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Preschool writing and premathematics predict Grade 3 achievement for low-income, ethnically diverse children

Louis Manfra^a, Christina Squires^a, Laura H. B. Dinehart^b, Charles Bleiker^b, Suzanne C. Hartman^c, and Adam Winsler^d

^aDepartment of Human Development & Family Science, University of Missouri, Columbia, Missouri, USA; ^bCollege of Education, Florida International University, Miami, Florida, USA; ^cDepartment of Learning Sciences and Human Development, West Virginia University, Morgantown, West Virginia, USA; ^dDepartment of Psychology, George Mason University, Fairfax, Virginia, USA

ABSTRACT

The present study was designed to explore the association between preschool academic skills and Grade 3 achievement among a sample of ethnically diverse children from low-income families. Data were collected from a sample of 1,442 low-income, ethnically diverse children in preschool and associated with Grade 3 achievement in reading and mathematics 4 years later. Mixed-effects modeling indicated that preschool skills significantly predicted Grade 3 achievement measures while controlling for various child-level factors and random school effects. While several preschool factors were predictive of Grade 3 achievement, writing/copying and counting/premathematics skills were consistently strong predictors of Grade 3 achievement across all measures and domains suggesting these are important foundational skills for academic success in midelementary school among low-income, ethnically diverse children. Findings also replicate studies demonstrating that writing plays an important role in learning and achievement. Findings have implications for early education policy and practice intended to support academic development among low-income, ethnically diverse children.

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Empirical studies have demonstrated that academic skills gained during the years prior to entering elementary school provide an important foundation for later academic achievement (e.g., Jordan, Kaplan, Ramineni, & Locuniak, 2009; La Paro & Pianta, 2000; Welsh, Nix, Blair, Bierman, & Nelson, 2010). Despite the expanse of this literature, not many studies exploring this association focus on ethnically diverse, multi-language learning, children living in poverty who face high risk for low academic success beginning in elementary school. Indeed, many of the samples recruited for these studies are limited to monolingual, English-speaking, White children from fairly stable families and do not include populations of children who are vulnerable for poor academic achievement (Hartman & Manfra, 2015). Further, few studies in this area include preschool early writing skills as a predictor that might influence long-term academic performance and achievement later during elementary school. Studies exploring early writing in preschool and kindergarten as a method for influencing learning and academic performance (e.g., Aram & Levin, 2004; Craig, 2006; Hall, Simpson, Guo, & Wang, 2015; Hall, Toland, Grisham-Brown, & Graham, 2014; Jones, 2015; Jones & Reutzell, 2015; Jones, Reutzell, & Fargo, 2010; Shatil, Share, & Levin, 2000) have demonstrated that early writing is a promising factor to explore further, particularly among vulnerable populations (Dinehart & Manfra, 2013).

Exploring the associations between school readiness skills, such as writing, premathematics skills, and preliteracy skills, acquired during preschool and long-term academic performance

among children vulnerable for low academic success who tend to be under-represented in this research is important for identifying the early skills that are important for later achievement of vulnerable populations and for improving early education programs and curricula. Generalizing findings from research conducted with one population to practice and policy of another population has been criticized as sub-optimal and problematic (Garcia Coll et al., 1996; Johnson, Jaeger, Randolph, Cauce, Ward, & NICHD ECCRN, 2003) and may contribute to lower success of education programs for some populations of children. As such, understanding how preschool skills relate to academic achievement in elementary school within various populations of children can help education and curricular experts and early education professionals develop more focused preschool programs designed to maximize vulnerable children's learning.

In the present study, a variety of early skills, including language, counting/premathematic, cognitive, writing, and fine motor manipulation, are correlated with Grade 3 performance on high-stakes standardized tests and classroom grades among low-income, ethnically diverse children. Preschool data were collected from predominantly Hispanic and Black children from low-income families in Miami-Dade, Florida, who received financial subsidies to attend an early education program. Four years later, when the children were in Grade 3, test scores, classroom grades, and other academic indicators were collected from the public school district and linked to children's skills at the end of preschool.

Association between early academic skills and later achievement

The association between early academic skills and academic achievement one or more years later has been explored in a wide variety of studies spanning a wide variety of countries and geographic areas, targeting a wide variety of time frames and age ranges, and including a wide variety of measured variables (Duncan et al., 2007; Grissmer et al., 2010; Jordan et al., 2009; Kern & Friendman, 2009; La Paro & Pianta, 2000; Pagani, Fitzpatrick, Archambault, & Janosz, 2010; Romano, Babchishin, Pagani, & Kohen, 2010; Welsh et al., 2010). In many of these studies, the focus tends to be on the impact of one or two early skills in a single domain and their association with later performance. For example, a number of researchers have explored the association between emergent literacy skills and later reading achievement in school (Bradley & Bryant, 1983; Bryant, MacLean, Bradley, & Crossland, 1990; Costa et al., 2013; Lonigan, Burgess, & Anthony, 2000; Wagner & Torgeson, 1987), emergent numeracy skills and later mathematical achievement in school (Geary, 2003; Geary, Hoard, & Hamson, 1999; Jordan, Kaplan, Nabors Oláh, & Locuniak, 2006; Manfra, Dinehart, & Sembiante, 2014; Östergren & Träff, 2013), and early writing skills and later letter and literacy achievement (Aram & Levin, 2004; Craig, 2006; Dinehart & Manfra, 2013; Hall et al., 2015; Hall et al., 2014; Jones & Reutzell, 2015; Jones et al., 2010; Shatil et al., 2000).

