducted using information that was available on about 70% of children's families (i.e., income, parental education, single-parent household, number of children in home). Some of these variables were uniquely associated with children's initial early literacy skills, but, except for TERA alphabet knowledge, none was associated with growth in early literacy skills. Controlling for

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these variables did not appreciably affect the predictive relations reported in Tables 4 and 5 (see Appendix S4 in SOM).

Effect of Instruction on Predictive Relations

To evaluate the degree to which the influence of the predictor variables on language and code-related skills across the preschool year was affected by differences in amounts of instructional activities in the two types of preschools, analyses using multi-sample models were conducted. The parameters for the four predictor variables on slope and intercept as well as the parameter for the intercept predicting slope were constrained to equality across type of preschool (i.e., Title I preschools vs. private preschools), and the fits of these models were compared to models without these constraints. Results of these analyses revealed no differences for all outcomes except the PCTOPPP Definitional Vocabulary (ΔY-B χ^2 = 27.35, $df = 9$, $p = .001$) and TERA Meaning (ΔY-B χ^2 = 21.79, $df = 9$, $p = .01$) subtests. For PCTOPPP Definitional Vocabulary, age was more strongly related to the intercept in Title I preschools (.19, $p < .001$) than it was in private preschools (.02, $p = .64$). Releasing this one constraint yielded a model that fit as well as the fully unconstrained model, ΔY-B χ^2 = 11.88, $df = 8$, $p = .16$. For TERA Meaning, age was more strongly related to the slope in Title I preschools (.68, $p = .06$) than it was in private preschools (−.37, $p = .23$). Releasing this one constraint yielded a model that fit as well as the fully unconstrained model, ΔY-B χ^2 = 11.52, $df = 8$, $p = .17$.

Discussion

In this study, the unique associations between two aspects of self-regulation, EF and attention, and growth in early literacy skills over the preschool year were examined using latent-growth-curve analysis. In general, both teacher-rated inattention and a direct measure of EF were consistently and uniquely related to initial skill levels, but only teacher-rated inattention consistently and uniquely predicted growth in skills. For most skills, children who started preschool with more of a skill gained less of that skill over the course of the preschool year. Because children with higher EF tended to start the preschool year with higher skill levels, the association between EF and growth was primarily indirect and negative. Overall, these findings demonstrate that inattention as rated by teachers and EF as measured directly reflect distinct self-regulatory constructs that are differentially related to the development of early literacy skills. Contrary to our expectations, there was no evidence of consistent differences in the association between self-regulation and different types of early literacy skills, and across outcomes, there was no evidence that the amount or quality of instruction in classrooms influenced the associations of self-regulation with early literacy skills.

Self-Regulation and Early Literacy Skill Development

The results of this study indicated that both inattention and EF were consistently and uniquely related to initial status for all early literacy skills. These results are in line with prior research demonstrating that self-regulatory processes are strong correlates of early academic skills (e.g., Blair & Razza, 2007; Fuhs et al., 2015; Walcott et al., 2010). In contrast to the associations with initial skill level, only teacher-rated inattention consistently

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and uniquely predicted growth in language and code-related skills. EF was only uniquely associated with growth for PCTOPPP Elision and TERA Alphabet Knowledge. This was the pattern observed both in the multivariate prediction models and in the univariate prediction models (i.e., zero-order correlations); therefore, the limited number of significant relations between EF and growth in early literacy skills was not the result of substantial overlapping variance of EF and inattention. Moreover, when corrections for multiple significance tests were applied, the two unique associations between EF and growth were no longer statistically significant.

