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Inhibitory Control of Spanish-Speaking Language-Minority Preschool Children: Measurement and Association with Language, Literacy, and Math Skills

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Abstract

Children's self-regulation, including components of executive function such as inhibitory control, is related concurrently and longitudinally with elementary school children's reading and math abilities. Although several recent studies have examined links between preschool children's self-regulation or executive function and their academic skill development, few included large numbers of Spanish-speaking language-minority children. Among the fastest growing segments of the U.S. school-age population, many of these children are at significant risk of academic difficulties. We examined the relations between inhibitory control and academic skills in a sample containing a large number of Spanish-speaking preschoolers. Overall, the children demonstrated substantial academic risk based on preschool-entry vocabulary scores in the below-average range. Children completed assessments of language, literacy, and math skills in English and Spanish, when appropriate, at the start and end of their preschool year, along with a measure of inhibitory control, the Head-Toes-Knees-Shoulders task, which was administered at the start of the preschool year in the child's dominant conversational language. Scores on this last measure were lower for children for whom it was administered in Spanish. For both English and Spanish outcomes, those scores were significantly and uniquely associated with higher scores on measures of phonological awareness and math skills but not vocabulary or print knowledge skills.

Keywords

self-regulation; academic skills; executive functions; inhibitory control; Spanish-speaking preschoolers

Self-regulation is a multifaceted construct that has been linked to a variety of important developmental outcomes in childhood. Children's self-regulation, including components of executive function such as inhibitory control (IC), is related both concurrently and longitudinally to elementary-school children's reading and math abilities (e.g., Best, Miller, & Naglieri, 2011; LeFevre et al., 2013; Liew, McTigue, Barrois, & Hughes, 2008). Although

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a number of studies have examined links between young children's self-regulation and their academic skill development (e.g., Blair & Razza, 2007; Willoughby, Blair, Wirth, & Greenberg, 2012), few of these studies have included large numbers of Spanish-speaking language-minority children. This group of children is among the fastest growing segment of the U.S. school-age population, and many of these children are at significant risk of academic difficulties. The purpose of this study was to examine the relations between one aspect of self-regulation, IC, and the development of early academic skills in a large sample of Spanish-speaking preschoolers and to compare relations between IC and early academic skills for Spanish-speaking and monolingual English-speaking children.

SELF-REGULATION, EXECUTIVE FUNCTION, AND ACADEMIC ACHIEVEMENT

Self-regulation is associated with development across several domains. One area that has received a considerable amount of attention during the past decade is the association between self-regulation and academic achievement.

Executive functioning (EF) skills are a component of self-regulation that have been the focus of a substantial amount of research that has examined factors that may contribute to children's academic performance. EF is typically conceptualized as the higher order cognitive processes involved in complex goal-directed behaviors (Welsh & Pennington, 1988), and it is a multidimensional construct comprising IC, working memory (WM), and attention shifting (e.g., Miyake, Friedman, Emerson, Witzki, & Howerter, 2000). IC is the ability to suppress a dominant response in favor of a subdominant response, typically in the context of pursuing a particular goal (Rothbart & Posner, 1985). WM is the ability to hold information in memory while simultaneously manipulating this information (Baddeley, Gathercole, & Papagno, 1998). Attention shifting, or attention flexibility, is the ability to shift flexibly across tasks or response sets (Garon, Bryson, & Smith, 2008; Miyake & Friedman, 2012).

Although there has been a burgeoning interest in the early linkage between EF and academic development, the majority of research examining the relations between EF and academic skills has been conducted with samples of school-age children (Jacob & Parkinson, in press). There is a growing body of research demonstrating both concurrent and longitudinal relations between these constructs across middle childhood and adolescence. For example, Best et al. (2011) examined the association between EF and academic achievement in a large sample of 5- to 17-year-olds. They reported significant correlations between EF and academic achievement across age levels, including math and reading performance. LeFevre et al. (2013) followed a group of children across Grades 2, 3, and 4 and reported both concurrent and longitudinal relations between EF and math skills. There also are a number of studies demonstrating that school-age children with disorders associated with EF deficits, such as attention-deficit/hyperactivity disorder, are likely to have difficulties in the academic arena (e.g., Johnson, McGue, & Iacono, 2005; McClelland, Acock, & Morrison, 2006).

The preschool and kindergarten years are a critical time period when children acquire the basic academic skills that provide the foundation for later academic success (Duncan et al.,

2007; Lonigan, Schatschneider, & Westberg, 2008). Children who display academic skill deficits during the early school years often continue to struggle throughout elementary school (e.g., Shaywitz et al., 1995; Wagner, Torgesen, & Rashotte, 1994). Consequently, there has been increased interest in understanding the early factors, such as EF and other aspects of self-regulation that are associated with the development of early academic skills.

Results of prior research indicate that there is a relation between EF and academic-related skills as early as the preschool and kindergarten years (see N. P. Allan, Hume, Allan, Farrington, & Lonigan, 2014, for a review). For example, in a study designed to examine the dimensionality of EF in a preschool sample, Willoughby et al. (2012) reported a strong association between two latent variables representing EF and early academic achievement. Blair and Razza (2007) examined the longitudinal interrelations among aspects of preschool EF and kindergarten academic skills. They reported that direct measures of EF in preschool were uniquely associated with three components of early academic development (i.e., math, phonological awareness, print knowledge) in kindergarten. Ponitz, McClelland, Matthews, and Morrison (2009) examined the longitudinal link between behavioral regulation (i.e., the manifestation of EF skills in observable behaviors) and early academic skills across the kindergarten year. They reported that better behavioral regulation at the beginning of kindergarten was associated with stronger math, vocabulary, and literacy skills at the end of the kindergarten year. There also was some evidence of domain specificity in that behavior regulation at the beginning of kindergarten predicted gains in math skills only.