Other larger scale studies have included a variety of school readiness skills as predictors of later performance. In a comprehensive study, Duncan et al. (2007) used six secondary datasets to explore associations between early skills and later achievement across multiple domains. In an exploration of the association between early mathematics, reading, attention, and socio-emotional skills and later reading and mathematics achievement, results revealed that kindergarten mathematics skills were associated the strongest with later achievement for both mathematics and reading (including Grade 3 and later grade levels), followed by kindergarten reading skills and attention skills. Two subsequent studies using large, secondary datasets were designed to replicate and extend the findings from Duncan et al. Romano et al. (2010) also concluded that kindergarten mathematics, literacy, and attention skills predicted achievement in Grade 3, reporting that kindergarten receptive vocabulary skills were associated with maternal report of reading skills in Grade 3 and assessed mathematics skills in Grade 3. Kindergarten mathematics skills were also found to be associated with Grade 3 reading.

Pagani et al. (2010) also used secondary data to replicate the findings from Duncan et al. (2007) utilizing a population of French-speaking children from Quebec, Canada. Findings supported the association between kindergarten cognitive and attention skills and second-grade achievement, with kindergarten mathematics skills explaining the largest amount of variance in second-grade achievement, as was found in Duncan et al. and Romano et al. (2010). Further, the findings supported an extension of these findings to include a significant amount of independent variance explained by early fine motor skills. This variance, explained by fine motor skills, has generated attention from other researchers. For example, Grissmer et al. (2010) utilized three of the datasets used by Duncan et al. that

included measures of fine motor skills and found that measures of fine motor skills were also strongly associated with later achievement.

Similar findings were also reported by Dinehart and Manfra (2013) who explored the association between fine motor skills in preschool and academic achievement in second grade while controlling for reading and mathematics skills in preschool. These authors found that fine motor skills involving copying letters, numbers, and symbols were a stronger predictor of later achievement than fine motor skills involving manipulations of objects. Dinehart and Manfra suggested that this type of fine motor development may be foundational to subsequent learning by (a) enhancing internal representations letters, numbers, and symbols; (b) increasing self-regulatory skills used in academic learning; or (c) aiding in the acquisition of general writing skills, which are integral in the learning curricula of elementary school education.

Despite the robust and consistent findings among the large-scale studies exploring the relation between early skills and later achievement, the samples in many of these studies are limited to predominantly White children from middle socioeconomic status (SES) families (Duncan et al., 2007; Grissmer et al., 2010; Pagani et al., 2010; Romano et al., 2010). With the exception of the National Longitudinal Survey of Youth (NLSY) dataset, which consists of nearly half non-White participants, the other datasets utilized in these studies contain predominantly White participants from middle-SES families. Given the increased likelihood for children in poverty to be more at risk for poorer performance in elementary school (Arnold & Doctoroff, 2003; Duncan, Brooks-Gunn, & Klebanov, 1994; McLoyd, 1998) and subsequently lower high school graduation rates (Hernandez, 2011), researchers have called for more research to be conducted with racial and ethnic minority populations (Brooks-Gunn, 2003; Garcia Coll et al., 1996; Johnson et al., 2003; Winsler, Tran, Hartman, Madigan, Manfra, & Bleiker, 2008).

Also limited in the current literature is research focusing specifically on the association between preschool skills and high-stakes test scores in middle elementary school (typically, Grade 3). Much of the current research exploring the associations between early competencies and later achievement have used kindergarten measures of cognitive and academic abilities to represent early skills. Further, researchers who have included preschool skills in their studies often do not include outcomes in third or fourth grade, when high-stakes testing typically begins.

Finally, existing studies have often used decontextualized, researcher-administered outcome measures of children's achievement in elementary school (e.g., Woodcock-Johnson subscales). The present study uses authentic, ecologically valid Grade 3 outcome measures used by the school district for making decisions about children in elementary school. It is noteworthy that the association between school readiness skills acquired during preschool and outcomes on high-stakes tests in middle elementary school is one of important interest to policymakers and stakeholders who devote resources to improve preschool experiences such that children will acquire relevant school readiness skills prior to kindergarten and subsequently have higher academic success throughout school.

The most obvious reason for the lack of exploration of these age ranges in research is that the large-scale secondary datasets, from which much of this information is obtained, do not

include these age ranges. Most of the datasets that begin early enough to include preschool skills end prior to children entering Grade 3, and most of the datasets that include Grade 3 and continue throughout elementary school and beyond do not have information prior to kindergarten (e.g., all of the datasets used in Duncan et al. [2007], Grissmer et al. [2010], Pagani et al. [2010], and Romano et al. [2010]). With such importance placed on enhancing school readiness skills in preschools that will increase the likelihood of children succeeding in elementary school and with Grade 3 and high-stakes testing marking important educational milestones, it is important to explore the association between preschool skills and Grade 3 achievement.

Importance of Grade 3 achievement

Academic achievement in Grade 3 has become a significant point of interest for many stakeholders and policy makers interested in the successful long-term learning of students through high school and beyond. Grade 3 has often been identified as an important transitional grade because it tends to be the last grade in which instruction focuses purposively on learning to read as an isolated academic skill as teachers in subsequent grade levels begin requiring students to read texts to learn scholastic material (Fiester, 2010; Lesnick, Goerge, Smithgall, & Gwynne, 2010). As such, some states have implemented programs that require all third-grade students to achieve at certain levels of proficiency in reading or risk being retained in Grade 3 until they do. For example, Florida's A+ program requires students to reach reading proficient status in Grades 3, 5, and 8 on the Florida Comprehensive Assessment Test (FCAT)—the state's high-stakes achievement test—to advance to the next grade.