The absence of unique predictive relations between EF and growth in children's early literacy skills appears contrary to the results of prior studies. Multiple prior studies have reported that direct assessments of EF are associated with children's scores on academic outcomes measured at some later point in time, controlling for assessment of the same or related skill measured at an earlier point in time (e.g., Blair & Razza, 2007; Fuhs et al., 2014, 2015; McClelland et al., 2007; Ponitz et al., 2009). However, these prior studies examined the relation between EF and scores on later skill measures conditionalized on earlier scores on the same measure. As noted previously, such regression-based residualized "growth" analyses may or may not accurately represent growth. Indeed, in the data from this study, autoregressive models (i.e., the effects of predictors on spring scores conditionalized on fall scores) also revealed statistically significant associations between EF and spring outcomes (see Tables S9 and S10 in SOM). For many of the outcomes examined in this study, rate of growth was dependent on initial level, which is the circumstance under which autoregressive models would be least expected to accurately represent growth. That is, because autoregressive models provide an answer to the question of what change across individuals would have been if all individuals started out the same at the initial time point (Rogosa et al., 1982), the residual is unlikely to approximate change when individuals are different at the initial time point and rates of growth are associated with initial scores. At least two prior studies that examined the relations between EF and later skills using growth modeling also reported that EF was not related to growth in reading-related skills (Blair et al., 2015; McClelland & Wanless, 2012).

In contrast to results for EF, teacher-rated inattention was more frequently associated with growth in early literacy skills (i.e., three of four language measures, five of six code-related measures). The pattern of differences for the direct measure of EF and the teacher reports of inattention indicates that these measures capture distinct manifestations of self-regulatory skills. Based on a review of performance-based and ratings-based measures of EF, in which only modest associations between these methods of measurement were reported, Toplak et al. (2013) suggested that direct measures and informant ratings assess different levels of self-regulatory processes. They argued that although direct measures may assess specific cognitive and behavioral processes that are important for self-regulation, informant ratings may provide a more global measure of how individuals use these processes in tandem to produce goal-oriented behavior in everyday activities.

Fuhs et al. (2015) reported that both direct measures and teacher-ratings of EF were unique predictors of academic skills, and they reported that teacher-ratings generally accounted for a greater amount of variance in early academic skills than did direct measures of EF. As

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discussed by Fuhs et al., teacher-ratings of self-regulatory behaviors seem to be an ecologically valid form of assessment that provide important information regarding children's ability to acquire early academic skills. In a recent study of preschoolers, Allan et al. (2015) reported that both a latent variable representing direct measures of EF (inhibitory control and working memory) and a latent variable representing direct measures of attention (i.e., omission errors on continuous performance tasks) uniquely predicted teachers' ratings of children's inattention, suggesting that what teachers rate when asked to rate children's attention may be a broader construct of global self-regulation. It also may be that teachers, in part, attribute children's difficulties with academic skills to problems of attention, leading directly to the linkage between teachers' ratings and children's academic skill.

In this study, both EF and teacher-rated attention were uniquely associated with initial skill levels. Children with more EF as measured by the HTKS and children with fewer teacher-rated attention problems had higher initial scores on all measures of early literacy skills than did children with lower HTKS scores and more teacher-rated inattention. For almost all measured early literacy outcomes, the amount of skill with which children started the preschool year was inversely related to growth across the preschool year. Consequently, one association between growth of early literacy skills for both EF and attention was indirect and negative: Children with higher levels of self-regulation had higher skills at the start of their preschool year but grew less in those skills across the preschool year. Such findings may reflect children's experiences before they enter preschool. That is, children exposed to higher quality learning environments prior to preschool entry may have both higher self-regulation and higher early literacy skills at the start of preschool than do children who have not had such exposure. Some children who initially have lower self-regulation and lower early literacy skills may gain more of both types of skills over the preschool period because these preschool experiences may be these children's first sustained exposure to environments and instructional routines that foster development of these skills. These children's low initial scores reflect lower quality early environments--perhaps associated with poverty (e.g., Blair & Raver, 2012)--not developmental constraints inherent to the individual, and once these children are exposed to environments supportive of these skills, their skills develop. In contrast, some children who initially have higher self-regulation and early literacy skills do not gain as much of these skills because their preschool experiences do not represent a substantial change in the quality of their environments.