Although results of multiple studies indicate that EF is a multidimensional construct for children elementary-school age and older (e.g., Lee, Bull, & Ho, 2013; Lehto, Juujärvi, Kooistra, & Pulkkinen, 2003), results from studies of preschool-age children often indicate that EF is unidimensional (e.g., D. M. Allan, Allan, Lerner, Farrington, & Lonigan, 2015; Fuhs, Farran, & Nesbitt, 2015; Wiebe et al., 2011); however, some studies with preschool children report distinct IC and WM dimensions, depending on the tasks used and the ages of the children (e.g., Lerner & Lonigan, 2014; Schoemaker et al., 2012). There are a variety of tasks that can be used to measure EF, only some of which are appropriate for use with preschool-age children. The Head-Toes-Knees-Shoulders (HTKS) task was designed by Ponitz et al. (2009) to assess self-regulation in young children. In this task, children engage in a Simon Says–like game in which they are required to respond unnaturally to an examiner’s commands. For example, when the examiner says, “touch your head,” the child is required to touch his or her toes.

The HTKS task has been proposed to measure multiple aspects of self-regulation including IC, WM, and attentional focusing (Ponitz et al., 2009). This task is easy to administer, is simple enough to be completed by preschool-age children, and has been used in a number of studies examining self-regulation in early childhood (e.g., Connor et al., 2010; Matthews, Ponitz, & Morrison, 2009; von Suchodoletz et al., 2013). Results of several factor-analytic studies indicate that HTKS is a strong indicator of EF with preschool children (D. M. Allan et al., 2015; Fuhs et al., 2015), and it has high loadings when included with measures of IC (N. P. Allan & Lonigan, 2011, 2014), suggesting that it is primarily a measure of IC.

EXECUTIVE FUNCTION AND ACADEMIC ACHIEVEMENT IN SPANISH-SPEAKING CHILDREN

Despite a relatively large body of research on the relations between children's EF and academic skills in monolingual English-speaking children, few studies have examined how these skills are related in U.S. children who speak a language other than English at home. These children are often referred to as language-minority children because their home language is one that is not spoken by the majority of the population of the United States. Children who speak Spanish at home constitute the largest group of language-minority children in the United States. As of 2012, 38.3 million people 5 years of age or older spoke Spanish as their home language (i.e., 13.0 percent of the total U.S. population; www.census.gov). Moreover, the population of Spanish speakers in the United States is growing rapidly. From 1990 to 2012, the population of Spanish speakers in the United States increased by 121%.

Many Spanish-speaking language-minority children are at a significantly increased risk for the development of academic difficulties. For example, data from the National Assessment of Education Progress indicate that there was a large achievement gap in math and reading skills at both fourth and eighth grades between Latino and White children in 2009 that has not diminished since 1990 (Hemphill, Vanneman, & Rahman, 2011). Furthermore, the achievement gap for math skills between Latino and White students in these data appeared to grow larger with increasing age, as there was a 21-point gap at fourth grade and a 26-point gap at eighth grade. Data on the achievement gap for reading skills between Latino and White students followed a similar pattern, although the gap was similar in fourth and eighth grades (i.e., 26 and 25 points, respectively). Within the Latino population, there was a significant achievement gap in math skills between children designated as English-language learners (ELLs) and non-ELL children at fourth (19 points) and eighth (34 points) grades. Similarly, there was a significant achievement gap in reading skills between ELL and non-ELL children at fourth (29 points) and eighth (39 points) grades. Understanding how EF and other self-regulation skills relate to early academic skills in language minority children could help identify those children who are at a particularly high risk for developing academic difficulties due to comorbid risk factors (e.g., low EF skills, low oral language ability).

There is some evidence that children who are learning two languages have more well-developed EF, and in particular IC skills, than do monolingual children (e.g., Esposito, Baker-Ward, & Mueller, 2013; Yang, Yang, & Lust, 2011). As an explanation of such findings, Bialystok and Martin (2004) hypothesized that, for bilingual individuals, both languages are activated during speech production and one language must be inhibited when the other is used. Inhibitory processes, therefore, may be recruited—or recruited more often—during speech production for bilingual but not monolingual individuals. Consequently, EF skills of Spanish-speaking language-minority children may have different relations with academic outcomes because the development of EF generally or IC specifically may be, in part, a function of learning two languages.

To date, at least three studies in which the relation between IC and academic outcomes was examined included a sizable number of children who were identified as ELLs or Spanish-speakers (i.e., McClelland et al., 2007; McClelland & Wanless, 2012; Ponitz et al., 2009). Results of each of these studies indicated that children with higher levels of IC measured near the start of children's preschool or kindergarten year were associated with higher scores on measures of math and reading skills, both concurrently and longitudinally. However, although children's language status (i.e., Spanish-speaker or ELL) was included as a main effect in the prediction analyses in these studies, whether the relation between the IC measure, HTKS, and the academic outcomes varied as a function of children's language status was not examined. Consequently, it is not known if the relation between EF and academic outcomes is the same for Spanish-speaking language-minority children and monolingual English-speaking children.

Swanson and colleagues (e.g., Swanson, 2015; Swanson, Sáez, & Gerber, 2006; Swanson, Sáez, Gerber, & Leafstedt, 2004) reported a series of studies that included measures of EF on two samples of Spanish-speaking children first assessed when they were in first grade. For example, in a sample of approximately 100 Spanish-speaking children, Swanson et al. (2004) reported that a general WM factor, comprising WM tests administered in English and Spanish, accounted for unique variance in first-grade children's word decoding, nonword decoding, and vocabulary skills in English; however, in the same sample, only WM measured in Spanish predicted growth in children's English and Spanish reading skills from first to third grade (Swanson et al., 2006). In another sample of approximately 480 children, Swanson, Orosco, Lussier, Gerber, and Guzman-Orth (2011) reported that WM predicted unique variance in word reading, reading comprehension, and vocabulary; however, in this sample, the unique predictive effects were language specific (i.e., Spanish WM predicted Spanish outcomes, and English WM predicted English outcomes). In a longitudinal analysis of this sample, Swanson (2015) reported that WM was uniquely associated with both initial status and growth in English and Spanish reading skills across 2 years, with some degree of language specificity. Consequently, it may be that aspects of EF are more or less predictive of the developing academic skills of language-minority children depending on the language in which children's EF is assessed.

