AN ANALYSIS OF CATTELL-HORN-CARROLL COGNITIVE ABILITIES

RELATING TO ACADEMIC ACHIEVEMENT

AMONG STUDENTS IN GRADES FIRST THROUGH FIFTH

A Dissertation Presented to the
Faculty of the College of Education
University of Houston

In Partial Fulfillment
Of the Requirements for the Degree

Doctor of Philosophy

by

Mertie Miller Gomez

December 2015

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Abstract

Relations between cognitive abilities and areas of achievement were analyzed in a review of archival data study. The participants in this study were students from grades 1 through 5 who were referred for an initial psycho-educational evaluation due to academic concerns by their school staff or by their parents and were identified as students with a Specific Learning Disability. Subtests from the Woodcock-Johnson III Tests of Cognitive Abilities (WJ III COG) and the Batería III Woodcock-Muñoz: Pruebas de habilidades cognitivas (Batería III COG) and Woodcock-Johnson III Tests of Achievement (WJ III ACH) and Batería III Woodcock-Muñoz: Pruebas de aprovechamiento (Batería III ACH) were analyzed for their contribution to basic reading, reading comprehension, math calculation, math reasoning, and written expression ability. The present study examined 684 records of student who met the inclusion criteria. The participants included 386 males (56.4%) and 298 females (43.6%). The ethnic distribution of the sample was: Hispanic (n = 470, 68.7%), African American (n = 200, 29.2%), and White (n = 14, 2.0%). Students included in this study were enrolled in grades 1 (6.3%), 2 (19%), 3 (25.9%), 4 (28.5%), and 5 (20.3%). Students identified as Limited English Proficient accounted for 46.2% of the sample. Multiple regressions were used to examine cognitive and achievement relations. Results indicated that the best predictors for Basic Reading for students assessed in English were Associative Memory (MA), Phonetic Coding 1 (PC), and Perceptual Speed 1 (P) and for students assessed in

Spanish were Working Memory (MW), Perceptual Speed 1 (P), and Lexical Knowledge (VL). Results indicated that the best predictors for Reading Comprehension for students assessed in English were Associative Memory (MA), Lexical Knowledge (VL), Phonetic Coding 1 (PC), and Memory Span (MS) and in Spanish were Lexical Knowledge (VL), Perceptual Speed 1 (P), Associative Memory (MA), and Phonetic Coding1 (PC). Results indicated that the best predictors for Math Calculation for students assessed in English when controlling for LEP were Perceptual Speed 1 (P), General Sequential Reasoning (RG), Perceptual Speed 2 (P), Ideational Fluency (FI), Visualization (Vz), and Lexical Knowledge (VL) and in Spanish were Working Memory (MW), Perceptual Speed 1 (P), and Visualization (Vz). Results indicated that the best predictors for Math Reasoning for students assessed in English when controlling for LEP were General Sequential Reasoning (RG) Lexical Knowledge (VL), Perceptual Speed 1 (P), Visualization (Vz), Working Memory (MW), and Phonetic Coding 1 (PC) and in Spanish were Lexical Knowledge (VL), Working Memory (MW), Visual Memory (MV), Perceptual Speed 1 (P), and General Sequential Reasoning (RG). Results indicated that the best predictors for Written Expression for students assessed in English when controlling for LEP were Lexical Knowledge (VL), Perceptual Speed 1 (P), Phonetic Coding 1 (PC), Associative Memory (MA), and General Sequential Reasoning (RG) and in Spanish were Perceptual Speed 1 (P), Phonetic Coding 1 (PC), Associative Memory (MA), and General Sequential Reasoning (RG). Moreover, the predictive worth of cognitive abilities on academic outcomes is evidenced by the significant relations between cognitive variables and academic factors in a sample of students with learning disabilities.

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# Chapter 1

# Introduction

The Cattell-Horn-Carroll (CHC) theory of cognitive abilities, which is currently hailed by many as the leading theory of intelligence, has roots that date back to the early 1900s. Its roots run deep and wide thanks to the extensive research of Spearman, Thurstone, Cattell, Horn, and Carroll. Hence, the CHC theory is well anchored and has not only endured, but has benefitted from new information and research, and the theory has been adapted through the years to integrate new research and findings. Therefore, the CHC theory is not simply a historical one whose roots date back to the early 1900s. Rather, the "CHC theory is grounded in more than half a century of factor analytic research, and developmental studies of cognitive abilities, genetic heritability research, and neurocognitive analyses have contributed to its validity base" (Evans, Floyd, McGrew, and Leforgee, 2001, p. 247). While the theory is named after the key contributors, Cattell, Horn, and Carroll, it stands on the shoulders of experts such as Spearman and Thurstone.

## Spearman g

The psychometric theory of intelligence began in England with Charles Spearman's *g* in 1904. Spearman's theory of *g* explained that a single score-factor accounts for an individual's general ability, "General Intelligence", or "General Discrimination". He pioneered the method called factor analysis by correlating a set of variables with g or the general factor (Schneider and McGrew, 2012; Spearman, 1904). In his 1904 article, he wrote of the importance of a "stably interconnected hierarchy" within general intelligence. In 1914, Spearman further explained a two-factor theory containing a general factor and a specific factor. Referencing his work and simultaneous work of Simpson and Thorndike, Spearman postulates that the two-factor theory potentially explains not only cognition, but also affection.

**Thurstone**

L.L. Thurstone, president of the American Psychological Association in 1932 and one of the founding members of the Psychometric Society, is considered the father of American factor analysis, as Spearman was considered the father of British factor analysis (Schneider and McGrew, 2012). In 1934, he discussed the need for factorial methods, a structural framework, to remove the ambiguity and convolution of measuring and studying intelligence, and to bring order and objectivity (Thurstone, 1934). Unlike Spearman, Thurstone put forward the concept of *g* and seven specific factors or primary mental abilities - i.e., word fluency, verbal comprehension, spatial visualization, number facility, associative memory, reasoning, and perceptual speed (Thurstone, 1938). He noted that individuals with similar *g* scores tended to have unique profiles of primary mental abilities. His work confirmed the notion of a framework within which resided general intelligence and multiple factors contributing to *g* (Thurstone, 1938).

**Cattell-Horn (Gf-Gc)**

Raymond Cattell's contributions to the field of psychology include the development of a theory of intelligence anchored by two similarly key mental abilities, fluid ability (G*f*) and crystallized ability (G*c*). In 1943, Cattell called for further research regarding what defines and encompasses intelligence. One researcher contributed extensively to this endeavor: John Horn, a student of Cattell at the University of Illinois. Cattell and Horn's prolific collaboration began with Horn's doctoral dissertation (unpublished) in 1965 that corroborated Cattell's G*f*-G*c* theory (Horn, 1965). They boldly postulated six additional "general dimensions" at the second order which, one year later, they proposed as an explanation for a major portion of the variance observed in intellectual abilities: 1) Fluid intelligence, 2) Crystallized intelligence, 3) General visualization, 4) General speediness, 5) Facility in the usefulness of concept labels, and 6) Carefulness (Horn and Cattell, 1966).

**Cattell-Horn-Carroll (CHC) Theory**

The writings of Raymond Cattell, John Horn, and John Carroll were the foundation for the three-strata framework, hereafter called Cattell-Horn-Carroll (CHC) theory of cognitive abilities. Initially proposed by McGrew (1997), the combination of the Cattell-Horn (G*f*-G*c*) and Carroll models of cognitive abilities, CHC is regarded as one of the most complete and corroborated models of cognitive abilities (Evans et al., 2001; Flanagan & Ortiz, 2001; McGrew & Flanagan, 1998; Woodcock, McGrew, & Mather, 2001). Cognitive tests, including Woodcock-Johnson III (WJ III COG), Kaufman Assessment Battery of Children II (KABC-II), Stanford Binet V (SB5), and Differential Ability Scales II (DAS-II), have utilized the structure of CHC theory in the development of the test batteries.

Cattell's G*f*-G*c* theory proposed a separation of cognitive abilities into two divisions that differed widely from one another. Crystallized intelligence (G*c*) encompassed abilities acquired through the environment, whereas, fluid intelligence (G*f*) consisted of inductive and deductive abilities, both inherent and learned.

In 1965, Horn increased the identified cognitive abilities to include visual processing (G*v*), short-term memory (G*sm*), long-term retrieval (G*lr*), and processing speed (G*s*). In

1968, he then added auditory processing (G*a*). Therefore, his research laid the foundation with seven identified broad cognitive abilities (Flanagan and Ortiz, 2001; Schneider and McGrew, 2012).

In 1993, Carroll identified a three-strata framework of cognitive abilities. The Carroll model identified general ability, "g", as strata III. The strata II broad abilities include G*c*, G*f*, G*lr*, G*sm*, G*s*, G*v*, G*a*, and the more recently added G*q* (Quantitative Knowledge), G*rw* (Reading and Writing), and G*t* (Decision Speed/Reaction Time). The strata I narrow abilities are included under the respective broad ability. These narrow abilities number over 70 and are added to as research allows (Horn, 1994); however, for the purposes of this study, the narrow abilities discussed are those assessed on the WJ III COG (see Figure 1). Carroll (1997) posited that intellectual ability does not determine the amount of learning that can occur; rather it impacts the "rate with which learning occurs or the time required for learning" (p. 43).

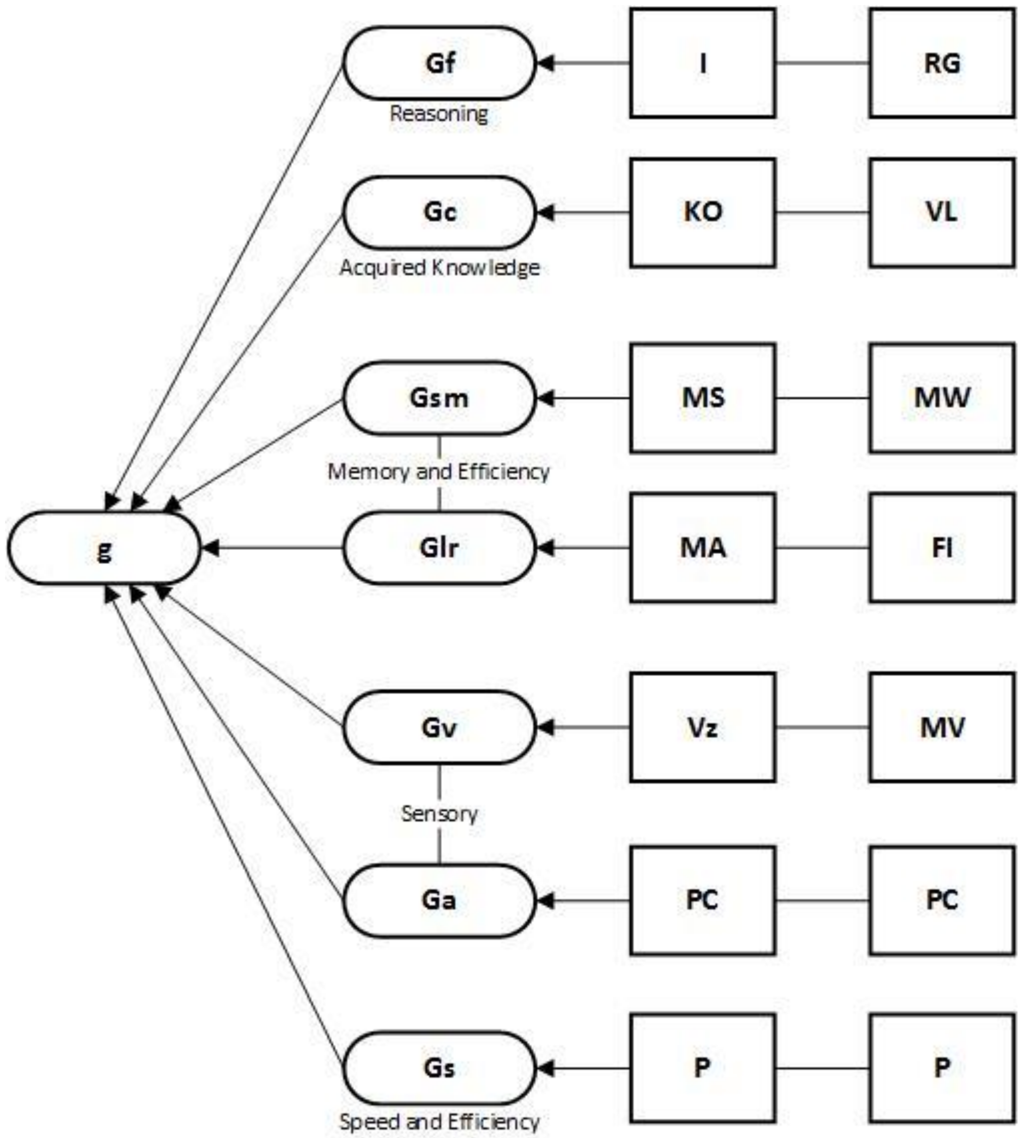


*Figure 1.* CHC Three-Stratum Structure of WJ III Tests of Cognitive Abilities as assessed in this study. Adapted from information in Schneider and McGrew (2012).

Kranzler and Keith's (1999) studies indicated while there are numerous other intelligence theories, such as Planning, Attention, and Simultaneous-Successive (PASS), each of these has clearly identifiable weaknesses which undermine the theory's effectiveness and validity. Current theories of intelligence, such as Howard Gardner's Multiple Intelligences and Robert Sternberg's Triarchic Theory of Human Intelligence, have appeal due to the descriptive nature of Gardner's intellectual modules and

Sternberg's contextual application of intelligence; however, both theories lack validation and empirical supporting data (Messick, 1989; Waterhouse, 2006). The efficacy of the three-stratum model of intellectual abilities is due, in part, to its flexibility--its ability to accommodate both broad and narrow abilities subsumed under *g*. This thoroughly researched and validated hierarchical framework of organizing cognitive processing abilities lends itself to assisting with the design and evaluation of intellectual assessment instruments (Carroll, 1997, 1998; Flanagan and McGrew, 1997; Keith and Kranzler, 1999; McGrew, 1997; Woodcock, 1990).

**Definitions of broad abilities and narrow abilities**

According to Flanagan, Ortiz, & Alfonso (2013), the broad abilities are defined as:

***Comprehension-Knowledge or Crystallized Intelligence (Gc).*** G*c* is the breadth and depth of a person's acquired knowledge of a culture and the effective application of this knowledge. Narrow abilities identified under Comprehension-Knowledge, as assessed by WJ III Tests of Cognitive Abilities, include Lexical Knowledge (VL) and General Verbal Information (KO).

***Long-term Retrieval or Long-term Storage and Retrieval (Glr).*** G*lr* is the ability to store information (e.g., concepts, ideas, items, and names) in long-term memory and to fluently retrieve it later through association. Narrow abilities identified under Long-term Retrieval, as assessed by WJ III Tests of Cognitive Abilities, include Associative Memory (MA) and Ideational Fluency (FI).

***Fluid Reasoning (Gf).*** G*f* involves mental operations that an individual may use when faced with a relatively novel task that cannot be performed automatically. Narrow abilities identified under Fluid Reasoning, as assessed by WJ III Tests of Cognitive Abilities, include Induction (I) and General Sequential Reasoning (RG).

***Short-term Memory (Gsm).*** G*sm* is the ability to generate, perceive, analyze, synthesize, manipulate, transform, and think with visual patterns and stimuli. Narrow abilities identified under Short-term Memory, as assessed by WJ III Tests of Cognitive Abilities, include Memory Spans (MS) and Working Memory (MW).

***Processing Speed (Gs).*** G*s* is the ability to fluently perform cognitive tasks automatically, especially when under pressure, and to maintain focused attention and concentration. The narrow ability under Processing Speed, as assessed by WJ III Tests of Cognitive Abilities, include Perceptual Speed (P).

***Visual Processing or Visual-Spatial Processing (Gv).*** G*v* is the ability to generate, perceive, analyze, synthesize, manipulate, transform, and think with visual patterns and stimuli. Narrow abilities under Visual Processing, as assessed by WJ III Tests of Cognitive Abilities, include Visualization (Vz) and Visual Memory (MV).

***Auditory Processing (Ga).*** G*a* is the ability to perceive, analyze, and synthesize patterns among auditory stimuli. The narrow ability under Auditory Processing, as assessed by WJ III Tests of Cognitive Abilities, include Phonetic Coding (PC).

# Chapter II

# Literature Review

## Empirical evidence to support cognitive linkages to academic deficits

Once it was determined that the hierarchical structure of the CHC theory was secure in its empirically-based research foundation, researchers then sought to address the association between cognitive abilities and academic skills. Beginning in the early 2000s, research began to define and measure academic abilities within a CHC framework. Recent research assists with this task by identifying numerous cognitive processes that have been empirically linked to academic achievement (Evans et al., 2001; Fiorello, Hale, & Snyder, 2006; Floyd, Keith, Taub & McGrew, 2007; Garcia & Stafford, 2000; Vanderwood, McGrew, Flanagan, & Keith, 2002). These recent studies that focused on narrow cognitive abilities provided a compelling response to McDermott & Glutting's (1997) "just say no to subtest analysis".

**Fluid Reasoning (Gf) - Reading.** Fluid reasoning involves one's ability to solve a unique problem when given rules and conditions (Flanagan, Ortiz, and Alfonso, 2007). It is strongly correlated with *g* and is one of the last cognitive processes to fully mature, typically not occurring until early teens (Dehn, 2006). Using multiple regression analyses, earlier research found that G*f* abilities were significantly linked to the area of reading comprehension in most age groups (McGrew, 1993); conversely, more recent research, using approximately 8,000 individuals from the nationally representative standardization sample of the WJ III, did not find a strong relation between G*f* and either reading cluster, basic reading skills, or reading comprehension (Evans et al., 2001).

Generally speaking, fluid reasoning abilities are related to higher-order comprehension skills; however, recent studies have not linked G*f*, or its narrow abilities, to either basic reading skills or reading comprehension skills.

**Fluid Reasoning (Gf) – Math.** Floyd, et al. (2003), conducted a series of regression analyses on the standardization sample of the WJ III Tests of Cognitive Abilities and Tests of Achievement. Their results found that the broad ability of Fluid Reasoning (G*f*) "demonstrated moderate relations with Math Calculation Skills and moderate-to-strong relations with Math Reasoning throughout childhood and adolescence." These results were similar to those of McGrew & Hessler's (1995) examination of the seven broad CHC abilities and their relations to basic math skills and math reasoning. Fluid reasoning exhibited moderate relations between both math clusters.

McGrew and Wendling's (2010) research synthesis of CHC cognitive-achievement relations involved nineteen studies. The criteria for inclusion in this synthesis necessitated that the study must: be overtly designed as per CHC (or G*f*-G*c*) cognitive abilities' framework, empirically explore the relations between cognitive variables and achievement variables in reading and math, report quantitative information, and include information from five or more of the seven primary CHC cognitive domains. The review only included school-age samples. Broad fluid reasoning (G*f*) consistently and significantly predicted basic math skills at all ages. A stronger relation was found between G*f* and math reasoning at younger ages. Broad fluid reasoning predicted math reasoning with high significance at ages 6-13 and medium significance at ages 14-19.

Using two subsamples of the national standardization sample of the WJ III and multiple regression analyses, the broad ability of G*f* exhibited consistently strong relations with math reasoning and moderate-to-strong relations with math calculation skills in this school-age sample (Floyd, Evans, & McGrew, 2003). The strong positive relationship between G*f* and math reasoning was reinforced in Proctor's (2012) findings involving college students. Using simultaneous multiple regression analyses, Proctor interpreted the WJ III COG and ACH results within a CHC framework. Contrary to studies with younger participants, there was no relationship between the broad ability and math calculation in college students diagnosed with a learning disability in math.

Proctor, Floyd, & Shaver (2005) conducted a profile analysis study with low-achieving math reasoning and math calculation groups and average-achieving math reasoning and math calculation groups of children from the standardization sample of the WJ III COG and ACH. The two low-achieving groups included children obtaining a standard score of 85 or below on either achievement cluster and a standard score of 90 or above on the Broad Reading cluster, to ensure a specific math delay. The group and individual level profile analyses demonstrated that fluid reasoning was the most common demonstrated cognitive weakness in the low achieving math reasoning group; however, fluid reasoning was implicated only at the individual level for math calculation.

**Fluid Reasoning (G*f*) – Written Expression.** The contributions of fluid reasoning to written expression are complicated. McGrew & Knopik (1993) found a consistent relationship between fluid reasoning and written expression across ones' lifetime; however, Floyd, McGrew, & Evans's (2008) study found that Fluid Reasoning demonstrated primarily negligible effects until late adolescence for basic writing and written expression. These late adolescent effects were in the lowest levels of the moderate range.

**Crystallized Intelligence or Comprehension-Knowledge (G*c*) - Reading.** An abundance of research has demonstrated the strong correlation between general ability (*g*), which is located in stratum III of CHC hierarchy, and Crystallized Intelligence (G*c*) which is located in stratum II. G*c*'s factor loading on *g* was 0.88 for all ages (McGrew and Woodcock, 2001). Furthermore, G*c*'s strongest relationship is with reading abilities in general, with the greatest effect being at the early school grades (Evans, et al., 2001; McGrew, Flanagan, Keith, & Vanderwood, 1997; Vanderwood et al., 2002). While G*c* is found to have an impact on basic reading skills (Durand, Hulme, Larking, & Snowling, 2005; Evans, et al., 2001; Hale, Fiorello, Kavanagh, Hoeppher, & Faither, 2001; McGrew, Werder, & Woodcock, 1991; Vanderwood et al., 2002), it is more influential on reading comprehension (Benson, 2007; Evans, et al., 2001; McGrew, Werder, & Woodcock, 1991; Woodcock, 1991; Vanderwood et al., 2002). G*c*'s predictive power for reading comprehension increases with age (Benson, 2007; McGrew, 1994; McGrew and Woodcock, 2001), which logically corresponds with the natural progression of reading tasks, moving from rudimentary word decoding to comprehending text.

Juel's (1988) longitudinal study of literacy development in 54 students in grades 1 – 4 found that as students progressed through the grades, print exposure increased. Her studies postulated that the average good reader spent more time reading at home than the average poor reader. The good readers made significant gains in listening comprehension, as compared to the poor readers. The ability for word recognition predicted reading comprehension, and increased with each grade level. Children with poor word recognition skills had lower vocabulary skills, were exposed to less print text, and had lower reading comprehension skills. The gap between good and poor readers widened by age, even when the disparity between decoding skills narrowed. Remediation of decoding abilities is possible and, therefore, a deficit in this area does not have to have a lasting negative effect on comprehension abilities. Juel reports that reading comprehension interventions show little effect since "it would seem hard to make up for years of lost experiences with the words and concepts found in print with relatively short-term treatments" (Juel, 1988, p. 446), reinforcing G*c*'s increasingly strong relation to reading comprehension with age (McGrew, 1994; McGrew and Woodcock, 2001). Implications include the identification of interventions related to cognitive processing delays that could positively impact achievement skill acquisition and the ability to begin remediation efforts as early as possible to decrease what would be an ever-widening ability gap.