Students with low reading proficiency in Grade 3 have higher rates of school dropout compared to children with high reading proficiency in Grade 3 (Fiester, 2010). Students retained in Grade 3 (which can result from low performance on reading high-stakes tests) are also at greater risk for long-term difficulty in school and high school dropout (Goos, Van Damme, Onghena, Petry, & de Bilde, 2013; Jimerson, Anderson, & Whipple, 2002; Jimerson & Schuder, 1996; Roderick, 1994). High school dropout rates are in turn related to higher unemployment, poverty, use of public assistance, and future criminal activity, among other nonproductive outcomes (Bjerk, 2012). Economically, individuals who drop out of high school contribute about half as much in tax revenue as individuals who graduate from high school, and also add costs related to healthcare for the uninsured and social services, such as welfare and unemployment (Laird, DeBell, & Chapman, 2006).

Given the nature of high-stakes testing—which includes holding schools and teachers accountable for student performance and setting minimum performance requirements for students to advance to the next grade level (Heubert & Hauser, 1998)—and the subsequent focus on student performance in Grade 3, many school officials feel compelled to do what ever it takes to increase Grade 3 test scores, sometimes resulting in tactics including teaching to the test, moving the best teachers from other grade levels to Grade 3, and dismissing teachers who have students consistently receiving low scores (Rothstein et al., 2010). More positive methods for increasing Grade 3 academics focus on increasing early foundational or school

readiness skills during preschool. These types of proactive methods will be most successful if important school readiness skills learned during the preschool years are identified and known to have a lasting and long-term impact on academic performance through Grade 3, especially for children more vulnerable for lower academic success.

The present study

The goal of the present study is to explore the association at 4 years old between school readiness skills and Grade 3 achievement in reading and mathematics and Grade 3 high-stakes tests. Results from previous studies exploring the early skills to later achievement association have a few notable limitations that will be addressed in the present study: (a) the studies utilizing achievement from Grade 3 or later generally do not include early skills prior to kindergarten and the studies utilizing early skills prior to kindergarten generally are limited in later achievement to second grade or earlier; (b) there are only a few studies that include fine motor skills in addition to other important school readiness skills in the early assessments; (c) very few studies include outcomes of high-stakes test scores; and (d) the datasets utilized in previous studies do not include the most vulnerable children for poor academic performance in school.

In the present study we address these considerations by exploring the associations between preschool skills and Grade 3 achievement using data from the Miami School Readiness Project (for a complete description, see Winsler et al., 2008). The Miami School Readiness Project was designed to assess the academic-based skill growth of low-income children receiving subsidies for early education in Miami-Dade, Florida. The children in the Miami School Readiness Project are predominantly Hispanic/Latino and Black/African-American (63% and 32%, respectively, in the present sample) with nearly 60% who speak two or more languages. The Miami School Readiness Project provides the opportunity to explore the association between preschool skills and Grade 3 academic achievement among a population that is under-represented in this type of research (Brooks-Gunn, 2003; Garcia Coll et al., 1996; Johnson et al., 2003), yet who make up a large portion of the population who may benefit the most from new knowledge in this area. Based on findings from previous work (Dinehart & Manfra, 2013; Duncan et al., 2007; Grissmer et al., 2010; Manfra et al., 2014), we expect that preschool mathematics/counting skills and writing/copying may be important factors related to Grade 3 outcome measures for this population of children.

Method

Participants

During the first wave of the Miami School Readiness Project, 2,447 children in their last year of preschool prior to entering kindergarten were assessed on cognitive, language, and motor school readiness skills using the Learning Accomplishment Profile-Diagnostic (LAP-D) assessment measure (Nehring, Nehring, Bruni, & Randolph, 1992). These assessment data

were then matched with these children's Grade 3 academic data obtained from the public school district four years later. Of the 2,447 children with preschool assessments, 1,472 were successfully matched with Grade 3 academic performance measures. Of the 975 preschool assessments not matched with Grade 3 data, 370 cases were due to children being retained in a previous grade and 605 cases were due to children not entering or leaving the public school system. Thirty of the matched cases did not contain Grade 3 high-stakes test scores or classroom grades for mathematics or reading and are therefore not included in the present study. Therefore, the dataset used for the present consists of 1,442 children with both preschool school readiness assessments and Grade 3 academic performance measures.

A final diverse sample of 1,442 low-income 4-year-olds receiving government subsidies to attend a center-based early education program (not public school pre-K programs) in Miami-Dade, FL participated in the present study. All 1,442 children subsequently attended public elementary school through Grade 3. At the time of preschool, families receiving subsidies for early education had a combined annual income at or below 185% of the federal income-to-needs poverty level. The mean family income was \$16,865 ($SD = \$7,929$) and ranged from \$0 to \$46,636 at the time of receipt of the subsidies. According to Grade 3 records, 88.2% of these children were registered for the free/reduced lunch program, which indicates fairly stable SES between preschool and Grade 3 for this sample.