Although the results of these studies indicate that EF skills of Spanish-speaking language-minority children are related to their academic skills, these studies either did not examine whether the relation between EF and academic skills was similar for the Spanish-speaking language-minority children and the monolingual English-speaking children or were conducted with samples that comprised almost entirely Spanish-speaking language-minority children. Consequently, whether the relation between EF and academic skills varies as a function of children's language backgrounds has not been examined. Moreover, no study of Spanish-speaking language-minority preschool children has examined the degree to which EF is related to Spanish-language skills. Consequently, the question of whether the EF skills measured in one language predict academic outcomes measured in another language has not yet been addressed for preschool-age children. In research on the development of cognitive skills of preschool children learning two languages, some skills (e.g., phonological awareness) appear to be language independent (i.e., the skills in both languages are significantly related across languages) and some skills (e.g., vocabulary) appear to be

language specific (i.e., the skills in each language are not related across languages; e.g., Goodrich, Lonigan, & Farver, 2014). The results of Swanson and colleagues' studies with elementary-school-age children suggest that at least some aspects of EF may be language specific.

CURRENT STUDY

The primary purpose of this study was to examine the concurrent and longitudinal relations between IC and academic skills in a large sample of preschool children that included a sizeable number of children whose home language was Spanish. Three research questions were evaluated. First, does a common measure of IC operate similarly across groups of children who are or are not Spanish-speaking language minority? Second, does a common measure of IC operate similarly for language minority children who are Spanish-dominant and those who are English-dominant? Third, is the relation between IC and academic outcomes the same across groups of children and English- and Spanish-language outcomes? Given the strong link between IC and early academic achievement found in previous studies of monolingual English-speaking samples (Blair & Razza, 2007; Ponitz et al., 2009; Willoughby et al., 2012), it was expected that, in general, IC at the beginning of the preschool year would be associated with early academic skills at the start and end of the preschool year. It was expected that a similar pattern would be found for both English-speaking and Spanish-speaking children and for both English- and Spanish-language outcomes, regardless of language of administration of the IC measure (i.e., IC would be language independent).

METHOD

Participants

The children in this study were recruited from private preschools, public preschools, and Head Start centers in Florida, California, Kansas, and New Mexico. These children were recruited from preschool classrooms in which a majority of children in the class spoke Spanish. The sample included 1,387 children from 115 preschool classrooms (83 distinct preschool centers). These children ranged in age from 35 to 73 months ($M = 54.0$, $SD = 5.09$) in the fall of their preschool year. Slightly more than half of the children were girls (51%), and 85% of the children were Latinos. The majority of the children were White (90.2%); other races represented included Black/African American (6.1%), Asian (2.0%), Native American (0.2%), multiracial (0.6%), or not reported (0.6%). Scores on two English-language standardized assessments at the start of the preschool year indicated significant educational risk, with the average standard score on a measure of vocabulary ($M = 79.6$, $SD = 19.81$) in the below-average range and the average standard score on an early literacy screening measure ($M = 87.1$, $SD = 14.86$) in the low-average range.

Of the 1,387 children, 960 children were identified as Spanish speakers (see below). This group of children was similar in age to the full sample ($M = 53.8$, $SD = 5.06$), but they scored lower on the English-language measure of vocabulary ($M = 74.6$, $SD = 19.45$) and the early literacy screening measure ($M = 85.5$, $SD = 15.07$) than did the full sample. Of

these 960 children, 52% were girls; 93.4% were Latinos; and almost all were White (95.4%).

Parent report on family demographic factors was available for 70% of the sample. Overall, 71% of mothers reported being born outside the United States (67% in Spanish-speaking countries); in contrast, only 6% of the children were born outside of the United States. Mothers of children who were identified as Spanish speakers were more likely to be born outside the United States (83%) than were mothers of non-Spanish-speaking children (41%; $\chi^2 = 189.19, p < .001$). Similarly, children identified as Spanish speakers were more likely to be born outside the United States (8%) than were non-Spanish-speaking children (1%; $\chi^2 = 19.58, p < .001$). Although median reported maternal and paternal education was completion of the 12th grade, a wide range was reported (i.e., finished 6th grade [10%] to finished college [20%]). Median family income was reported to be \$20,000 per year but ranged from less than or equal to \$5,000 per year (7%) to greater than or equal to \$125,000 per year (3%). Parents of children identified as.

Spanish speakers reported lower maternal education (median = 12th grade), $F(1, 989) = 38.33, p < .001$, lower paternal education (median = 12th grade), $F(1, 889) = 41.67, p < .001$, and lower family income (median = \$20,000/year), $F(1, 842) = 25.41, p < .001$, than did parents of non-Spanish-speaking children (medians = some college, some college, \$25,000/year, for maternal education, paternal education, and family income, respectively).

Measures

Revised Get Ready to Read! (R-GRTR) screening tool—The R-GRTR screening tool is a revision of the original 20-item version (Whitehurst & Lonigan, 2001). R-GRTR is a 25-item test that measures print knowledge and phonological awareness. For each item, the child is shown a page with four pictures. The test administrator reads the question at the top of each page aloud, and the child answers by pointing to one of the four pictures. Internal consistency reliability for the R-GRTR in the normative sample ($N = 866$ 3-, 4-, and 5-year-old children) was .88 (Lonigan & Wilson, 2008).

Preschool Comprehensive Test of Phonological and Print Processing (Pre-CTOPPP)—Children were administered Pre-CTOPPP (Lonigan, Wagner, Torgesen, & Rashotte, 2002), which was the development version of the *Test of Preschool Early Literacy* (Lonigan, Wagner, Torgesen, & Rashotte, 2007). Pre-CTOPPP has excellent psychometric properties for 3- to 5-year-olds (i.e., α s = .86 to .96) and substantial evidence of validity (e.g., concurrent validity coefficients of .59 to .77 with other measures of similar constructs).