Using 1,604 children, ages 5-10, from the Woodcock Diagnostic Reading Battery (WDRB) standardization sample, Konold, Juel, & McKinnon (2003) studied reading outcomes and the associations with the cognitive processing abilities of G*a*, G*c*, G*s*, and G*sm*. Average-ability readers with a secondary strength of comprehension-knowledge (G*c*) exhibited increasing improvement for reading abilities with age. Moreover, children with a secondary strength of comprehension-knowledge (G*c*) outperformed average reading ability children with secondary strengths in auditory processing (G*a*) or processing speed (G*s*) on measures of reading vocabulary. These results confirmed previous research findings of G*c*'s significant influence on reading comprehension abilities (Garcia & Stafford, 2000; Hale et al., 2001).

**Crystallized Intelligence or Comprehension-Knowledge (G*c*) - Math.** Hale et al. (2001) studied the relations between WISC-III subtests and academic achievement. Results from 174 children ranging in ages 6 to 16 indicated that G*c* uniquely accounted for 10% of the variance in Math Computation. These are notable results given that the WISC-III subtests measuring G*c*, Information, Similarities, Vocabulary, and Comprehension did not contain math questions. Utilizing the CHC framework, these measures assess abilities found within the broad ability of G*c*. Consistent with Hale et al's (2001) WISC-III study, Floyd et al.'s (2003) WJ III study found moderate G*c* relations with Math Calculation Skills after age 9. The influence of G*c* on Math Reasoning increased with age, moderate through age 10, and moderate-to-strong throughout childhood and adolescence. "Memory for general information" and "previous knowledge" were distinct cognitive deficits in children with a math computation disability (Swanson & Jerman, 2006).

At the individual profile analysis level, more children evidenced a broad ability G*c* normative deficit than those who exhibited a normative strength in the math reasoning low-achieving group, but the same could not be said for the math calculation low-achieving group (Proctor, Floyd, & Shaver, 2005).

**Crystallized Intelligence or Comprehension-Knowledge (G*c*) – Written Expression.** McGrew and Knopik (1993) studied the seven broad abilities and their relationships to the achievement cluster of written expression derived from the Woodcock-Johnson Tests of Cognitive Abilities and Achievement-Revised (WJ-R). The G*c* broad ability relationship with written expression increases with age, beginning at seven years. Using a G*c*-G*f* framework to interpret WISC-III associations with written expression, G*c* contributed significantly to the total variance of written expression in a study of archival data involving children in ages 6 to 16 (Hale et al., 2001). The two narrow abilities, lexical knowledge and general verbal information--as assessed on the WJ III--are measures of language ability (McGrew, 1994), which is foundational to the writing process (Berninger, 1999).

The broad ability of G*c* strongly predicted written expression results across all age groups studied (ages 7 to 16). Thereafter from ages 7 to 10, the effects increased from moderate to strong. Of all seven broad abilities studied, G*c* was the strongest and most stable predictor of writing skills (Floyd et al., 2008).

**Short-Term Memory (G*sm*) - Reading.** In 2007, Floyd et al. used the three-stratum model, or CHC, as a framework to analyze subsamples from the standardization sample of the WJ III COG. Using five age ranges and various sample sizes (totaling 6,378 participants), the Short-Term Memory narrow ability of Memory Span was more critical to reading decoding skills--as measured by Letter-Word Identification and Word Attack subtests--than was the narrow ability of Working Memory. Memory Span involves a single auditory exposure to ordered words, after which the subject must instantly recollect the words in the correct order. The task is designed to parallel the abilities needed to both analyze and synthesize phonemes. Working Memory, instead, entails the "ability to temporarily store and perform a set of cognitive operations on information that requires divided attention and the management of the limited capacity of short-term memory," (Flanagan et al., 2007, p. 303), which more closely mimics the abilities necessary for understanding what is read.

Using the WJ III ACH and WJ III COG's nationally representative standardization sample, Evans et al.'s (2001) findings demonstrated moderate relations between both the G*sm* and Working Memory clusters and Basic Reading, as measured by Letter-Word Identification and Word Attack subtests. The narrow abilities of Working Memory and Memory Span comprise the G*sm* cluster; whereas, two subtests of the *Gsm* narrow ability of Working Memory comprise the Working Memory cluster (Numbers Reversed and Auditory Working Memory). The broad ability of G*sm* was found to have no significant relation to Reading Comprehension from ages 6 through 19. In contrast, the G*sm* narrow ability of Working Memory was found to have moderate relations to Reading Comprehension that diminished with age. These findings point out that the ability to immediately recall information in the presented order (Memory Span) is less important than the ability to mentally manipulate data that is audibly presented (Working Memory) when measuring one's ability to understand what was read (Evans et al., 2001).

Hale et al. (2001) analyzed results from 174 comprehensive evaluations from two university-affiliated hospitals in the Midwest U.S. The assessments consisted of achievement subtests from various instruments, including WJ-R, Wechsler Individual Achievement Test (WIAT), Wide Range Achievement Test – 3 (WRAT3), Woodcock Reading Mastery Test-Revised (WRMT-R), Test of Written Spelling-2 (TOWS-2), Test of Written Language-2 (TOWL-2), and Key Math-Revised. Additionally, the 174 participants were administered the Wechsler Intelligence Scale for Children-Third Edition (WISC-III). Using the framework of both broad and narrow abilities (G*f*-G*c*), the conclusions indicated that working memory, as assessed by Digit Span, was related to both reading comprehension and basic reading skills.

Not all Short-Term Memory tasks are measured in the same manner. Some G*sm* abilities are measured utilizing visually represented symbols, figures, or photographs that do not depend on phonological coding. Conversely, G*sm* abilities measured on the WJ III Tests of Cognitive Abilities (Numbers Reversed, Auditory Working Memory and Memory for Words subtests) rely on the use of phonological coding through the use of digits and words. The G*sm* subtests that measured the construct through the use of phonological coding are associated with reading achievement; while, those not using phonological coding were not associated with reading achievement (John, 1998). Verbal working memory predicted basic reading skills in a longitudinal study of first through fifth graders (Geary, 2011) and contributed unique variance to 2nd and 4th graders basic reading and reading comprehension outcomes (Berninger at al., 2010).

**Short-term memory (G*sm*) – Math.** The two short-term memory narrow abilities tested by the WJ III COG are working memory and memory span. The preponderance of the research focused on working memory as it relates to math. The relationship between working memory and mathematical skills is remarkably strong (Geary, Hoard, Byrd-Craven, Nugent, & Numtee, 2007; Passolunghi, & Siegel, 2004; Swanson & Jerman, 2006). The working memory system functions through several systems as explained in Baddeley's (2000) multisystem model of working memory (WM) involving the central executive system and its three passive "slave" storage systems: visual sketchpad, phonological loop, and episodic buffer. The subtest studied in this research, Numbers Reversed, involves the phonological loop of working memory. Mannamaa, Kikas, Peets, and Palu (2012) explored the cognitive correlates of three areas of math skills: knowing, applying, and problem solving. The participants were 723 third graders from Estonian elementary schools. Of the five types of working memory studied (visuo-spatial WM, verbal WM–successive, verbal WM-simultaneous, phonological awareness, and phonological WM), only simultaneous verbal working memory directly related to math problem solving skills. Children involved in multi-step mental arithmetic problem-solving apply verbal working memory skills, as each preceding step is stored in short-term memory for use in the next step (Dehn, 2008). In a longitudinal Swedish study of preschool children, verbal working memory was found to support number knowledge and arithmetic ability (Ostergren & Traff, 2012).

The WISC-III subtest of Digit Span assesses working memory since the digits presented must be recalled verbatim (digits forward – memory span) and in reverse order (digits backward – working memory). The digits backwards subtest requires the child to actively manipulate the numerical information in working memory. This combined cognitive ability contributed significant variance to math computation in children between the ages of 6 – 16 (Hale et al., 2001). Substantiating Mannamaa et al.'s (2012) study, the working memory visuo-sketchpad (visual-spatial working memory) was not predictive of either mathematical reasoning or math calculations; however, digit span, which measured memory span, significantly predicted math reasoning in 48 second graders, but not their third-grade counterparts (Meyer, Salimpoor, Wu, Geary, & Menon, 2010).

Swanson (2004) studied the impact of working memory on the mathematical problem solving of 8 and 11 year olds. He found that working memory predicted performance in math word problems, even when the influence of phonological processing (G*a*) was partialed out. The missing relation between the visuo-sketchpad and math achievement noted in Mannamaa et al. (2012) and Meyer et al.'s (2010) studies was contradicted by Swanson & Jerman's (2006) meta-analysis of 28 studies. Swanson & Jerman's review indicated that both the phonological loop (verbal working memory) and the visuo-sketchpad (visual-spatial working memory) were related to a math computation disability (Geary et al., 2007). Both verbal working memory (Barrouillet & Lepine, 2005) and visual-spatial working memory (visuo-sketchpad) showed relations to math achievement during the early school years (Bull et al., 2008), at third and fifth grades (Passolunghi & Cornoldi, 2008), and with children and adults (Wilson & Swanson, 2001). However, by the second primary school year of Bull et al.'s study, only visual-spatial short-term memory predicted math achievement.

The broad ability of G*sm*, when including the narrow abilities of memory span and working memory, moderate relations with Math Calculation Skills after age 7, and moderate relations with Math Reasoning until age 17. However, when two measures of working memory from the WJ III Tests of Cognitive Abilities were combined creating a Working Memory cluster, the relations were usually stronger in degree than the broad ability (Floyd et al., 2003).

Similar to previous research, Proctor (2012) found that working memory was strongly related to both math calculation and math reasoning in a sample of college students. Unlike studies with younger participants, the broad ability, G*sm*, was not related to either math cluster.

The narrow ability of memory span displayed significant contributions to math problem solving (Andersson, 2007; Swanson & Beebe-Frankenberger, 2004) and math calculation, independent of reading ability (Bull & Johnson, 1997).

**Short-term Memory (G*sm*) – Written Expression.** The broad ability of G*sm* exhibited a significant relationship in children ages 6 to 16 (Hale et al., 2001) and ages 7 to 18 (Floyd et al., 2008). When including measures of both phonological and orthographic coding at the word level, working memory uniquely predicted composition at second and fourth grades and remained correlated at sixth grade (Berninger et al., 2010). When analyzing both the visual-spatial and phonological loop systems, each working memory system significantly contributed to variance in writing skills in children ages 9-16 (Swanson & Berninger, 1996).

McGrew & Knopik (1993) utilized multiple regression analyses with the WJ-R to determine the degree of relationship between Short-term Memory and Written Expression as a function of age. A subsample of the WJ-R standardization sample was divided into 21 distinct age-based groups. Significant regression coefficients were irregular and indicated no stable relationship. McGrew & Knopik's (1993) conflicting results may be due in part to the subtests studied measuring the Short-Term Memory cluster, Memory for Sentences and Memory for Words. Both subtests measure only one narrow ability of memory span; whereas, Hale et al. (2001) and Floyd et al's (2008) research measured two short-term memory narrow abilities, memory span (Digits Forward, Memory for Words) and working memory (Digits Backward, Numbers Reversed), respectively.

**Long-Term Retrieval (G*lr*) - Reading.** The assessment of long-term retrieval focuses on the process of storing and retrieving information rather than the accumulation of content. Efficiency of storage and retrieval strategies and abilities, or lack thereof, is measured by G*lr* subtests on intellectual assessment instruments. Short-term memory is intricately involved and vital to long-term retrieval. The individual must transfer information from short-term memory to long-term memory through the storage process (Dehn, 2006). G*lr* is assessed by the Visual-Auditory Learning and Retrieval Fluency subtests on the WJ III Tests of Cognitive Abilities. The Visual-Auditory Learning subtest measures the narrow ability of Associative Memory (MA). This subtest mimics the process that early readers undertake when learning to read. For example, participants are asked to learn and remember a symbol that represents a word.

Associative Memory, also called paired visual-verbal paired associate learning (PA), is necessary at the beginning stages of reading skill acquisition. Pre-reading skills involve acquiring sound-letter correspondences and letter-name correspondences, a paired associate learning task. The pre-reading learning task then entails moving these nearly learned correspondences into long-term memory. Paired associate learning is a predictor of reading (Vellutino et al., 1996), even when phonological awareness was controlled. In addition, associate learning was strongly related to word recognition (basic sight words), even when non-word reading performance was controlled (Windfuhr and Snowling, 2001).

Using the nationally representative standardization sample of the WJ- III Tests of Cognitive Abilities and Tests of Achievement, Evans et al. (2001) found the broad ability of G*lr* and the reading clusters (Basic Reading Skills and Reading Comprehension) are moderately related. These relations are only exhibited during the early years of reading skill acquisition, from ages 6 through 9 for basic reading and from ages 6 through 11 for reading comprehension. Naming facility, also termed rapid automatized naming (RAN), was established as a second core deficit in the “double-deficit” hypothesis of dyslexics. Low naming speed abilities were found (Niileksela & Renolds, 2014), in addition to and independent of, phonological deficits in poor readers (Schatschneider, Carlson, Francis, Foorman, & Fletcher, 2002; Wolf and Bowers, 1999). Referencing neuroscience research, Wolf and Bowers explained that "there is extensive evidence that many severely impaired readers have naming-speed deficits, that is, deficits in the processes underlying the rapid recognition and retrieval of visually presented linguistic stimuli" (p. 415). Confusing this issue is Vellutino et al.'s (1996) results establishing that semantic fluency or retrieval ability--the rapid naming of words in a semantic category as assessed by Retrieval Fluency subtest--was not significantly related to reading abilities.

**Long-Term Retrieval (G*lr*) – Math.** The broad ability of G*lr* exhibited significant relations with both Math Calculation Skills and Math Reasoning only during the first few school years. Moderate relations were noted with Math Calculation Skills and Math Reasoning skills between ages 6 and 8 (Floyd et al., 2003). Verbal fluency or ideational fluency, the ability to rapidly produce a series of words related to a specific provision, contributes to both math calculation and math reasoning in a sample of Swedish children whose mean age was 9 years old (Andersson, 2007). One possible explanation of the importance of ideational fluency is the ability to access pertinent information from long-term storage when solving multi-step math problems or retrieving math facts. In a sample of 15 kindergarten children, Geary et al. (2007) utilized a cut-off score of more than one standard deviation below the norm on a math achievement test for two consecutive years as an indicator of a math learning disability. When compared to typically developing peers and low-achieving peers, the group of children with a math learning disability exhibited a deficit in the ability to rapidly recall objects (e.g., letters and numbers) by their names (naming facility).

**Long-Term Retrieval (G*lr*) – Written Expression.** Contrary to McGrew & Knopik's (1993) study, G*lr* demonstrated moderate effects on written expression at ages 6 and 7 (Floyd et al., 2008). The discrepancy in findings might be due to the narrow abilities assessed by the different studies. McGrew & Knopik's (1993) G*lr* cluster measured the narrow ability of associative memory, whereas Floyd et al.'s (2008) G*lr* cluster included both associative memory and ideational fluency narrow abilities.

**Visual-Spatial Thinking or Visual Processing (G*v*) – Reading.** Dehne (2006) explains that visual-spatial thinking (G*v*) skills refer to "the ability to perceive, analyze, synthesize, and think with visual patterns, including the ability to store and recall visual representations" (p. 28). Studies have consistently found a weak relation between Visual-Spatial Thinking (G*v*) abilities and reading skills at ages 6 through 19 (Evans et al., 2001; McGrew, 1993; McGrew & Flanagan, 1997; Vellutino et al., 1996); thus confirming that G*v* is not predictive of reading skills.

**Visual-Spatial Thinking or Visual Processing (G*v*) – Math.** Analyzing WISC-III subtests with a G*f*-G*c* theoretical framework, Hale et al. (2001) found that the subtests measuring G*v*, Block Design and Object Assembly, contributed significantly to the total and unique variance of Math Computation. The authors postulated that "column alignment and paper and pencil calculation" ostensibly require visual-spatial skills. Using the CHC model, the DAS-II subtest of Pattern Construction measures the narrow ability of visualization (Vz). That is the ability to observe complex patterns and mentally replicate how they might look when altered. Niileksela & Reynolds (2014) utilized a subsample of the DAS-II standardization and validity sample, which included 43 children between the ages of 7 to 14 years who were previously identified with a learning disability (LD) in the area of math. The LD math group displayed weaknesses in the narrow ability of visualization.

Geary's (1993) review of neuropsychological studies substantiated the affect that visual spatial skills have on low-level math skills, such as the depiction and understanding of numerical information. Visual-spatial skills are utilized during hands-on learning activities as a young child interacts with numerical information through manipulatives, such as counters and base-10 blocks. These visual-spatial activities are not limited to early math skills. Manipulatives, such as pattern blocks, geoboards, and measuring cups are used in algebra, geometry, and measurement, respectively.

Floyd et al.'s results (2003) differed, in that there were no significant relations found between the broad ability of G*v* and either Math Calculation skills or Math Reasoning. These results were from two subsamples of the nationally representative standardization sample of the WJ III (*n* = 4,498 for Math Calculation Skills and *n* = 3,064 for Math Reasoning). McGrew & Wendling's (2010) research synthesis concluded that the broad ability (G*v*) was not found to predict mathematics; nevertheless, approximately 94% of the studies reviewed involved WJ-R and WJ III. The disparity between the findings of relations between the cognitive measures of G*v* (including WJ-R, WJ III, DAS-II, and WISC-IV) and mathematics point towards the possibility that the cognitive measures could be assessing differing skills.

**Visual-Spatial Thinking or Visual Processing (G*v*) – Written Expression.** Visual-spatial cognitive abilities did not contribute to writing skills at any age (Floyd et al., 2008; Hale et al., 2001; McGrew & Knopik, 1993).

**Auditory Processing (G*a*) – Reading.** Auditory processing abilities, measured by phonetic coding tasks, involve an awareness of phonemes or sound-letter correspondences, which is robustly associated with basic reading skills (Evans et al., 2001; Fletcher et al., 1994; Juel, 1988; Konold, Juel, McKinnon, & Deffes, 2003; Muter, Hulme, Snowling, & Taylor, 2004; Vanderwood et al., 2002; Vellutino et al., 1996; Wolf and Bowers, 1999). In a reticulated structure such as the three-stratum CHC structure, phonemic and phonological awareness would be subsets of G*a*.

In a confirmatory factor analysis study of WJ III Tests of Cognitive Abilities results, auditory processing abilities correlated most strongly with basic reading subtests. Further, the Phonemic Awareness cluster (Sound Blending and Incomplete Words subtests) showed moderate correlations with reading comprehension at the early grade levels and strong correlations with basic reading at ages 6 through 8 (Evans et al., 2001).

G*a* was found to have the strongest relation to basic reading skills than any other G*f*-G*c* factor studied, when using a series of structural models. Furthermore, the relation of G*a* to reading comprehension was strongest at the earlier years and declined to the point of non-existence by age 20 (Konold et al., 2003). While other cognitive processes make an impact on the acquisition of reading skills, phonological awareness most significantly enables early reading success (Stanovich, 1986). As Snow, Burns, and Griffin (1998) have noted, phonological awareness is "the ability to attend explicitly to the phonological structure of spoken words, rather than just to their meanings and syntactic roles" (p. 111).

Concurring with previous research that phonological awareness is a strong predictor of reading (Plaza & Cohen, 2003), general language measures such as verbal memory and lexical skills were identified as strongly related, as well (Snow, Burns and Griffin, 1998). Phonological awareness, of which phonemic awareness is a subset, is vitally important to the accretion of early reading skills because an early reader must attain an understanding of sound-letter correspondence—i.e., that letters make sounds. Furthermore, an early reader must be able to manipulate these letters and sounds. This phonological-based ability is the precursor to phonetic decoding skills, which are the primary cause for reading delays, such as word recognition (Stanovich, 1986).

Research with 5 to 10-year-olds found that average-ability readers with a secondary strength in auditory processing out-performed average-ability readers without an auditory processing secondary strength; thus a higher G*a* predicts better reading achievement outcomes (Konold et al., 2003). Research involving adolescent dyslexics found that brain dysfunction was exhibited in the phonological processing systems in some participants with reading disorders, using electroencephalography (EEG) technology. Interestingly, dysphonetics (those participants exhibiting a decoding delay) exhibiting the presence of orthographic abilities while exhibiting phonological deficits demonstrated that dysphonetics could store and activate orthography, but had difficulty decoding orthography into phonology. Consequently, researchers were able to specifically identify that the cause for some reading delays was the individual's lack of capacity for processing phonological information (McPherson, Ackerman, Holcomb, and Dykman, 1998).

**Auditory Processing (G*a*) – Math.** Auditory processing involves the encoding of phonological depictions of symbols, which includes numerals and mathematical expressions. For example, when a child is presented with a math problem (e.g., "2 + 3

=”), the child exchanges the numerals and mathematical expressions to reading-based code. Geary (1993) speculated that phonological processes impacted math computational skills due to speech-sound production utilized during problem solving. The narrow ability of phonological processing influenced growth in math computation skills (De Smedt & Boets, 2010; Hecht, Torgesen, Wagner, & Rashotte, 2001).

Research by Fuchs et al. (2006) supported a direct link between phonological decoding skills and the arithmetic skills of third graders, even when controlling for other abilities such as working memory, long term memory, processing speed, and attention. While Hecht et al. (2001) controlled for reading ability, phonological awareness was found to be a significant predictor of math computation skills in a longitudinal study of second graders who were assessed over a three-year period. Additionally, the cognitive abilities involved in phonological awareness significantly added to the growth in general computation skills at each assessed grade level.

Fuchs et al.’s (2005) intervention study of first graders randomly assigned to a math tutoring group or a control group found that phonological processing and attention were the two unique predictors for basic math fact fluency. Phonological processing was related to basic math skills and math reasoning for pre-treatment students even after word identification skills were added as a predictor to the model.

Other research is contradictory, finding no relation between phonological awareness and the assessed math skills (Durand et al., 2005), including recalling, computing, applying, and problem solving (Mannamaa et al., 2012). Mannamaa et al. (2012) hypothesized that their third grade sample might have achieved adequate phonological awareness by the time of the study, since students should be proficient readers by third grade.