As part of the subsidy program, families were asked to consent to participate in screening and school readiness assessment projects to evaluate the success of the community childcare. Of the total population of 4-year-olds receiving government subsidies to attend a nonpublic school center-based early education programs in the county (approximately 3,250 children), 3% did not provide consent to be a part of the school readiness evaluation assessment program and 22% were unreachable. Among the children who did participate in the school readiness program, those who subsequently entered the public school system in Miami-Dade, Florida, and whose Grade 3 records were successfully matched with the preschool evaluation data (as described previously) were available for the present study ($N = 1,442$). Children were dispersed across 220 public elementary schools in the county. One hundred and twelve of these elementary school were attended by five or more (up to 25) participating children. As such, mixed-effects models were used to control for dependency in the outcome variables associated with school.

All of the children in the present study had on-time entry into kindergarten (i.e., being five years old by the cut-off date of September 1) and were not retained during kindergarten through second grade for poor academics or other reasons. Children were initially assessed during the latter half of their last year in preschool prior to entering kindergarten and then again assessed by the school district (as part of the typical public school testing procedures) during Grade 3.

There was a near equal distribution of boys and girls (52.3% girls; $n = 754$) in the sample. Nearly all of the children in the sample were identified as either Hispanic/Latino (63.2%; $n = 911$) or Black (32.3%; $N = 466$), with 4.5% of the children identified as White (3.3%; $n = 48$) or other (1.2%; $n = 17$). Because so few children in the sample were identified as White/

Caucasian or other, we elected to group these two groups into one category.

Nearly 12.8% of the children ($n = 184$) were identified as immigrants based on their Grade 3 country of birth record (i.e., the child was born in another country). Because this is not an insignificant number of children and most of these children (90.8%) are also identified as Hispanic/Latino ($n = 167$), we included this variable as a control factor in subsequent analyses.

Procedures

All data used in the present study were collected by a local early education agency that provided oversight for subsidy distribution and data collection from the local public school district's data management office. With the help of the public schools, data from both entities were gathered and merged based on matches between demographic information (name, date of birth, gender). Child demographic information, preschool information, and preschool school readiness assessment data were collected from the local early education agency. Immigration information, number of days absent, classroom grades, achievement test scores, and other demographic information in Grade 3 were collected from the public school district.

Measures

Preschool skills assessment

The LAP-D (Nehring et al., 1992) was used to measure children's school readiness during preschool. The LAP-D was administered by trained bilingual assessors. It includes domains (and subscales) for cognitive (matching, counting/premathematics), language (comprehension, naming), and fine motor (manipulation, writing/copying) development, all of which were used in the present study. The cognitive matching subscale includes questions about matching pictures of the same shapes, objects, and animals. The cognitive counting/premathematics subscale includes questions that have children perform tasks related to counting and quantitative differences, including reciting number words chronologically to 10, counting objects, and understanding quantity differences with questions such as the following: Which is bigger? Which is shorter? Which is longer? The language comprehension subscale measures children's receptive language ability by having children point to pictures that match words orally stated by the assessor. The language naming subscale measures children's expressive language ability by having children state orally the word associated with a picture. The fine motor manipulation subscale focuses on children's ability to manipulate objects with small motor movements, such as folding, building towers, and weaving string. The fine motor writing/copying subscale focuses on children's ability to use a writing utensil to copy letters, numerals, and shapes and to trace and draw simple objects.

The LAP-D is a norm-referenced and standardized instrument. Each subscale yields a raw score and several age-standardized scores, including z scores, T scores, and percentiles. All analyses in the present study use T scores, which have a mean of 50 ($SD = 10$). As shown in Table 1, T scores ranged from 27 to 73 across the various subscales.

Table 1. Bivariate correlations between all variables, as well as number, percentage, mean and standard deviation, and range.

	Demographic information						Preschool academic skills						Grade 3 performance			
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.
1. Age																
2. Gender	.01															
3. Hispanic	-.03	-.06*														
4. Black	.04	-.05*	-.91***													
5. Immigrant status	-.10***	.06*	.22***	-.20***												
6. Days absent	-.00	.01	.03	-.04	-.02											
7. Manipulation	.09***	-.26***	-.04	.02	-.03	-.03										
8. Writing/copying	.13***	-.15***	-.17***	-.19***	.01	-.03	.45***									
9. Matching	-.01	-.08**	-.10***	-.13***	.03	-.02	.48***	.47***								
10. Counting/mathematics	.16***	-.06*	.13***	.09***	-.11***	-.05	.35***	.45***	.42***							
11. Naming	.08*	-.11***	-.05*	-.00	-.00	.01	.34***	.41***	.47***	.51***						
12. Comprehension	.02	-.13***	-.11***	.08**	-.04	-.01	.31***	.39***	.40***	.61***	.57***					
13. Reading GPA	-.08***	-.14***	.05	-.09***	.06*	-.13***	.18***	.26***	.17***	.20***	.22***	.21***				
14. Mathematics GPA	-.10***	-.05	.13***	-.17***	.09***	-.14***	.24***	.27***	.24***	.23***	.20***	.21***	.62***			
15. Reading NRT	-.07**	-.08**	.16***	-.19***	.11***	-.11***	.18***	.33***	.24***	.25***	.26***	.27***	.63***	.51***		
16. Mathematics NRT	-.07*	.05	.18***	-.23***	.11***	-.11***	.24***	.35***	.29***	.32***	.24***	.27***	.52***	.61***	.69***	
<i>n</i>	1,423	1,442	1,442	1,442	1,442	1,442	1,442	1,441	1,442	1,442	1,441	1,440	1,429	1,427	1,427	1,427
%		48	63	32	13											
<i>M</i>	0.49					5.35	52.50	50.94	53.00	48.15	45.86	46.64	2.17	2.41	627.04	626.40
<i>SD</i>	0.29					5.40	9.44	9.43	9.41	9.23	9.32	9.64	0.94	0.89	39.54	43.22
Range	0–1	0–1	0–1	0–1	0–1	0–54	27–71	27–73	27–73	27–73	27–73	27–71	0–4	0–4	503–763	507–741

Note. All factors are continuous unless otherwise noted. Relations presented between dichotomous factors and continuous factors are point biserial correlations. Relations between two dichotomous factors are phi coefficients. All express the magnitude of relation between two factors. Gender is coded male = 1 and female = 0. Hispanic, Black, and immigrant status are coded yes = 1 and no = 0. Age is in years and centered on 4.00.

