ABSTRACT

CHC NARROW AND BROAD PROCESSES AS PREDICTORS OF BASIC READING ACHIEVEMENT

Cattell-Horn-Carroll's (CHC) theory seeks to address the issue of specific learning disability identification by linking particular areas of cognitive abilities with academic achievement. Recent research has examined individual patterns of strengths and weaknesses in cognitive and academic abilities to identify students with Specific Learning Disabilities (SLDs). The basis for this assertion is the research linking specific cognitive abilities, defined within the CHC framework, with specific academic domains. The present study examines the correlations between CHC cognitive abilities and reading achievement. This study was conducted through the use of archival data from a large urban school district in the Southwest United States. All students were evaluated for their academic achievement using Woodcock-Johnson Psychoeducational Battery–Third Edition Tests of Academic Achievement (W-J III ACH). Participants were administered selected subtests from the WJ-III Tests of Cognitive Ability (W-J III COG) by district school psychologists in relation to specific referral concerns. Results of this study indicate that the broad ability of Ga is not significantly related to basic reading achievement within a clinical population. Focusing assessment and intervention on the narrow ability Ga-PC may be more effective in accurate identification and intervention for students with reading difficulties.

Cynthia Marie Van Doren
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CHC NARROW AND BROAD PROCESSES AS PREDICTORS OF BASIC READING ACHIEVEMENT

by

Cynthia Marie Van Doren

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For the Department of Psychology:

We, the undersigned, certify that the thesis of the following student meets the required standards of scholarship, format, and style of the university and the student’s graduate degree program for the awarding of the master’s degree.

Cynthia Marie Van Doren
Thesis Author

Carlos O. Calderón (Chair) Psychology

Marilyn S. Wilson Psychology

Kaitlin Hendricks School Psychologist, Fresno Unified

For the University Graduate Committee:

Dean, Division of Graduate Studies

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CHAPTER 1: INTRODUCTION

Researchers within the fields of neurology, psychology, and education have been defining learning disabilities (LD) since the late 1800s. The earliest definitions were developed by clinicians observing individuals who struggled to acquire basic academic skills or individuals who suffered brain trauma resulting in the loss of their abilities to perform specific tasks (Sotelo-Dynega, Flanagan, & Alfonso, 2011). These first clinicians did not have the technology to test their hypotheses about a presumed neurological etiology underlying the condition (Kaufman, 2008; Sotelo-Dynega et al., 2011).

The development of the modern definitions of LD has been greatly influenced by American psychologist and educator Samuel A. Kirk. In 1963, Kirk presented a paper at the *Exploration into the Problems of the Perceptually Handicapped Child* conference in Chicago, Illinois. Kirk's paper entitled "Learning Disabilities" defined an LD as

> a retardation, disorder, or delayed development in one or more processes of speech, language, reading writing, arithmetic, or other subjects resulting from a psychological handicap caused by a possible cerebral dysfunction and/or emotional or behavioral disturbance. It is not the result of mental retardation, sensory deprivation, or cultural and instructional factors. (Kirk, 1962, p. 263)

Subsequent to Kirk's paper, a number of organizations and researchers have proposed definitions for LD with similar depictions. Most definitions contain the common elements of a disorder in psychological processing (neurologically based) and manifestation of that disorder as an academic skill weakness (Sotelo-Dynega et al., 2011).

As both public awareness and congressional interest in learning disabilities intensified, the U.S. Office of Education was charged with creating a federal definition for what constituted an LD. Samuel Kirk chaired this committee. By the end of 1968, “specific learning disability” became a federally designated category of special education (National Association of Special Education Teachers [NASET], n.d.). Subsequent legislation followed, including the 1969 Specific Learning Disabilities Act (P.L. 91-230) and the 1975 Education for All Handicapped Children’s Act (P.L. 94-142). In 1990, The Individuals with Disabilities Education Improvement Act (hereinafter referred to as “IDEA”) reauthorized by congress in 1997 and 2004, renamed and changed PL 94-142 replacing the term “handicap” with “disability.” Consistent with prior legislation, IDEA (P.L. 108-446) uses the term “specific” learning disability in the legal definition of LD. IDEA legislation codifies the implication of a specific academic skill or domain being affected by the learning disability (IDEA, 2004). Furthermore, the *Diagnostic and Statistical Manual of Mental Disorders* (5th ed.*; DSM–5*), revised in 2013, also uses the term specific learning disorder to describe impairments in reading, written expression, or mathematics (American Psychiatric Association, 2013).

Multiple cognitive abilities have been correlated to specific academic achievement areas (Mather & Wendling, 2012; Proctor, 2012). For example, in the case of math achievement, specific cognitive processing areas have correlated with specific math skills (e.g., long-term memory retrieval and math calculation; processing speed and math fluency; fluid reasoning and math problem solving (Calderón-Tena, 2016; Calderón-Tena & Caterino, 2016). In the case of reading, phonological processing has been identified as a key cognitive area associated with reading achievement (Vanderwood, McGrew, Flanagan, & Keith, 2002).

Phonological awareness, the ability to attend to the sound structure of speech, is important to understanding reading, writing, and math disabilities (McGrew & Wendling, 2010; Vellutino, Tunmer, Jaccard, & Chen, 2007). Additionally, verbal ability, lexical processing, and short-term memory have strong links to reading achievement as demonstrated by a large body of research (Mather & Wendling, 2012).

The development of intelligence and cognitive ability batteries has been important to identification of the neurologically based processing deficits potentially interfering with academic skill development (Flanagan & Harrison, 2012). Intelligence testing is a necessary part of a school psychologist’s repertoire. Traditional identification of an LD has historically required an overall full scale Intelligence Quotient (IQ). A “one-complete-standard-battery-fits-all” approach to intelligence testing may not be germane to the application of current and best-supported intelligence research (Newton & McGrew, 2010, p. 622). Some researchers are advocating for the deemphasizing of full scale IQ in exchange for a more selective and focused cognitive assessment (CA). In lieu of the present emphasis on the relationship between academic achievement and full scale IQ for identification of LD, practitioners should be looking for which specific cognitive abilities individually, or collectively as a pattern, indicate a potential LD (McGrew & Wendling, 2010). The identification of specific abilities or patterns that may indicate an LD is particularly relevant to reading achievement, as the prevailing majority of students identified as LD have deficits in reading (Feifer, 2011).

CHAPTER 2: LITERATURE REVIEW

Reading is the most fundamental skill school-aged children can acquire. Students with well-developed literary skills enjoy greater success across all academic areas (Lonigan, Burgess, & Anthony, 2009). Poor readers can experience failure in school and are at greater risk for delinquency than are their peers. In 2011, one of every two reading disabled students faced school disciplinary action, such as suspension or expulsion (National Center for Learning Disabilities [NCLD], 2014). The impact of reading failure continues into adulthood, where unemployment can be twice the national average for adults still struggling with reading (Gerber, 2012).

Reading failure has also been linked to negative socio-emotional consequences. Students experiencing reading failure reported feelings of anger and distractibility and experience a greater likelihood of peer rejection (Morgan, Farkas, & Wu, 2012). Boys struggling with reading were three times more likely to report high levels of depressed mood than were their peers (Maugban, 2003). The negative socio-emotional consequences of reading difficulties are experienced by children early in their education. As early as within the first 2 years of schooling, negative self-concepts can develop in children who struggle with learning to read (Chapman, Tunmer, & Prochnow, 2000).