While the broad ability of auditory processing was not consistently significant at any age range, the narrow ability of phonetic coding was moderately related to math reasoning at ages 6-8 and low at ages 9-19, according to a synthesis of literature (McGrew & Wendling, 2010). Floyd et al.'s (2003) study implicated the broad ability (G*a*) as exhibiting moderate relations with Math Calculations Skills in the very early years and non-significant relations after age 7 in Math Calculations Skills and in all ages of Math Reasoning.

**Auditory Processing (G*a*) – Written Expression.** The auditory processing broad ability demonstrated significant relations to written expression, principally before the age of 11 in a subsample of the WJ-Revised Tests of Cognitive Abilities and Tests of Achievement standardization sample (McGrew & Knopik, 1993). In a subsample of the nationally representative norming sample of the WJ III, the broad ability of G*a* and the Phonemic Awareness cluster demonstrated negligible effects, for the most part; however, at age 7 and late adolescence, moderate effects were noted.

**Processing Speed (G*s*) – Reading.** Within CHC theory, processing speed refers to how quickly an individual executes moderately uncomplicated assignments (Dehn, 2006). There is little disagreement concerning the moderate relation between processing speed and both basic reading skills and reading comprehension at the early stages of attaining reading skills (Evans et al., 2001; McGrew, 1994; McGrew et al., 1991). The G*s* relation to reading comprehension exhibited a slow but continual regression through the age of 70 (McGrew, 1994).

Participants demonstrating average reading ability with a secondary strength in processing speed exhibited better reading achievement than those with average reading ability and no secondary strengths. Additionally, average reading ability participants with a secondary strength of auditory processing (G*a*) rather than one of processing speed (G*s*) exhibited statistically greater reading results in the areas of both basic reading skills and reading comprehension. The implication of these studies is that auditory processing strengths are more important at the early years of reading skill acquisition than processing speed strengths. Basic reading skills that are not reflexive or fluent will tax a child's ability to process more difficult reading skills (Konold et al., 2003).

Contradicting previous research findings, Vanderwood et al. (2002) found that there were either weak or nonexistent paths from G*s* to basic reading and reading comprehension abilities. It was explained that this discrepancy might be due to the use of a multivariate approach that included *g*. Recently, Cirino, Fuchs, Elias, Powell, & Schumacher (2015) found that the narrow ability of perceptual speed, which measures "the speed at which visual stimuli can be compared for similarity or difference" (Flanagan, et al., 2013) is not related to basic reading performance.

**Processing Speed (G*s*) – Math.** There are conflicting results involving processing speed as it relates to math skills, as well. Processing speed was not predictive of math computation in Hale et al.'s (2001) study of WISC-III subtests. However, when the processing speed instruments included rapid naming and coding, cognitive deficits were noted in children with math calculation disabilities (Swanson & Jerman, 2006). Niileksela and Reynolds' (2014) study involving children with learning disabilities presented delays on the Speed of Information Processing subtest from the DAS-II.

Utilizing a CHC framework, this DAS-II subtest measures the narrow cognitive ability of perceptual speed since the speed at which visual stimuli can be compared is tapped (Flanagan et al., 2013). The Speed of Information Processing subtest does not require the student to respond verbally, rather the student circles the largest number in a row.

Within a nationally representative sample, the broad ability of Processing Speed (G*s*) exhibited moderate-to-strong relations with Math Calculations through childhood and adolescence and moderate relations with Math Reasoning until age 14 (Floyd et al., 2003). Children with a math learning disability (Cirino et al., 2015) or math difficulty (Bull & Johnson, 1997) exhibited deficits in perceptual speed.

Utilizing profile analyses, a deficit in the broad ability of processing speed was noted in children identified as low achieving in the math calculation cluster, but not in the math reasoning cluster (Proctor, Floyd, & Shaver, 2005). Since the math calculation cluster includes a fluency measure, it is logical to conclude that processing speed was associated.

**Processing Speed (G*s*) – Written Expression.** Utilizing the standardization sample of the WJ-R Tests of Cognitive Abilities and Tests of Achievement to investigate the relations between the broad cognitive clusters and Written Expression, processing speed exhibited a moderate relationship from ages 2 to 90+ (McGrew and Knopik, 1993). Floyd et al.'s (2008) study of the WJ III Tests of Cognitive Abilities and Tests of Achievement found consistent results. Perceptual speed was consistently significant in the prediction of Writing Fluency, one of the two measures of Written Expression, in children ages 6 to 16 (Williams, Zolten, Rickert, Spence, & Ashcraft, 1993).

**Hispanic and Limited English Proficient Students**

To date, there has been a paucity of research regarding Hispanic students and the cognitive predictors for academic achievement. Educational outcomes vary between Hispanics and the white students who represent the largest portion of the researched population. The No Child Left Behind (NCLB) Act, a reauthorization of the Elementary and Secondary Education Act, requires schools to identify and implement effective research-based intervention and remediation programs (No Child Left Behind Act of 2001) in order to improve academic outcomes. Since many of the previously mentioned studies involved few Hispanic children in their samples, the conclusions may not accurately reflect Hispanic student results and, therefore, generalizing the results to a Hispanic population may not be suitable.

According to the federal government, a Limited English Proficient (LEP) or English Language Learner (ELL) individual is a student between the ages of 3-21 who: is enrolled in an elementary or secondary school; was not born in the United States; has a native language other than English; and has difficulties in speaking, reading, writing, or understanding the English language that may be sufficient to deny the individual academic access or achievement (No Child Left Behind Act of 2001: Title IX, Part A, § 9101). Additionally, about 71% of the ELL population in the United States speaks Spanish in the home, with an even larger representation in the state of Texas (88.5%) (Batalova & McHugh, 2010).

In 1974, the Supreme Court of the United States found that LEP students could not meaningfully participate in the educational system unless the schools developed and implemented programs that produced measurable results despite the impediment caused by their language limitations (Lau v. Nichols, 1974). Empirical research was needed to determine evidence-based intervention and instructional practices that would reap positive educational outcomes for LEP students. Researching LEP populations has its difficulties, which include the linguistic diversity of LEP students. According to a U.S. Census Bureau report studying responses from the 2007 American Community Survey, the number of people in the United States who spoke a language other than English at home increased by 140% since 1980. Furthermore, the largest increase was seen in Spanish speakers, a 211% increase over almost 30 years (Shin & Kominski, 2010). Moreover, children may identify their native language as Spanish but countries of origin may include Mexico, Spain, Costa Rica, Colombia, Puerto Rico, Ecuador, and other Spanish-speaking countries. The state of Texas is rich in dialectal varieties of Spanish.

Nationally, Hispanics have the lowest education attainment levels of any group in the United States, despite being the largest and fastest growing minority group (Kena et al., 2015).

Kena et al.'s (2015) study found the following:

> From fall 2002 through fall 2012, the number of White students enrolled in public elementary and secondary schools decreased from 28.6 million to 25.4 million, and their share of public school enrollment decreased from 59 to 51 percent. In contrast, the number of Hispanic students enrolled during this period increased from 8.6 million to 12.1 million students, and their share of public school enrollment increased from 18 to 24 percent (p. xxx).

Hispanic students are increasingly born in the United States: kindergartners (93%), grades 1-8 (86%) and high school (77%), with more than half (52%) of all

Hispanic students in the United States enrolled in only two states, Texas and California. Languages spoken in the home of the enrolled Hispanic students include, Spanish (69.9%), English (29.8), another Indo-European language (0.2%), and an Asian or other Pacific Island language (0.1%) (Fry & Gonzales, 2008). Since Texas is an immigration gateway, approximately 33% of the state reported speaking a language other than English in the home on the 2007 American Community Survey (ACS). Of the enrolled public elementary school students, one-in-four (24.7%) are Hispanic, while slightly fewer (23.9%) of enrolled elementary and secondary students are Hispanic. As Figure 2 reveals, the Hispanic enrollment in public and private elementary schools maintains an ascending trajectory. As the 26% Hispanic Kindergarten students advance through the grades, the high school percentage will rise from its 2011 rate of 21%. The upward trend has manifested itself over four decades (Fry & Lopez, 2012). As projected by the U.S. Census, Hispanics are predicted to comprise one-third of the school-age children in the United States by 2036 (Colby & Ortman, 2015).

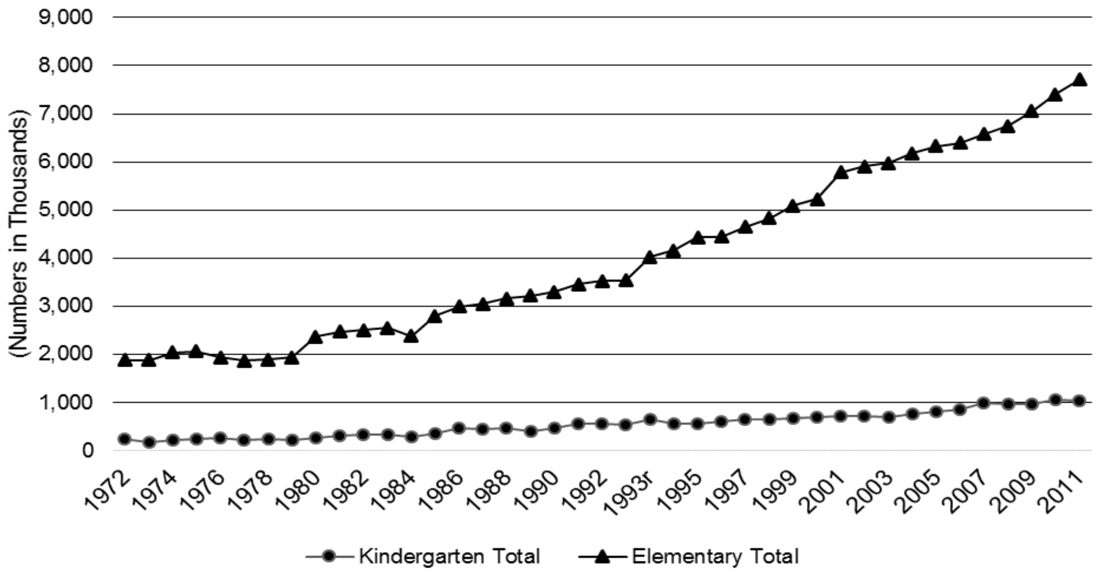


*Figure 2.* Hispanics enrolled in public and private schools in the United States. *Note*. Includes enrollment in any type of graded public, parochial, or other private schools. Source: U.S. Census Bureau, Current Population Survey (CPS), October, selected years, 1972 through 2013.

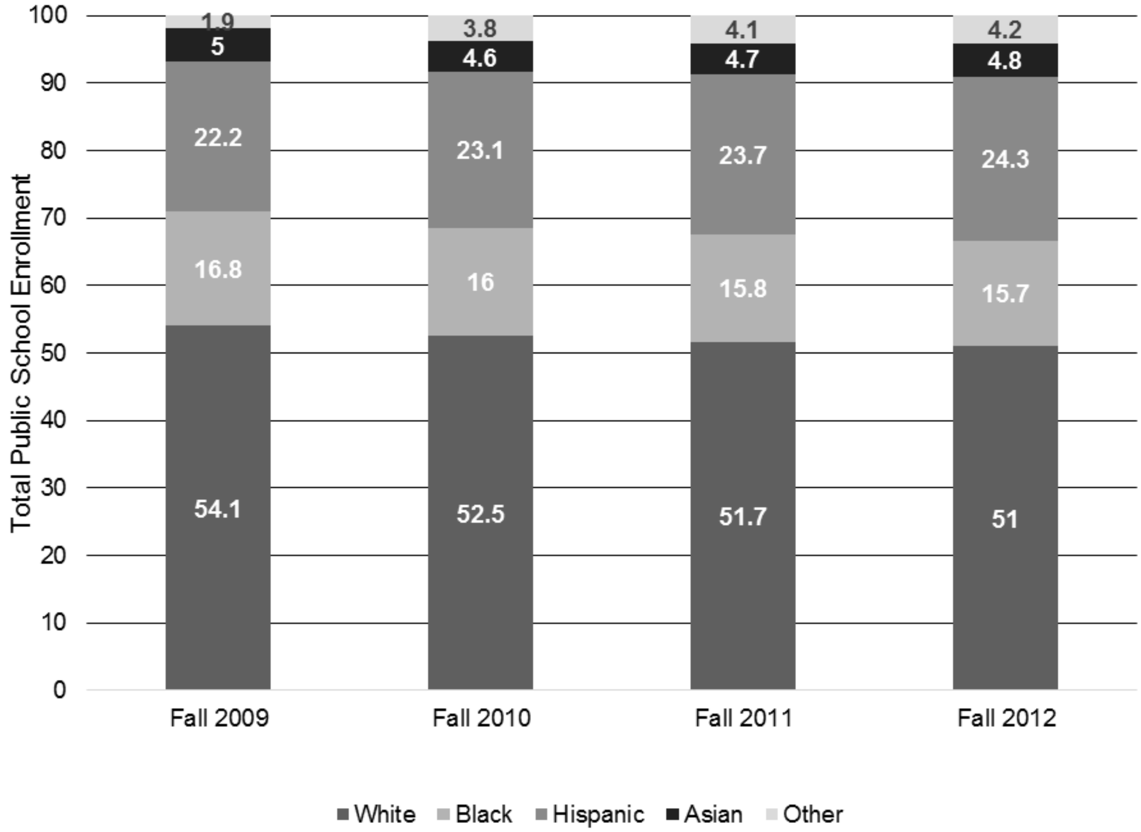


*Figure 3.* Public elementary and secondary school enrollment in the United States. *Note*: "Other" includes the following race categories: Native Hawaiian or Other Pacific Islander, American Indian/Alaska Native, and two or more races.
Source: U.S. Department of Education, National Center for Education Sciences, Table 214.40. Public elementary and secondary school enrollment, number of schools, and other selected characteristics, by locale: 2009-10 through 2012-13.

Similar to national enrollment trends (Figure 3), public schools in the state of Texas have seen increases in Asian, Hispanic, and multiracial enrollment, stagnant African American enrollment, and decreases in White enrollment for the 2012-2013 and 2013-2014 school years. Figure 4 depicts the steady increase of Hispanic enrollment in Texas public schools. During the 2013-2014 school year, Hispanics accounted for the largest percentage of total enrollment in Texas public schools, at 51.8% (Texas Education Agency, 2014).

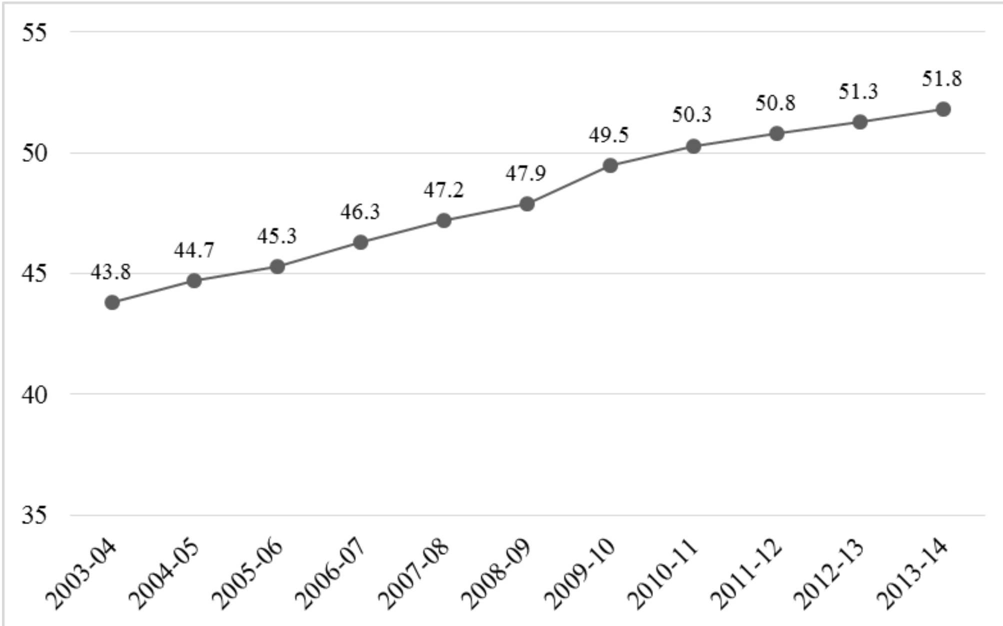


*Figure 4*. Hispanic enrollment as a percent of Texas public schools, 2003-2004 through 2013-2014.
Source: Texas Education Agency (2014). Enrollment in Texas public schools, 2013-2014.

According to the federal government, a Limited English Proficient (LEP) or English Language Learner (ELL) individual is a student between the ages of 3-21 who: is enrolled in an elementary or secondary school; was not born in the United States; has a native language other than English; and has difficulties in speaking, reading, writing, or understanding the English language that may be sufficient to deny the individual academic access or achievement (No Child Left Behind Act of 2001: Title IX, Part A, § 9101). Additionally, about 71% of the ELL population in the United States speaks Spanish in the home, with an even larger representation in the state of Texas (88.5%) (Batalova & McHugh, 2010).

Students participating in ELL programs in the United States continue to rise from 8.7 percent of public school students in 2002-2003, to 9.1 percent in 2011-2012, and to 9.2 percent in 2012-2013 (U.S. Department of Education, National Center for Education

Sciences, Table 214.40, 2013). The figures in the state of Texas are more robust for similar time frames: 14.9 percent in both 2002-2003 and 2011-2012 (U.S. Department of Education, National Center for Education Sciences, Table 214.20, 2013). Public Law 107-110--No Child Left Behind Act of 2001-- was an amendment of the Elementary and Secondary Education Act of 1965 (20 U.S.C. 6301 et seq.) that sought to meet the needs of various subgroups of the K-12 population, including limited English proficiency children, low-achieving children, and children with disabilities.

With the increased Hispanic population in public and private schools, in particular in the state of Texas, it is essential to conduct research regarding the achievement outcomes for this population. Many LEP and ELL students need specialized or individualized instruction due to their unique learning needs. They struggle significantly in developing English proficiency, educational skills, and meeting grade-level standards. Better understanding the cognitive predictors of achievement in Spanish-speaking and English-speaking Hispanic children will assist schools to identify the following: appropriate interventions, areas to screen when children exhibit academic difficulty, assessment practices, and teacher recommendations.

**Research Questions**

Research Question 1: What are the group differences between students assessed in English or Spanish?

Research Question 2: What narrow cognitive abilities for students identified with a specific learning disability best predict Basic Reading, Reading Comprehension, Math Calculation, Math Reasoning, and Written Expression abilities when assessed in English or Spanish?

# Chapter III

# Method

## Participants

Participants included students from first grade through fifth grade who were referred for an initial psycho-educational evaluation due to academic concerns by their school staff or by their parents and met the eligibility criteria for a specific learning disability. The participants were enrolled in an urban Texas public independent school district or in a private or parochial school within the attendance boundaries of an urban Texas public independent school district during the 2012-2014 school years. All participants were evaluated during that time frame. The present study was conducted through a review of archival data records, which screened for the administration of the WJ III or Batería III ACH and COG instruments. The inclusion criteria was that the students were tested on the Basic Reading, Reading Comprehension, Math Calculation, Math Reasoning, and Written Expression clusters and were tested on the cognitive narrow abilities. Of the 4,358 students initially referred for a special education evaluation during the 2012-14 school years, 684 met the criteria for inclusion in the current study.

Prior to the psychoeducational assessment, the language of testing was determined based on a variety of information sources including the language used in the home, the primary language of the child as reported by the parent, Texas English Language Proficiency Assessment System (TELPAS) results, the number of years instructed in a bilingual classroom, oral language proficiency testing results, and LEP status. Once a testing language determination was made, the child was administered either the WJ III or the Batería III COG and ACH.

## Instrumentation

Table 1 illustrates the measures obtained from WJ III and the Batería III COG and ACH that were studied (Mather, & Woodcock, 2001).

Table 1.

*Descriptions of WJ III/Batería III Achievement and Cognitive Subtests and Clusters*

| WJ III/Batería III Cluster | Description of Cluster | Tests Forming Cluster |
|---|---|---|
| Tests of Achievement | | |
| Basic Reading Skills<br>Destrezas básicas en lectura | Ability to identify individual printed letters and words and to pronounce phonically regular nonsense words | Letter-Word Identification/ Identificación de letras y palabras<br>Word Attack/Análisis de palabras |
| Reading Comprehension<br>Comprensión de lectura | Ability to read words and understand written text, produce appropriate synonyms, antonyms, and complete analogies | Passage Comprehension/Comprensión de textos<br>Reading Vocabulary/Vocabulario de lectura |
| Math Calculation<br>Destrezas en cálculus matemáticos | Ability to use computation skills and basic math facts with automaticity | Calculation/ Cálculo<br>Math Fluency/Fluidez en matemáticas |
| Math Reasoning<br>Razonamiento en matemáticas | Ability to use math knowledge and math reasoning | Applied Problems/Problemas aplicados<br>Quantitative Concepts/Conceptos cuantitativos |
| Written Expression<br>Expresión escrita | Ability to fluently write and write with quality of expression | Writing Fluency/Fluidez en la escritura<br>Writing Samples/Muestras de redacción |
| Tests of Cognitive Abilities | | |
| Comprehension-Knowledge (G*c*)<br>Comprensión-conocimiento (G*c*) | Ability to use language and acquired knowledge effectively | Verbal Comprehension/Comprensión verbal (VL)<br>General Information/Información general (KO) |

Table 1.