The Pre-CTOPPP Definitional Vocabulary subtest included 40 items. Each item included two parts. For the first part of each item, the child had to label a single image or group of images that she or he was shown, and for the second part of each item, the child had to respond to a follow-up question regarding function or relevant context for the item. These second questions enable the measure to tap a more definitional, depth of vocabulary dimension in addition to the simple confrontational naming task. The maximum possible raw score was 80. To measure phonological awareness, children were administered the Elision and Blending subtests of Pre-CTOPPP. The Elision subtest included 18 items that

required children to remove a part of a word spoken by the examiner to form a new word (e.g., removing “snow” from “snowshoe” to create “shoe,” removing /d/ from “raid” to create “ray”). The Blending subtest included 21 items that required children to blend components of words spoken by the examiner to form a new word (e.g., blending “star” and “fish” to form “starfish,” blending /f/ and “ox” to form “fox”). All answers on the Elision and Blending subtests were real words, and items spanned the range of linguistic complexity (e.g., compound words to phonemes). Each subtest included both multiple-choice items, which required children to point to one picture out of four that represented the correct response, and free-response items, which required children to verbally produce the correct response. Each subtest included nine multiple-choice items. The Pre-CTOPPP Print Knowledge subtest included 36 items that include content related to print concepts (e.g., “which one is a letter,” “which can you read”), letter-name recognition, letter-sound recognition, and letter-name and letter-sound production. All Pre-CTOPPP subtests included at least one practice item. All items were administered to all children without ceiling criteria.

Spanish Test of Preschool Early Literacy (STOPEL)—To measure children’s vocabulary in Spanish, the Definitional Vocabulary subtest of STOPEL (see Farver, Lonigan, & Eppe, 2009) was used. This subtest is a direct Spanish-language translation of the Definitional Vocabulary subtest of the Pre-CTOPPP. Like the Definitional Vocabulary subtest of the Pre-CTOPPP, it contains 40 items, with each item consisting of a naming component and a definitional component in which children were asked to describe the function of the object or one of the important features of the object. The Definitional Vocabulary subtest of STOPEL has strong psychometric properties for 3- to 5-year-olds (e.g., $\alpha > .93$; test-retest $r > .80$).

Spanish Preschool Early Literacy Assessment (SPELA)—The Elision, Blending, and Print Knowledge subtests of SPELA (Lonigan, 2013) were used in this study. These three subtests of SPELA are patterned after the format of the related subtests of the Pre-CTOPPP; however, each subtest was developed following an iterative process of item generation, evaluation, modification, and retention using Item Response Theory analyses. Both the Elision and Blending subtests included 21 items that spanned the range of linguistic complexity (e.g., compound words, syllables, phonemes). All correct responses were real words. For Elision, 12 of the 21 items were multiple-choice items, and for Blending, 7 of the 21 items were multiple-choice items. Multiple-choice items required children to point to the one picture out of four that represented the correct response. The Print Knowledge subtest of SPELA included 38 items that assessed print concepts (e.g., “which one is a letter,” “which can you read”), letter-name recognition, letter-sound recognition, and letter-name and letter-sound production. All three subtests have good internal consistency (α s = .87, .94, and .93, for Elision, Blending, and Print Knowledge subtests, respectively) and evidence of concurrent validity as demonstrated by correlations with similar constructs ranging from .23 to .53. Note that the lower validity coefficients for SPELA compared to the Pre-CTOPPP likely represent differences in criterion measures (i.e., there are well-established English-language code-related measures but few available Spanish-language code-related measures for this age group).

Math assessments—The Applied Problems subtests of the third edition of the *Woodcock-Johnson Tests of Achievement* (WJAP; Woodcock, McGrew, & Mather, 2001), the Applied Problems subtest of the *Woodcock-Muñoz* (WM-AP; Woodcock, Muñoz-Sandoval, McGrew, & Mather, 2002), the *Child Math Assessment* (CMA; Klein & Starkey, 2004), and the Math subtest from the *Florida Voluntary Pre-Kindergarten Assessment* (VPK Math; Florida Department of Education, 2012) were used to assess children's math skills. The WJ-AP and WM-AP subtests assess children's quantitative reasoning by requiring them to listen to a simple math problem spoken by the examiner and to analyze and solve the problem. Initial items on the subtest included simple number concepts, whereas later items involved simple calculations. WJ-AP is an English-language assessment, and WM-AP is a Spanish-language assessment. Both versions have evidence of reliability as shown by test-retest correlations that range from .85 to .90. The 39 items of CMA measure young children's informal math knowledge across a range of concepts (i.e., counting, one-set addition/subtraction, two-set addition/subtraction and transformation, constructing equivalent sets, geometric reasoning, measurement, shape recognition, pattern duplication, division). Internal consistency of the scale is good ($\alpha = .79$), and scores on the measure correlate with other measures of children's math skills (i.e., $r_s > .50$). The VPK Math subtest included 13 tasks (yielding 18 scored items) involving counting, counting sets, number identification, number sense, counting up, subtraction, and simple addition. The measure has strong psychometrics as indicated by good internal consistency ($\alpha = .85$), a 3-month test-retest r of .76, and concurrent correlations with other math assessments of .73.

HTKS task—Children's IC was assessed using the HTKS task (McClelland et al., 2007; Ponitz et al., 2009). 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 his or 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 3-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 HTKS is high ($\alpha = .93$), and scores on HTKS correlate with teachers' ratings of classroom behavior (Ponitz et al., 2009) and other direct measures of IC (e.g., N. P. Allan & Lonigan, 2011, 2014).