In this study, the effects of self-regulation on children's early literacy skills were examined in the context of children's general cognitive abilities. The pattern of predictive results for children's cognitive abilities was similar to that for EF. Children with higher general cognitive abilities had higher initial language and early literacy skills, but general cognitive ability was only uniquely associated with growth in elision as measured by the PCTOPPP and alphabet knowledge as measured by the TERA. Although these results indicate a limited role of children's general cognitive abilities on the rate at which their language and early literacy skills develop, the inclusion of general cognitive abilities in the models rules out the possibility that the observed relations between self-regulation and both initial scores and growth in early academic skills are the result of overlap between measures of self-regulation and children's overall cognitive capacities.

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Self-Regulation and Growth in Different Types of Early Literacy Skills

The results of this study were not consistent with the expectation that self-regulation would be more associated with growth in early literacy skills that involved more than knowledge access (i.e., syntax, phonological awareness) than with early skills that require primarily knowledge access (i.e., vocabulary, letter knowledge). HTKS scores were uniquely associated with growth on just two code-related measures and none of the language measures. Although one of these, PCTOPPP Elision, is a complex task requiring memory, inhibition, and effortful processing, fitting the definition of the type of task Blair et al. (2015) suggested should be more associated with self-regulation, the other, TERA Alphabet, is a task that requires simple recall of letter names and letter sounds, fitting the definition of the type of task Blair et al. suggested should not be associated with self-regulation. In general, self-regulation, as indexed by teacher-rated inattention, appeared to be more related to all types of code-related skills than it was to language skills. In part, this pattern may have been due to the more limited variability among children in rates of growth for the language skills relative to the code-related skills. Within language, inattention was significantly related to growth for both a measure of vocabulary and a measure including syntax. Within code-related skills, inattention was significantly associated with growth in phonological awareness measures and print knowledge measures, including those requiring simple knowledge access and those involving both access and integration. The reasons for differences in findings for code-related skills between this study and other studies that have used a growth modeling approach (e.g., Blair et al., 2015; McClelland & Wanless, 2012) are not clear. Perhaps before acquiring the alphabetic principle (Ehri, 2005) processing of code-related information is more effortful than after acquiring the insight that letters correspond to the sounds in words.

Instructional Influences on the Effects of Self-Regulation

The result of this study revealed no effect of the preschool environments to which the children were exposed on the relations between self-regulation and early academic skills. Despite the differences in the amount and quality of instruction between Title I and private preschools, there were no differences in the relations between self-regulation and early academic skills across type of preschool. These results suggest that the relations between self-regulation and the development of early academic skills are not simply a function of self-regulation’s effect on children’s ability to benefit from instruction. Alternatively, it is possible that the magnitude of differences in the amount and quality of instruction between the types of preschool, although statistically detectible, was not sufficiently large to yield moderation effects.

Limitations and Future Directions

Although this study has several strengths in that the association between self-regulation and early literacy skill development was examined using two important components of self-regulation, multiple age-appropriate measures of early literacy skills, a large sample, and an analytic approach that addressed the shortcomings of other commonly used approaches for analyzing longitudinal data, it is not without limitations. First, although the self-regulation measures used in this study were those that are frequently used in studies of young

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children's self-regulation, we had only a single measure of each self-regulation construct. Future studies using multiple measures to index each construct will allow more clear specification of relations for different components of self-regulation. Second, although the HTKS is purported to measure several aspects of EF simultaneously, it is possible that other direct measures may assess different aspects of EF that have stronger associations with growth in early academic skill (e.g., working memory), and future studies should explore this possibility. Third, because the larger project for this study was focused on children at risk for later reading difficulties, children's math skills were not measured in a way that allowed analyses parallel to those of literacy skills; consequently, we were unable to compare growth across preschool in components of early literacy and early math skills, which will be an important question to be answered in future studies. Fourth, the tests of instructional influences on the relations between self-regulation and growth in early literacy skills was indirect--based on differences in instructional frequency and quality in two type of preschools--and may have been influenced by unmeasured differences between the types of preschools; future studies should evaluate potential influences of self-regulation on skill acquisition from instruction more directly (e.g., randomized intervention studies) or controlling for additional factors. Finally, the children in this study were selected to represent children with higher than average risk of reading difficulties. Although there was substantial variability both for self-regulation and early academic skills, the sample was not representative of the full spectrum of the preschool-age population. Future studies should address the relation between self-regulation and growth in early academic skills among children who represent those with lower risk or among children representative of both higher and lower risk.