*Descriptions of WJ III/Batería III Achievement and Cognitive Subtests and Clusters (cont.)*

| WJ III/Batería III Cluster | Description of Cluster | Tests Forming Cluster |
|---|---|---|
| Long-term Retrieval (G*lr*)<br>Recuperación a largo plazo (G*lr*) | Ability to store and readily retrieve information in long-term memory | Visual-Auditory Learning/Aprendizaje visual-auditivo (MA)<br>Retrieval Fluency/Fluidez de recuperación (FI) |
| Visual-Spatial Thinking (G*v*)<br>Percepción visual-espacial (G*v*) | Ability to recognize spatial relationship and to analyze and manipulate visual stimuli | Spatial Relations/Relaciones espaciales (Vz)<br>Picture Recognition/Reconocimiento de dibujos (MV) |
| Auditory Processing (G*a*)<br>Procesamiento auditivo (G*a*) | Ability to perceive, attend to, and analyze patterns of sound and speech | Sound Blending/Integración de sonidos (PC1)<br>Incomplete Words/Palabras incompletas (PC2) |
| Fluid Reasoning (G*f*)<br>Razonamiento fluido (G*f*) | Ability to form and recognize logical relationships among patterns, and to make deductive and inductive inferences, and to transform novel stimuli | Concept Formation/Formación de conceptos (I)<br>Analysis-Synthesis/Análisis-Síntesis (RG) |
| Processing Speed (G*s*)<br>Rapidez en el procesamiento (G*s*) | Ability to perform simple cognitive tasks quickly, especially when under pressure to maintain focused attention and concentration | Visual Matching/Pareo visual (P1)<br>Decision Speed/Rapidez en la decision (P2) |
| Short-term Memory (G*sm*)<br>Memoria a corto plazo (G*sm*) | Ability to understand and store information in immediate awareness and then use it within a few seconds | Numbers Reversed/Inversión de números (MW)<br>Memory for Words/Memoria para palabras (MS) |

Woodcock and McGrew (2001) developed the WJ III tests. Studies involving both the WJ III norming sample and an additional 775 validity study subjects provide empirical evidence to support the interpretation of specific cognitive abilities and achievement (Woodcock, McGrew, & Mather, 2001). More than 100 geographically diverse communities were utilized for the norming sample that endeavored to replicate the U.S. population per the 2000 census. Median reliability was established on the norming sample with Cronbach's Alphas of .80 or higher for nine cognitive subtests and .90 or higher for four cognitive subtests utilized in this study. The following were the median reliabilities for the achievement clusters: Basic Reading (0.95), Reading Comprehension (not provided), Math Calculation Skills (0.91), Math Reasoning (0.95), and Written Expression (0.91). Validity (content, developmental, internal structure, and relationships to other external variables) has been established through exploratory and confirmatory factor analysis (CFA) according to CHC theory (Schrank, McGrew, & Woodcock, 2001).

According to Schrank, McGrew, Ruef, Alvarado, Muñoz-Sandoval, and Woodcock (2005), "All of the Batería III tests are either translations or adaptations of the parallel tests in the WJ III" (p. 12). Translation of subtests occurred when all WJ III test items stayed unchanged and only the directions were expressed in Spanish. Adaptation occurred when the subtest concept stayed fundamentally the same, however the test items were altered in some way. Of the cognitive measures involved in this study, six were adapted and eight were translated. Of the academic measures involved in this study, seven were adapted, two were translated, and one was partially translated and partially adapted.

Native Spanish-speaking domestic and international subjects were utilized for the standardization-calibration process. Of the 1,413 total sample, 279 were from the United States, with the state of Texas representing the largest number of domestic subjects ($n$ = 92). Subsequently, the calibration results and the WJ III norms were equated. Median reliability for the adapted cognitive subtests was established on the calibration sample with Cronbach's Alphas .80 or higher for three subtests and .90 or higher for three subtests utilized in this study. Median reliability coefficients for the adapted Batería III achievement clusters are similar to those of the WJ III: Basic Reading (0.97), Reading Comprehension (0.96), Math Reasoning (0.97), and Written Expression (0.90). Validity (content, developmental, internal structure, and relationships to other external variables) has been established through exploratory and confirmatory factor analysis (CFA) according to CHC theory (Schrank et al., 2005). A full description of the dependent variables and the independent variables is listed in Table 2.

Table 2.

*List of Independent and Dependent Variables*

| Variable | Operationalization |
|---|---|
| Independent Variables | |
| Gender | Categorical<br>0 = female<br>1 = male |
| Grade | Categorical<br>1 = First grade<br>2 = Second grade<br>3 = Third grade<br>4 = Fourth grade<br>5 = Fifth grade |
| Ethnicity | Categorical<br>0 = Hispanic<br>1 = Other (African-American and White) |
| Retained | Categorical<br>0 = No<br>1 = Yes |
| LEP Status | Categorical<br>0 = Non-LEP<br>1 = LEP |
| Economically Disadvantaged | Categorical<br>0 = No<br>1=Yes |
| Language of Assessment | Categorical<br>0 = English<br>1 = Spanish |

Table 2.

*List of Independent and Dependent Variables (cont.)*

| Variable | Operationalization |
|---|---|
| Lexical Knowledge (G*c*:VL) | Continuous |
| General Verbal Information (G*c*:KO) | Continuous |
| Variable | Operationalization |
| Independent Variables | |
| Associative Memory (G*lr*:MA) | Continuous |
| Ideational Fluency (G*lr*:FI) | Continuous |
| Induction (G*f*:I) | Continuous |
| General Sequential Reasoning (G*f*:RG) | Continuous |
| Memory Span (G*sm*:MS) | Continuous |
| Working Memory (G*sm*:MW) | Continuous |
| Perceptual Speed (G*s*:P1) | Continuous |
| Perceptual Speed (G*s*:P2) | Continuous |
| Visualization (G*v*:Vz) | Continuous |
| Visual Memory (G*v*:MV) | Continuous |
| Phonetic Coding (G*a*:PC1) | Continuous |
| Phonetic Coding (G*a*:PC2) | Continuous |
| Dependent Variables | |
| Basic Reading Skills<br>Destrezas básicas en lectura | Continuous |
| Reading Comprehension<br>Comprensión de lectura | Continuous |
| Math Calculation<br>Destrezas en cálculus matemáticos | Continuous |
| Math Reasoning<br>Razonamiento en matemáticas | Continuous |
| Written Expression<br>Expresión escrita | Continuous |

**Procedure**

A proposal to conduct the study was submitted to the research department of an urban Texas public independent school district.  Upon the approval of the research department, the University of Houston's Institutional Review Board, and the dissertation committee, data collection was initiated. In order to maintain confidentiality, the district used for the purpose of this study will hereby be known as a large school district in Texas. Once received, the research approval letter was placed on file in the IRB office at the University of Houston. Then, the examiner collected data from individual student reports that were maintained electronically by the district.

The participants were tested using the WJ III or Batería III COG and ACH. In addition to the results of the WJ III and Batería III COG and ACH, demographic data (grade, gender, ethnicity, retention, economically disadvantaged, and Limited English Proficiency or LEP status) was collected. Students who were assessed with an instrument other than the WJ III or Batería III COG and ACH were excluded from this study. In addition, students who were not enrolled in first through fifth grades during the 2012-2014 school years were excluded.

As part of the evaluation, broad cognitive abilities were measured with two subtests. The participants were assessed by qualified examiners in a Texas public school system and certified as such by the State Board of Education.

**Research Design and Analysis**

The current research is a correlational study with an archival design. For the first research question, the data was analyzed using descriptive statistics to explain the demographics of the groups and their profiles. Additionally, independent samples t-tests were utilized to investigate group differences. For the second research question, the variables were examined using Pearson Product Moment Correlations. This allowed for the examination of both independent variables (narrow cognitive abilities and LEP status) and the dependent variables, Basic Reading, Reading Comprehension, Math Calculation, Math Reasoning, and Written Expression. Determinations were made to run the multiple regressions on the achievement domains using the correlated cognitive scales as independent variables.

Statistically, there were several methods through which relations between cognitive abilities and achievement outcomes could have been analyzed. Knowing the best combination of cognitive abilities that relate to academic outcomes would be of benefit at the school, classroom, and individual child level; therefore, the stepwise method was chosen. This method allows for the removal of independent variables that do not have a substantial unique contribution (Meyers, Gamst, Guarino, 2013, p. 360).

Multiple regression is a parametric statistical procedure which requires that all its variables be in continuous form. A multiple regression has a criterion variable, Y, also known as the intercept, which is being predicted by one or more independent variables using their calculated slopes and multiplied by their raw values. An example of a regression estimate equation would be $Y = \beta_0 + = \beta_1 (X1) + \beta_2 (X2) + \beta_3 (X3)$. The regression tells how much the independent variables account for the variance in the dependent variable, Y, using the $R^2$.

The coefficients of determination were found for the achievement domains and the independent variables that did not contribute to prediction were dropped in each model (Meyers, Gamst, & Guarino, 2013, p. 334). The data was analyzed in Statistic Program for Social Science (SPSS), Version 23.0. The variables that were retained and removed in the final models were reviewed in light of previous research.

# Chapter IV

## Results

The purpose of this study was to determine what narrow cognitive abilities for students identified with a specific learning disability best predict Basic Reading, Reading Comprehension, Math Calculation, Math Reasoning, and Written Expression abilities when assessed in English or Spanish for students identified with a specific learning disability in grades 1 through 5. To further analyze the data, subgroups were created based on the language of the assessment and the data is presented by subgroups in this chapter: 1) students assessed in English and 2) students assessed in Spanish.

There were 684 participants who met the inclusion criteria for this study. As noted in Table 3, the participants included 386 males (56.4%) and 298 females (43.6%). Demographics for the urban school district for the same time period indicate that 51% of the students enrolled were male and 49% were female. The ethnic distribution of the sample was: Hispanic (n = 470, 68.7%), African American (n = 200, 29.2%), and White (n = 14, 2.0%). At the time of the study, 62.6% of enrolled students at the urban school district were Hispanic, 25.2% were African American and 7.9% were White. Students included in this study were enrolled in grades 1 (6.3%), 2 (19%), 3 (25.9%), 4 (28.5%), and 5 (20.3%). Students identified as Limited English Proficient accounted for 46.2% of the sample, exceeding the district's percentage of the enrolled population (30%). Moreover, students who were retained were equally represented in the total sample as compared to those who were not retained (49.4% and 50.6%, respectively). Students in this sample identified as economically disadvantaged were more robustly accounted for

(92.7%) than in the district’s population (80.7%). For the current study, the participants were not receiving special education services at the time of testing.

Table 3.

*Frequency Distribution of Student Demographic Characteristics of Students*

| Gender | Total Sample N | Total Sample Percent | English N | English Percent | Spanish N | Spanish Percent | Hispanic English N | Hispanic English Percent | Hispanic Spanish N | Hispanic Spanish Percent |
|---|---|---|---|---|---|---|---|---|---|---|
| Male | 386 | 56.4 | 242 | 53.2 | 144 | 62.9 | 132 | 54.8 | 144 | 62.9 |
| Female | 298 | 43.6 | 213 | 46.8 | 85 | 37.1 | 109 | 45.2 | 85 | 37.1 |
| Ethnicity | | | | | | | | | | |
| Hispanic | 470 | 68.7 | 241 | 53.0 | 229 | 100.0 | 241 | 100.0 | 229 | 100.0 |
| African American | 200 | 29.2 | 200 | 44.0 | | | | | | |
| White | 14 | 2.0 | 14 | 3.1 | | | | | | |
| LEP | | | | | | | | | | |
| No | 368 | 53.8 | 368 | 80.9 | 229 | 100.0 | 158 | 65.6 | 0 | 0 |
| Yes | 316 | 46.2 | 87 | 19.1 | | | 83 | 34.4 | 229 | 100.0 |
| Grade | | | | | | | | | | |
| 1 | 43 | 6.3 | 18 | 4.0 | 25 | 10.9 | 13 | 5.4 | 25 | 10.9 |
| 2 | 130 | 19.0 | 84 | 18.5 | 46 | 20.1 | 50 | 20.7 | 46 | 20.1 |
| 3 | 177 | 25.9 | 115 | 25.3 | 62 | 27.1 | 57 | 23.7 | 62 | 27.1 |
| 4 | 195 | 28.5 | 138 | 30.3 | 57 | 24.9 | 81 | 33.6 | 57 | 24.9 |
| 5 | 139 | 20.3 | 100 | 22.0 | 39 | 17.0 | 40 | 16.6 | 39 | 17.0 |
| Retained | | | | | | | | | | |
| No | 338 | 49.4 | 239 | 52.5 | 99 | 43.2 | 121 | 50.2 | 99 | 43.2 |
| Yes | 346 | 50.6 | 216 | 47.5 | 130 | 56.8 | 120 | 49.8 | 130 | 56.8 |
| Economically Disadvantaged | | | | | | | | | | |
| No | 50 | 7.3 | 43 | 9.5 | 7 | 3.1 | 22 | 9.1 | 7 | 3.1 |
| Yes | 634 | 92.7 | 412 | 90.5 | 222 | 96.9 | 219 | 90.9 | 222 | 96.9 |
| Total | 684 | | 455 | | 229 | | | | | |

English = students assessed in English; Spanish = students assessed in Spanish; Hispanic English = Hispanic students assessed in English; Hispanic Spanish = Hispanic students assessed in Spanish

Research Question 1: What are the group differences between students assessed in English or Spanish?

Means and standard deviations for the sample are presented in Table 4. There is slight variation in the number of subtests administered, which is due to the archival dataset and the inability to conduct follow up testing.

Table 4.

*Mean Scores for Groups*

| | | Total Sample | English | Spanish | Hispanic English | Hispanic Spanish |
|---|---|---|---|---|---|---|
| G*c*:VL | Mean | 79.63 | 81.12 | 76.68 | 80.89 | 76.68 |
| | (SD) | (10.83) | (10.75) | (10.38) | (10.57) | (10.38) |
| | N | 682 | 453 | 229 | 241 | 229 |
| G*c*:KO | Mean | 78.98 | 82.15 | 72.69 | 80.90 | 72.69 |
| | (SD) | (12.56) | (11.37) | (12.45) | (12.12 | (12.45) |
| | N | 682 | 453 | 229 | 241 | 229 |
| G*f*: RG | Mean | 90.46 | 90.29 | 90.80 | 92.89 | 90.80 |
| | (SD) | (13.57) | (13.34) | (14.04) | (12.80) | (14.04) |
| | N | 672 | 449 | 223 | 237 | 223 |
| G*f*:I | Mean | 87.77 | 87.80 | 87.71 | 89.68 | 87.71 |
| | (SD) | (12.52) | (12.88) | (11.78) | (13.81) | (11.78) |
| | N | 671 | 448 | 223 | 236 | 223 |
| G*lr*:FI | Mean | 82.24 | 82.80 | 81.14 | 82.58 | 81.14 |
| | (SD) | (14.65) | (14.17) | (15.52) | (14.39) | (15.52) |
| | N | 683 | 454 | 229 | 240 | 229 |
| G*lr*:MA | Mean | 74.61 | 73.12 | 77.58 | 75.26 | 77.58 |
| | (SD) | (16.02) | (16.29) | (15.07) | (15.53) | (15.07) |
| | N | 683 | 454 | 229 | 240 | 229 |
| G*sm*:MW | Mean | 80.89 | 82.69 | 77.29 | 82.75 | 77.29 |
| | (SD) | (16.15) | (15.78) | (16.32) | (17.04) | (16.32) |
| | N | 680 | 453 | 227 | 240 | 227 |
| G*sm*:MS | Mean | 85.65 | 86.91 | 83.16 | 85.70 | 83.16 |
| | (SD) | (13.76) | (13.58) | (13.81) | (12.46) | (13.81) |
| | N | 682 | 453 | 229 | 240 | 229 |

Table 4.

*Mean Scores for Groups (cont.)*

| | | Total Sample | English | Spanish | Hispanic English | Hispanic Spanish |
|---|---|---|---|---|---|---|
| G*s*:P1 | Mean | 85.88 | 85.12 | 87.40 | 87.28 | 87.40 |
| | (SD) | (14.10) | (13.77) | (14.65) | (13.18) | (14.65) |
| | N | 683 | 454 | 229 | 241 | 229 |
| G*s*:P2 | Mean | 93.07 | 92.26 | 94.68 | 94.49 | 94.68 |
| | (SD) | (14.75) | (15.02) | (14.08) | (14.18) | (14.08) |
| | N | 683 | 454 | 229 | 241 | 229 |
| G*a*:PC1 | Mean | 97.09 | 97.68 | 95.92 | 100.42 | 95.92 |
| | (SD) | (15.07) | (14.83) | (15.50) | (15.06) | (15.50) |
| | N | 675 | 448 | 227 | 235 | 227 |
| G*a*:PC2 | Mean | 91.72 | 91.80 | 91.55 | 94.34 | 91.55 |
| | (SD) | (15.06) | (16.08) | (12.85) | (15.92) | (12.85) |
| | N | 675 | 448 | 227 | 235 | 227 |
| G*v*:MV | Mean | 99.63 | 100.42 | 98.05 | 101.51 | 98.05 |
| | (SD) | (12.94) | (12.37) | (13.90) | (12.27) | (13.90) |
| | N | 680 | 453 | 227 | 240 | 227 |
| G*v*:SR | Mean | 93.85 | 93.66 | 94.22 | 94.92 | 94.22 |
| | (SD) | (9.54) | (9.38) | (9.85) | (9.19) | (9.85) |
| | N | 680 | 453 | 227 | 240 | 227 |
| Basic Reading | Mean | 87.39 | 83.52 | 95.08 | 85.09 | 95.08 |
| (BR) | (SD) | (16.70) | (12.66) | (20.66) | (12.37) | (20.66) |
| | N | 684 | 455 | 229 | 241 | 229 |
| Reading | Mean | 70.09 | 70.88 | 68.52 | 71.43 | 68.52 |
| Comprehension | (SD) | (13.71) | (12.97) | (14.99) | (12.04) | (14.99) |
| (RC) | N | 681 | 453 | 228 | 240 | 228 |
| Math | Mean | 77.97 | 79.08 | 75.75 | 82.85 | 75.75 |
| Calculation | (SD) | (16.92) | (12.97) | (19.86) | (14.20) | (19.86) |
| (MC) | N | 680 | 453 | 227 | 239 | 227 |
| Math | Mean | 76.98 | 78.19 | 74.59 | 80.17 | 74.59 |
| Reasoning | (SD) | (10.96) | (10.43) | (11.60) | (9.74) | (11.60) |
| (MR) | N | 682 | 453 | 229 | 239 | 229 |
| Written | Mean | 81.04 | 79.29 | 84.52 | 81.26 | 84.52 |
| Expression | (SD) | (14.47) | (13.68) | (15.37) | (13.30) | (15.37) |
| (WE) | N | 684 | 455 | 229 | 241 | 229 |

*Note*. English = Students assessed in English; Spanish = Students assessed in Spanish; Hispanic English = Hispanic students assessed in English; Hispanic Spanish = Hispanic students assessed in Spanish.

To help determine any group differences in the five dependent variables and the fourteen independent variables, independent samples t-tests were run to compare those tested in English versus Spanish (Table 5). Levine's test of equality of variance was significant for the independent variables, Associative Memory (MA) and Phonetic Coding 2 (PC2). Therefore, equal variances of these groups were not assumed. In the other twelve comparisons (VL, KO, RG, I, FI, MS, MW, P1, P2, PC1, MV, and SR), equal variances could be assumed since the assumption was not violated. Significant differences by group were found ($p<.01$) for VL, KO, MA, MS, and MW. Further exploration of the means found that students assessed in English scored significantly higher in VL, KO, MS, and MW; students assessed in Spanish scored significantly higher in MA.

Levine's test of equality of variance was significant for the dependent variables, Basic Reading and Math Calculation. Therefore, equal variances of these groups were not assumed. In the other three comparisons (Reading Comprehension, Math Reasoning, and Written Expression), equal variances could be assumed since the assumption was not violated. Significant differences by group were found ($p<.01$) for Basic Reading, Math Reasoning, and Written Expression. Further exploration of the means found that student assessed in English scored significantly higher in Math Reasoning; students assessed in Spanish scored significantly higher in Basic Reading and Written Expression.

Table 5.

*Independent Samples t-Tests for All Measures – Comparing Students Assessed in English versus Spanish*

| | | Levine's Test of Equality of Variances | | | | | | | 95% Confidence Interval of the Difference | |
|---|---|---|---|---|---|---|---|---|---|---|
| Measure | | F | Sig | t | df | Sig. (2 tailed) | Mean Difference | Std. Error Difference | Lower | Upper |
| Basic Reading (BR) | Equal variances assumed | 64.339 | .000 | -9.037 | 682 | .000 | -11.562 | 1.279 | -14.074 | -9.050 |
| | **Equal variances not assumed** | | | **-7.767** | **316.588** | **.000*** | **-11.562** | **1.489** | **-14.491** | **-8.633** |
| Reading Comprehension (RC) | **Equal variances assumed** | **2.875** | **.090** | **2.128** | **679** | **.034** | **2.363** | **1.111** | **.183** | **4.544** |
| | Equal variances not assumed | | | 2.029 | 401.653 | .043 | 2.363 | 1.165 | .073 | 4.653 |
| Math Calculation (MC) | Equal variances assumed | **13.724** | **.000** | 2.422 | 678 | .016 | 3.322 | 1.371 | .629 | 6.014 |
| | **Equal variances not assumed** | | | **2.218** | **361.529** | **.027** | **3.322** | **1.498** | **.376** | **6.267** |
| Math Reasoning (MR) | **Equal variances assumed** | **4.210** | **.041** | **4.093** | **680** | **.000*** | **3.596** | **.879** | **1.871** | **5.321** |
| | Equal variances not assumed | | | 3.952 | 417.306 | .000 | 3.596 | .910 | 1.808 | 5.384 |
| Written Expression (WE) | **Equal variances assumed** | **1.163** | **.281** | **-4.525** | **682** | **.000*** | **-5.232** | **1.156** | **-7.502** | **-2.962** |
| | Equal variances not assumed | | | -4.354 | 413.004 | .000 | -5.232 | 1.201 | -7.594 | -2.870 |
| G*c*:VL | **Equal variances assumed** | **.146** | **.702** | **5.156** | **680** | **.000*** | **4.42** | **.862** | **2.751** | **6.134** |
| | Equal variances not assumed | | | 5.214 | 471.969 | .000 | 4.42 | .852 | 2.768 | 6.117 |
| G*c*:KO | **Equal variances assumed** | **1.384** | **.240** | **9.932** | **680** | **.000*** | **9.458** | **.952** | **7.588** | **11.328** |
| | Equal variances not assumed | | | 9.642 | 423.029 | .000 | 9.458 | .981 | 7.530 | 11.386 |
| G*f*: RG | **Equal variances assumed** | **.393** | **.531** | **-.465** | **670** | **.642** | **-.518** | **1.112** | **-2.701** | **1.666** |
| | Equal variances not assumed | | | -.458 | 423.726 | .648 | -.518 | 1.131 | -2.741 | 1.706 |
| G*f*:I | **Equal variances assumed** | **.202** | **.653** | **.088** | **669** | **.930** | **.091** | **1.027** | **-1.925** | **2.106** |
| | Equal variances not assumed | | | .091 | 480.343 | .928 | .091 | .996 | -1.867 | 2.048 |

Table 5.