Procedure

Prior to any data collection, parents or guardians of children provided written permission/consent for their children's participation in the assessments. All children completed the English-language measures. Children who were identified as Spanish speakers by their preschool teachers or for whom other observations revealed that a child was a Spanish speaker (e.g., child's classroom conversation with teacher or peers, interaction with project assessment staff) were administered the Spanish-language assessments as well as the English-language assessments. In the fall of their preschool year (i.e., August–October), all

children completed the Definitional Vocabulary subtest of Pre-CTOPPP and R-GRTR. Children identified as Spanish speakers also completed the STOPEL Definitional Vocabulary subtest. All children also completed HTKS in the fall. HTKS was administered to children in either English or Spanish, depending on the assessment staff member's evaluation of the child's dominant conversational language. Of the full sample, 38% completed HTKS in Spanish; of the children who were identified as Spanish speakers, 52% completed HTKS in Spanish. Near the end of children's preschool year (e.g., April–June), all children completed the full battery of language, phonological awareness, print knowledge, and math skills in English, and children who had been assessed in Spanish in the fall also completed assessments of these skills in Spanish.

Analyses—Because children were nested within classrooms, all analyses other than descriptive statistics and correlations (i.e., group comparisons, multivariate prediction analyses) were conducted as mixed models using restricted maximum likelihood estimation and classroom as a random factor in the models. For the multilevel prediction models, the variance accounted for in the outcomes is reported as a pseudo R^2 . In multilevel models, estimation of variance components changes depending on the variables in the model; however, pseudo- R^2 can typically be interpreted the same way as R^2 from multiple regression. Estimates of the unique contribution of a predictor variable were calculated as changes in the pseudo- R^2 with the variable in and out of the model. Intraclass correlation coefficients are reported as an index of variance due to the nesting of children in classrooms. Analyses were conducted on all children for whom data were available for the variables in the analyses. No children had missing data on the measures administered in the fall of the preschool year; however, some children were missing some data on the measures administered at the end of the preschool year. The degree of missing data ranged from 2% (Definitional Vocabulary, Print Knowledge) to 14% (VPK Math) for English-language outcomes and from 3% (Definitional Vocabulary) to 18% (WM-AP) for the Spanish-language outcomes.

RESULTS

Descriptive Statistics and Preliminary Analyses

Descriptive statistics for fall and spring raw scores on the English-language measures and HTKS are shown in Table 1. Table 1 also includes partial correlations, controlling for age, between all measures. As noted in the table, children's HTKS scores were significantly correlated with all language, literacy, and math outcomes, with correlations ranging from .14 to .34 (all $ps < .001$). Consequently, after controlling for age, scores on HTKS and scores on the English measures of language, literacy, and math shared 2% to 10% of their variance (average = 4%).

Descriptive statistics for fall and spring raw scores on the Spanish-language measures and HTKS for children who were assessed in Spanish are shown in Table 2. Table 2 also includes partial correlations, controlling for age, between all measures. As noted in the table, children's HTKS scores were significantly correlated with phonological awareness and math outcomes but not with definitional vocabulary or print knowledge outcomes. The statistically

significant correlations ranged from .09 to .28. Consequently, after controlling for age, scores on HTKS and scores on the Spanish measures of language, literacy, and math shared 1% to 8% of their variance (average = 4%).

As noted above, children were administered HTKS in either English or Spanish, depending on whether their dominant conversational language appeared to be English or Spanish, respectively. There were no differences in age between children administered HTKS in English versus Spanish ($p > .33$). Controlling for age, children who were administered HTKS in Spanish (adjusted $M = 6.05$, $SD = 9.83$) scored lower on HTKS than did children who were administered HTKS in English (adjusted $M = 7.63$, $SD = 11.09$), $F(1, 1374.10) = 7.04$, $p = .008$. Children also scored substantially lower on the Definitional Vocabulary subtest of Pre-CTOPPP in the fall if they were administered HTKS in Spanish (adjusted $M = 15.85$, $SD = 16.74$) than if they were administered HTKS in English (adjusted $M = 38.13$, $SD = 15.93$), $F(1, 1370.86) = 653.57$, $p < .001$, and children scored lower on R-GRTR if they were administered HTKS in Spanish (adjusted $M = 9.89$, $SD = 16.74$) than if they were administered HTKS in English (adjusted $M = 12.56$, $SD = 15.93$), $F(1, 1369.90) = 114.46$, $p < .001$. However, children scored substantially higher on the Spanish Definitional Vocabulary subtest if they were administered HTKS in Spanish (adjusted $M = 27.92$, $SD = 15.61$) than if they were administered HTKS in English (adjusted $M = 11.47$, $SD = 14.73$), $F(1, 1127.64) = 340.32$, $p < .001$. When these analyses were conducted controlling for family socioeconomic status (SES)–related variables (i.e., maternal education, paternal education, family income [with expected maximization imputation of missing data]), there continued to be statistically significant (i.e., $ps < .001$) and substantial differences (i.e., effect sizes = .43–1.23) on the language and literacy measures, but the difference on HTKS became nonsignificant ($p = .64$).

Children who completed the Spanish-language measures, regardless of the language in which HTKS was completed, were similar in age ($M = 53.79$, $SD = 5.02$) to children who did not complete the Spanish-language measures ($M = 54.06$, $SD = 5.22$), $F(1, 1384.47) = 0.86$, $p = .35$. For children who completed the Spanish-language measures, scores on the Definitional Vocabulary subtest of the Pre-CTOPPP in the fall (adjusted $M = 24.86$, $SD = 19.67$) were substantially lower than for children who did not complete the Spanish-language measures (adjusted $M = 40.75$, $SD = 15.01$), $F(1, 1370.76) = 226.70$, $p < .001$. Children also scored lower on R-GRTR if they completed the Spanish-language measures (adjusted $M = 11.10$, $SD = 5.12$) than if they did not complete the Spanish-language measures (adjusted $M = 12.59$, $SD = 4.74$), $F(1, 1,383.80) = 28.28$, $p < .001$; children who completed the Spanish-language measures also scored slightly lower on HTKS (adjusted $M = 6.66$, $SD = 10.26$) than if they did not complete the Spanish-language measures (adjusted $M = 7.91$, $SD = 11.47$), $F(1, 1314.89) = 4.00$, $p < .05$. When these analyses were conducted controlling for family SES-related variables, there continued to be statistically significant differences for definitional vocabulary and R-GRTR scores (i.e., $ps < .001$; effect sizes = .18–.72), but the difference on HTKS became nonsignificant ($p = .73$).