Deficiencies in phonological awareness, defined by Pilat and Kilanowski-Press (2011) as the ability to understand and recognize the sound structure of the spoken language, have been demonstrated to be characteristic of individuals who struggle to acquire basic reading skills and children who are learning disabled (Frijters et al., 2011). Fuchs et al. (2012) followed a sample of low-performing readers longitudinally from fall of first grade through spring of fifth grade. Weak phonological processing in first grade was a significant predictor of later reading disabled status. These findings indicate phonological awareness is important for explaining reading comprehension as well as reading at the word level (Fuchs et al., 2012).

Reading requires the acquisition of specific skills. The National Reading Panel (NRP) identified five skills that are necessary for children to become independent readers: (a) phonemic awareness, (b) phonics, (c) vocabulary, (d) fluency, and (e) comprehension (NRP, 2013). Children with learning disabilities have been conceptualized by researchers as having weak core cognitive abilities that interfere with their acquisition and development of these critical reading skills (Floyd, Keith, Taub, & McGrew, 2007). Specifically, researchers have identified deficits in speeded lexical retrieval and verbal short-term memory to be strongly associated with reading difficulties (Vellutino, Fletcher, Snowling, & Scanlon, 2004).

Specific Learning Disability Identification

The most frequently occurring school-related disability is specific learning disability. (U.S. Department of Education, National Center for Education Statistics [NCES], 2012). The NCES reported that 37.5% of children receiving special education services in the United States were students with specific learning disabilities (SLDs). This number represents 2.4 million children (NCES, 2012). The National Institutes of Health reported that 75%-80% of special education students identified as SLD had their deficits in basic reading skills (Feifer, 2011).

The federal definition of SLD has remained consistent over the past 30 years.

IDEA 2004 § 300.8 [c] (10) defines SLD as

> [a] disorder in one or more of the basic psychological processes involved in understanding or using language, spoken or written, that may manifest itself in the imperfect ability to listen, think, speak, read, write, spell, or to do mathematical calculations, including conditions, such as perceptual disabilities, brain injury, minimal brain dysfunction, dyslexia, and development aphasia. (IDEA, 2004)

The methodology by which practitioners identify children with SLD has changed in the most recent reauthorization of IDEA (Sotelo-Dynega et al., 2011). The 2006 Federal Regulations (34 CFR § 300.307-309) require states to adopt criteria for the identification of SLD. However, the adopted criteria cannot require the use of a severe discrepancy between intellectual ability and achievement (Ability-Achievement Discrepancy). Additionally, states are permitted to identify SLD using the child's response to scientific, research-based interventions and may permit other research-based procedures as a basis of identification. The increase in SLD identification methodologies afforded by the IDEA reauthorization has resulted in varying perspectives regarding reliability and validity of different procedures (Kovaleski et al., 2015).

<u>Ability-Achievement Discrepancy</u>. Ability-Achievement Discrepancy methods (AB-Ach) provide an operational definition of unexpected achievement as a "severe discrepancy between intellectual ability and academic achievement" (Sotelo-Dynega et al., 2011, p. 11). This assessment approach typically involves a focus on low achievement in a specific academic area, a severe discrepancy

between the academic achievement and intellectual ability, and the exclusion of other causes, such as poor instruction, other disabilities, and cultural factors (Johnson, Mellard, & Byrd, 2006).

The use of AB-Ach methods to identify SLD has its detractors (Johnson et al., 2006). For example, AB-Ach is widely criticized as a “wait-to-fail” method because the discrepancy between ability and achievement may not manifest until the child reaches the fourth grade (Sotelo-Dynega et al., 2011). The inconsistency of guidelines and statistical methods to define and measure discrepancy is another weakness (Cottrell & Barrett, 2016). A comparison among 57 districts in one state yielded district discrepancy guidelines that ranged from a 1-standard-deviation difference (15 points) between cognitive and achievement scores and a 2-standard-deviation difference (30 points) between scores (Reschly & Hosp, 2004). Additionally, Reschly and Hosp (2004) found that school-based teams were manipulating the assessment process to achieve desired outcomes. Cognitive and achievement assessments were selected for the purpose of producing a significant discrepancy that allowed students to receive services that the teams believed were needed (Reschly & Hosp, 2004). Additional criticisms include the failure to inform interventions, over-identification of minority students, and the failure to identify areas of processing deficit (Johnson et al., 2006; Sotelo-Dynega et al., 2011).

As it relates specifically to reading disabilities, the AB-Ach model has been criticized for not focusing on specific neuro-cognitive processes involved in reading. Creating “artificial cut-points” in achievement-ability discrepancies does not recognize the biological basis of learning disabilities (Feifer, 2011, p. 22). Furthermore, achievement of proficient reading skills is heavily impacted by the “wait-to-fail” aspect of AB-Ach models. Wait-to-fail models demonstrate a stark contrast to the importance of early intervention for struggling readers (Feifer, 2011).

Response to Intervention. Response to Intervention (RTI) service delivery model provides schools an alternative identification method for identifying children for special education services by using “a process that determines if the child responds to scientific, research-based intervention” (IDEA§ 1414(b)(6)). RTI identifies students with academic difficulties through multiple tiers of assessments and interventions (Cottrell & Barrett, 2016). RTI begins with universal screening for all students in the general education classroom to identify those not benefitting from instruction (Tier 1). Those students are provided with scientifically based interventions to address the lower rate of performance (Tier 2). If the student fails to respond to an evidence-based intervention tailored to the student’s problem (nonresponder), more intensive interventions (Tier 3) would be implemented to increase the student’s rate of learning (Sotelo-Dynega et al., 2011).

In some ways, RTI shares similar criticisms as the AB-Ach approach. Many schools that have implemented RTI as a means of identification for SLD are unclear in their guidelines. There is a lack of standard treatment protocol (Fletcher, Barth, & Stuebing, 2011). A study completed by Cottrell and Barrett (2016) found that schools operationalized RTI differently. Most notable was the variation in the number of interventions needed and the length of time given to a student to respond to the interventions. Many schools lacked guidelines giving definitive answers for those issues. The remaining sample had varying timelines for determining responsiveness, ranging from as few as 2 to 3 weeks to 6 or more (Cottrell & Barrett, 2016). This variation in methodology may lead to different children being labeled as responders/nonresponders. Additional weaknesses of

RTI as a method of SLD identification include lack of agreement on which curricula, instructional methods, or measurement tools to use and no consensus on how to insure treatment integrity (Sotelo-Dynega et al., 2011).

Feifer (2011) argued that RTI insufficiently identified SLD in reading. RTI emphasizes the correction of curriculum deficiencies and poor instruction techniques (Feifer, 2011). In contrast, SLD is the interruption of learning by internal disorder or dysfunction (Flanagan, Alfonso, & Mascolo, 2011). Reynolds (2007) defined a learning disability as an intrinsic condition within the child. RTI's focus on the child-school interaction may ignore the existence of a disability within the child. For this reason, RTI should not be viewed as a sufficient diagnostic tool for the identification of SLD in reading (Feifer, 2011).

School psychology experts have argued over the different approaches to SLD identification without consensus. The identification of SLD is typically made by assessments completed by school multidisciplinary teams, including the psychologist and other school personnel (Barrett, Cottrell, Newman, Pierce, & Anderson, 2015). Kovaleski et al. (2015) argued that "Weighing the merits of different approaches … is of great interest, relevance, and importance to school psychologists" (p. 6). School psychologists are estimated to spend half their time in assessment of students to determine eligibility for special education services (Castillo, Curtis, & Gelley, 2012).