Summary and Conclusions

In this study, both teachers' ratings of inattention and a direct-measure of EF were uniquely associated with children's language and code-related skills at the start of the preschool year; however, only teachers' ratings consistently predicted growth in these skills over the preschool year. Type of preschool did not affect the relations between self-regulation and children's early academic skills--in terms of initial skill levels or growth in these skills, despite differences in the frequency and quality of instruction between different types of preschools. Results of this study--particularly the absence of a robust relation between EF and growth in early literacy skills--raise questions concerning the degree to which some aspects of self-regulation, like EF, represent important contributors to the development of early literacy skills versus representing skills that co-develop with early literacy skills. The results of this study also highlight the significant relations between teachers' ratings of attention and the acquisition of early literacy skills--independent of EF. Additional research is needed to identify the dimensions of children's behaviors that teachers are rating to better understand the linkages between attentional components of self-regulation and the development of early literacy skills. Such knowledge may help guide efforts to identify and intervene with children at-risk for educational difficulties.

Supplementary Material

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Acknowledgments

This research was supported by grants from the Eunice Kennedy Schriver National Institute of Child Health and Human Development (HD052120, HD060292) and the Institute of Education Sciences, United States Department of Education (R305B090021). The views expressed herein are those of the authors and have neither been reviewed nor approved by the granting agency.

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Table 1

Descriptive statistics for overall sample and children attending Title I preschools versus private preschools on standardized measures of cognitive, language, and literacy measures

	Overall		Public Pre-K Centers		Private Pre-K Centers		
Measure/Outcome	**Mean**	**(*SD*)**	**Mean**	**(*SD*)**	**Mean**	**(*SD*)**	**Effect Size**
Age (months)	55.01	(3.72)	55.33	(3.75)	54.60	(3.65)	−.20**
WPPSI Block Design	8.06	(3.25)	7.53	(3.22)	8.76	(3.16)	.39***
WPPSI Matrix Reasoning	8.48	(3.40)	7.96	(3.41)	9.16	(3.28)	.36***
TOPEL Definitional Vocabulary	94.70	(13.39)	90.37	(13.48)	100.30	(11.01)	.80***
TOPEL Phonological Awareness	93.11	(14.25)	89.62	(13.63)	97.61	(13.77)	.58***
TOPEL Print Knowledge	97.41	(14.77)	94.28	(13.82)	101.40	(14.98)	.50***
CELF-P Receptive Language	90.22	(18.23)	83.60	(17.25)	98.80	(15.73)	.92***
CELF-P Expressive Language	89.52	(15.24)	83.85	(14.57)	96.87	(12.76)	.94***
TERA Alphabet	8.58	(2.96)	7.98	(2.79)	9.36	(2.99)	.48***
TERA Conventions	8.21	(2.11)	7.72	(2.00)	8.84	(2.09)	.55***
TERA Meaning	8.43	(2.74)	7.82	(2.71)	9.23	(2.57)	.53***
Head-Toes-Knees-Shoulders	11.12	(11.35)	9.35	(10.48)	13.43	(12.02)	.37***
CTRS - Inattention Subscale[1]	0.78	(0.70)	0.90	(0.73)	0.59	(0.61)	−.45***

Notes. $N = 1{,}082$ ([1] $N = 934$); WPPSI = Wechsler Preschool and Primary Scales of Intelligence; TOPEL = Test of Preschool Early Literacy; CELF-P = Clinical Evaluation of Language Fundamentals-Preschool; TERA = Test of Early Reading Achievement; CTRS = Connors Teacher Rating Scale.