*Independent Samples t-Tests for All Measures – Comparing Students Assessed in English versus Spanish (cont.)*

| | | Levine's Test of Equality of Variances | | | | | | | 95% Confidence Interval of the Difference | |
|---|---|---|---|---|---|---|---|---|---|---|
| Measure | | F | Sig | t | df | Sig. (2 tailed) | Mean Difference | Std. Error Difference | Lower | Upper |
| G*lr*:FI | **Equal variances assumed** | **.549** | **.459** | **1.394** | 6**81** | **.164** | **1.653** | **1.186** | **-.676** | **3.983** |
| | Equal variances not assumed | | | 1.352 | 422.422 | .177 | 1.653 | 1.222 | -.750 | 4.056 |
| G*lr*:MA | Equal variances assumed | **6.636** | **.010** | -3.461 | 681 | .001 | -4.457 | 1.288 | -6.986 | -1.929 |
| | **Equal variances not assumed** | | | **-3.551** | **490.141** | **.000*** | **-4.457** | **1.255** | **-6.924** | **-1.991** |
| G*sm*:MW | **Equal variances assumed** | **.833** | **.362** | **4.166** | **678** | **.000*** | **5.407** | **1.298** | **2.858** | **7.955** |
| | Equal variances not assumed | | | 4.119 | 439.189 | .000 | 5.407 | 1.313 | 2.827 | 7.986 |
| G*sm*:MS | **Equal variances assumed** | **.635** | **.426** | **3.386** | **680** | **.001*** | **3.750** | **1.107** | **1.576** | **5.924** |
| | Equal variances not assumed | | | 3.368 | 451.043 | .001 | 3.750 | 1.113 | 1.562 | 5.938 |
| G*s*:P1 | **Equal variances assumed** | **.382** | **.537** | **-2.000** | **681** | **.046** | **-2.281** | **1.140** | **-4.520** | **-.041** |
| | Equal variances not assumed | | | -1.959 | 433.251 | .051 | -2.281 | 1.164 | -4.568 | .007 |
| G*s*:P2 | **Equal variances assumed** | **.966** | **.326** | **-2.027** | **681** | **.043** | **-2.417** | **1.193** | **-4.758** | **-.075** |
| | Equal variances not assumed | | | -2.070 | 484.589 | .039 | -2.417 | 1.167 | -4.711 | -.123 |
| G*a*:PC1 | **Equal variances assumed** | **.666** | **.415** | **1.434** | **673** | **.152** | **1.760** | **1.227** | **-.649** | **4.169** |
| | Equal variances not assumed | | | 1.414 | 436.893 | .158 | 1.760 | 1.245 | -.686 | 4.207 |
| G*a*:PC2 | Equal variances assumed | **14.108** | **.000** | .210 | 673 | .834 | .257 | 1.228 | -2.153 | 2.668 |
| | **Equal variances not assumed** | | | **.225** | **551.206** | **.822** | **.257** | **1.142** | **-1.986** | **2.501** |
| G*v*:MV | **Equal variances assumed** | **1.416** | **.234** | **2.258** | **678** | **.024** | **2.369** | **1.049** | **.309** | **4.428** |
| | Equal variances not assumed | | | 2.173 | 408.978 | .030 | 2.369 | 1.090 | .226 | 4.512 |
| G*v*:SR | **Equal variances assumed** | **.208** | **.649** | **-.716** | **678** | **.474** | **-.556** | **.776** | **-2.079** | **.968** |
| | Equal variances not assumed | | | -.705 | 433.200 | .481 | -.556 | .789 | -2.106 | .994 |

*Note*. *$p$<.01

Research Question 2: What narrow cognitive abilities for students identified with a specific learning disability best predict Basic Reading, Reading Comprehension, Math Calculation, Math Reasoning, and Written Expression abilities when assessed in English or Spanish?

The sample was parsed into two groups, students assessed in English and students assessed in Spanish. For both groups, Pearson's correlations were computed to examine the relationships between the independent variables--narrow cognitive abilities, and the dependent variables--five areas of achievement. Table 6 reports results of correlations between independent and dependent variables for students assessed in English or Spanish. Pearson's correlations between independent and dependent variables for Hispanic students assessed in English or Spanish are reported in Table 7.

The correlations with Basic Reading yielded eleven statistically significant cognitive predictors in the English sample and seven in the Spanish sample. Pearson's bivariate correlations for Math Calculation produced eleven significant predictors in the English or Spanish samples. The statistically significant correlations with Math Reasoning totaled fourteen for the English sample and twelve for the Spanish sample. Lastly, there were twelve cognitive abilities significantly statistically correlated with Written Expression for the English sample and seven for the Spanish sample.

Table 6.

*Pearson Product Moments Between All Measures for All Students*

| Measure | G*c* VL | G*c* KO | G*f* I | G*f* RG | G*lr* FI | G*lr* MA | G*sm* MS | G*sm* MW | Gs P1 | G*s* P2 | G*a* PC1 | G*a* PC2 | G*v* MV | G*v* SR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| English | | | | | | | | | | | | | | |
| BR | 0.165** | 0.089 | 0.102* | 0.124** | 0.171** | 0.287** | 0.118** | 0.116** | 0.133** | 0.008 | 0.237** | 0.176** | 0.046 | 0.114* |
| RC | 0.369** | 0.288** | 0.195** | 0.171** | 0.221** | 0.377** | 0.186** | 0.197** | 0.113* | 0.017 | 0.176** | 0.210** | 0.078 | 0.117* |
| MC | 0.170** | 0.044 | 0.249** | 0.320** | 0.214** | 0.146** | 0.047 | 0.217** | 0.334** | 0.315** | 0.105* | 0.074 | 0.170** | 0.251** |
| MR | 0.315** | 0.201** | 0.306** | 0.348** | 0.209** | 0.179** | 0.176** | 0.303** | 0.297** | 0.220** | 0.198** | 0.158** | 0.165** | 0.330** |
| WE | 0.257** | 0.148** | 0.157** | 0.207** | 0.202** | 0.216** | 0.133** | 0.176** | 0.254** | 0.134** | 0.254** | 0.219** | 0.091 | 0.079 |
| Spanish | | | | | | | | | | | | | | |
| BR | 0.228** | -0.036 | -0.098 | -0.011 | -0.065 | 0.132* | 0.170* | 0.233** | 0.211** | -0.021 | 0.136* | 0.014 | 0.148* | 0.092 |
| RC | 0.377** | 0.203** | 0.096 | 0.192** | 0.172** | 0.316** | 0.198** | 0.291** | 0.278** | 0.086 | 0.255** | 0.160* | 0.125 | 0.095 |
| MC | 0.257** | 0.038 | 0.218** | 0.200** | 0.159* | 0.187** | 0.291** | 0.338** | 0.352** | 0.239** | 0.111 | -0.050 | 0.178** | 0.167* |
| MR | 0.469** | 0.243** | 0.249** | 0.300 | 0.152* | 0.191** | 0.355** | 0.395** | 0.324** | 0.180** | 0.147* | 0.106 | 0.259** | 0.214** |
| WE | 0.197** | 0.109 | 0.103 | 0.220** | 0.093 | 0.194** | 0.123 | 0.251** | 0.257** | 0.103 | 0.279** | 0.187** | 0.095 | 0.075 |

BR = Basic Reading; RC = Reading Comprehension; MC = Math Calculation; MR = Math Reasoning; WE = Written Expression
*Note*. *$p$<.05, **$p$<.01, ***$p$<.001

Table 7.

*Pearson Product Moments Between All Measures for Hispanic Students*

| Measure | G*c* VL | G*c* KO | G*f* I | G*f* RG | G*lr* FI | G*lr* MA | G*sm* MS | G*sm* MW | Gs P1 | G*s* P2 | G*a* PC1 | G*a* PC2 | G*v* MV | G*v* SR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hispanic English | | | | | | | | | | | | | | |
| BR | .130* | .044 | .052 | .099 | .160* | .161* | .241** | .169** | .142* | .053 | .270** | .171** | .155* | .139* |
| RC | .322** | .241** | .143* | .171** | .226** | .275** | .368** | .255** | .142* | .083 | .223** | .194** | .175** | .130* |
| MC | .156* | .058 | .216** | .349** | .174** | .125 | .136* | .182** | .281** | .283** | .076 | .015 | .137* | .233** |
| MR | .331** | .216** | .254** | .411** | .222** | .121 | .211** | .303** | .181** | .147* | .165* | .115 | .181** | .331** |
| WE | .234** | .126 | .047 | .133* | .223** | .123 | .265** | .145* | .256** | .186** | .230** | .188** | .128* | .022 |
| Hispanic Spanish | | | | | | | | | | | | | | |
| BR | .228** | -.036 | -.098 | -.011 | -.065 | .132* | .170* | .233** | .211** | -.021 | .136* | .014 | .148* | .092 |
| RC | .377** | .203** | .096 | .192** | .172** | .316** | .198** | .291** | .278** | .086 | .255** | .160* | .125 | .095 |
| MC | .257** | .038 | .218** | .200** | .159* | .187** | .291** | .338** | .352** | .239** | .111 | -.050 | .178** | .167* |
| MR | .469** | .243** | .249** | .300** | .152* | .191** | .355** | .395** | .324** | .180** | .147* | .106 | .259** | .214** |
| WE | .197** | .109 | .103 | .220** | .093 | .194** | .123 | .251** | .257** | .103 | .279** | .187** | .095 | .075 |

Hispanic English = Hispanic Students Assessed in English; Hispanic Spanish = Hispanic Students Assessed in Spanish; BR = Basic Reading; RC = Reading Comprehension; MC = Math Calculation; MR = Math Reasoning; WE = Written Expression

*Note*. *$p$<.05, **$p$<.01, ***$p$<.001

To study the relationship between cognitive abilities and academic outcomes, hierarchical multiple linear regression analyses were conducted. For students assessed in English, LEP status was entered at the first step of the hierarchical multiple linear regression analysis. Then, the correlated cognitive abilities were entered stepwise at the second step. Thus, LEP status was controlled in the results. For students assessed in Spanish, the correlated cognitive abilities were entered stepwise. All continuous predictors met the minimum criteria for assumptions of normality and absence of outliers. In addition, examination of residuals revealed that there were no violations of linearity or homoscedasticity assumptions.

As shown in Table 8, the results of the stepwise linear regression produced four significant models predicting Basic Reading for students assessed in English. The fourth stepwise multiple linear regression model was significant, ($F[4,435] = 18.75$, $p < .001$), explained the greatest amount of variance (14.7%, adjusted $R^2 = .139$) and is presented in Table 9. The results revealed that Associative Memory, Phonetic Coding 1, and Perceptual Speed 1were significant predictors of Basic Reading for students assessed in English, with higher scores on Associative Memory. LEP Status was not a significant predictor of Basic Reading scores for students assessed in English, indicating that students identified as LEP (compared to non-LEP) did not predict Basic Reading scores for students assessed in English.

Table 8.

*Basic Reading - Model Summary for Students Assessed in English Controlling for LEP Status*[a]

| Model | *R* | $R^2$(SEE) | Adjusted $R^2$ | *F* | *F* change |
|---|---|---|---|---|---|
| 1[b] | .106 | .011(12.665) | .009 | 4.980* | 4.980* |
| 2[c] | .300 | .090(12.166) | .086 | 21.541*** | 37.685*** |
| 3[d] | .372 | .138(11.850) | .132 | 21.348*** | 24.632*** |
| 4[e] | .383 | .147(11.804) | .139 | 18.749*** | 4.403* |

a. Dependent Variable: Basic Reading
b. Predictors: LEP Status
c. Predictors: LEP Status, Associative Memory
d. Predictors: LEP Status, Associative Memory, Phonetic Coding1
e. Predictors: LEP Status, Associative Memory, Phonetic Coding 1, Perceptual Speed 1
*Note*. *$p$<.05, **$p$<.01, ***$p$<.001

Table 9.

*Basic Reading - Stepwise Multiple Regression Summary Table for Students Assessed in English Controlling for LEP Status*[a]

| Model | Variables | B | Standard Error | Standardized Coefficients | *t* | *p* |
|---|---|---|---|---|---|---|
| 1 | LEP Status | .422 | .189 | .106 | 2.232 | .026 |
| 2 | LEP Status | .327 | .182 | .082 | 1.792 | .074 |
| | Associative Memory | .219 | .036 | .281 | 6.139 | .000 |
| 3 | LEP Status | .317 | .178 | .080 | 1.787 | .075 |
| | Associative Memory | .213 | .035 | .273 | 6.115 | .000 |
| | Phonetic Coding 1 | .191 | .038 | .221 | 4.963 | .000 |
| 4 | LEP Status | .323 | .177 | .081 | 1.823 | .069 |
| | Associative Memory | .204 | .035 | .262 | 5.838 | .000 |
| | Phonetic Coding 1 | .188 | .038 | .217 | 4.900 | .000 |
| | Perceptual Speed 1 | .086 | .041 | .094 | 2.098 | .036 |

a. Dependent Variable: Basic Reading

As shown in Table 10, the results of the stepwise linear regression produced three significant models predicting Basic Reading for students assessed in Spanish. The third stepwise multiple linear regression model was significant, ($F[3,219] = 8.02$, $p < .001$), explained the greatest amount of variance (9.9%, adjusted $R^2 = .087$) and is presented in Table 11. The results revealed that Working Memory, Perceptual Speed1, and Lexical knowledge were significant predictors of Basic Reading for students assessed in Spanish, with higher scores on Working Memory.

Table 10.

*Basic Reading - Model Summary for Students Assessed in Spanish*[a]

| Model | *R* | $R^2$(SEE) | Adjusted $R^2$ | *F* | *F* change |
|---|---|---|---|---|---|
| 1[b] | .232 | .054(20.058) | .050 | 12.622*** | 12.622*** |
| 2[c] | .286 | .082(19.807) | .073 | 9.797*** | 6.650* |
| 3[d] | .315 | .099(19.665) | .087 | 8.020*** | 4.182* |

a. Dependent Variable: Basic Reading
b. Predictors: Working Memory
c. Predictors: Working Memory, Perceptual Speed 1
d. Predictors: Working Memory, Perceptual Speed 1, Lexical Knowledge
*Note*. **p*<.05, ***p*<.01, ****p*<.001

Table 11.

*Basic Reading - Stepwise Multiple Regression Summary Table for Students Assessed in Spanish*[a]

| Model | Variables | B | Standard Error | Standardized Coefficients | *t* | *p* |
|---|---|---|---|---|---|---|
| 1 | Working Memory | .293 | .082 | .232 | 3.553 | .000 |
| 2 | Working Memory | .239 | .084 | .190 | 2.853 | .005 |
| | Perceptual Speed 1 | .240 | .093 | .172 | 2.579 | .011 |
| 3 | Working Memory | .190 | .087 | .151 | 2.187 | .030 |
| | Perceptual Speed 1 | .213 | .093 | .153 | 2.290 | .023 |
| | Lexical Knowledge | .275 | .134 | .140 | 2.045 | .042 |

a. Dependent Variable: Basic Reading

As shown in Table 12, the results of the stepwise linear regression produced five significant models predicting Reading Comprehension for students assessed in English. The fifth stepwise multiple linear regression model was significant, (F[5,432] = 28.28, p < .001), explained the greatest amount of variance (24.7%, adjusted R2 = .238) and is presented in Table 13. The results revealed that Associative Memory, Lexical Knowledge, Phonetic Coding 1, and Memory Span were significant predictors of Reading Comprehension for students assessed in English, with higher scores on Associative Memory. LEP Status was not a significant predictor of Reading Comprehension scores for students assessed in English, indicating that students identified as LEP (compared to non-LEP) did not predict Reading Comprehension scores for students assessed in English.

Table 12.

*Reading Comprehension - Model Summary for Students Assessed in English Controlling for LEP Status*[a]

| Model | $R$ | $R^2$(SEE) | Adjusted $R^2$ | $F$ | $F$ change |
|---|---|---|---|---|---|
| 1[b] | .060 | .004(12.915) | .001 | 1.590 | 1.590 |
| 2[c] | .393 | .154(11.913) | .150 | 39.662*** | 77.45*** |
| 3[d] | .477 | .227(11.399) | .222 | 42.567*** | 41.071*** |
| 4[e] | .489 | .239(11.323) | .232 | 34.079*** | 6.884** |
| 5[f] | .497 | .247(11.283) | .238 | 28.276*** | 4.092* |

a. Dependent Variable: Reading Comprehension
b. Predictors: LEP Status
c. Predictors: LEP Status, Associative Memory
d. Predictors: LEP Status, Associative Memory, Lexical Knowledge
e. Predictors: LEP Status, Associative Memory, Lexical Knowledge, Phonetic Coding 1
f. Predictors: LEP Status, Associative Memory, Lexical Knowledge, Phonetic Coding 1, Memory Span

*Note*. *$p$<.05, **$p$<.01, ***$p$<.001

Table 13.

*Reading Comprehension - Stepwise Multiple Regression Summary Table for Students Assessed in English Controlling for LEP Status*[a]

| Model | Variables | B | Standard Error | Standardized Coefficients | *t* | *p* |
|---|---|---|---|---|---|---|
| 1 | LEP Status | -1.976 | 1.567 | -.060 | -1.261 | .208 |
| 2 | LEP Status | -3.373 | 1.454 | -.103 | -2.319 | .021 |
| | Associative Memory | .309 | .035 | .390 | 8.801 | .000 |
| 3 | LEP Status | -1.086 | 1.437 | -.033 | -.756 | .450 |
| | Associative Memory | .245 | .035 | .309 | 6.973 | .000 |
| | Lexical Knowledge | .347 | .054 | .289 | 6.409 | .000 |
| 4 | LEP Status | -1.220 | 1.428 | -.037 | -.854 | .393 |
| | Associative Memory | .245 | .035 | .309 | 7.018 | .000 |
| | Lexical Knowledge | .325 | .054 | .270 | 5.965 | .000 |
| | Phonetic Coding 1 | .098 | .037 | .111 | 2.624 | .009 |
| 5 | LEP Status | -.886 | 1.433 | -.027 | -.618 | .537 |
| | Associative Memory | .238 | .035 | .301 | 6.829 | .000 |
| | Lexical Knowledge | .312 | .055 | .260 | 5.711 | .000 |
| | Phonetic Coding 1 | .093 | .037 | .105 | 2.476 | .014 |
| | Memory Span | .083 | .041 | .087 | 2.023 | .044 |

a. Dependent Variable: Reading Comprehension

As shown in Table 14, the results of the stepwise linear regression produced four significant models predicting Reading Comprehension for students assessed in Spanish.

The fourth stepwise multiple linear regression model was significant, (F[4,213] = 18.42, p < .001), explained the greatest amount of variance (25.7%, adjusted $R^2$ = .243), and is presented in Table 15. The results revealed that Lexical Knowledge, Perceptual Speed 1, Associative Memory, and Phonetic Coding 1 were significant predictors of Reading Comprehension for students assessed in Spanish, with higher scores on Lexical Knowledge.

Table 14.

*Reading Comprehension - Model Summary for Students Assessed in Spanish*[a]

| Model | *R* | $R^2$(SEE) | Adjusted $R^2$ | *F* | *F* change |
|---|---|---|---|---|---|
| 1[b] | .381 | .145(14.001) | .141 | 36.649*** | 36.649*** |
| 2[c] | .440 | .193(13.631) | .186 | 25.777*** | 12.887*** |
| 3[d] | .482 | .232(13.333) | .221 | 21.530*** | 10.708** |
| 4[e] | .507 | .257(13.144) | .243 | 18.417*** | 7.205** |

a. Dependent Variable: Reading Comprehension
b. Predictors: Lexical Knowledge
c. Predictors: Lexical Knowledge, Perceptual Speed 1
d. Predictors: Lexical Knowledge, Perceptual Speed 1, Associative Memory
e. Predictors: Lexical Knowledge, Perceptual Speed 1, Associative Memory, Phonetic Coding 1

*Note*. *$p$<.05, **$p$<.01, ***$p$<.001

Table 15.

*Reading Comprehension - Stepwise Multiple Regression Summary Table for Students Assessed in Spanish*[a]

| Model | Variables | B | Standard Error | Standardized Coefficients | *t* | *p* |
|---|---|---|---|---|---|---|
| 1 | Lexical Knowledge | .549 | .091 | .381 | 6.054 | .000 |
| 2 | Lexical Knowledge | .485 | .090 | .337 | 5.386 | .000 |
| | Perceptual Speed 1 | .229 | .064 | .224 | 3.590 | .000 |
| 3 | Lexical Knowledge | .388 | .093 | .269 | 4.169 | .000 |
| | Perceptual Speed 1 | .226 | .062 | .222 | 3.628 | .000 |
| | Associating Memory | .205 | .063 | .208 | 3.272 | .001 |
| 4 | Lexical Knowledge | .359 | .092 | .249 | 3.888 | .000 |
| | Perceptual Speed 1 | .218 | .062 | .214 | 3.540 | .000 |
| | Associative Memory | .185 | .062 | .187 | 2.971 | .003 |
| | Phonetic Coding 1 | .161 | .060 | .162 | 2.684 | .008 |

a. Dependent Variable: Reading Comprehension

As shown in Table 16, the results of the stepwise linear regression produced seven significant models predicting Math Calculation for students assessed in English. The seventh stepwise multiple linear regression model was significant, ($F[7,431] = 20.13$, $p < .001$), explained the greatest amount of variance (24.6%, adjusted $R^2 = .234$), and is presented in Table 17. The results revealed that Perceptual Speed 1, General Sequential Reasoning, Perceptual Speed 2, Ideational Fluency, and Visualization were significant predictors of Math Calculation for students assessed in English, with higher scores on

Perceptual Speed 1. LEP Status was not a significant predictor of Math Calculation scores for students assessed in English, indicating that students identified as LEP (compared to non-LEP) did not predict Math Calculation scores for students assessed in English.

Table 16.