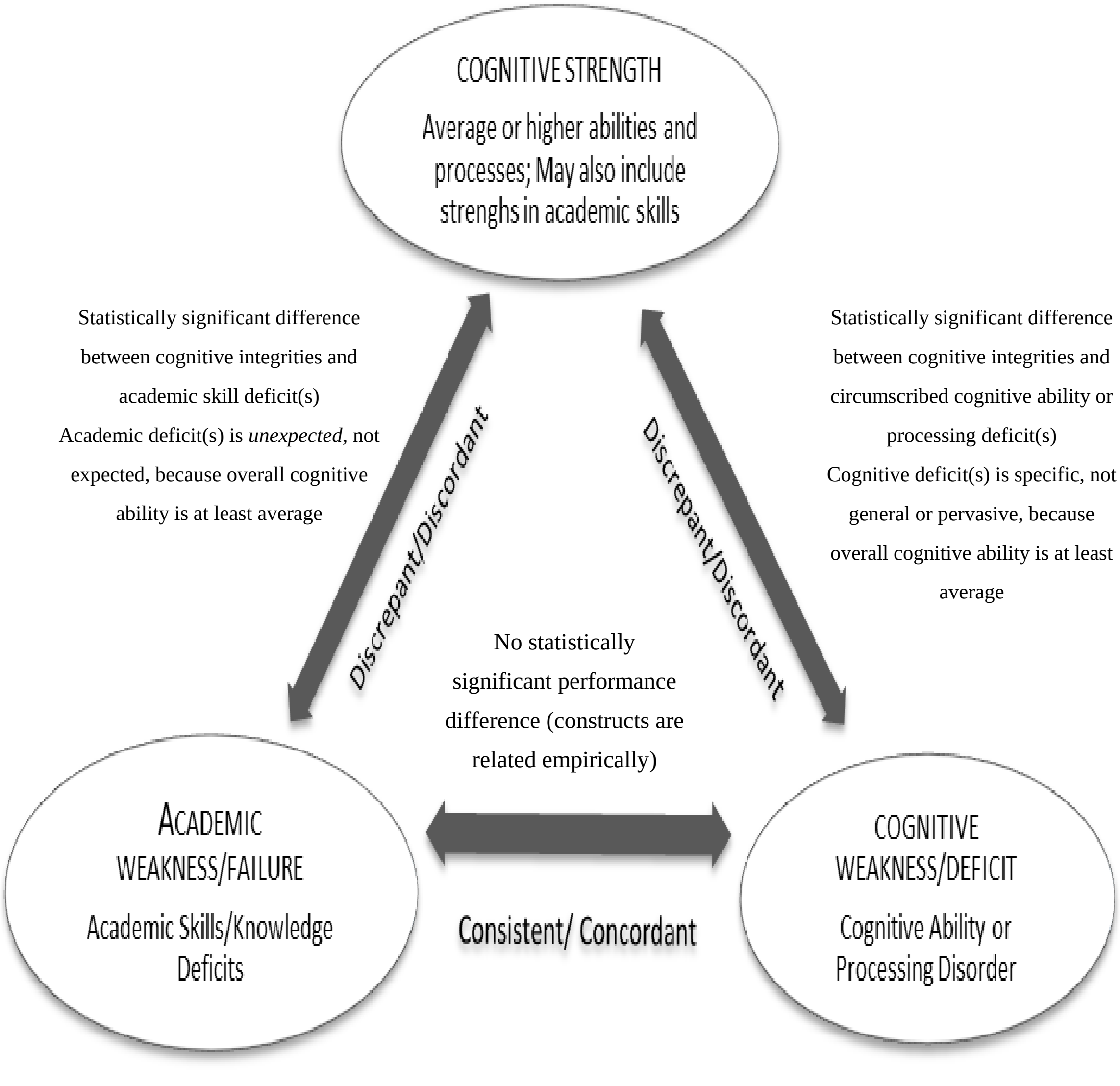
Proper and accurate identification of SLD is necessary since a false positive (inaccurately identified as having a SLD) can lead to a deterioration in skills due to insufficient academic rigor and unnecessary accommodations. Conversely, a false negative (inaccurately identified as not having a SLD) can deprive a student of needed supports, resulting in additional lost progress (Cottrell & Barrett, 2016).

The National Joint Committee on Learning Disabilities (NJCLD) supports CA and evaluation of students because CA allows for proper and accurate identification of students with SLDs (NJCLD, 2010). Research has demonstrated that specific cognitive processes are associated with reading disabilities and should be directly assessed (Stuebing, Fletcher, Branum-Martin, & Francis, 2012). As an alternative to AB-Ach and RTI, the use of patterns of strengths and weaknesses for SLD identification has been interpreted to fall under the 2006 regulation permitting “the use of other alternative researched-based procedures” (Fletcher et al., 2011). This alternative-researched-based method is related to the processing deficit component of SLD required by IDEA (Cottrell & Barrett, 2016).

Third-method Approaches

Cognitive discrepancy methods (third-method approaches) evaluate patterns of strengths and weaknesses (PSW) in cognitive skills, combined with low achievement in an academic domain (Stuebing et al., 2012). Third-method approaches share common components: cognitive strength(s), cognitive weakness(es), and academic weakness (see Figure 1). These third approach methods are intended to address the weaknesses in both AB-Ach and RTI and utilize the research demonstrating the relationship between cognitive abilities and processes and academic achievement (Flanagan, Fiorello, & Ortiz, 2010). This relationship between cognitive abilities and achievement is unique to the PSW model and is not a requirement of AB-Ach or RTI methods of SLD identification (Flanagan et al., 2010).

Three psychometric methods have been proposed to operationalize the third-approach method. While all models fall under the umbrella of the third-approach, the proposed methods differ in meaningful ways. The three models



Statistically significant difference between cognitive integrities and academic skill deficit(s)
Academic deficit(s) is *unexpected*, not expected, because overall cognitive ability is at least average

Statistically significant difference between cognitive integrities and circumscribed cognitive ability or processing deficit(s)
Cognitive deficit(s) is specific, not general or pervasive, because overall cognitive ability is at least average

No statistically significant performance difference (constructs are related empirically)

Figure 1. Common components of third-method approaches to SLD identification (Flanagan et al., 2010).

specify discrepant thresholds for achievement deficits, discrepant methods for establishing a cognitive discrepancy, and discrepant theoretical links between achievement deficits and cognitive weaknesses (Miciak, Fletcher, Stuebing, Tolar, & Vaughn, 2014).

<u>Discrepancy/Consistency</u>. The first third-approach model to be proposed was Naglieri's (1999) "Discrepancy/Consistency" (D/CM) model. If SLD is present under the D/CM model, a child must meet the following criteria: (a) a discrepancy among processing scores, (b) a discrepancy among achievement scores, (c) consistency between low processing and achievement scores, and (d) low scores are substantially below average (Naglieri, 2011). The method was developed using the Planning, Attention, Simultaneous, and Successive (PASS) factors of intelligence measured by a specific battery, the Cognitive Assessment System (CAS; Naglieri & Das, 1997). The D/CM model requires evidence of a disorder in one of the four PASS psychological processes (Naglieri, 2011).

<u>Concordance-Discordance</u>. Hale and Fiorello's (2004) "Concordance-Discordance" (C-DM) model was developed for use in conjunction with "Cognitive Hypothesis Testing" (CHT), a broad cognitive-neuropsychological processing model. C/DM specifies that SLD is marked by an intraindividual pattern of concordance and discordance that includes (a) a concordance between a theoretically related academic achievement weakness and a cognitive processing weakness, (b) a discordance between the academic achievement weakness and a cognitive processing strength, and (c) a discordance between the cognitive processing weakness and a cognitive processing strength (Hale & Fiorello, 2004).