* $p < .05$; ** $p < .01$; *** $p < .001$.

The LAP-D has been shown to have good internal consistency reliability within the norming sample (Cronbach's $\alpha = .76-.92$) and good content and construct validity. Correlations between the subscales of the LAP-D and subscales from other established instruments are large: correlations between the LAP-D and the Battelle Developmental Inventory (Newborg, Stock, Wnek, Guidubaldi, & Svinicki, 1984) ranged from .64 to .86; correlations between the LAP-D and Developmental Indicators for the Assessment of Learning-Revised (Mardell-Czudnowski & Goldenberg, 1998) ranged from .55 to .87; and correlations between the LAP-D and the Wechsler Preschool and Primary Scale of Intelligence-Revised (Wechsler, 1989) ranged from .43 to .89. Children were assessed in their strongest language (English or Spanish) as determined by teacher report and an initial interactions and a report-building exercise between the bilingual assessor and the child.

Missing data for the LAP-D was very low. There were no missing data for the cognitive matching, cognitive counting, and fine motor manipulation subscales. There were data missing for only one participant for the fine motor writing and language naming subscales. There were data missing for two participants for the language comprehension subscale.

Grade 3 high-stakes test: FCAT

The FCAT is the state-wide test given to third-grade students in Florida used as a measure of student achievement (Florida Department of Education, 2004). It is considered a high-stakes test because it is also used to determine whether students pass or are retained in Grade 3. The FCAT consists of two separate tests: a norm-referenced test (NRT) and a criterion-referenced test (CRT). The CRT portion of the FCAT is a test created within the state under the supervision of the Florida Department of Education and is used to assess student achievement of the state's education standards. The NRT portion of the FCAT

is the Stanford Achievement Test 10th Edition (Harcourt Brace, 2003) and is used to compare student performance to a national norm. By design, these two tests are highly correlated (with the present sample, the reading portions of these two tests correlate at .81 and the mathematics portions of these two tests correlate at .83).

Due to the very high correlations between the two portions of the FCAT, only one portion of the test is used in the present study. Because the Stanford Achievement Test 10th Edition (i.e., the NRT portion of the FCAT) is used in many states as a measure of student achievement, the NRT portion of the FCAT is used in the present study. The NRT includes both reading and mathematics domains. Reliability and validity were established with a nationally represented sample of students and compared to other similar tests of academic achievement (Harcourt Brace, 2003). Scores have a theoretical range from 0 to 800. As shown in Table 1, scores ranged from just over 500 to just over 760. Both reading and mathematics domain scores were available for 1,427 participants (1.0% missing data).

Grade 3 classroom performance in reading and mathematics

Grade 3 classroom performance was based on the grade (A–F) assigned by the teacher for reading and mathematics. Grades for each subject were scored on a 4-point scale with an A equaling a 4 and an F equaling a 0. Reading grades were available for 1,429 participants (0.9% missing data), and mathematics grades were available for 1,427 participants (1.0% missing data).

Demographic and attendance information

Basic demographic information, including age (in years), gender, and race/ethnicity, immigration status, and Grade 3 free/reduced lunch status were collected from all participants (no missing data) from Grade 3 public school records. Total yearly income at the time of receiving the subsidy for preschool was gathered

from the early education agency. Number of days absent during Grade 3 was also collected for all participants (no missing data) from the school district and used as a covariate because it has been shown to be related to concomitant grades and test scores (Chang & Romero, 2008).

Results

Preliminary analyses

Correlations between all the variables, n values, means and standard deviations, or percentages, and ranges are presented in Table 1. The first five columns contain correlations (Pearson bivariate or point biserial) between demographic information and achievement measures. As is shown, each of the five demographic and school variables are significantly related to one or more of the Grade 3 achievement measures (bottom four rows). Therefore, all five factors will be used as control variables in subsequent regression analyses exploring the relations between preschool school readiness skills and Grade 3 achievement.

Table 1 also displays correlations among the preschool skills displayed in columns six through 10. As shown, the preschool school readiness measures have moderate correlations among themselves (r s between .32 and .61) indicating shared variance between these factors. This is to be expected to some degree given that all of these measures are from the same assessment and therefore share measurement variance. Three of the correlations are above .50 (among counting/mathematics and language naming, counting/mathematics and language comprehension, and language naming and language comprehension). The r values of these correlations, however, do not reach the level where multicollinearity is a concern and as such were each included in the subsequent analyses as independent factors.

Correlations among the four Grade 3 achievement measures are presented in columns 12–14 of Table 1. Based on these moderate to high correlations (r s between .51 and .69), it is clear that there is overlap between these achievement measures. These relations are expected given that students who tend to do well in class are also likely to do well on achievement tests.