*Math Calculation - Model Summary for Students Assessed in English Controlling for LEP Status*[a]

| Model | *R* | $R^2$(SEE) | Adjusted $R^2$ | F | F change |
|---|---|---|---|---|---|
| 1[b] | .075 | .066(15.039) | .003 | 2.459 | 2.459 |
| 2[c] | .341 | .116(14.194) | .112 | 28.676*** | 54.590*** |
| 3[d] | .423 | .179(13.696) | .173 | 31.635*** | 33.304*** |
| 4[e] | .452 | .204(13.498) | .197 | 27.882*** | 13.826*** |
| 5[f] | .475 | .225(13.335) | .216 | 25.196*** | 11.703** |
| 6[g] | .488 | .238(13.242) | .227 | 22.480*** | 7.118** |
| 7[h] | .496 | .246(13.183) | .234 | 20.132*** | 4.845* |

a. Dependent Variable: Math Calculation
b. Predictors: LEP Status
c. Predictors: LEP Status, Perceptual Speed 1
d. Predictors: LEP Status, Perceptual Speed 1, General Sequential Reasoning
e. Predictors: LEP Status, Perceptual Speed 1, General Sequential Reasoning, Perceptual Speed 2
f. Predictors: LEP Status, Perceptual Speed 1, General Sequential Reasoning, Perceptual Speed 2, Ideational Fluency
g. Predictors: LEP Status, Perceptual Speed 1, General Sequential Reasoning, Perceptual Speed 2, Ideational Fluency, Visualization
h. Predictors: LEP Status, Perceptual Speed 1, General Sequential Reasoning, Perceptual Speed 2, Ideational Fluency, Visualization, Lexical Knowledge

*Note*. *$p$<.05, **$p$<.01, ***$p$<.001

Table 17.
*Math Calculation - Stepwise Multiple Regression Summary Table for Students Assessed in English Controlling for LEP Status*[a]

| Model | Variables | B | Standard Error | Standardized Coefficients | *t* | *p* |
|---|---|---|---|---|---|---|
| 1 | LEP Status | 2.862 | 1.825 | .075 | 1.568 | .118 |
| 2 | LEP Status | 2.816 | 1.722 | .074 | 1.635 | .103 |
| | Perceptual Speed 1 | .361 | .049 | .333 | 7.389 | .000 |
| 3 | LEP Status | 2.291 | 1.664 | .060 | 1.376 | .169 |
| | Perceptual Speed 1 | .302 | .048 | .278 | 6.258 | .000 |
| | General Seq Reasoning | .289 | .050 | .257 | 5.771 | .000 |
| 4 | LEP Status | 2.035 | 1.642 | .053 | 1.240 | .216 |
| | Perceptual Speed 1 | .207 | .054 | .190 | 3.821 | .000 |
| | General Seq Reasoning | .277 | .049 | .246 | 5.601 | .000 |
| | Perceptual Speed 2 | .182 | .049 | .183 | 3.718 | .000 |
| 5 | LEP Status | 2.601 | 1.630 | .068 | 1.595 | .111 |
| | Perceptual Speed 1 | .196 | .054 | .181 | 3.666 | .000 |
| | General Seq Reasoning | .259 | .049 | .230 | 5.268 | .000 |
| | Perceptual Speed 2 | .169 | .049 | .170 | 3.477 | .001 |
| | Ideational Fluency | .156 | .046 | .148 | 3.421 | .001 |
| 6 | LEP Status | 2.449 | 1.620 | .064 | 1.512 | .131 |
| | Perceptual Speed 1 | .195 | .053 | .179 | 3.660 | .000 |
| | General Seq Reasoning | .225 | .050 | .200 | 4.462 | .000 |
| | Perceptual Speed 2 | .155 | .049 | .156 | 3.198 | .001 |
| | Ideational Fluency | .135 | .046 | .128 | 2.295 | .004 |
| | Visualization | .193 | .072 | .120 | 2.668 | .008 |
| 7 | LEP Status | 3.243 | 1.653 | .085 | 1.963 | .050 |
| | Perceptual Speed 1 | .196 | .053 | .180 | 3.702 | .000 |
| | General Seq Reasoning | .212 | .051 | .188 | 4.184 | .000 |
| | Perceptual Speed 2 | .154 | .048 | .154 | 3.178 | .002 |
| | Ideational Fluency | .120 | .046 | .114 | 2.597 | .010 |
| | Visualization | .176 | .073 | .110 | 2.428 | .016 |
| | Lexical Knowledge | .136 | .062 | .098 | 2.201 | .028 |

a. Dependent Variable: Math Calculation

As shown in Table 18, the results of the stepwise linear regression produced three significant models predicting Math Calculation for students assessed in Spanish. The third stepwise multiple linear regression model was significant, ($F[3,216] = 21.59$, $p < .001$), explained the greatest amount of variance (23.1%, adjusted $R^2 = .220$), and is presented in Table 19. The results revealed that Working Memory, Perceptual Speed 1, and Visualization were significant predictors of Math Calculation for students assessed in Spanish, with higher scores on Working Memory.

Table 18.

*Math Calculation - Model Summary for Students Assessed in Spanish*[a]

| Model | *R* | $R^2$(SEE) | Adjusted $R^2$ | *F* | *F* change |
|---|---|---|---|---|---|
| 1[b] | .349 | .122(18.613) | .118 | 30.159*** | 30.159*** |
| 2[c] | .439 | .193(17.886) | .185 | 25.872*** | 19.083*** |
| 3[d] | .480 | .231(17.499) | .220 | 21.586*** | 10.701** |

a. Dependent Variable: Math Calculation
b. Predictors: Working Memory
c. Predictors: Working Memory, Perceptual Speed 1
d. Predictors: Working Memory, Perceptual Speed 1, Visualization
*Note*. **p*<.05, ***p*<.01, ****p*<.001

Table 19.

*Math Calculation - Stepwise Multiple Regression Summary Table for Students Assessed in Spanish*[a]

| Model | Variables | B | Standard Error | Standardized Coefficients | *t* | *p* |
|---|---|---|---|---|---|---|
| 1 | Working Memory | .419 | .076 | .349 | 5.492 | .000 |
| 2 | Working Memory | .336 | .076 | .280 | 4.446 | .000 |
| | Perceptual Speed 1 | .368 | .084 | .275 | 4.368 | .000 |
| 3 | Working Memory | .322 | .074 | .268 | 4.347 | .000 |
| | Perceptual Speed 1 | .376 | .082 | .281 | 4.558 | .000 |
| | Visualization | .406 | .124 | .196 | 3.271 | .001 |

a. Dependent Variable: Math Calculation

As shown in Table 20, the results of the stepwise linear regression produced seven significant models predicting Math Reasoning for students assessed in English. The seventh stepwise multiple linear regression model was significant, (F[7,431] = 27.53, p <

.001), explained the greatest amount of variance (30.9%, adjusted $R^2$ = .298), and is presented in Table 21. The results revealed that General Sequential Reasoning, Lexical Knowledge, Perceptual Speed 1, Visualization, Working Memory, and Phonetic Coding 1 were significant predictors of Math Reasoning for students assessed in English, with higher scores on General Sequential Reasoning. LEP Status was not a significant predictor of Basic Reading scores for students assessed in English, indicating that students identified as LEP (compared to non-LEP) did not predict Math Reasoning scores for students assessed in English.

Table 20.

*Math Reasoning - Model Summary for Students Assessed in English Controlling for LEP Status*[a]

| Model | *R* | $R^2$(SEE) | Adjusted $R^2$ | *F* | *F* change |
|---|---|---|---|---|---|
| 1[b] | .032 | .001(10.481) | -.001 | .437 | .437 |
| 2[c] | .348 | .121(9.843) | .117 | 29.988*** | 59.480*** |
| 3[d] | .438 | .192(9.450) | .186 | 34.357*** | 38.006*** |
| 4[e] | .495 | .245(9.142) | .238 | 35.244*** | 30.835*** |
| 5[f] | .529 | .280(8.942) | .271 | 33.605*** | 20.664*** |
| 6[g] | .546 | .298(8.836) | .288 | 30.587*** | 11.444** |
| 7[h] | .556 | .309(8.778) | .298 | 27.528*** | 6.734* |

a. Dependent Variable: Math Reasoning
b. Predictors: LEP Status
c. Predictors: LEP Status, General Sequential Reasoning
d. Predictors: LEP Status, General Sequential Reasoning, Lexical Knowledge
e. Predictors: LEP Status, General Sequential Reasoning, Lexical Knowledge, Perceptual Speed 1
f. Predictors: LEP Status, General Sequential Reasoning, Lexical Knowledge, Perceptual Speed 1, Visualization
g. Predictors: LEP Status, General Sequential Reasoning, Lexical Knowledge, Perceptual Speed 1, Visualization, Working Memory
h. Predictors: LEP Status, General Sequential Reasoning, Lexical Knowledge, Perceptual Speed 1, Visualization, Working Memory, Phonetic Coding 1

*Note*. $*p<.05$, $**p<.01$, $***p<.001$

Table 21.

*Math Reasoning - Stepwise Multiple Regression Summary Table for Students Assessed in English Controlling for LEP Status*[a]

| Model | Variables | B | Standard Error | Standardized Coefficients | *t* | *p* |
|---|---|---|---|---|---|---|
| 1 | LEP Status | .841 | 1.272 | .032 | .661 | .509 |
| 2 | LEP Status | .341 | 1.196 | .013 | .285 | .776 |
| | General Seq Reasoning | .271 | .035 | .347 | 7.712 | .000 |
| 3 | LEP Status | 1.984 | 1.179 | .075 | 1.683 | .093 |
| | General Seq Reasoning | .234 | .034 | .299 | 6.812 | .000 |
| | Lexical Knowledge | .268 | .043 | .276 | 6.165 | .000 |
| 4 | LEP Status | 2.004 | 1.140 | .075 | 1.757 | .080 |
| | General Seq Reasoning | .195 | .034 | .249 | 5.749 | .000 |
| | Lexical Knowledge | .263 | .042 | .272 | 6.258 | .000 |
| | Perceptual Speed 1 | .179 | .032 | .237 | 5.553 | .000 |
| 5 | LEP Status | 1.738 | 1.117 | .065 | 1.556 | .120 |
| | General Seq Reasoning | .156 | .034 | .199 | 4.554 | .000 |
| | Lexical Knowledge | .237 | .042 | .245 | 5.720 | .000 |
| | Perceptual Speed 1 | .167 | .032 | .221 | 5.264 | .000 |
| | Visualization | .219 | .048 | .197 | 4.546 | .000 |
| 6 | LEP Status | 1.600 | 1.104 | .060 | 1.448 | .148 |
| | General Seq Reasoning | .146 | .034 | .186 | 4.278 | .000 |
| | Lexical Knowledge | .214 | .042 | .221 | 5.137 | .000 |
| | Perceptual Speed 1 | .149 | .032 | .198 | 4.717 | .000 |
| | Visualization | .202 | .048 | .181 | 4.216 | .000 |
| | Working Memory | .099 | .029 | .144 | 3.383 | .001 |
| 7 | LEP Status | 1.519 | 1.098 | .057 | 1.384 | .167 |
| | General Seq Reasoning | .144 | .034 | .185 | 4.274 | .000 |
| | Lexical Knowledge | .199 | .042 | .205 | 4.755 | .000 |
| | Perceptual Speed 1 | .148 | .031 | .196 | 4.710 | .000 |
| | Visualization | .195 | .048 | .175 | 4.094 | .000 |
| | Working Memory | .096 | .029 | .139 | 3.292 | .001 |
| | Phonetic Coding 1 | .075 | .029 | .106 | 2.595 | .010 |

a. Dependent Variable: Math Reasoning

As shown in Table 22, the results of the stepwise linear regression produced five significant models predicting Math Reasoning for students assessed in Spanish. The fifth stepwise multiple linear regression model was significant, ($F[5,213] = 25.05$, $p < .001$), explained the greatest amount of variance (37.0%, adjusted $R^2 = .356$), and is presented in Table 23. The results revealed that Lexical Knowledge, Working Memory, Visual Memory, Perceptual Speed 1, and General Sequential Reasoning were significant predictors of Math Reasoning for students assessed in Spanish, with higher scores on Lexical Knowledge.

Table 22.

*Math Reasoning - Model Summary for Students Assessed in Spanish*[a]

| Model | *R* | $R^2$(SEE) | Adjusted $R^2$ | *F* | *F* change |
|---|---|---|---|---|---|
| 1[b] | .457 | .209(10.287) | .205 | 57.188*** | 57.188*** |
| 2[c] | .532 | .283(9.817) | .276 | 42.545*** | 22.291*** |
| 3[d] | .574 | .329(9.516) | .320 | 35.156*** | 14.902*** |
| 4[e] | .595 | .354(9.361) | .342 | 29.276*** | 8.135** |
| 5[f] | .609 | .370(9.262) | .356 | 25.053*** | 5.630* |

a. Dependent Variable: Math Reasoning
b. Predictors: Lexical Knowledge
c. Predictors: Lexical Knowledge, Working Memory
d. Predictors: Lexical Knowledge, Working Memory, Visual Memory
e. Predictors: Lexical Knowledge, Working Memory, Visual Memory, Perceptual Speed 1
f. Predictors: Lexical Knowledge, Working Memory, Visual Memory, Perceptual Speed 1, General Sequential Reasoning

*Note*. *$p$<.05, **$p$<.01, ***$p$<.001

Table 23.

*Math Reasoning - Stepwise Multiple Regression Summary Table for Students Assessed in Spanish*[a]

| Model | Variables | B | Standard Error | Standardized Coefficients | *t* | *p* |
|---|---|---|---|---|---|---|
| 1 | Lexical Knowledge | .503 | .066 | .457 | 7.562 | .000 |
| 2 | Lexical Knowledge | .401 | .067 | .364 | 5.987 | .000 |
| | Working Memory | .202 | .043 | .287 | 4.721 | .000 |
| 3 | Lexical Knowledge | .378 | .065 | .343 | 5.796 | .000 |
| | Working Memory | .187 | .042 | .266 | 4.494 | .000 |
| | Visual Memory | .190 | .049 | .218 | 3.860 | .000 |
| 4 | Lexical Knowledge | .356 | .065 | .324 | 5.512 | .000 |
| | Working Memory | .164 | .042 | .234 | 3.940 | .000 |
| | Visual Memory | .176 | .049 | .202 | 3.614 | .000 |
| | Perceptual Speed 1 | .128 | .045 | .164 | 2.852 | .005 |
| 5 | Lexical Knowledge | .334 | .065 | .303 | 5.167 | .000 |
| | Working Memory | .155 | .041 | .221 | 3.742 | .000 |
| | Visual Memory | .165 | .048 | .190 | 3.418 | .001 |
| | Perceptual Speed 1 | .115 | .045 | .148 | 2.575 | .011 |
| | Gen Seq Reasoning | .110 | .047 | .135 | 2.373 | .019 |

a. Dependent Variable: Math Reasoning

As shown in Table 24, the results of the stepwise linear regression produced six significant models predicting Written Expression for students assessed in English. The sixth stepwise multiple linear regression model was significant, ($F[6,434] = 17.30$, $p < .001$), explained the greatest amount of variance (19.3%, adjusted $R^2 = .182$), and is presented in Table 25. The results revealed that Lexical Knowledge, Perceptual Speed 1, Phonetic Coding 1, Associative Memory, and General Sequential Reasoning were significant predictors of Written Expression for students assessed in English with higher scores on Lexical Knowledge. LEP Status was not a significant predictor of Written Expression scores for students assessed in English, indicating that students identified as LEP (compared to non-LEP) did not predict Basic Reading scores for students assessed in English.

Table 24.

*Written Expression - Model Summary for Students Assessed in English Controlling for LEP Status*[a]

| Model | $R$ | $R^2$(SEE) | Adjusted $R^2$ | F | F change |
|---|---|---|---|---|---|
| 1[b] | .018 | .000(13.649) | -.002 | .135 | .135 |
| 2[c] | .269 | .072(13.164) | .068 | 17.034*** | 33.923*** |
| 3[d] | .364 | .133(12.742) | .127 | 22.286*** | 30.497*** |
| 4[e] | .415 | .172(12.463) | .165 | 22.670*** | 20.791*** |
| 5[f] | .431 | .185(12.378) | .176 | 19.797*** | 7.047** |
| 6[g] | .439 | .193(12.334) | .182 | 17.297*** | 4.095* |

a. Dependent Variable: Written Expression
b. Predictors: LEP Status
c. Predictors: LEP Status, Lexical Knowledge
d. Predictors: LEP Status, Lexical Knowledge, Perceptual Speed 1
e. Predictors: LEP Status, Lexical Knowledge, Perceptual Speed 1, Phonetic Coding 1
f. Predictors: LEP Status, Lexical Knowledge, Perceptual Speed 1, Phonetic Coding 1, Associative Memory
g. Predictors: LEP Status, Lexical Knowledge, Perceptual Speed 1, Phonetic Coding 1, Associative Memory, General Sequential Reasoning

*Note*. *$p$<.05, **$p$<.01, ***$p$<.001

Table 25.

*Written Expression - Stepwise Multiple Regression Summary Table for Students Assessed in English Controlling for LEP Status*[a]

| Model | Variables | B | Standard Error | Standardized Coefficients | *t* | *p* |
|---|---|---|---|---|---|---|
| 1 | LEP Status | .609 | 1.655 | .018 | .368 | .713 |
| 2 | LEP Status | 2.644 | 1.634 | .076 | 1.618 | .106 |
| | Lexical Knowledge | .346 | .059 | .274 | 5.824 | .000 |
| 3 | LEP Status | 2.497 | 1.582 | .072 | 1.578 | .115 |
| | Lexical Knowledge | .327 | .058 | .259 | 5.665 | .000 |
| | Perceptual Speed 1 | .242 | .044 | .246 | 5.522 | .000 |
| 4 | LEP Status | 2.260 | 1.548 | .065 | 1.460 | .145 |
| | Lexical Knowledge | .283 | .057 | .224 | 4.949 | .000 |
| | Perceptual Speed 1 | .235 | .043 | .239 | 5.474 | .000 |
| | Phonetic Coding 1 | .186 | .041 | .202 | 4.560 | .000 |
| 5 | LEP Status | 1.558 | 1.560 | .045 | .999 | .318 |
| | Lexical Knowledge | .241 | .059 | .191 | 4.074 | .000 |
| | Perceptual Speed 1 | .222 | .043 | .226 | 5.169 | .000 |
| | Phonetic Coding 1 | .186 | .041 | .202 | 4.599 | .000 |
| | Associative Memory | .101 | .038 | .121 | 2.655 | .008 |
| 6 | LEP Status | 1.336 | 1.558 | .039 | .857 | .392 |
| | Lexical Knowledge | .225 | .059 | .178 | 3.798 | .000 |
| | Perceptual Speed 1 | .205 | .044 | .208 | 4.699 | .000 |
| | Phonetic Coding 1 | .184 | .040 | .199 | 4.551 | .000 |
| | Associative Memory | .092 | .038 | .110 | 2.413 | .016 |
| | Gen Seq Reasoning | .093 | .046 | .091 | 2.024 | .044 |

a. Dependent Variable: Written Expression

As shown in Table 26, the results of the stepwise linear regression produced four significant models predicting Written Expression for students assessed in Spanish. The fourth stepwise multiple linear regression model was significant, ($F[5,432] = 13.02$, $p <$

.001), explained the greatest amount of variance (19.6%, adjusted R2 = .181), and is presented in Table 27. The results revealed that Perceptual Speed 1, Phonetic Coding, Associative Memory, and General Sequential Reasoning were significant predictors of Written Expression for students assessed in Spanish, with higher scores on Perceptual Speed 1.

Table 26.

*Written Expression - Model Summary for Students Assessed in Spanish*[a]

| Model | $R$ | $R^2$(SEE) | Adjusted $R^2$ | $F$ | $F$ change |
|---|---|---|---|---|---|
| 1[b] | .309 | .096(13.293) | .091 | 22.926*** | 22.926*** |
| 2[c] | .390 | .152(12.899) | .144 | 19.394*** | 14.442*** |
| 3[d] | .425 | .181(12.711) | .169 | 15.797*** | 7.445** |
| 4[e] | .442 | .196(12.623) | .181 | 13.019*** | 4.021* |

a. Dependent Variable: Written Expression
b. Predictors: Perceptual Speed
c. Predictors: Perceptual Speed 1, Phonetic Coding 1
d. Predictors: Perceptual Speed 1, Phonetic Coding 1, Associative Memory
e. Predictors: Perceptual Speed 1, Phonetic Coding 1, Associative Memory, General Sequential Reasoning

*Note*. *$p$<.05, **$p$<.01, ***$p$<.001

Table 27.

*Written Expression - Stepwise Multiple Regression Summary Table for Students Assessed in Spanish*[a]

| Model | Variables | B | Standard Error | Standardized Coefficients | *t* | *p* |
|---|---|---|---|---|---|---|
| 1 | Perceptual Speed 1 | .292 | .061 | .309 | 4.788 | .000 |
| 2 | Perceptual Speed 1 | .273 | .059 | .289 | 4.596 | .000 |
| | Phonetic Coding 1 | .217 | .057 | .239 | 3.800 | .000 |
| 3 | Perceptual Speed 1 | .263 | .059 | .278 | 4.482 | .000 |
| | Phonetic Coding 1 | .190 | .057 | .210 | 3.333 | .001 |
| | Associative Memory | .156 | .057 | .171 | 2.729 | .007 |
| 4 | Perceptual Speed 1 | .242 | .059 | .257 | 4.101 | .000 |
| | Phonetic Coding 1 | .180 | .057 | .199 | 3.168 | .002 |
| | Associative Memory | .139 | .058 | .153 | 2.420 | .016 |
| | Gen Seq Reasoning | .126 | .063 | .127 | 2.005 | .046 |

a. Dependent Variable: Written Expression

Table 28.

*Results of Regressions with Magnitude in Order of Contribution to the Final Model*

| Measure | G*c* VL | G*c* KO | G*f* I | G*f* RG | G*lr* FI | G*lr* MA | G*sm* MS | G*sm* MW | G*s* P1 | G*s* P2 | G*a* PC1 | G*a* PC2 | G*v* MV | G*v* SR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BR - E | | | | | | 1 | | | 3 | | 2 | | | |
| BR - S | 3 | | | | | | | 1 | 2 | | | | | |
| RC - E | 2 | | | | | 1 | 4 | | | | 3 | | | |
| RC - S | 1 | | | | | 3 | | | 2 | | 4 | | | |
| MC - E | 6 | | | 2 | 4 | | | | 1 | 3 | | | | 5 |
| MC - S | | | | | | | | 1 | 2 | | | | | 3 |
| MR - E | 2 | | | 1 | | | | 5 | 3 | | 6 | | | 4 |
| MR - S | 1 | | | 5 | | | | 2 | 4 | | | | 3 | |
| WE - E | 1 | | | 5 | | 4 | | | 2 | | 3 | | | |
| WE - S | | | | 4 | | 3 | | | 1 | | 2 | | | |

BR = Basic Reading; RC = Reading Comprehension; MC = Math Calculation; MR = Math Reasoning; WE = Written Expression; E = Students assessed in English; S = Students assessed in Spanish

# Chapter V

## Discussion

The purpose of this study was to investigate group differences between students who were assessed with either the Woodcock-Johnson III (WJ III) or Bateria III Tests of Cognitive Abilities (COG) and Tests of Achievement (ACH) and identified with a Specific Learning Disability. Moreover, this study analyzed the CHC variables and their relations to achievement outcomes. While there are numerous studies analyzing the WJ III COG and ACH in normally developing samples of children, there are few known studies analyzing cognitive predictors of academic outcomes of Hispanic students with a Specific Learning Disability who were assessed in Spanish.