Cross-Battery Assessment. Flanagan et al.'s (2007) "Cross-Battery Assessment" (XBA) is grounded in the Cattell-Horn-Carroll (CHC) theory of cognitive abilities (Stuebing et al., 2012). CHC theory is an expansion on the Cattell-Horn *Gf*-*Gc* theory to encompass a three-stratum model that contains more than 70 narrow abilities, 8 broad second-order abilities, and an overall general intelligence (*g*) ability. The commonly assessed broad CHC abilities are fluid reasoning (Gf), comprehension-knowledge (Gc), visuospacial ability (Gv), long-term storage and retrieval (Glr), auditory processing (Ga), cognitive processing speed (Gs), and short-term memory (Gsm). Reaction Time (*Gt*), while included in the CHC model, is not currently assessed by any major intellectual ability test (Newton & McGrew, 2010; Table 1).

CHC Theory and Reading Disabled Identification

The use of a CHC-based PSW model in the identification of students with SLD in reading requires the school psychologist to evaluate the relationship between CHC abilities, processes, and unexpected academic underachievement in basic reading skills (BRS). The assessment will determine if the weakness or deficit in the academic skill may be related to cognitive areas of weakness or deficit (Flanagan et al., 2011). The empirical relationship between the identified cognitive or neurological processing weakness or deficit and the weakness or deficit in BRS is the critical component to SLD identification (Flanagan et al., 2011).

It is not unusual for people to have intraindividual differences in cognitive abilities and processes. However, for the purpose of SLD identification, a weakness or deficit in academic achievement is required (Flanagan et al., 2011): "A particularly salient aspect of CHC-based operational definition of SLD is the

Table 1

Cattell-Horn-Carroll (CHC) Broad Cognitive Ability Definitions

Fluid Reasoning (*Gf*): The use of deliberate and controlled mental operations, often in a flexible manner, to solve novel problems that cannot be performed automatically. Mental operations often include drawing inferences, concept formation, classification, generalization, generating and testing hypothesis, identifying relations, comprehending implications, problem solving, extrapolating, and transforming information.

Comprehension - Knowledge *(Gc)*: The knowledge of the culture that is incorporated by individuals vis-á-vis a process of acculturation. Gc is typically described a person's breadth and depth of acquired knowledge of the language, information, and concepts of a specific culture and/or the application of this knowledge.

Visual Processing *(Gv)*: The ability to generate, store, retrieve, and transform visual images and sensations.

Auditory Processing *(Ga)*: Abilities that depend on sound as input and on the functioning of our hearing apparatus. A key characteristic is the extent to which an individual can cognitively control (i.e. handle the competition between signal and noise) the perception of auditory information.

Short-Term Memory (*Gsm)*: The ability to apprehend and maintain awareness of a limited number of elements of information in the immediate situation (events that occurred in the last minute or so).

Long-Term Storage and Retrieval *(Glr)*: The ability to store and consolidate new information in long-term memory and later fluently retrieve the stored information (e.g., concepts, ideas, items, names) through association.

Processing Speed (*Gs*): The ability to automatically and fluently perform relatively easy or overlearned elementary cognitive tasks, especially when high mental efficiency (i.e., attention and focused concentration) is required.

Reaction and Decision Speed (*Gt*): The ability to make decisions and/or responses at the onset of simple stimuli typically measures by chronometric measures of reaction time (in milliseconds).

Note. Definitions from Newton & McGrew (2010).

concept that a weakness or deficit in cognitive ability or process underlies difficulties in academic performance and skill development" (Flanagan et al., 2011, p. 247). Unlike other psychometric models, XBA does not focus exclusively on intraindividual differences in subtests or clusters, but rather weakness and deficits are delineated by the student's performance on standardized, norm-referenced tests (Flanagan et al., 2011). An average score falls between 90 and 110, based on a mean of 100 and a standard deviation of 15. A normative weakness falls below 90 and a normative deficit falls below 85 (Flanagan et al., 2011). This applies to both cognitive and academic scores.

The CHC taxonomy has been regarded as a significant advance in the assessment of cognitive processing and is the result of 100 years of psychometric research integrated into the multifactor, hierarchical model (Niileksela & Reynolds, 2014). CHC theory, due to a broad base of validity evidence, has proved influential in the organization and design of nearly all major intelligence batteries (Niileksela & Reynolds, 2014). The technical or administration manuals for the Woodcock-Johnson III Tests of Cognitive Ability, the Stanford–Binet Intelligence Scales, 5th Edition, the Kaufman Assessment Battery for Children, 2nd Edition, and the Differential Ability Scales, 2nd Edition all make specific reference to CHC theory in their designs (Keith & Reynolds, 2010). Wechsler intelligence scales have not specifically identified CHC theory as the basis of design; however, recent revisions have increasingly aligned with CHC theory as the theoretical orientation (Flanagan & Harrison, 2012; Flanagan & Kaufman, 2009).

<u>CHC cognitive abilities and reading achievement</u>. There is a large body of research demonstrating the links between CHC cognitive abilities and reading

achievement (Flanagan et al., 2010; Mather & Wendling, 2012; Newton & McGrew, 2010). It is the interrelationship between cognitive and academic abilities that allows individuals to complete specific academic tasks. The CHC model connects academic domains, such as BRS, to specific cognitive abilities (McGrew & Wendling, 2010).

In 2010, McGrew and Wendling (2010) summarized CHC research via examining the correlations between CHC factors and academic achievement from 1988 to 2009. To qualify for the summary, a study had to (a) be explicitly designed within the CHC framework, (b) investigate the relationship between CHC cognitive abilities and achievement in reading or the study reported quantitative information regarding the relative strength of the CHC ability and the achievement domain, and (3) include at least five of the seven CHC broad abilities.

McGrew and Wendling (2010) reviewed 19 ability-achievement studies and found that Gc was a strong predictor of Basic Reading Skills (BRS), citing research that general language and vocabulary development (included in Gc) are used in reading skill development (McGrew & Wendling, 2010). The ability to fluently retrieve from long-term memory storage lexical and general knowledge (Glr) is also a predictor of early reading development (McGrew & Wendling, 2010). Skills related to processing speed (Gs), such as rapid automatic naming, speed of semantic access, and automaticity were found to be consistently significant to early reading (Shaywitz, Morris, & Shaywitz, 2008). Short-term memory (Gsm) was also found to be significant to BRS development (McGrew & Wendling, 2010). As the student ages, reading skill growth relies more heavily on vocabulary and language development, aspects of Gc (Shaywitz et al., 2008). Surprisingly, the broad CHC ability of auditory processing (Ga) was not found to be significantly related to the development of BRS in the studies (McGrew & Wendling, 2010); however, within broad Ga, the narrow ability of Ga-PC (phonemic awareness) has consistently correlated to BRS (McGrew & Wendling, 2010). Phonemic awareness has emerged as a critical prerequisite skill in the development of reading skills (Shaywitz et al., 2008). Although the Ga-BRS link has not been consistent, according to McGrew and Wendling, other researchers have found a significant association between Ga and BRS (Evans, Floyd, McGrew, & Lef, 2001; Garcia & Stafford, 2000; Vanderwood et al., 2002).

The narrow Gc abilities consistently related to BRS are general information (Gc-KO) and listening ability (Gc-LS). Gc-KO relates to the importance of a cultural basis of knowledge and the ability to integrate that knowledge (Kintsch, 2005). The significance of Gc-LS confirms the importance of the ability to comprehend spoken language in the development of BRS (McGrew & Wendling, 2010).