Predicting Grade 3 achievement from preschool school readiness assessments

Four mixed-effects models were conducted to explore the impact of preschool school readiness skills on Grade 3 academic performance, while controlling for demographic factors and days absent in Grade 3 as fixed effects and elementary school as random effects (to control for dependency of the outcome variables related to the schools children attended). Results from these analyses are presented in Tables 2 (reading and mathematics NRT) and Table 3 (reading and mathematics grade point average [GPA]). Findings are described subsequently separately for Grade 3 reading achievement and mathematics achievement.

Reading achievement in Grade 3

Results of the mixed-effects models for Grade 3 reading achievement are presented on the left sides of Tables 2 and 3. Models for both Grade 3 reading measures (NRT and GPA)

Table 2. Mixed-effects models associating preschool assessments with Grade 3 high-stakes norm-referenced test (NRT) scores.

	NRT Reading		NRT mathematics	
	<i>B</i>	<i>SE</i>	<i>B</i>	<i>SE</i>
Intercept (constant)	545.62***	9.10	510.44***	9.57
Age	−14.89***	3.36	−17.26***	3.54
Gender	−3.06	1.98	10.06***	2.08
Hispanic	0.02	4.66	−4.52	4.89
Black	−13.77**	4.82	−22.27***	5.07
Immigrant status	9.69***	2.93	9.44**	3.08
Days absent	−0.74***	0.19	−0.78***	0.20
LAP-D				
Fine manipulation	0.01	0.12	0.49***	0.13
Writing/copying	0.74***	0.13	0.72***	0.14
Matching	0.04	0.13	0.12	0.14
Counting/mathematics	0.40**	0.14	0.95***	0.15
Naming	0.41**	0.13	0.05	0.14
Comprehension	0.38**	0.14	0.32*	0.14

Note. Gender is coded male = 1 and female = 0. Hispanic, Black, and immigrant status are coded yes = 1 and no = 0. Age is in years and centered on 4.00.

* $p < .05$; ** $p < .01$; *** $p < .001$.

were significant and both indicated that the preschool school readiness subscales explained a significant portion of unique variance not explained by control variables. As shown on the left side of Table 2, preschool writing/copying ($p < .001$), language naming ($p < .01$), counting/mathematics ($p < .01$), and language comprehension ($p < .01$), were all significant predictors of Grade 3 NRT reading while controlling for other factors. In this model, school (random effect) accounted for 5.0% of the explained variance. As shown on the left side of Table 3, preschool writing/copying ($p < .001$), language naming ($p < .01$), and counting/mathematics ($p < .05$) were significant predictors of Grade 3 GPA reading while controlling for other factors. In this model, school attended (random effect) accounted for 7.6% of the explained variance.

Mathematics achievement in Grade 3

Results of the mixed-effects models for Grade 3 mathematics achievement are presented on the right sides of Tables 2 and 3.

Table 3. Multilevel mixed model associating preschool assessments with Grade 3 classroom GPA.

	GPA reading		GPA mathematics	
	<i>B</i>	<i>SE</i>	<i>B</i>	<i>SE</i>
Intercept (constant)	1.021***	0.220	0.729***	0.205
Age	−0.376***	0.082	−0.405***	0.076
Gender	−0.169***	0.048	0.022	0.045
Hispanic	−0.261*	0.114	−0.089	0.106
Black	−0.418***	0.118	−0.368***	0.110
Immigrant status	0.171*	0.071	0.137*	0.066
Days absent	−0.021***	0.004	−0.022***	0.004
LAP-D				
Fine manipulation	0.004	0.003	0.012***	0.003
Writing/copying	0.013***	0.003	0.008**	0.003
Matching	−0.002	0.003	0.003	0.003
Counting/mathematics	0.008*	0.004	0.012***	0.003
Naming	0.009**	0.003	0.003	0.003
Comprehension	0.005	0.003	0.004	0.003

Note. Gender is coded male = 1 and female = 0. Hispanic, Black, and immigrant status are coded yes = 1 and no = 0. Age is in years and centered on 4.00.

* $p < .05$; ** $p < .01$; *** $p < .001$.

Models for both Grade 3 mathematics measures (NRT and GPA) were significant and both indicated that the preschool school readiness subscales explained a significant portion of unique variance not explained by control variables. As shown on the right side of Table 2, preschool counting/mathematics ($p < .001$), writing/copying ($p < .001$), fine motor object manipulation ($p < .001$), and language comprehension ($p < .05$) were all significant predictors of Grade 3 NRT mathematics while controlling for other factors. In this model, school (random effect) accounted for 5.6% of the explained variance. As shown on the right side of Table 3, preschool counting/mathematics ($p < .001$), fine motor object manipulation ($p < .001$), and writing/copying ($p < .001$) were significant predictors of Grade 3 GPA mathematics while controlling for other factors. In this model, school attended (random effect) accounted for 6.0% of the explained variance.

Discussion

The goal of the present study was to explore the impact of preschool academic skills on Grade 3 achievement among low-income, ethnically diverse children. Results indicated several preschool academic skills predicted Grade 3 achievement while controlling for demographic information and school attended. Writing/copying and premathematics skills were found to be important predictors for all Grade 3 outcome measures in both reading and mathematics. The model coefficients for preschool academic skills (presented in Tables 2 and 3) reflect the amount of change in the outcome measure per one unit change in the given predictor. While all of the coefficients reflect less than one point change in Grade 3 outcome measure for every one point change in preschool academic skill, it is important to view these coefficients in context.