The participants in this archival record study were students from grades 1 through 5 whose school staff or parents had referred them for an initial psycho-educational evaluation due to academic concerns. Criteria for inclusion were the administration of the Woodcock-Johnson III COG and ACH or the Bateria-III COG and ACH during the 2012-14 school years and the ensuing identification as a student with a Specific Learning Disability. Initially, the relations between the fourteen cognitive abilities and five achievement outcomes were analyzed with correlation analyses. Subsequently, hierarchical regression analyses were used to investigate which of the predictor variables contributed to the explanation of the variance in students' academic skills.

The present study expanded upon previous CHC theory research. Most importantly for the research base, this study addressed the scarcity of CHC research regarding Hispanic children identified with a Specific Learning Disability, more specifically Hispanic children assessed in Spanish. This chapter will examine the results of the present study in the context of prior research by addressing each academic outcome. In conclusion, strengths and limitations of the current study will be reviewed, and implications and future areas of inquiry will be proffered.

**Basic Reading**

In the current study of students assessed in English, predictors in the final model for Basic Reading are Associative Memory (MA), Phonetic Coding 1 (PC), and Processing Speed 1 (P). For students assessed in Spanish, predictors in the final model included: Working Memory (MW), Perceptual Speed 1 (P), and Lexical Knowledge (VL). The following is a description of these predictive cognitive abilities for students assessed in English or Spanish:

**Associative Memory (MA).** Associative Memory (MA) is "the ability to remember previously unrelated information as having been paired" (Schneider & McGrew, 2012). The Visual-Auditory Learning subtest measures the ability to learn and recall relationships between disparate items. In essence, the examinees must learn and recollect a novel "code"; thus, these test items mimic the process of acquiring early reading skills. In the current study, Associative Memory predicted the greatest proportion of variance in Basic Reading in the English group which highlighted the role that learning plays in the attainment of reading skills. This cognitive ability was absent from the significant predictors for students assessed in Spanish.

A child's journey of learning to read begins with acquiring the letter names (visually) and their corresponding sounds (auditorially). Initially, the letters are meaningless visual symbols that then later are correlated to letter names and sounds. The Basic Reading cluster consisted of both word and nonword measures; hence this study confirms Windfuhr and Snowling's (2001) research findings that visual-verbal (also known as visual-auditory) paired learning accounted for unique variance in word and non-word reading. In a sample of normally developing children between the ages of 5 and 6 assessed in English, Floyd et al.'s (2007) study found large direct effects between MA and Basic Reading skills. However, these same effects did not hold for students who were seven years or older (Floyd et al., 2007). In the current study, MA exhibited no predictive value in students assessed in Spanish. This study illustrates that with little research on CHC abilities as they relate to academic outcomes in students assessed in Spanish, further study is essential to tease out impact of these findings on the needs of students and the field of assessment.

**Lexical Knowledge (VL).** Lexical Knowledge (VL), a narrow ability subsumed under G*c*, is defined as the "extend of vocabulary that can be understood in terms of correct word meanings" (Flanagan, Ortiz & Alfonso, 2013). The cognitive ability of Lexical Knowledge (VL) was a significant predictor of Basic Reading skills for students assessed in Spanish, albeit smaller in magnitude than the other two significant predictors in the final model; furthermore, this G*c* narrow ability was absent from predictors for students assessed in English. Fletcher et al.'s (2002) study found that vocabulary abilities accounted for unique variance in both real word and pseudoword decoding skills. Previous research identified the significant relation to be at the broad ability level (G*c*) (Durand, Hulme, Larking, & Snowling, 2005; Evans, et al., 2001; Hale, Fiorello, Kavanagh, Hoeppher, & Faither, 2001; McGrew, Werder, & Woodcock, 1991;

Vanderwood et al., 2002); however, similar to the current study findings for students assessed in English, Floyd et al. (2007) found that Lexical Knowledge was not a significant predictor of basic reading skills.

**Perceptual Speed 1 (P)**. Perceptual Speed (P) is the “ability with which visual stimuli can be compared for similarity or difference” (Flanagan, Ortiz, & Alfonso, 2013). The CHC cognitive ability of Perceptual Speed 1 (P) was consistently predictive of Basic Reading ability across both the English and Spanish groups. The Visual Matching subtest, which measures Perceptual Speed 1 and is identical in English and Spanish, is a non-verbal three-minute assessment of rapid visual perception and matching (Schrank & Wendling, 2009). When reading real and nonsense words, this finding is similar to Elliot et al.’s (2010) conclusion that processing speed is more germane for students with a learning disability than for typically developing children. The broad ability of Processing Speed (G*s*), under which Perceptual Speed (P) is subsumed, showed moderate relations with basic reading skills for children from approximately ages 6 to 10 in a nationally representative standardization sample (Evans et al., 2001).

**Phonetic Coding 1 (PC**). Phonetic Coding (PC) is the “ability to hear phonemes distinctly” (Flanagan, Ortiz, & Alfonso, 2013). Phonetic Coding was assessed by two subtests in this study, Sound Blending and Incomplete Words. Curiously, only Sound Blending--which measures the ability to “synthesize language sounds (phonemes) through the process of listening to a series of syllables or phonemes and then blending the sounds into a word” (Woodcock, McGrew & Mather, 2001)--was predictive of Basic Reading abilities in only the English group. This finding is consistent with a large number of strong and convincing studies (Evans et al., 2001; Konold, Juel & McKinnon, 1999; Muter, Hume, Snowling & Taylor, 2004; Nation & Snowling, 2004; Schatschneider et al., 2002; Vanderwood, McGrew, Flanagan & Keith, 2002; Vellutino et al., 1996). The strongest evidence of the causal relationship is the conclusive research demonstrating gains in reading skills after the use of an "explicit, systematic, synthetic" phonics program (National Reading Panel, 2000). Since Spanish is a phonetic language, meaning that words are pronounced the way they are written, the lack of direct effects of Phonetic Coding on Basic Reading cluster for students assessed in Spanish needs additional research.

**Working Memory (MW).** Working Memory is the "ability to direct the focus of attention to perform relatively simple manipulations, combinations, and transformations of information within primary memory, while avoiding distracting stimuli and engaging in strategic/controlled searches for information in secondary memory" (Schneider & McGrew, 2012). Similar to Floyd et al.'s (2007), Working Memory (MW) was not predictive of basic reading skills in students assessed in English; on the other hand, it was significantly predictive in the Spanish group. The outcome difference may be due to the participant contrasts, since the significant relation of Working Memory was evidenced in the group consisting of all Hispanic students; whereas, Floyd's sample was derived from the WJ III national standardization sample, which was comprised of 570 Hispanic students out of 4784 students in grades K -12 (Schrank, McGrew, & Woodcock, 2001).

In summary, higher Basic Reading ability was associated with higher cognitive abilities of Associative Memory, Phonetic Coding 1, and Perceptual Speed 1 for students assessed in English. Moreover, higher Basic Reading ability was associated with higher cognitive abilities of Working Memory, Perceptual Speed 1, and Lexical Knowledge for students assessed in Spanish.

**Reading Comprehension**

Predictors in the final model for Reading Comprehension are Associative Memory (MA), Lexical Knowledge (VL), Phonetic Coding 1 (PC), Memory Span (MS), for students assessed in English, when controlling for LEP status. For students assessed in Spanish, predictors in the fourth and final model included Lexical Knowledge, Perceptual Speed 1 (P), Associative Memory (MA), and Phonetic Coding 1 (PC). The following is a description of these cognitive abilities:

**Associative Memory (MA).** Associative Memory was found to be the strongest predictor of Reading Comprehension outcomes for students assessed in English and one of the five significant predictors for students assessed in Spanish. It is a logical conclusion that when students are able to pair the information they are reading, it will positively impact their ability to remember the new information and hence, support reading comprehension. Extant research has shown the broad ability of G*lr* related to reading comprehension (Evans et al., 2001).

**Lexical Knowledge (VL).** For both groups of students assessed in English and students assessed in Spanish, Lexical Knowledge displayed strong relations to the Reading Comprehension cluster. These results are consistent with more general research confirming the influence of language-based abilities on reading comprehension (Nation & Snowling, 2004). A more expansive vocabulary base positively impacted the students' reading comprehension. Numerous studies have reported significant relations between the broad ability of Comprehension-Knowledge (G*c*) and reading comprehension (Benson 2007; Floyd, Meisinger, Gregg & Keith, 2012).

**Memory Span (MS).** Memory Span is the ability to "encode information, maintain it in primary memory, and immediately reproduce the information in the same sequence in which it was represented" (Schneider & McGrew, 2012). The predictive value of Memory Span for students assessed in English is consistent with previous research (Evans et al., 2001); nonetheless, this cognitive ability was not predictive for students assessed in Spanish. Swanson and Ashbaker's (2000) results indicated that when considering the reading comprehension abilities of students with reading learning disabilities, deficits were evident in short-term memory proficiencies when information was recalled in exact order of presentation. It stands to reason that a deficit in short-term memory proficiency would negatively impact reading comprehension.

**Perceptual Speed 1 (P).** Perceptual Speed 1 was found to be predictive of reading comprehension abilities of students assessed in Spanish, but not in English. This finding in the Spanish group is consistent with studies of students between the ages of 6 to 10 years old who were tested in English (Evans et al., 2001). Additionally, McGrew et al.'s (1997) research found significant relations between the broad ability of G*s* and reading comprehension across five school-age samples, encompassing grades 1 through 12. Complicating findings include Vanderwood et al.'s (2002) study that found direct effects between G*s* and reading comprehension only in students in grades 5 to 6. This lack of evidence for strong relations may be attributed to the type of analysis utilized.

**Phonetic Coding 1 (PC1).** The cognitive variable of Phonetic Coding 1, as assessed by the subtest Sound Blending, was significantly related to the criterion variable of Reading Comprehension for students assessed in English and Spanish. The results of this study confirm Evans et al.'s (2001) findings that the Phonemic Awareness (PA) clinical cluster, consisting of Sound Blending and Incomplete Words, demonstrated moderate-to-strong relations with the Reading Comprehension cluster in the early elementary school years. Understandably, manipulation of phonemes can have direct (Fletcher et al., 1994) and indirect effects on reading comprehension through basic reading skills (Floyd, Bergeron & Alfonso, 2006); thus, deficit in this regard would negatively impact reading comprehension. Cain, Oakhill & Bryant (2000) implied an indirect relation between phonological skills and reading comprehension based on their contradictory findings that reading comprehension difficulties result from more complex and higher-order cognitive skills, including working memory.

In summary, higher Reading Comprehension ability was associated with higher cognitive abilities of Associative Memory, Lexical Knowledge, Phonetic Coding 1, and Memory Span for students assessed in English. However, Reading Comprehension ability did differ by LEP Status in students assessed in English. Moreover, higher Basic Reading ability was associated with higher cognitive abilities of Lexical Knowledge, Perceptual Speed 1, Associative Memory, and Phonetic Coding 1 for students assessed in Spanish.

## Math Calculation

Predictors in the seventh and final model for Math Calculation are Perceptual Speed 1 (P), General Sequential Reasoning (RG), Perceptual Speed 2, Ideational Fluency (FI), Visualization (Vz), and Lexical Knowledge (VL) for students assessed in English, when controlling for LEP status. For students assessed in Spanish, Working Memory (MW), Perceptual Speed 1 (P), and Visualization (Vz) were significantly predictive of Math Calculation skills. The following is a description of these cognitive abilities:

**General Sequential Reasoning (RG).** General Sequential Reasoning, or deductive reasoning, was predictive of math calculation proficiency in students with a learning disability who were assessed in English and was not predictive for students assessed in Spanish. Previous studies reported relations between the broad ability of G*f* and basic math skills at various ages (Floyd et al., 2001; Floyd, Evans, & McGrew, 2003; McGrew & Hessler, 1995); nevertheless, Proctor's (2012) research with college-aged students with learning disabilities found no relation. This disparity in research results may be due to Proctor's (2012) college-aged sample and the assumption that basic math skills are mastered at that point.

**Ideational Fluency (FI).** Ideational Fluency is the "ability to rapidly produce a series of ideas, words, or phrases related to a specific condition or object" (Flanagan, Ortiz & Alfonso, 2007). For students assessed in English, the present study's findings were consistent with Andersson's (2007) research, which found that Ideational Fluency significantly predicted Math Calculation achievement, but the same cannot be said for students assessed in Spanish. Ideational Fluency, as measured by Retrieval Fluency, is a timed subtest. It stands to reason that an individual's ability to focus under pressured time constraints would impact both the cognitive and the achievement measures.

**Lexical Knowledge (VL).** Lexical Knowledge, a narrow ability subsumed under the broad ability of Comprehension-Knowledge (G*c*), refers to the understanding of words in isolation. The subtest, Verbal Comprehension, evaluates this word knowledge through images, synonyms, antonyms, and analogies. In the current study, Lexical Knowledge played a significant, albeit small, role in math calculation achievement for students assessed in English, but was not significantly predictive for students assessed in Spanish. Similar to the current study's outcomes, previous studies are have mixed conclusions, as well. In some studies, the broad ability, G*c*, explained significant variance in math computation achievement outcomes of students with disabilities (Floyd et al., 2003; Hale et al., 2001), whereas in other studies, it has not (Proctor, 2005; Proctor, Floyd & Shaver 2005).

**Perceptual Speed 1 and 2 (P).** The Math Calculation cluster consists of a time and an untimed measure; therefore, it is plausible that the two narrow abilities of Perceptual Speed are predictive of Math Calculation skills. The Perceptual Speed 1 subtest, Visual Matching, evaluates one's competence in locating matching stimuli among a selection of assorted figures. The Perceptual Speed 2 subtest, Decision Speed, gauges the examinee's speeded facility of semantic processing (Schrank & Wendling, 2009). Quickly processing both visual symbols and acquired information were found to be predictive of Math Calculation skills in the present study. Rapidly matching visual symbols was strongly related for students in the English and Spanish groups, whereas processing acquired knowledge was only related for students tested in English. These findings are consistent with studies involving students both with (Cirino et al., 2015; Niileksela & Reynolds, 2014; Swanson & Jerman, 2006) and without learning disabilities (Floyd et al., 2003). Logically, when the math calculation measure was not timed, the predictive nature of processing speed was not significant (Fuchs et al., 2005).

**Visualization (Vz).** Visualization, a narrow ability subsumed under the broad ability of G*v*, involves the awareness and manipulation of visual patterns and shapes (Flanagan, Ortiz, & Alfonso, 2007). Consistent with Hale et al.'s (2001) study which found that the broad visual spatial ability (G*v*) significantly predicted math computational skills in students with learning disabilities, the present study found that the G*v* narrow ability of Visualization was significantly related to basic math skills for students in the English and Spanish groups. The current study's finding is in contrast to most research that is not limited to students with disabilities, which found that G*v* abilities were significantly related to higher-level math abilities, rather than the lower-level basic mathematics abilities (Floyd et al., 2003; McGrew & Wendling, 2010).

**Working Memory (MW).** Working memory capacity tests involve the encoding and manipulation of letters, letters and numbers, and symbols. Successful performance on the working memory subtest utilized in this study necessitates the effective storage and manipulation of numbers. As has been the case in previous research involving students with disabilities (Geary, Hoard, Byrd-Craven, Nugent, & Numtee, 2007; Hale et al., 2001) and students with math difficulties (Passolunghi, & Siegel, 2004; Swanson & Jerman, 2006), the current study found that Working Memory was significantly related to Math Calculation achievement outcomes in students with learning disabilities assessed in Spanish. Noticeably absent is this significant relation for students assessed in English.

To review, higher Math Calculation ability was associated with higher cognitive abilities of Perceptual Speed, General Sequential Reasoning, Ideational Fluency, Visualization, and Lexical Knowledge for students assessed in English. However, Math Calculation ability did not differ by LEP Status in students assessed in English. Moreover, higher Math Calculation ability was associated with higher cognitive abilities of Working Memory, Perceptual Speed and Visualization for students assessed in Spanish.

**Math Reasoning**

Predictors in the seventh and final model for Math Reasoning are General Sequential Reasoning (RG), Lexical Knowledge (VL), Perceptual Speed 1 (P), Visualization (Vz), Working Memory (MW), and Phonetic Coding 1 (PC) for students assessed in English, when controlling for LEP status. For students assessed in Spanish, Lexical Knowledge (VL), Working Memory (MW), Visual Memory (MV), Perceptual Speed 1 (P), and General Sequential Reasoning (RG) were significantly predictive of Math Reasoning skills. The following is a description of these cognitive abilities:

**General Sequential Reasoning (RG).** General Sequential Reasoning, or deductive reasoning, necessitates the application of known rules to novel situations. For students in the English and Spanish group, the significant predictive value of deductive reasoning abilities on math reasoning skills is consistent with previous research (Floyd et al., 2003; McGrew, 1997; McGrew & Hessler, 1995). Additionally, deductive reasoning abilities correspond with the task demands of math problem solving, which include applying mathematical knowledge and rules (Flanagan et al., 2006).

**Lexical Knowledge (VL).** In the current study, Lexical Knowledge significantly predicted Math Reasoning academic outcomes in students in the English and Spanish groups. The language facets of math significantly impact Math Reasoning achievement outcomes and increase with age (Floyd et al., 2003). The ability to read the math word problem was mitigated by the examiner orally reading the items to the student when administering the Math Reasoning subtest; nonetheless, a deficit in the ability to understand the meaning of the words and comprehend verbal directions may result in confusion (Mather & Wendling, 2015). Comprehending mathematics' specific vocabulary, in addition to the ability to understand word problems, notably impacts math problem-solving skills (Mather & Wendling, 2012). Language deficits differentiated those students with math computational difficulties from those exhibiting math problem-solving difficulties in a prospective four-year study of third-grade students (Fuchs et al., 2008).

**Perceptual Speed 1 (P).** The significant relation between the cognitive ability of processing speed and math problem-solving skills found in previous studies (Bull & Johnson, 1997; Cirino et al., 2015; Floyd et al., 2003; McGrew & Hessler, 1995) was corroborated in the current study for students in the English and Spanish groups.

**Phonetic Coding 1 (PC).** In the present study, Phonetic Coding 1 was predictive of Math Reasoning achievement outcomes for the English group, but not the Spanish group. This predictive result was analogous to McGrew & Wendling (2010) synthesis of literature that found Phonetic Coding was moderately related at the early years. Floyd et al.'s (2003) study demonstrated moderate relations between Auditory Processing (G*a*) and Math Reasoning skills at all ages. However, lack of a significant relation for students assessed in Spanish is in line with Swanson and Beebe-Frankenberger's (2004) study that found phonological processing demonstrated no significant relations with math problem solving when other variable were controlled.

**Visualization (Vz).** For students assessed in English, the significance of the cognitive ability of Visualization in the present study is contrary to a large body of research (Floyd, Evans, & McGrew, 2003; Geary, Hamson, & Hoard, 2000; McGrew & Wendling, 2010; Proctor, 2012). For students assessed in Spanish, extant research aligns with the current study's finding of no significant relations between G*v* and math achievement. McGrew & Wendling (2010) referred to the lack of evidence of G*v* significance as the "G*v* Mystery", reasoning that the way in which G*v* is evaluated or that many CHC research studies have utilized WJ III measures may account for the ambiguity.

**Visual Memory (MV).** Similar to earlier studies (Floyd, Evans, & McGrew, 2003; Geary, Hamson, & Hoard, 2000; Proctor, 2012), visual spatial abilities were not significantly predictive of Math Reasoning academic performance for students assessed in English. However, higher Visual Memory ability was associated with higher Math Reasoning ability for students assessed in Spanish in the present study. The disparity between the results of the English and Spanish groups is interesting as the language of administration is the only difference between the English and Spanish versions of the Picture Recognition subtest, which measures Visual Memory.

**Working Memory (MW).** Word problems involve two steps: determining a strategy for solving the problem and utilizing accurate calculations. The requisite multi-dimensional task necessitates the ability to retain and manipulate information. For students in the English and Spanish groups in the current study, higher Working Memory skills were associated with higher Math Reasoning skills. In a sample of college-age students with learning disabilities, the narrow ability of Working Memory was found to be significantly predictive of Math Reasoning skills, even when the broad ability of Short-Term Memory (G*sm*) was not (Proctor, 2012).

To review, higher Math Reasoning ability was associated with higher cognitive abilities of General Sequential Reasoning, Lexical Knowledge, Perceptual Speed 1, Visualization, Working Memory, and Phonetic Coding 1 for students assessed in English. However, Math Reasoning ability did not differ by LEP Status in students assessed in English. Moreover, higher Math Reasoning ability was associated with higher cognitive abilities of Lexical Knowledge, Working Memory, Visual Memory, Perceptual Speed 1, and General Sequential Reasoning for students assessed in Spanish.

**Written Expression**

In the current study of students assessed in English, predictors in the final model for Written Expression are Lexical Knowledge (VL), Perceptual Speed 1 (P), Phonetic Coding 1 (PC), Associative Memory (MA), and General Sequential Reasoning (RG). For students assessed in Spanish, predictors in the final model included: Perceptual Speed 1 (P), Phonetic Coding 1 (PC), Associative Memory, and General Sequential Reasoning (RG). The following is a description of these cognitive abilities:

**Associative Memory (MA).** The cognitive ability of Associative Memory was significantly predictive of writing skills for students assessed in English or Spanish. These findings are consistent with Floyd, McGrew, and Evans' (2008) study, where

Long-Term Retrieval abilities demonstrated significant relations to Written Expression at the youngest age levels, but contrary to McGrew and Knopik (1993)'s study that found no significant relation. While both studies employed multiple regressions using the *W* scores (an equal-interval scale) as the metric of analysis for various age groups, McGrew and Knopik's (1993) study utilized the WJ-R standardization sample, where the Floyd, McGrew, & Evans' (2008) study utilized the WJ-III standardization sample. The current study's consistency of findings with Floyd, McGrew, and Evans (2008) could plausibly be due to the use of uniform measurement instruments.

**General Sequential Reasoning (RG).** Albeit the smallest relation in magnitude, General Sequential Reasoning significantly predicted writing skills in students assessed in English or Spanish. The higher order thinking skill of deductive learning, or applying a rule to a novel situation, indeed applies to writing measures that necessitate the application of the rules of writing, such as grammar, sentence structure, and spelling. The current study's results are consistent with research results that indicated significant relations between fluid reasoning abilities and writing skills at the early ages (Floyd, McGrew, & Evans, 2008) and across ages (McGrew & Knopik, 1993).