Three narrow abilities related to memory were found to be significant to BRS. Working memory (Gsm-MW) was consistently significant over all age groups and emphasizes the importance of working memory in reading (McGrew & Wendling, 2010). Memory span (Gsm-MS) was less significant with younger students, but increased with age. Associative memory (Glr-MA) was associated only for very young students (McGrew & Wendling, 2010). Perpetual speed (Gs-P) appears to explain most of the variance in the relation between broad processing speed (Gs) and phonological processing (McGrew & Wendling, 2010).

Research Question

The purpose of this study is twofold: First, it seeks to duplicate previous findings regarding correlations among CHC broad and narrow abilities and basic reading achievement. Secondly, this study seeks to provide additional clarification specifically of the role of the broad ability Ga and the narrow ability of phonemic awareness, and their relationship to reading achievement. Prior research has consistently supported the impact of the narrow ability Ga-PC on reading achievement; however, there is a discrepancy in the literature about the impact of the broad ability Ga. Furthermore, the present research focuses on a sample referred for special education eligibility. Existing research focuses on normative samples obtained by the test companies and not children suspected of being at-risk for a learning disability.

Based on the findings of recent research, the following hypotheses can be formulated for the present study.

Confirmatory Hypotheses

1. Gc will be positively correlated with Basic Reading Skills. A student who presents with a deficit in Gc will be more likely to have low achievement scores, as measured by Letter-Word Identification and Reading Fluency. Conversely, a student with a strength in Gc will be more likely to have high achievement scores in Letter-Word Identification and Reading Fluency.
2. Glr will be positively correlated with Basic Reading Skills. A student who has a deficit in Glr will be more likely to have low achievement scores, as measured by Letter-Word Identification and Reading Fluency. Conversely, a student with a strength in Glr will be more likely to have high achievement scores in Letter-Word Identification and Reading Fluency.

3. Gs will be positively correlated with Basic Reading Skills. A student who has a deficit in Gs will be more likely to have low achievement scores, as measured by Letter-Word Identification and Reading Fluency. Conversely, a student with a strength in Gs will be more likely to have high achievement scores in Letter-Word Identification and Reading Fluency.
4. Gsm will be positively correlated with Basic Reading Skills. A student who has a deficit in Gsm will be more likely to have low achievement scores, as measured by Letter-Word Identification and Reading Fluency. Conversely, a student with a strength in Gsm will be more likely to have high achievement scores in Letter-Word Identification and Reading Fluency.

Clarifying Hypotheses

1. Ga will be positively correlated with Basic Reading Skills. A student who has a deficit in Ga will be more likely to have low achievement scores, as measured by Letter-Word Identification and Reading Fluency. Conversely, a student with a strength in Ga will be more likely to have high achievement scores in Letter-Word Identification and Reading Fluency.
2. Ga-PC will be positively correlated with Basic Reading Skills. A student who has a deficit in Ga-PC will be more likely to have low achievement scores, as measured by Letter-Word Identification and Reading Fluency. Conversely, a student with a strength in Ga-PC will be more likely to have high achievement scores in Letter-Word Identification and Reading Fluency.

CHAPTER 3: METHODS

Participants

Archival data used for this present study included 2008 students referred for psychoeducational evaluations for SLD in a large urban elementary school district in the Southwest United States. The ages ranged from 5 years 3 months to 15 years 0 months (M = 9.8 years, SD = 1.9 years). The ethnic composition was 82.8% European American, 8.5% African American, 0.7% Asian American, and 3.1% Other. Hispanics, who can be of any race, were 41.8%. Sixty-seven percent of the students were male and 33% were female.

Measures

Selected subtests from the W-J III COG were administered by district school psychologists in relation to specific referral concerns. In addition, special education teachers evaluated the students using the W-J III ACH.

The W-J III has a theoretical foundation grounded in the CHC theory of cognitive abilities and is a measurement model for CHC theory (Navarro, 2010). The W-J III batteries were developed for a wide age range, including children as young as 2 years and adults over age 90 (Blackwell, 2001). The WJ-COG and W-J III ACH are co-normed based on data from the same subject samples, which provides more accurate comparisons between cognitive abilities and academic achievement than separately normed instruments (Woodcock, McGrew & Mather, 2001). According to Blackwell (2001), “evidence for the validity of the W-J III is provided for three categories: content, construct, and concurrent,” and, “the authors present an extensive list of studies that have provided a broad variety of content and construct validity evidence supporting the W-J III” (Blackwell, 2001, p. 234).

Cognitive clusters and subtests. The W-J III COG (Table 2) is an individually administered test of cognitive ability. The measure contains 10 standard and 10 supplemental subtests, with a mean of 100 and a standard deviation of 15 (Schrank, McGrew, & Woodcock, 2001). Each W-J III COG broad cluster is comprised of two qualitatively different narrow abilities, which are subsumed by a broad cognitive ability (McGrew, & Woodcock, 2001). This study analyzed five CHC factor clusters from the WJ-COG to represent the five CHC broad cognitive abilities associated with reading achievement, as well as the narrow ability of Ga-PC. Median reliability coefficients of cluster items is .90 or higher (Navarro, 2010).

Reading subtests. The W-J III ACH (Table 3) is an individually administered test of academic achievement. The measure contains 10 standard and 10 supplemental subtests, with a mean of 100 and a standard deviation of 15 (Schrank et al., 2001). The W-J III ACH is co-normed with the W-J III COG (Woodcock et al., 2001). This study utilized standard battery scores from the Letter-Word Identification and Reading Fluency subtests. For the purposes of this study, Letter-Word Identification and Reading Fluency are indicators of basic reading skills. Basic reading skills are measured by the ability to decode, recognize letters and words, and read with fluency. Letter-Word Identification requires decoding skills for a student to read words of increasing difficulty in isolation (words are in list form rather than in context). Reading Fluency measures the speed of reading sentences.

Internal consistency reliability coefficients have been reported for the reading subtests utilized in the present study. Letter-Word Identification has a reported reliability coefficient of .91 in the age 5 to 19 years range and Reading

Table 2

Description of W-J III COG Subtests and CHC Abilities

W-J III COG subtest	Broad CHC ability	Narrow CHC ability	Description of subtest
Verbal comprehension	Comprehension-knowledge (Gc)	Lexical knowledge	Identifying objects; knowledge of antonyms and synonyms; completing verbal analogies
Visual - auditory learning	Long-term retrieval (Glr)	Associative memory	Learning and recalling pictographic representations of words.
Spatial relations	Visual-spatial thinking (Gv)	Spatial relations	Identifying the subset of pieces needed to form a complete shape.
Sound blending	Auditory processing (Ga)	Phonetic coding: synthesis	Synthesizing language sounds (phonemes)
Concept formation	Fluid reasoning (Gf)	Induction	Identifying, categorizing, and determining rules.
Visual matching	Processing speed (Gs)	Perceptual speed	Rapidly locating and circling identical numbers from a defined set of numbers.
Numbers reversed	Short term working memory (Gsm)	Working memory	Holding a span of numbers in immediate awareness while reversing the sequence
General information	Comprehension-knowledge (Gc)	General (verbal) information	Identifying where objects are found and what people typically do with an object
Retrieval fluency	Long term retrieval (Glr)	Ideational fluency	Naming as many examples as possible from a given category
Picture recognition	Visual-spatial recognition (Gv)	Visual memory	Identifying a subset of previously presented pictures within a field of distracting pictures.
Auditory attention	Auditory processing (Ga)	Speech-sound discrimination	Identifying auditorily-presented words amid increasingly intense background noise
Analysis-synthesis	Fluid reasoning (Gf)	Deductive reasoning	Analyzing puzzles (using symbolic formations) to determine missing components
Decision speed	Processing speed (Gs)	Semantic processing speed	Locating and circling two pictures most similar conceptually in a row
Memory for words	Short-term memory (Gsm)	Memory span	Repeating a list of unrelated words in correct sequence

Table 3

Description of W-J III ACH Subtests Utilized in Study

W-J III ACH subtest	Curricular area	Stimuli	Test requirement	Timed	Response
Letter-word identification	Reading	Visual (text)	Identifying printed letters/words with increasing difficulty (need not know meaning of word)	No	Oral (letter name, word)
Reading fluency	Reading	Visual (text)	Silently reading printed statements (gradually increased difficulty) rapidly, decide if true, and respond true or false (Yes or No)	Yes (3 minutes)	Motoric (circling)

Note. Descriptions from Woodcock-Johnson III Examiner's and Technical Manuals

Fluency has a reported reliability coefficient of .90 in the same age range (Mather & Woodcock, 2001). Evidence of content validity, construct validity, and concurrent validity with other academic measures is reported (Mather & Woodcock, 2001).