Prediction of Fall and End-of-Year Scores in English

Results from multilevel models predicting English-language outcomes are shown in Table 3. All models were conducted in two stages. First, models that included the interaction between language of HTKS administration and HTKS scores and the main effect of language of HTKS administration were examined. If the interaction term was statistically significant (i.e., language of HTKS administration affected the relation of HTKS scores with outcomes), both terms were retained in the model; otherwise, both terms were dropped from the model (because in these models, we were not interested in the main effects of language dominance on the outcomes, which are reported above). Then, the models with or without the language of HTKS administration were examined. Language of HTKS administration interacted with HTKS scores only for the prediction of the fall R-GRTR and the spring WJ-AP.

As seen in Table 3, higher HTKS scores were uniquely associated with fall vocabulary scores, fall R-GRTR scores, spring Elision and Blending scores, and spring math scores but not spring vocabulary scores or spring Print Knowledge scores. HTKS scores uniquely accounted for 4% of the variance in fall Definitional Vocabulary scores and 6% of the variance in fall R-GRTR scores. For the significant effects for spring scores, HTKS scores accounted for 2% of the variance in Elision, 1% of the variance in Blending, 3% of the variance in WJ-AP, 1% of the variance in VPK Math scores, and 1% of the variance in CMA scores. For children who completed HTKS in Spanish, HTKS scores were significantly less predictive of R-GRTR scores in the fall and of WJ-AP scores in the spring than they were for children who completed HTKS in English. Children who completed HTKS in Spanish scored lower on R-GRTR but higher on WJ-AP than did children who completed HTKS in English. Models in which the family SES-related variables were included as predictors did not alter any of the substantive results of the models without these predictors.

A parallel set of analyses for the English-language outcomes was conducted that examined whether there were differences in the predictive relation between HTKS scores and language, literacy, and math outcomes for children who did or did not complete the Spanish-language measures. Whether children completed the Spanish-language measures did not significantly change the relations between HTKS scores and fall Definitional Vocabulary subtest scores ($p = .73$) or R-GRTR scores ($p = .16$); however, it did have a main effect on both definitional vocabulary scores ($p < .001$) and R-GRTR scores ($p = .001$). Similarly, completing the Spanish-language measures did not significantly change the relations between HTKS scores and any of the spring English-language outcomes (all $ps > .31$), and there were no main effects on any of the spring scores ($ps > .14$). Models in which the family SES-related variables were included as predictors did not alter any of the substantive results of the models without these predictors.

Prediction of Fall and End-of-Year Scores in Spanish

Results from multilevel models predicting Spanish-language outcomes are shown in Table 4. As with English-language outcomes, all models were conducted in two stages to evaluate whether language of HTKS administration affected the predictive relation between HTKS scores and Spanish-language outcomes. Language of HTKS administration interacted with

HTKS scores only for the prediction of fall Definitional Vocabulary scores. Overall, the models accounted for about equal amounts of overall variance in Spanish-language outcomes (i.e., .13 Psuedo- R^2 .38) as was accounted for in English-language outcomes (i.e., .10 Psuedo- R^2 .49).

As seen in Table 4, higher HTKS scores were uniquely associated with spring Elision scores, spring Blending scores, and spring WM-AP scores, but HTKS scores were not uniquely associated with fall vocabulary scores, spring vocabulary scores, or Print Knowledge scores measured in Spanish. For the significant effects for spring scores, HTKS scores accounted for 2% of the variance in Elision, less than 1% of the variance in Blending, and 3% of the variance in WM-AP. For children who completed HTKS in Spanish.

HTKS scores were significantly less predictive of Definitional Vocabulary scores in the fall than they were for children who completed HTKS in English. Children who completed HTKS in Spanish scored higher on the.

Definitional Vocabulary subtest in the fall than did children who completed HTKS in English. Models in which the family SES-related variables were included as predictors did not alter any of the substantive results of the models without these predictors.

DISCUSSION

Overall, the results of this study demonstrated that IC early in the preschool year was associated with academic outcomes at the end of the preschool year for both monolingual English-speaking children and Spanish-speaking language-minority children. This finding is consistent with prior research showing longitudinal links between IC and early academic development with children who were primarily monolingual-English speakers (e.g., Blair & Razza, 2007; Fuhs et al., 2015) or samples of children that included both monolingual-English speakers and Spanish-speaking language-minority children (Fuhs, Nesbitt, Farran, & Dong, 2014; McClelland et al., 2007; Ponitz et al., 2009). The results of this study extend prior findings in this area by demonstrating that whether a child was a Spanish speaker or a child's dominant language was Spanish had limited influence on the relations between IC and academic outcomes, consistent with the conceptualization of IC as a domain-general skill, and by demonstrating that IC is associated with young children's skills both in their home language and in the societal language.

Although small in absolute terms, the strengths of the relations between children's HTKS scores and different components of early academic development in this study were similar, and sometimes larger, than those reported in previous studies. For example, Fuhs et al. (2015) reported that their EF factor, comprising measures of IC, WM, and shifting, accounted for 3% of the variance in children's literacy skills, 1% of the variance in children's language skills, and 5% of children's math skills. McClelland et al. (2007) reported that spring HTKS scores accounted for 0.2% of the variance in literacy, 0.5% of the variance in math, and 0.9% of the variance in spring language scores after controlling for fall HTKS scores and fall literacy, math, and language scores, respectively, and Ponitz et al. (2009) reported that fall HTKS scores accounted for 2.3% of the variance in spring of

kindergarten math scores after controlling for fall of kindergarten math scores. Seemingly small, unique relations can be of practical significance over time, particularly if these effects cumulate over development, provide unique information about growth of a skill, identify a factor that signals that certain instructional activities may have larger or smaller impacts, or provide an alternative route to preventive or remedial intervention.