** $p < .01$;

*** $p < .001$.

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Table 2

Fit and model statistics for unconditional latent growth curve models of children's language and literacy skills assessed at three time points across the preschool year

Outcome Measure	Y-B χ^2	CFI	TLI	RMSEA [90% CI]	Intercept	Intercept Variance	Slope	Slope Variance
PCTOPPP Receptive Vocabulary	**1.56**^{ns}	**1.00**	**1.00**	**.02 [.00–.09]**	**29.03*****	**18.65*****	**2.01*****	**1.52****
PCTOPPP Definitional Vocabulary	7.56**	1.00	.99	.08 [.03–.13]	47.89***	135.51***	4.52***	1.91^{ns}
CELF Receptive Language	1.19^{ns}	1.00	1.00	.01 [.00–.08]	24.44***	65.32***	1.32***	2.48^{ns}
CELF Expressive Language	.24^{ns}	1.00	1.00	.00 [.00–.06]	24.54***	45.88***	1.26***	1.93^{+}
PCTOPPP Elision	1.98^{ns}	1.00	.99	.03 [.00–.09]	8.64***	10.59***	1.46***	1.56***
PCTOPPP Blending	3.39^{ns}	1.00	.99	.05 [.00–.11]	13.21***	9.51***	1.39***	1.10*
PCTOPPP Print Knowledge	29.59***	.98	.97	.11 [.08–.15]	18.41***	86.28***	3.87***	9.36***
TERA Alphabet	.33^{ns}	1.00	1.00	.00 [.00–.07]	5.34***	21.30***	2.03***	3.57***
TERA Conventions	.68^{ns}	1.00	1.00	.00 [.00–.08]	3.06***	3.70***	1.16***	0.40^{+}
TERA Meaning	.002^{ns}	1.00	1.00	.00 [.00–.00]	5.99***	4.43***	0.62***	0.16^{ns}

Notes. PCTOPPP = Preschool Comprehensive Test of Phonological and Print Processing; CELF = Clinical Evaluation of Language Fundamentals; TERA = Test of Early Reading Achievement; Y-B χ^2 = Yuan-Bentler chi-square; CFI = Comparative Fit Index; TLI = Tucker-Lewis Index; CI = Confidence Interval.

^{ns} $p > .10$;

$^{+}$ $p < .10$;

* $p < .05$;

** $p < .01$;

*** $p < .001$.

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Table 3

Zero-order correlations of predictor variables with intercept and slope parameters for children's language and literacy skills

	Intercept	Chronological Age		WPPSI IQ		HTKS		CTRS Inattention	
Outcome	Slope	Intercept	Slope	Intercept	Slope	Intercept	Slope	Intercept	Slope
PCTOPP Receptive Vocabulary	−.45***	.17***	−.10	.56***	−.27*	.44***	−.26**	−.48***	.18**
PCTOPP Definitional Vocabulary	−.69***	.18***	−.23*	.52***	−.39*	.45***	−.41*	−.36***	.17+
CELF Receptive Language	−.20*	−.09*	.01	.55***	−.15**	.48***	−.17**	−.44***	−.04
CELF Expressive Language	.04	−.15***	.05	.42***	.12+	.38***	.11+	−.36***	−.20**
PCTOPP Elision	−.16*	.15***	−.01	.50***	.08	.50***	.04	−.43***	−.17**
PCTOPP Blending	−.15	.18***	−.08	.56***	−.11	.49***	−.12	−.40	−.08
PCTOPP Print Knowledge	−.40***	.22***	−.10**	.47***	−.15***	.38***	−.16***	−.50***	−.03
TERA Alphabet	−.02	.17***	.09*	.42***	.16***	.34***	.15***	−.38***	−.32***
TERA Conventions	.36	.17***	.16*	.53***	.32***	.44***	.24**	−.44***	−.41***
TERA Meaning	−.33*	.18***	−.06	.49***	−.20	.42***	−.16	−.44	.01

Notes. PCTOPPP = Preschool Comprehensive Test of Phonological and Print Processing; CELF = Clinical Evaluation of Language Fundamentals; TERA = Test of Early Reading Achievement; *r* slope-int = zero-order correlation between intercept and slope terms in models; WPPSI = Wechsler Preschool and Primary Scales of Intelligence; HTKS = Head-Toes-Knees-Shoulders Task; CTRS = Connors Teacher Rating Scale.