Statistical Analyses

Correlation analysis using Statistical Package for Social Sciences (SPSS) will be performed to examine the relationship among the five broad W-J III COG clusters (Gc, Glr, Ga, Gs, Gsm), the narrow CHC ability (Ga-PC), and both W-J III ACH variables (Letter-Word Identification and Reading Fluency) to determine if any significant associations exist. Next, linear regression analyses will be conducted to determine the predictive value of Ga and Ga-PC on both achievement variables: Letter-Word Identification and Reading Fluency subtests of the W-J III ACH.

CHAPTER 4: RESULTS

Preliminary Analyses

Descriptive analyses were conducted on all of the measured variables to assess their distribution. All of the measured variables had relatively normal distributions, with skewness values between -.533 and .296, and kurtosis values between .361 and 1.256 (Table 4).

Table 4

Descriptive Statistics of Measured Variables

Variable	Min.	Max.	Mean	S.D.	Skewness	Kurtosis
Letter word identification	22	127	80.3	15.0	-.167	.751
Reading fluency	48	127	81.0	11.4	.296	.361
Ga-PC	43	156	100.0	13.4	-.023	1.256
Ga	43	141	98.8	12.9	-.503	1.215
Gc	36	121	88.8	12.4	-.357	.395
Glr	24	130	82.1	14.7	-.408	.401
Gsm	39	129	88.1	12.8	-.223	.473
Gs	25	132	89.2	14.7	-.533	1.081

Note. [1] Ga-PC = phonological awareness, Ga = auditory processing, Gc = crystallized intelligence, Glr = long-term memory storage and retrieval, Gsm = short-term memory, Gs = processing speed.

Main Analyses

A Pearson product-moment correlation coefficient was computed to determine if any significant associations existed among the study variables of the 5 broad CHC factors of Gc, Glr, Ga, Gs, Gsm, the narrow CHC ability of Ga-PC, and the Letter Word Identification and Reading Fluency subtests from the Woodcock-Johnson III Test of Achievement (Table 5). Within the variables of interest, all cognitive skills demonstrated significant positive correlations with one another ($p<.05$ for all correlations). Additionally, achievement subtests were significantly positively correlated with one another ($p< .05$ for all correlations). Regarding relationship between Letter-Word Identification and CHC cognitive factors, there was a positive correlation among the variables Gc (r = 0.35), Glr (r = 0.38), Gsm (r = 0.37), Ga (r = 0.35) and Ga-PC (r = 0.37). According to Cohen (1988), this suggests a medium effect size. A positive significant correlation, but small effect was found in the relationship between Letter-Word Identification and Gs (r = 0.21). Regarding the relationship between Reading Fluency and CHC cognitive factors, there was a positive correlation among all variables (Gc r = 0.22, Glr r = 0.27, Gsm r = 0.28, Gs r = .24, Ga r = 0.14 and Ga-PC r = 0.19). However, the effect size is small (Cohen, 1988).

Table 5

Pearson Correlations Among Cattell-Horn-Carroll (CHC) Cognitive Ability Subtests and the Woodcock-Johnson III Subtests of Letter Word Identification and Reading Fluency

	Gc	Glr	Gsm	Gs	Ga	Ga-PC	LWI	RF
Gc	1.00							
Glr	.52*	1.00						
Gsm	.39*	.34*	1.00					
Gs	.21*	.31*	.22*	1.00				
Ga	.43*	.34*	.37*	.27*	1.00			
Ga-PC	.19*	.24*	.34*	.18*	.88*	1.00		
LWI	.35*	.38*	.37*	.21*	.35*	.37*	1.00	
RF	.22*	.27*	.28*	.24*	.14*	.19*	.76*	1.00

Note. [1] LWI = Letter Word Identification subtest of the Woodcock-Johnson III; RF = Reading Fluency subtest of the Woodcock-Johnson III. * $p < .05$

Next, linear regression analyses were conducted to determine (a) if performance on the Letter-Word Identification subtest of the Woodcock-Johnson III could be predicted by Ga and Ga-PC, and (b) if performance on the Reading Fluency subtest of the Woodcock-Johnson III could be predicted by Ga and Ga-PC. For all regression analyses age, Gc, Glr, Gsm, and Gs were included in the models as controls.

First, regression analyses demonstrated that Ga and Ga-PC individually predicted performance on Letter-Word Identification. Specifically, Ga-PC predicted greater performance ($b = .180$, $SE = .053$, $\beta = .170$, $p < .01$) than Ga ($b = .141$, $SE = .056$, $\beta = .133$, $p < .05$). When analyzing the predictive value of Ga on Letter-Word Identification, the control variables Gsm ($b = .247$, $SE = .057$, $\beta = .221$, $p < .01$) and Glr ($b = .184$, $SE = .048$, $\beta = .215$, $p < .01$) were found to be significant (Table 6). When analyzing the predictive value of Ga-PC on Letter-Word Identification, the following control variables were found to be significant: Glr ($b = .199$, $SE = .048$, $\beta = .229$, $p < .01$) Gsm ($b = .245$, $SE = .056$, $\beta = .218$, $p < .01$) and age ($b = .720$, $SE = .348$, $\beta = .096$, $p < .05$) (Table 6).

Secondly, results demonstrated that demonstrated that neither Ga nor Ga-PC significantly predicted performance on the Reading Fluency subtest. The regression coefficients for Ga ($b = -.010$, $SE = .054$, $\beta = -.012$, $p > .05$) as well as Ga-PC were not statistically significant ($b = .023$, $SE = .050$, $\beta = .028$, $p > .05$). However, the regression coefficients for specific control variables were statistically significant in the Ga-Reading Fluency model, including Gsm ($b = .205$, $SE = .055$, $\beta = .205$, $p < .05$), Gs ($b = .135$, $SE = .046$, $\beta = .185$, $p < .01$) Glr ($b = .106$, $SE = .047$, $\beta = .155$, $p < .01$) and age ($b = 1.112$, $SE = .394$, $\beta = .173$, $p < .01$). The regression coefficients for specific control variables were statistically significant in the Ga-PC-Reading Fluency model, including Gsm ($b = .189$, $SE = .054$, $\beta = .215$, $p < .01$), Gs ($b = .130$, $SE = .045$, $\beta = .177$, $p < .01$) Glr ($b = .122$, $SE = .047$, $\beta = .177$, $p < .01$) and age ($b = 1.117$, $SE = .395$, $\beta = .171$, $p < .01$ (Table 7).