A change from the lowest T score (27) to the highest (73) on preschool writing/copying reflects an increase of 34.04 points (e.g., an increase from 630 to 664) or 0.86 standard deviations on the Grade 3 standardized reading measure, and an increase of 0.60 GPA points (e.g., an increase from a 2.50 to a 3.10 GPA) or 0.64 standard deviations for Grade 3 reading GPA.

A change from the lowest T score (27) to the highest (73) on counting/premathematics reflects an increase of 43.7 points or 1.01 standard deviations on the Grade 3 standardized mathematics measure, and an increase of 0.55 GPA points or 0.62 standard deviations for Grade 3 mathematics GPA. These differences indicate that low-income, ethnically diverse children at the lowest end of the writing/copying or counting/premathematics scale in preschool may be close to one standard deviation lower in standardized achievement test scores and over 0.5 standard deviations lower on GPA four years later during Grade 3 than children at the highest end of these scales in preschool.

While the findings from this study are consistent with previous findings suggesting academic skills in early childhood are important correlates of later academic success (Duncan et al., 2007), they also add important new information about the association between early academic skills and later academic achievement. First, academic skills measured in preschool have long-term positive associations with mathematics and reading GPA and NRT scores in Grade 3. Second, this association is

true for ethnic-minority children from low-income families, the population sampled in the present study. Third, consistent with Duncan et al.'s (2007) finding of the importance of early mathematics skills for long-term success in both mathematics and reading, later mathematics and reading scores were both associated with preschool counting skills for all measures. Fourth, writing/copying skills in preschool predict Grade 3 mathematics and reading performance on all measures. Collectively, these findings indicate that preschool writing/copying and counting/premathematics skills are important foundational skills for long-term success in the classroom and on high-stakes achievement tests in Grade 3 for low-income, ethnically diverse children attending public elementary school.

In recent years, policies have made achievement tests in mid-elementary school (typically third or fourth grade) extremely important for children's success and advancement in school. In states such as Florida, from which the present participants were recruited, the results of these high-stakes tests, as they are often called, can be directly related to academic failure and repetition of the same grade level. With such high importance placed on these tests, it has become a central concern for educators to understand how to promote and increase success on these tests. The results of the present study indicate that academic skills demonstrated in preschool explain variance in school-administered, norm-referenced achievement tests and GPA in Grade 3. Interestingly, these relations were not just within domain (e.g., early reading skills predicting later reading achievement) but extended across domain (e.g., early mathematics skills predicting later reading achievement).

A number of explanations have been offered for why preschool school readiness skills are associated with long-term academic outcome. First, the foundational knowledge explanation posits that children who enter elementary school with more academic skills will have a steeper (positive) learning trajectory because they have the necessary base or foundational skills for which other academic knowledge are built (Cunha, Heckman, Lochner, & Masterov, 2006; Entwisle, Alexander, & Olson, 2005). From this perspective, it is important that children gain certain academic-based school readiness skills during the preschool years to be more successful later in school.

Second, upon entering elementary school, children with more school readiness skills are thought to experience fewer or no negative effects associated with making the transition from preschool to elementary school and thus are more successful academically and behaviorally (Kurdek & Sinclair, 2001; Pianta & Kraft-Sayre, 2003; Rimm-Kaufman, Pianta, & Cox, 2000). While similar to the first explanation, this transition explanation focuses on the socioemotional impact of making the life transition from preschool to elementary school and how school readiness skills can act as a protective factor against negative adjustment. Third, the teacher perceptions explanation suggests that early skills relate to later achievement due to the way in which teachers (and others) interact with the children within the school environment (Alvidrez & Weinstein, 1999). Teachers are thought to be positively biased toward children with more academic knowledge and thus provide them with more opportunities to be successful.

Interestingly, the findings indicate that early counting/premathematics skills and writing/copying fine motor skills are

among the strongest and most consistent predictors of both mathematics and reading performance in Grade 3 across both measurements for low-income, ethnically diverse children. These associations are true while statistically controlling receptive and expressive language skills, fine motor manipulation skills, cognitive shape-matching skills, and several demographic factors in the fixed-effects model and elementary school attended in the random effects model. Specifically, classroom mathematics performance in Grade 3 was predicted by preschool counting/premathematics skills, writing/copying skills, and fine motor manipulation. Mathematics performance on the Grade 3 norm-referenced high-stakes test were predicted by counting/premathematics skills, writing/copying skills, fine motor object manipulation, and language comprehension. Classroom reading performance in Grade 3 was predicted by preschool writing/copying skills, language naming, and counting/premathematics skills. Reading performance on the Grade 3 norm-referenced high-stakes test was predicted by writing/copying skills, language naming, counting/premathematics skills, and language comprehension. Thus, all four of the Grade 3 measures were significantly predicted by preschool writing/copying skills and preschool counting/premathematics skills.

The association between early mathematics skills and later academic success in mathematics and reading is important for consideration. Duncan et al. (2007) suggests that the dual competencies of conceptual and procedural knowledge that mathematics requires might explain the cross-domain prediction of early mathematics skills and later reading achievement. These authors did not describe this possibility extensively in their report as they were tentative about concluding that this cross-domain association illuminated a “real” (p. 1443) effect. Because we have found similar results using two methods for evaluating reading skills, we believe it is important that this early mathematics-predicting-later-reading effect is considered further and that potential mechanisms resulting in this association are discussed.