+ $p < .10$;

* $p < .05$;

** $p < .01$;

*** $p < .001$.

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Table 4

Standardized parameters for endogenous and exogenous predictors of intercepts and slopes in latent growth models for language outcomes

			Predictor Variables				
Outcome		**Intercept**	**CA**	**WPPSI IQ**	**HTKS**	**CTRS-I**	R^{2a}
PCTOPPP Receptive Vocabulary	Intercept	---	.05⁺	.37***b	.24***b	−.29***b	.46***
	Slope	−.42***	−.02	−.03	−.08	−.05	.21**
PCTOPPP Definitional Vocabulary	Intercept	---	.07**b	.33***b	.27***b	−.27***b	.42***
	Slope	−.67***	−.10	−.06	−.12	−.20**b	.52⁺
CELF Receptive Language	Intercept	---	−.22***b	.38***b	.34***b	−.25***b	.50***
	Slope	−.18	−.00	−.08	−.09	−.17⁺	.07⁺
CELF Expressive Language	Intercept	---	−.26***b	.29***b	.28***b	−.22***b	.34***
	Slope	−.09	−.01	.07	.08	−.18*b	.05⁺

Notes. PCTOPPP = Preschool Comprehensive Test of Phonological and Print Processing; CELF = Clinical Evaluation of Language Fundamentals; CA = chronological age (months); WPPSI = Wechsler Preschool and Primary Scales of Intelligence; HTKS = Head-Toes-Knees-Shoulders Task; CTRS-I = Connors Teacher Rating Scale, Inattention subscale.

[a]Because analyses were conducted controlling for clustering of children in schools, the values reflect the pseudo-R^2, a metric related to but not identical to R^2.

[b]Significance of predictor remained significant at $p < .05$ following Benjamini-Hochberg correction for multiple significance tests.

⁺ $p < .10$;

* $p < .05$;

** $p < .01$;

*** $p < .001$.

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Table 5

Standardized parameters for endogenous and exogenous predictors of intercepts and slopes in latent growth models for literacy outcomes

Outcome		Predictor Variables					
		Intercept	CA	WPPSI IQ	HTKS	CTRS-I	R^{2a}
PCTOPPP Elision	Intercept	---	.03	.30***b	.34***b	−.25***b	.43***
	Slope	−.41***	−.02	.15*b	.13*	−.26***b	.12**
PCTOPPP Blending	Intercept	---	.06	.39***b	.30***b	−.19***b	.45***
	Slope	−.14	−.05	−.07	−.06	−.18*b	.06
PCTOPPP Print Knowledge	Intercept	---	.12***b	.27***b	.18***b	−.35***b	.40***
	Slope	−.54***	−.01	.01	−.03	−.30***b	.23***
TERA Alphabet	Intercept	---	.08*b	.27***b	.18***b	−.24***b	.28***
	Slope	−.24***	.06	.10*	.10*	−.34***b	.15***
TERA Conventions	Intercept	---	.06	.35***b	.25***b	−.25***b	.41***
	Slope	.13	.08	.13	.06	−.28***b	.23+
TERA Meaning	Intercept	---	.07+	.31***b	.25***b	−.27***b	.38***
	Slope	−.36	.00	−.08	−.03	−.19+	.14

Notes. PCTOPPP = Preschool Comprehensive Test of Phonological and Print Processing; TERA = Test of Early Reading Achievement; CA = chronological age (months); WPPSI = Wechsler Preschool and Primary Scales of Intelligence; HTKS = Head-Toes-Knees-Shoulders Task; CTRS-I = Connors Teacher Rating Scale, Inattention subscale.

[a] Because analyses were conducted controlling for clustering of children in schools, the values reflect the pseudo-R^2, a metric related to but not identical to R^2.

[b] Significance of predictor remained significant at $p < .05$ following Benjamini-Hochberg correction for multiple significance tests.

+ $p < .10$;

* $p < .05$;

** $p < .01$;

*** $p < .001$.