Age was a significant predictor of performance on both Letter-Word Identification and Reading Fluency subtests. This finding resulted in further analysis of that variable. The study sample was divided into two groups (younger

Table 6

Linear Regression: Woodcock-Johnson III Subtest of Letter-Word Identification predicted by Cattell-Horn-Carroll (CHC) Cognitive Ability Ga and Ga-PC controlling for Age, Gc, Glr, Gsm, and Gs

Outcome	Predictors	*b*	*SE*	*β*	*R*	*SEE*	R^2	R^2_{change}	*F*	*Df*	*P*
LWI					.516	11.652	.266	.253	21.431	361	.000**
	Ga	.141	.056	.133							.012*
	Gc	.111	.063	.101							.079
	Glr	.184	.048	.215							.000**
	Gs	.068	.047	.072							.146
	Gsm	.247	.057	.221							.000**
	Age	.647	.346	.087							.065
LWI					.533	11.565	.284	.272	8.324	255	.000**
	Ga-PC	.180	.053	.170							.001**
	Gc	.104	.062	.094							.096
	Glr	.199	.048	.229							.000**
	Gs	.071	.046	.075							.123
	Gsm	.245	.056	.218							.000**
	Age	.720	.348	.096							.040*

Note. [1] LWI = Letter Word Identification subtest of the Woodcock-Johnson III

* *p* < .05; ** *p* < .01

Table 7

Linear Regression: Woodcock-Johnson III Subtest of Reading Fluency Predicted by Cattell-Horn-Carroll (CHC) Cognitive Ability Ga and Ga-PC Controlling for Age, Gc, Glr, Gsm, and Gs

Outcome	Predictors	*b*	*SE*	*β*	*R*	*SEE*	R^2	R^2_{change}	*F*	*Df*	*P*
RF					.409	9.592	.167	.147	8.324	255	.000**
	Ga	-.010	.054	-.012							.854
	Gc	.076	.061	.088							.214
	Glr	.106	.047	.155							.025*
	Gs	.135	.046	.185							.004**
	Gsm	.179	.055	.205							.001**
	Age	1.112	.394	.173							.005**
RF					.436	9.485	.191	.171	9.768	255	.000**
	Ga-PC	.023	.050	.028							.640
	Gc	.077	.060	.089							.200
	Glr	.122	.047	.176							.009**
	Gs	.130	.045	.177							.004**
	Gsm	.189	.054	.215							.001**
	Age	1.117	.395	.171							.005**

Note. [1] RF = Reading Fluency subtest of the Woodcock-Johnson III.

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

and older) at the approximate mean age of 10 years (actual mean age 9.84). The younger group included 1,084 study participants ages 5-10 and the older group included 924 participants ages 11-15. Linear regression analyses were conducted to determine if differences existed in the predictive value of the variables between the two age groups. For all regression analyses age, Gc, Glr, Gsm, and Gs continued to be included in the models as controls.

Unlike the sample as a whole, regression analysis demonstrated Ga (b = .116, SE = .067, β = .126, $p > .05$), did not individually predict performance on Letter-Word Identification for the younger group. Control variables Glr (b = .272, SE = .057, β = .350, $p < .01$) and age (b = -1.783, SE = .770, β = -.138, $p < .05$) were found to be significant (Table 5). Ga-PC however, continued to be a significant predictor for the younger group (b = .131, SE = .065, β = .139, $p < .05$). When analyzing the predictive value of Ga-PC on Letter-Word Identification for the younger group, the control variables Glr (b = .283, SE = .057, β = .358, $p < .01$), Gsm (b = .147, SE = .072, β = .142, $p < .05$) and age (b = -1.626, SE = .775, β = -.124, $p < .05$) were found to be significant (Table 8). It is important to note that Glr demonstrated the strongest relations with the Letter-Word Identification subtest in both models (Ga and Ga-PC).

For the Ga-Reading Fluency model among younger students, the regression equation was not significant (R^2= .099, F=1.693, Df= 98, $p > .05$), rendering the coefficients for Ga and control variables uninterpretable (Table 6). By contrast, for the Ga-PC-Reading Fluency model the overall regression equation was statistically significant (F =2.655, Df =98, $p < .05$), however, Ga-PC (b = .000, SE = .092, β = .000, $p > .05$) was not a significant predictor of Reading Fluency.

Table 8

Linear Regression: Woodcock-Johnson III Subtest of Letter-Word Identification Predicted by Cattell-Horn-Carroll (CHC) Cognitive Ability Ga and Ga-PC Controlling for Age, Gc, Glr, Gsm, and Gs Among Younger Students

Outcome	Predictors	*b*	*SE*	*β*	*R*	*SEE*	R^2	R^2_{change}	*F*	*Df*	*P*
LWI					.608	10.190	.369	.348	17.655	187	.000**
Younger students											
	Ga	.116	.067	.126							.087
	Gc	.057	.073	.057							.438
	Glr	.272	.057	.350							.000**
	Gs	.100	.061	.107							.106
	Gsm	.140	.071	.137							.051
	Age	-1.783	.770	-.138							.022*
LWI					.612	10.283	.374	.354	18.046	187	.000**
Younger students											
	Ga-PC	.131	.065	.139							.048*
	Gc	.049	.073	.049							.497
	Glr	.283	.057	.358							.000**
	Gs	.097	.061	.103							.115
	Gsm	.147	.072	.142							.042*
	Age	-1.626	.775	-.124							.037*

Note. [1] LWI = Letter Word Identification subtest of the Woodcock-Johnson III

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

The control variable Glr ($b = .228$, $SE = .086$, $\beta = .288$, $p < .01$) was the only variable found to be significant (Table 9).

Regression analyses of older students demonstrated that Ga-PC was a significant predictor for Letter-Word Identification ($b = .223$, $SE = .086$, $\beta = .183$, $p < .05$), while Ga was not a significant predictor for Letter-Word Identification ($b = .159$, $SE = .091$, $\beta = .126$, $p > .05$) (Table 10). For the Ga-Letter-Word Identification model, results indicated that specific control variables were statistically significant: Gc ($b = .249$, $SE = .107$, $\beta = .200$, $p < .05$); Gsm ($b = .331$, $SE = .087$, $\beta = .060$, $p < .01$); and age ($b = 1.862$, $SE = .927$, $\beta = .136$, $p < .05$). For the Ga-PC-Letter-Word Identification model, the same control variables were found to be significant: Gc ($b = .229$, $SE = .106$, $\beta = .183$, $p < .05$), Gsm ($b = .320$, $SE = .086$, $\beta = .262$, $p < .01$), and age ($b = 2.130$, $SE = .921$, $\beta = .155$, $p < .05$) (Table 7). These results indicate the first emergence of Gc as a significant variable, and are consistent with previous findings (McGrew & Wendling, 2010). It also should be noted that among older students, Gsm replaced Glr as the variable demonstrating the strongest relation to the Letter-Word Identification subtest.

For the older students, neither Ga ($b = -.011$, $SE = .064$, $\beta = -.013$, $p > .05$) nor Ga-PC ($b = .035$, $SE = .060$, $\beta = .043$, $p > .05$) significantly predicted performance on the Reading Fluency subtest (Table 8). Similar to Letter-Word Identification case, the same control variables in both Reading Fluency models were found to be significant. For the Ga-Reading Fluency model, Gs ($b = .196$, $SE = .049$, $\beta = .289$, $p < .01$) and Gsm ($b = .213$, $SE = .061$, $\beta = .259$, $p < .01$) were statistically significant (Table 11). For the Ga-PC-Reading Fluency model, Gs ($b = .195$, $SE = .049$, $\beta = .289$, $p < .01$) and Gsm ($b = .201$, $SE = .061$, $\beta = .246$, $p < .01$) were also statistically significant.