Not surprisingly, the language of HTKS administration was associated with initial scores on the English and Spanish Definitional Vocabulary measures. Children administered HTKS in Spanish, which was done when the children's dominant conversational language appeared to be Spanish, initially had lower scores on the English vocabulary measure but higher scores on the Spanish vocabulary measure. HTKS scores were significantly and positively correlated with English vocabulary at both the fall and spring assessments; however, as revealed by the multivariate models, the relation with spring vocabulary scores was indirect, mediated by fall vocabulary scores. In contrast to the results for English vocabulary, scores on HTKS were unrelated to either fall or spring Spanish vocabulary scores—except for children who completed HTKS in Spanish. For these children, higher HTKS scores were associated with higher fall vocabulary scores. These results are consistent with findings reported by McClelland et al. (2007) in which the language of administration of HTKS was significantly related to children's vocabulary abilities but not to their early literacy or math abilities.

This study expanded on previous studies that have evaluated the associations between children's IC and their language, literacy, and math abilities (e.g., McClelland et al., 2007; McClelland & Wanless, 2012) by examining each of the three components of emergent literacy skills and early math abilities in both English and Spanish. Whereas previous research has focused on how children's IC is related to early academic skills assessed in English (e.g., McClelland et al., 2007), in this study we evaluated both English and Spanish academic abilities. The results of this study indicated that children's IC predicted phonological awareness and early math abilities in both English and Spanish, such that children with higher IC performed better than children with lower IC. Moreover, IC was significantly related to phonological awareness and math ability in both English and Spanish regardless of the language in which HTKS was administered. Evidence that IC operates similarly across languages of administration suggests that it is a domain-general skill that is language independent. This result is in contrast to prior evidence of language specificity of some components of EF (e.g., Swanson et al., 2011).

Results indicated that IC was longitudinally predictive of Spanish-speaking language-minority children's math and phonological awareness skills but not their vocabulary or print knowledge. These results were consistent regardless of whether English or Spanish outcomes were examined. Although prior studies have included only language-minority children as a small portion of their overall samples (e.g., McClelland et al., 2007; McClelland & Wanless, 2012; Ponitz et al., 2009), these studies reported a similar pattern of results. For example, Ponitz et al. (2009) reported that children's IC predicted gains from the beginning to the end of the kindergarten year in math skills but not in vocabulary or print knowledge.

Math and phonological awareness skills are skills that require mental operations to be performed on information, whereas vocabulary and print knowledge are skills that require the learning and retention of language-specific information (e.g., vocabulary, letter names). Evidence indicates that cross-language correlations between skills such as phonological awareness are often stronger than are cross-language correlations for skills such as print knowledge and vocabulary (Goodrich, Lonigan, & Farver, 2013; Lindsey, Manis, & Bailey, 2003). For example, once language-minority children develop phonological awareness and understand that words can be broken apart into their constituent sounds and that those sounds can be manipulated, they should have underlying knowledge about how words are composed of sounds in both of their languages. With few exceptions (e.g., cognates), different vocabulary words need to be learned to communicate in a second language. Like phonological awareness and math, IC is a language-independent construct that taps into underlying mental processes rather than specific knowledge, and IC tasks also require children to operate on information with which they are presented (e.g., do the opposite of what they are told). Therefore, it is not surprising that IC was more strongly predictive of phonological awareness and math than it was of print knowledge and vocabulary.

There are several ways in which self-regulatory processes, like IC, have been proposed to facilitate learning. Self-regulatory processes, such as IC, may work at a cognitive level to modulate attentional focus in a way that maximizes the acquisition, synthesis, retention, and retrieval of information. Self-regulatory skills also may be associated with broader organizational skills that help children learn and perform academically. Such skills may lead to better behavior in the classroom, which allows for more active engagement in learning activities and decreases the likelihood that children will be removed from the classroom for disciplinary purposes. Although the mechanisms driving the relation between self-regulation and academic achievement are not completely clear, the results of this study add to the growing body of literature showing the robust association between these constructs.

Limitations and Future Directions

Although the current study had a number of strengths, such as examining the longitudinal relation between IC and early academic development in a large sample of both Spanish-speaking and English-speaking children, including measures of multiple subdomains of early academic development, and including both English and Spanish measures of academic skills, there are a few limitations that should be considered when interpreting the results. One limitation concerns the use of only one measure to represent IC. Although the HTKS task has been shown to be a good index of IC (e.g., N. P. Allan & Lonigan, 2011, 2014), future research is needed to determine whether results hold across other measures that are designed to assess IC, as well as other aspects of EF. In addition, the results of this study are correlational, and thus, they cannot be interpreted as causal. Future research utilizing experimental designs is needed to better understand the degree to which the relations between EF and other developmental outcomes are causal in nature.

Summary

Consistent with a growing body of research (e.g., see N. P. Allan et al., 2014), the results of this study demonstrate that preschool children's EF skills are associated with their

developing academic skills, particularly phonological awareness and math. Comparable results were obtained for Spanish-speaking language-minority children and monolingual English-speaking children who were primarily from low-income backgrounds and for both English- and Spanish-language outcomes. Language of administration of the HTKS measure had limited effects on the relation between EF and academic outcomes. Whereas the correlational nature of this study precludes drawing conclusions concerning the causal status of EF in the development of early academic skills, these results indicate that the construct of EF can be an important consideration when identifying young children's likely developmental trajectories—including developmental trajectories that place children at risk for later learning disabilities.

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Table 1

Descriptive Statistics and Partial Correlations (Controlling for Age) for Inhibitory Control and Language, Literacy, and Math English-Language Outcomes Administered to All Children in Sample.