**Lexical Knowledge (VL).** Lexical Knowledge was the strongest predictor of Written Expression achievement performance for students assessed in English. This finding is not surprising as both abilities, cognitive and achievement, require specific language skills. These findings are consistent with prior research determining a strong relation between acquired knowledge or vocabulary and written language achievement (Floyd et al., 2008; Hale et al., 2001; McGrew & Knopik, 1993). The task demands of the Written Expression measures include meaningfully expressing ideas in writing and fluently writing simple sentences. Thus, it was unexpected that neither measure of Comprehension-Knowledge (VL or KO) demonstrated significant effects on Written Expression skills for students assessed in Spanish.

**Perceptual Speed 1 (P).** Higher Written Expression ability was associated with higher cognitive abilities of Perceptual Speed for students in the English and Spanish groups. This finding is logical as a timed measure is included in the Written Expression cluster. A similar conclusion was reached by previous research, where the processing speed was consistently and significantly related across the ages (McGrew & Knopik, 1993; Floyd, McGrew, & Evans, 2008). Processing speed predicted writing dysfluency in a clinical sample of students with learning disabilities (Williams, Zolten, Rickert, Spence, & Ashcraft, 1993). The fluency with which a student is able to write is particularly critical to present day timed local, state and national tests, some of which are mandated by NCLB.

**Phonetic Coding 1 (PC).** In the current study, a weakness in Phonetic Coding was substantiated as a significant predictor of difficulty with writing skills for students in the English and Spanish groups. This finding concurs with previous work that found at the earlier age levels, Auditory Processing (G*a*) was significantly related to Written Expression (Floyd, McGrew & Evans, 2008; McGrew & Knopik, 1993). Individuals with poorly developed phonological awareness exhibit spelling difficulties and basic writing delays.

To review, higher Written Expression ability was associated with higher cognitive abilities of Lexical Knowledge, Perceptual Speed 1, Phonetic Coding 1, Associative

Memory, and General Sequential Reasoning for students assessed in English. However, Written Expression ability did not differ by LEP Status in students assessed in English. Moreover, higher Written Expression ability was associated with higher cognitive abilities of Perceptual Speed 1, Phonetic Coding 1, Associative Memory, and General Sequential Memory for students assessed in Spanish.

**Limitations**

First, the demographics of the sample provide several limitations. The student assessments reviewed were geographically restricted to a single large urban school district in the state of Texas. While the sample's demographics were similar to those of the originating school district, they may be disparate from other school districts, states and geographic regions. The highly Hispanic, LEP and low-socio-economic status (SES) proportions of the participants in this study are beneficial given that Hispanics are the fastest growing minority group and increasing their share of public school enrollment (Kena et al., 2015). However, the study's sample proportions are a double edged sword, as the results of this study should be interpreted with caution with regard to students not demographically represented in the sample population. Moreover, the findings cannot be generalized to typically developing children since the sample consists entirely of students with learning disabilities. Additionally, this study merged the various types of learning disabilities (i.e., Basic Reading, Reading Comprehension, Math Calculation, Math Problem Solving, and Written Expression) into one group, thus the findings may not apply to all children with a learning disability. The absence of age or grade differentiation is a key limitation of the present study. Existing research validates the changing influence of cognitive abilities over time (McGrew & Wendling, 2010).

Furthermore, Perceptual Speed (P) necessitates further research since it demonstrated predictive value for all five academic outcomes in the present study.

**Implications**

The present study was one of a few to examine the relations between cognitive abilities and academic performance in a largely Hispanic sample of students with learning disabilities. Given the changing makeup of the public school enrolled population in the United States (Figure 3), future research should continue to focus on culturally and linguistically diverse populations. This study provided confirmation for cross-ethnic significant relations between cognitive abilities and academic performance in students with a learning disability who were tested in English (Table 28). More research is needed in a broader population of students assessed in Spanish, such as a non-referred, bilingual education, or general education population. While the data was not available for the present study, further research utilizing structural equation modeling (SEM) and the second stratum of broad ability cluster scores would remove error and more accurately estimate the effects of individual variables (McGrew, 1997).

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## Appendix A

## Pearson Product Moments Between All Cognitive Measures

Table A1.

*Pearson Product Moments Between All Cognitive Measures for Students Assessed in English*

| Measure | G*c* VL | G*c* KO | G*f* I | G*f* RG | Gl*r* FI | Gl*r* MA | G*sm* MS | G*sm* MW | G*s* P1 | Gs P2 | G*a* PC1 | G*a* PC2 | G*v* MV | G*v* SR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| G*c*VL | 1.00 | 0.677** | 0.246** | 0.167 | 0.205** | 0.248** | 0.185** | 0.197** | 0.054 | 0.061 | 0.164** | 0.227** | 0.141** | 0.171** |
| G*c*KO | | 1.00 | 0.251** | 0.143** | 0.208** | 0.189** | 0.209** | 0.158** | 0.039 | 0.028 | 0.181** | 0.182** | 0.109* | 0.151** |
| G*f*I | | | 1.00 | 0.458** | 0.176** | 0.180** | 0.058 | 0.195** | 0.125** | 0.074 | 0.077 | 0.127** | 0.145** | 0.281** |
| G*f*RG | | | | 1.00 | 0.134** | 0.187** | 0.071 | 0.196** | 0.213** | 0.161** | 0.067 | 0.057 | 0.213** | 0.297** |
| G*lr*FI | | | | | 1.00 | 0.298** | 0.223** | 0.251** | 0.130** | 0.136** | 0.103* | 0.085 | 0.198** | 0.217** |
| G*lr*MA | | | | | | 1.00 | 0.107* | 0.179** | 0.125** | 0.065 | 0.054 | 0.117* | 0.101* | 0.254** |
| G*sm*MS | | | | | | | 1.00 | 0.387** | 0.004 | 0.024 | 0.110* | 0.145** | 0.155** | 0.076 |
| G*sm*MW | | | | | | | | 1.00 | 0.195** | 0.149** | 0.099* | 0.120* | 0.186** | 0.174** |
| G*s*P1 | | | | | | | | | 1.00 | .492** | 0.014 | 0.025 | 0.094* | 0.184** |
| G*s*P2 | | | | | | | | | | 1.00 | 0.046 | 0.093 | 0.092* | 0.135** |
| G*a*PC1 | | | | | | | | | | | 1.00 | 0.628** | 0.043 | 0.108* |
| G*a*PC2 | | | | | | | | | | | | 1.00 | 0.052 | 0.030 |
| G*v*MV | | | | | | | | | | | | | 1.00 | 0.323** |
| G*v*SR | | | | | | | | | | | | | | 1.00 |

*Note*. $*p<.05$, $**p<.01$, $***p<.001$

Table A2.

*Pearson Product Moments Between All Cognitive Measures for All Students Assessed in Spanish*

| Measure | G*c* VL | G*c* KO | G*f* I | G*f* RG | G*lr* FI | G*lr* MA | G*sm* MS | G*sm* MW | G*s* P1 | G*s* P2 | G*a* PC1 | G*a* PC2 | G*v* MV | G*v* SR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| G*c*VL | 1.00 | .446** | .261** | .220** | .226** | .317** | .288** | .321** | .207** | .181** | .168* | .155* | .114 | .127 |
| G*c*KO | | 1.00 | .160* | .169* | .347** | .231** | .058 | .131* | .063 | .137* | .032 | .214** | -.003 | -.033 |
| G*f*I | | | 1.00 | .436** | .152* | .180** | .146* | .146* | .141* | .132* | .116 | .091 | .108 | .120 |
| G*f*RG | | | | 1.00 | .180** | .174** | .180** | .183** | .191** | .236** | .121 | .108 | .133* | .290** |
| G*lr*FI | | | | | 1.00 | .286** | .071 | .174** | .129 | .266** | .158* | .013 | .077 | .001 |
| G*lr*MA | | | | | | 1.00 | .114 | .271** | .080 | .032 | .168* | .119 | .048 | .102 |
| G*sm*MS | | | | | | | 1.00 | .516** | .194** | .150* | .209** | .107 | .184** | .144* |
| G*sm*MW | | | | | | | | 1.00 | .245** | .206** | .213** | .034 | .129 | .046 |
| G*s*P1 | | | | | | | | | 1.00 | .555** | .034 | .121 | .155* | .090 |
| G*s*P2 | | | | | | | | | | 1.00 | .086 | .130 | .109 | -.043 |
| G*a*PC1 | | | | | | | | | | | 1.00 | .575** | .119 | .112 |
| G*a*PC2 | | | | | | | | | | | | 1.00 | .164* | .054 |
| G*v*MV | | | | | | | | | | | | | 1.00 | .419** |
| G*v*SR | | | | | | | | | | | | | | 1.00 |

*Note*. $*p<.05$, $**p<.01$, $***p<.001$

Table A3.

*Pearson Product Moments Between All Cognitive Measures for Hispanic Students Assessed in English*

| Measure | G*c* VL | G*c* KO | G*f* I | G*f* RG | G*lr* FI | G*lr* MA | G*sm* MS | G*sm* MW | G*s* P1 | Gs P2 | G*a* PC1 | G*a* PC2 | G*v* MV | G*v* SR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| G*c*VL | 1.00 | .710** | .238** | .205** | .300** | .154* | .314** | .189** | .147* | .105 | .169** | .197** | .161* | .259** |
| G*c*KO | | 1.00 | .274** | .170** | .255** | .165* | .262** | .162* | .127* | .057 | .206** | .220** | .144* | .175** |
| G*f*I | | | 1.00 | .404** | .135* | .145* | .111 | .200** | .062 | .093 | .007 | .104 | .174** | .271** |
| G*f*RG | | | | 1.00 | .127 | .131* | .162* | .270** | .199** | .113 | .002 | .032 | .272** | .328** |
| G*lr*FI | | | | | 1.00 | .254** | .310** | .270** | .197** | .211** | .225** | .112 | .157* | .208** |
| G*lr*MA | | | | | | 1.00 | .276** | .203** | .131* | .107 | -.062 | -.017 | .091 | .263** |
| G*sm*MS | | | | | | | 1.00 | .429** | .091 | .114 | .210** | .160* | .211** | .130* |
| G*sm*MW | | | | | | | | 1.00 | .165* | .127 | .116 | .088 | .212** | .163* |
| G*s*P1 | | | | | | | | | 1.00 | .464** | .010 | .017 | .042 | .228** |
| G*s*P2 | | | | | | | | | | 1.00 | -.002 | .089 | .116 | .146* |
| G*a*PC1 | | | | | | | | | | | 1.00 | .636** | .116 | .100 |
| G*a*PC2 | | | | | | | | | | | | 1.00 | .051 | -.029 |
| G*v*MV | | | | | | | | | | | | | 1.0 | .285** |
| G*v*SR | | | | | | | | | | | | | | 1.00 |

*Note*. *$p$<.05, **$p$<.01, ***$p$<.001

Table A4.

*Pearson Product Moments Between All Cognitive Measures for Hispanic Students Assessed in Spanish*

| Measure | G*c* VL | G*c* KO | G*f* I | G*f* RG | G*lr* FI | G*lr* MA | G*sm* MS | G*sm* MW | G*s* P1 | Gs P2 | G*a* PC1 | G*a* PC2 | G*v* MV | G*v* SR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| G*c*VL | 1.00 | .446** | .261** | .220** | .226** | .317** | .288** | .321** | .207** | .181** | .168* | .155* | .114 | .127 |
| G*c*KO | | 1.00 | .160* | .169* | .347** | .231** | .058 | .131* | .063 | .137* | .032 | .214* | -.003 | -.033 |
| G*f*I | | | 1.00 | .436** | .152* | .180** | .146* | .146* | .141* | .132* | .116 | .091 | .108 | .120 |
| G*f*RG | | | | 1.00 | .180** | .174** | .180** | .183** | .191** | .236** | .121 | .108 | .133* | .290** |
| G*lr*FI | | | | | 1.00 | .286** | .071 | .174** | .129 | .266** | .158* | .013 | .077 | .001 |
| G*lr*MA | | | | | | 1.00 | .114 | .271** | .080 | .032 | .168* | .119 | .048 | .102 |
| G*sm*MS | | | | | | | 1.00 | .516** | .194** | .150* | .209** | .107 | .184** | .144* |
| G*sm*MW | | | | | | | | 1.00 | .245** | .206** | .213** | .034 | .129 | .046 |
| G*s*P1 | | | | | | | | | 1.00 | .555** | .034 | .121 | .155* | .090 |
| G*s*P2 | | | | | | | | | | 1.00 | .086 | .130 | .109 | -.043 |
| G*a*PC1 | | | | | | | | | | | 1.00 | .575** | .119 | .112 |
| G*a*PC2 | | | | | | | | | | | | 1.00 | .164* | .054 |
| G*v*MV | | | | | | | | | | | | | 1.00 | .419** |
| G*v*SR | | | | | | | | | | | | | | 1.00 |

*Note*. *$p$<.05, **$p$<.01, ***$p$<.001

# Appendix B

## Model and Regression Summaries

## Hispanic Students Assessed in English or Spanish

Table B1.

*Basic Reading - Model Summary for Hispanic Students Assessed in English Controlling for LEP Status* and in Spanish[a]

| Model | $R$ | $R^2$(SEE) | Adjusted $R^2$ | F | F change |
|---|---|---|---|---|---|
| English | | | | | |
| 4[b] | .385 | .148(11.787) | .140 | 19.105*** | 4.418* |
| Spanish | | | | | |
| 3[c] | .315 | .099(19.665) | .087 | 8.020*** | 4.182* |

a. Dependent Variable: Basic Reading
b. Associative Memory, Phonetic Coding 1, Perceptual Speed 1
c. Working Memory, Perceptual Speed 1, Lexical Knowledge
*Note*. *p<.05, **p<.01, ***p<.001

Table B2.

*Basic Reading - Stepwise Multiple Regression Summary Table for Hispanic Students Assessed in English Controlling for LEP Status*[a]

| Model | Variables | B | Standard Error | Standardized Coefficients | *t* | *p* |
|---|---|---|---|---|---|---|
| English | | | | | | |
| 4 | Associative Memory | .200 | .035 | .257 | 5.752 | .000 |
| | Phonetic Coding 1 | .189 | .038 | .220 | 4.986 | .000 |
| | Perceptual Speed 1 | .086 | .041 | .093 | 2.102 | .036 |
| Spanish | | | | | | |
| 3 | Working Memory | .190 | .087 | .151 | 2.187 | .030 |
| | Perceptual Speed 1 | .213 | .093 | .153 | 2.290 | .023 |
| | Lexical Knowledge | .275 | .134 | .140 | 2.045 | .042 |

a. Basic Reading

Table B3.

*Reading Comprehension - Model Summary for Hispanic Students Assessed in English Controlling for LEP Status* and in Spanish[a]

| Model | *R* | $R^2$(SEE) | Adjusted $R^2$ | F | F change |
|---|---|---|---|---|---|
| English | | | | | |
| 5[b] | .497 | .247(11.283) | .238 | 28.276*** | 4.092* |
| Spanish | | | | | |
| 4[c] | .507 | .257(13.144) | .243 | 18.417*** | 7.205** |

a. Dependent Variable: Reading Comprehension
b. Associative Memory, Lexical Knowledge, Phonetic Coding 1, Memory Span
c. Lexical Knowledge, Perceptual Speed, Associative Memory, Phonetic Coding 1
*Note*. *p<.05, **p<.01, ***p<.001

Table B4.

*Reading Comprehension - Stepwise Multiple Regression Summary Table for Hispanic Students Assessed in English Controlling for LEP Status*[a]

| Model | Variables | B | Standard Error | Standardized Coefficients | *t* | *p* |
|---|---|---|---|---|---|---|
| English | | | | | | |
| 5 | Associative Memory | .238 | .035 | .301 | 6.829 | .000 |
| | Lexical Knowledge | .312 | .055 | .260 | 5.711 | .000 |
| | Phonetic Coding 1 | .093 | .037 | .105 | 2.476 | .014 |
| | Memory Span | .083 | .041 | .087 | 2.023 | .044 |
| Spanish | | | | | | |
| 4 | Lexical Knowledge | .359 | .092 | .249 | 3.888 | .000 |
| | Perceptual Speed | .218 | .062 | .214 | 3.540 | .000 |
| | Associative Memory | .185 | .062 | .187 | 2.971 | .003 |
| | Phonetic Coding 1 | .161 | .060 | .162 | 2.684 | .008 |

a. Reading Comprehension

Table B5.

*Math Calculation - Model Summary for Hispanic Students Assessed in English Controlling for LEP Status* and in Spanish[a]

| Model | *R* | $R^2$(SEE) | Adjusted $R^2$ | F | F change |
|---|---|---|---|---|---|
| English | | | | | |
| 7[b] | .492 | .243 | .230 | 19.852*** | 4.713* |
| Spanish | | | | | |
| 3[c] | .480 | .231(17.499) | .220 | 21.586*** | 10.701** |

a. Dependent Variable: Math Calculation
b. Perceptual Speed 1, General Sequential Reasoning, Ideational Fluency, Perceptual Speed 2, Visualization, Lexical Knowledge
c. Working Memory, Perceptual Speed 1, Lexical Knowledge
*Note*. *p<.05, **p<.01, ***p<.001

Table B6.

*Math Calculation - Stepwise Multiple Regression Summary Table for Hispanic Students Assessed in English Controlling for LEP Status*[a]

| Model | Variables | B | Standard Error | Standardized Coefficients | *t* | *p* |
|---|---|---|---|---|---|---|
| English | | | | | | |
| 7 | Perceptual Speed 1 | .208 | .053 | .191 | 3.943 | .000 |
| | Gen Seq Reasoning | .213 | .051 | .189 | 4.207 | .000 |
| | Ideational Fluency | .120 | .046 | .114 | 2.594 | .010 |
| | Perceptual Speed 2 | .147 | .048 | .148 | 3.041 | .003 |
| | Visualization | .158 | .072 | .099 | 2.186 | .029 |
| | Lexical Knowledge | .135 | .062 | .096 | 2.171 | .030 |
| Spanish | | | | | | |
| 3 | Working Memory | .322 | .074 | .268 | 4.347 | .000 |
| | Perceptual Speed 1 | .376 | .082 | .281 | 4.558 | .000 |
| | Visualization | .406 | .124 | .196 | 3.271 | .001 |

a. Math Calculation

Table B7.

*Math Reasoning - Model Summary for Hispanic Students Assessed in English Controlling for LEP Status* and in Spanish[a]

| Model | $R$ | $R^2$(SEE) | Adjusted $R^2$ | F | F change |
|---|---|---|---|---|---|
| English | | | | | |
| 7[b] | .556 | .309(8.778) | .298 | 27.528*** | 6.734* |
| Spanish | | | | | |
| 5[c] | .609 | .370(9.262) | .356 | 25.053*** | 5.630* |

a. Dependent Variable: Math Reasoning
b. Predictors: General Sequential Reasoning, Lexical Knowledge, Perceptual Speed 1, Visualization, Working Memory, Phonetic Coding 1
c. Predictors: Lexical Knowledge, Working Memory, Visual Memory, Perceptual Speed 1, General Sequential Reasoning

*Note*. *p<.05, **p<.01, ***p<.001

Table B8.

*Math Reasoning - Stepwise Multiple Regression Summary Table for Hispanic Students Assessed in English Controlling for LEP Status*[a]

| Model | Variables | B | Standard Error | Standardized Coefficients | $t$ | $p$ |
|---|---|---|---|---|---|---|
| English | | | | | | |
| 7 | Gen Seq Reasoning | .144 | .034 | .185 | 4.274 | .000 |
| | Lexical Knowledge | .199 | .042 | .205 | 4.755 | .000 |
| | Perceptual Speed 1 | .148 | .031 | .196 | 4.710 | .000 |
| | Visualization | .195 | .048 | .175 | 4.094 | .000 |
| | Working Memory | .096 | .029 | .139 | 3.292 | .001 |
| | Phonetic Coding 1 | .075 | .029 | .106 | 2.595 | .010 |
| Spanish | | | | | | |
| 5 | Lexical Knowledge | .334 | .065 | .303 | 5.167 | .000 |
| | Working Memory | .155 | .041 | .221 | 3.742 | .000 |
| | Visual Memory | .165 | .048 | .190 | 3.418 | .001 |
| | Perceptual Speed 1 | .115 | .045 | .148 | 2.575 | .011 |
| | Gen Seq Reasoning | .110 | .047 | .135 | 2.373 | .019 |

a. Math Reasoning

Table B9.

*Written Expression - Model Summary for Hispanic Students Assessed in English Controlling for LEP Status* and in Spanish[a]

| Model | $R$ | $R^2$(SEE) | Adjusted $R^2$ | F | F change |
|---|---|---|---|---|---|
| English | | | | | |
| 6[b] | .436 | .190 | .179(12.352) | 16.943*** | 4.496* |
| Spanish | | | | | |
| 4[c] | .442 | .196(12.623) | .181 | 13.019*** | 4.021* |

a. Dependent Variable: Written Expression
b. Predictors: Lexical Knowledge, Perceptual Speed 1, Phonetic Coding 1, Ideational Fluency, General Sequential Reasoning
c. Predictors: Perceptual Speed 1, Phonetic Coding 1, Associative Memory, General Sequential Reasoning
*Note*. *p<.05, **p<.01, ***p<.001

Table B10.

*Written Expression - Stepwise Multiple Regression Summary Table for Hispanic Students Assessed in English Controlling for LEP Status*[a]

| Model | Variables | B | Standard Error | Standardized Coefficients | $t$ | $p$ |
|---|---|---|---|---|---|---|
| English | | | | | | |
| 7 | Lexical Knowledge | .235 | .058 | .186 | 4.057 | .000 |
| | Perceptual Speed 1 | .203 | .044 | .207 | 4.646 | .000 |
| | Phonetic Coding 1 | .180 | .041 | .194 | 4.414 | .000 |
| | Ideational Fluency | .100 | .043 | .105 | 2.336 | .020 |
| | Gen Seq Reasoning | .098 | .046 | .096 | 2.120 | .035 |
| Spanish | | | | | | |
| 4 | Perceptual Speed 1 | .242 | .059 | .257 | 4.101 | .000 |
| | Phonetic Coding 1 | .180 | .057 | .199 | 3.168 | .002 |
| | Associative Memory | .139 | .058 | .153 | 2.420 | .016 |
| | Gen Seq Reasoning | .126 | .063 | .127 | 2.005 | .046 |

a. Dependent Variable: Written Expression