The dual qualities, conceptual knowledge and processing, of mathematics explanation offered by Duncan et al. (2007) will serve as a starting point. Given that the mathematics and counting skills assessed by the preschool measure in the present study were largely (if not exclusively) conceptually based (rather than both conceptually and procedurally based), it is not likely that the dual qualities of mathematics can explain why early mathematics skills related to later nonmathematics achievement. Procedurally based competencies in mathematics are those that involve the steps one takes to solve a mathematics problem. For example, if children were asked to find the summation of multiple values, they would need to understand the procedure of summation as well as have a conceptual understanding of quantitative values. The questions used in the preschool counting/premathematics measure in the present study did not include these types of questions. Instead, they primarily consisted of counting objects, reciting numbers chronologically, and indicating mathematics vocabulary knowledge by selecting pictures that demonstrated knowledge of mathematics concepts (e.g., big/little, long/short).

Because the present preschool assessment is largely conceptual and there is an association with all mathematics and reading measures in Grade 3, it is likely that there is another mechanism

resulting in this association. It is not likely that specific mathematics skills, such as counting, are directly related to later reading achievement. It is more likely that early mathematics skills are related to later reading achievement through indirect means. It is possible that this association exists because children with more early mathematics knowledge have easier school experiences. It is possible that teachers recognize young children with high mathematics skills as being smarter than children with lower mathematics skills and subsequently provide those children with more opportunities for advanced learning. It is also possible that because much of learning in early elementary school is cross-domain learning—that is, it is hard to distinguish mathematics learning from vocabulary learning in early elementary school particularly because early mathematics skills are primarily learned conceptually—children who have higher early mathematics skills have more foundational concepts to build new knowledge across many domains. Thus, learning mathematics concepts (i.e., vocabulary), which tends to be demanding due to the size and less concrete meaning of mathematics words compared to general vocabulary (e.g., addition, subtraction, parameter), may increase children’s general language development and provide a framework for children to learn large vocabulary words with more abstract meanings.

It is also possible that a related factor, such as executive function, might be involved in this association and that the reason for the association between early mathematics skills and later reading achievement is not entirely related to mathematics knowledge, *per se*. Learning mathematics skills in preschool may promote executive function skills, which in turn provide the basis for success in all elementary school disciplines (Best, Miller, & Naglieri, 2011).

Another important factor predictive of both mathematics and reading performance in Grade 3 is preschool writing/copying. Several other recent investigations have implicated fine motor skills as important for later academic success among a variety of school readiness skills (Dinehart & Manfra, 2013; Grissmer et al., 2010; Pagani et al., 2010). Except for Dinehart and Manfra, these studies have explored general fine motor skills (e.g., threading a needle) and not writing/copying specifically. In the present study, we included both a fine motor manipulation measure and a fine motor writing/copying measure. The results revealed that fine motor writing/copying in preschool was more predictive of both reading and mathematics Grade 3 academic performance, while fine motor manipulation was consistently predictive of only Grade 3 mathematics performance.

Numerous reasons for the importance of writing/copying skills in early childhood were offered by Dinehart and Manfra (2013). First, writing/copying provides a means for creating internal representations of letters, numbers, and symbols, which are used throughout school in reading and mathematics subjects. Second, writing/copying in early childhood may increase self-regulation or executive function skills—which are highly necessary for copying and writing symbols well—that are also associated with general academic success. Third, children who are better able to write symbols earlier are more successful in elementary school because writing is an integral part of the learning process. All of these explanations are consistent with the findings of the present study and may all provide good explanations for why early writing/copying skills predict later academic performance in Grade 3.

Jones et al. (2010) also note that writing might help children better navigate the transition from learning preliteracy skills to learning formal reading skills. Often in formal reading instruction, children are asked to translate written letters and words into oral language. Experience writing may provide children with deeper cognitive processing of letters making the conversion of letters from graphemic forms to phonemic forms easier. It is possible that easier transitions to reading result in more interest in and enjoyment of reading and other academic disciplines that are taught using reading as a means for learning and evaluating (e.g., the mathematics portion of many Grade 3 standardized achievement tests include various word problems).

Finally, it is important to consider the implication of these findings for policy and practice related to early education. One obvious implication is that writing/copying needs to continue to play an important role in early education and elementary curricula. A recent trend has been to move away from writing as a non-essential skill for academic learning (Cahill, 2009). The findings from the present and other studies suggest this is not in the best interest of academic learning. For example, Longcamp, Zerbato-Poudou, and Velay (2005) asked 4-year-olds to either copy letters with a writing utensil or using a keyboard on a computer. They found large significant differences in letter recognition between groups, such that children writing out the letters showed much higher letter recognition than children using a computer keyboard. If nothing else, the findings from Longcamp et al. demonstrate the unique value of writing out letters compared to finding and pressing them on a keyboard.

Another point for policy and practice is that the importance of early mathematics and counting knowledge should not be underestimated. Present trends have been to include mathematics curricula in early childhood programs (Hachey, 2013). Given the amount of recent empirical evidence supporting the role of early mathematics knowledge for long-term academic outcome in both mathematics and reading (Duncan et al., 2007; Romano et al., 2010), it seems very important that mathematics not only be included in early childhood curricula but be integrated thoroughly in early education practices. Similar to language and literacy practices, which are embedded in most activities in an early education classroom, mathematics practices should also be embedded in most activities in an early education classroom. The more mathematics training becomes second nature to early educators, the more young children will be exposed to mathematics concepts and the more mathematics will be learned. This might be especially important for ethnic-minority children and children from low-income backgrounds who are more likely to experience difficulty in school.

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