Measure	1	2	3	4	5	6	7	8	9	10
1. HTKS T1	—									
2. Definitional Vocabulary T1	.25	—								
3. R-GRTR T1	.34	.57	—							
4. Definitional Vocabulary T2	.19	.68	.46	—						
5. Elision T2	.21	.33	.30	.50	—					
6. Blending T2	.15	.31	.33	.49	.57	—				
7. Print Knowledge T2	.14	.25	.38	.41	.46	.49	—			
8. WJ-AP T2	.24	.39	.44	.57	.49	.51	.54	—		
9. VPK Math T2	.20	.37	.39	.50	.47	.46	.55	.62	—	
10. <i>Child Math Assessment</i> T2	.20	.33	.36	.49	.41	.42	.54	.57	.60	—
<i>M</i>	7.00	29.54	11.59	44.23	10.22	15.39	26.72	12.74	11.25	34.30
<i>SD</i>	10.68	19.84	5.09	15.95	4.83	4.93	8.76	5.51	4.34	6.64
Unconditional ICC	.11	.16	.25	.26	.25	.28	.32	.31	.23	.20

Note. HTKS = Head-Toes-Knees-Shoulders; T1 = Time 1; R-GRTR = Revised Get Ready to Read!; T2 = Time 2; WJ-AP = Applied Problems subtests of the third edition of the *Woodcock-Johnson Tests of Achievement*; VPK Math = Math subtest from the *Florida Voluntary Pre-Kindergarten Assessment*; ICC = intraclass correlation coefficient. $N = 1,387$. All correlations and unconditional ICCs are significant at $p < .001$.

Table 2

Descriptive Statistics and Partial Correlations (Controlling for Age) for Inhibitory Control and Language, Literacy, and Math Spanish-Language Outcomes Administered to Spanish-Speaking Children in Sample.

Measure	1	2	3	4	5	6	7	8
1. HTKS T1	—							
2. Definitional Vocabulary T1	.06 ⁺	—						
3. R-GRTR T1	.28***	.17*	—					
4. Definitional Vocabulary T2	.03	.67***	-.02	—				
5. Elision T2	.16***	.39***	.19***	.51***	—			
6. Blending T2	.11**	.42***	.16***	.54***	.65***	—		
7. Print Knowledge T2	.09*	.39***	.24***	.52***	.55***	.57***	—	
8. WM-AP T2	.18***	.42***	.27***	.48***	.53***	.65***	.62***	—
<i>M</i>	6.43	22.06	10.96	29.28	14.83	22.24	20.17	10.02
<i>SD</i>	10.26	17.08	5.11	19.91	8.50	9.55	8.74	5.88
Unconditional ICC	.18***	.22***	.28***	.29***	.27***	.38***	.30***	.37***

Note. HTKS = Head-Toes-Knees-Shoulders; T1 = Time 1; R-GRTR = Revised Get Ready to Read!; T2 = Time 2; WM-AP = Applied Problems subtest of the Woodcock-Muñoz; ICC = intraclass correlation coefficient. *N* = 960.

⁺ $p < .10$.

* $p < .05$.

** $p < .01$.

*** $p < .001$.

Table 3

Model Statistics and Unstandardized Model Parameters from Multilevel Models Predicting English-Language Outcomes for All Children in Sample.

Outcome	Cond. ICC	Pseudo- <i>R</i> ²	CA	Unstandardized parameters for predictor variables				
				HTKS T1	Lang. of HTKS	HTKS by lang.	Def. Vocab. T1	R-GRTR T1
Time 1 measure								
Def. vocab.	.15***	.10	.81***	.38***	—	—	—	—
R-GRTR	.21***	.20	.20***	.18***	-2.22***	-.05*	—	—
Time 2 measure								
Def. vocab.	.25***	.49	.12 ⁺	-.02	—	—	.48***	.36***
Elision	.24***	.21	.14***	.06***	—	—	.06***	.10***
Blending	.29***	.15	.06**	.03*	—	—	.06***	.15***
Print Knowledge	.29***	.20	.22***	.01	—	—	.06***	.48***
WJ-AP	.29***	.25	.06*	.09***	1.10***	-.09***	.07***	.24***
VPK Math	.23***	.27	.14***	.03**	—	—	.05***	.19***
Child Math Assessment	.19***	.19	.20***	.06***	—	—	.07***	.21***

Note. Cond. ICC = conditional intraclass correlation coefficient; CA = chronological age; HTKS = Head-Toes-Knees-Shoulders; T1 = Time 1; Lang. = language; Def. Vocab. = Definitional Vocabulary; R-GRTR = *Revised Get Ready to Read!*; WJ-AP = Applied Problems subtests of the third edition of the *Woodcock-Johnson Tests of Achievement*; VPK Math = Math subtest from the *Florida Voluntary Pre-Kindergarten Assessment*. $N = 1,387$. Dashes indicate that predictor variable was not included in final model for the outcome.

⁺ $p < .10$.

* $p < .05$.

** $p < .01$.

*** $p < .001$.

Table 4

Model Statistics and Unstandardized Model Parameters from Multilevel Models Predicting Spanish-Language Outcomes for Spanish-Speaking Children in Sample.

Outcome	Cond. ICC	Pseudo-R ²	CA	Unstandardized parameters for predictor variables				
				HTKS T1	Lang. of HTKS	HTKS by lang.	Def. Vocab. T1	R-GRTR T1
Time 1 measure								
Def. vocab.	.14***	.13	.62***	.01	10.86***	.20*	—	—
Time 2 measure								
Def. vocab.	.18***	.38	.23*	.02	—	—	.73***	-.24*
Elision	.25***	.21	.19***	.10***	—	—	.17***	.23***
Blending	.36***	.15	.15**	.05*	—	—	.19***	.19+
Print Knowledge	.22***	.14	.20***	.03	—	—	.15***	.32***
WM-AP	.30***	.18	.08*	.08***	—	—	.11***	.15***

Note. Cond. ICC = conditional intraclass correlation coefficient; CA = chronological age; HTKS = Head-Toes-Knees-Shoulders; T1 = Time 1; Lang. = language; Def. Vocab. = Definitional Vocabulary; R-GRTR = *Revised Get Ready to Read!*; WM-AP = Applied Problems subtest of the *Woodcock-Muñoz*. $N = 960$. Dashes indicate that predictor variable was not included in final model for the outcome.

+ $p < .10$.

* $p < .05$.

** $p < .01$.

*** $p < .001$.