Table 9

Linear Regression: Woodcock-Johnson III Subtest of Reading Fluency Predicted by Cattell-Horn-Carroll (CHC) Cognitive Ability Ga and Ga-PC Controlling for Age, Gc, Glr, Gsm, and Gs Among Younger Students

Outcome	Predictors	*b*	*SE*	*β*	*R*	*SEE*	R^2	R^2_{change}	*F*	*Df*	*P*
RF					.315	11.135	.099	.041	1.693	98	.131
Younger students											
	Ga	-.005	.101	-.005							.963
	Gc	.057	.107	.059							.595
	Glr	.192	.088	.249							.031*
	Gs	.015	.096	.017							.873
	Gsm	.065	.110	.067							.555
	Age	-.337	1.519	-.023							.825
RF					.382	10.901	.146	.091	2.655	99	.020*
Younger students											
	Ga-PC	.000	.092	.000							.997
	Gc	.075	.102	.078							.464
	Glr	.228	.086	.288							.009**
	Gs	.008	.094	.008							.936
	Gsm	.102	.110	.102							.356
	Age	-.371	1.504	-.026							.806

Note. [1] RF = Reading Fluency subtest of the Woodcock-Johnson III.

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

Table 10

Linear Regression: Woodcock-Johnson III Subtest of Letter-Word Identification Predicted by Cattell-Horn-Carroll (CHC) Cognitive Ability Ga and Ga-PC Controlling for Age, Gc, Glr, Gsm, and Gs Among Older Students

Outcome	Predictors	*b*	*SE*	*β*	*R*	*SEE*	R^2	R^2_{change}	*F*	*Df*	*P*
LWI					.500	12.667	.250	.224	9.302	173	.000**
Older students											
	Ga	.159	.091	.126							.082
	Gc	.249	.107	.200							.021*
	Glr	.059	.080	.062							.462
	Gs	.060	.069	.060							.388
	Gsm	.331	.087	.270							.000**
	Age	1.862	.927	.136							.046*
LWI					.526	12.481	.277	.250	10.579	172	.000**
Older students											
	Ga-PC	.223	.086	.183							.010*
	Gc	.229	.126	.183							.033*
	Glr	.093	.080	.097							.246
	Gs	.071	.068	.071							.302
	Gsm	.320	.086	.262							.000**
	Age	2.130	.921	.155							.022*

Note. [1] LWI = Letter-Word Identification subtest of the Woodcock-Johnson III

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

Table 11

Linear Regression: Woodcock-Johnson III Subtest of Reading Fluency Predicted by Cattell-Horn-Carroll (CHC) Cognitive Ability Ga and Ga-PC Controlling for Age, Gc, Glr, Gsm, and Gs Among Older Students

Outcome	Predictors	*b*	*SE*	*β*	*R*	*SEE*	R^2	R^2_{change}	*F*	*Df*	*P*
RF					.520	8.484	.270	.241	9.250	156	.000**
Older students											
	Ga	-.011	.064	-.013							.859
	Gc	.143	.076	.169							.062
	Glr	.039	.057	.061							.495
	Gs	.196	.049	.289							.000**
	Gsm	.213	.061	.259							.001**
	Age	1.102	.652	.119							.093
RF					.526	8.444	.277	.248	9.516	155	.000**
Older students											
	Ga-PC	.035	.060	.043							.564
	Gc	.138	.076	.163							.070
	Glr	.046	.057	.072							.417
	Gs	.195	.049	.289							.000**
	Gsm	.201	.061	.246							.001**
	Age	1.217	.655	.131							.065

Note. [1] RF = Reading Fluency subtest of the Woodcock-Johnson III.

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

Results Summary

The results of this study confirm well-established correlations among five broad and one narrow CHC cognitive factors and reading achievement, as measured by the Letter-Word Identification and Reading Fluency subtests of the Woodcock-Johnson III. Within the variables of interest, all cognitive skills demonstrated significant positive correlations with one another. Four regression models utilizing the entire sample were created to analyze the predictive value of Ga and Ga-PC on the Letter-Word Identification and Reading Fluency subtests. For all regression analyses, age, Gc, Glr, Gsm, and Gs were included in the models as controls. Letter-Word Identification predicted by Ga found Ga to be predictive to performance; however, control variables Glr and Gsm demonstrated the strongest relations. Letter-Word Identification predicted by Ga-PC also found Ga-PC to be predictive with Glr, Gsm, and age having significance. Reading Fluency performance was not found to be predicted by Ga or Ga-PC. Control variables of Glr, Gs, Gsm, and age were all significant. In both models, Gsm demonstrated the highest predictive value.

Dividing the study sample into younger and older groups resulted in the differences in the predicative value of variables for performance on the Letter-Word Identification and Reading Fluency subtests, as compared to the sample as a whole. The regression model of Letter-Word Identification predicted by Ga did not find Ga to be predictive of performance for either group. The control variable Glr demonstrated the strongest relations for younger students and Gsm for older students. The regression model of Letter-Word Identification predicted by Ga-PC did find Ga-PC, along with Gsm, to be predictive for both the younger and older group. The variable Glr, while significant for the younger group, lost significance for the older group and was replaced with Gc as a predictor of performance.

For the Ga-Reading Fluency model among younger students, the regression equation was not significant. For the Ga-Reading Fluency model among older students, Ga was found not to be predictive. Control variables Gs and Gsm were significant. In both the younger and older Reading Fluency models, performance was not found to be predicted by Ga-PC for either group. Similar to the regression models of Letter-Word Identification, Ga-PC Fluency models indicated Glr was significant for the younger group, but not for older students. Unlike the regression models of Letter-Word Identification, Gc did not become significant for older students.

CHAPTER 5: DISCUSSION

Specific Learning Disability is the most frequently occurring disability in the United States, affecting over 2 million children (NCES, 2012). Over 75% of children with disabilities experience difficulties in reading (Feifer, 2011). Federal law provides for three methodologies for identification: AB-Ach model, RTI, and other empirically based methods, including PSW. Unlike AB-Ach and RTI, PSW models utilize empirical evidence to connect cognitive processing deficits to academic underachievement.

A large body of research has identified cognitive processing weaknesses that interfere with learning disabled students' acquisition of reading skills (Floyd et al., 2007). CHC theory (a foundational underpinning for some PSW models) encompasses a three-stratum model that contains more than 70 narrow abilities, 8 broad second-order abilities, and an overall general intelligence (*g*) ability. The CHC taxonomy has been regarded as a significant advance in the assessment of cognitive processing due to a broad base of validity evidence (Niileksela & Reynolds, 2014). The CHC model connects academic domains, such as BRS, to specific cognitive abilities (McGrew & Wendling, 2010).

This study intended to duplicate previous findings regarding correlations among CHC broad and narrow abilities and basic reading achievement. Secondly, this study sought clarification on the discrepancy in existing research between the impact of the broad ability Ga (broad auditory processing) on reading achievement and the narrow ability, Ga-PC (phonological processing), which has consistently been demonstrated to have a significant relationship to reading achievement. Notably, the present research focuses on a referred sample of children suspected of being at-risk for a learning disability, distinguishing it from most existing research focused on normative samples obtained by test companies.

The present investigation tested four confirmatory hypotheses and two clarifying hypotheses. The confirmatory hypothesis investigated the broad abilities of Gc, Glr, Gs, and Gsm and their relationship to basic reading skills (BRS). It was hypothesized that Gc, Glr, Gs, and Gsm would be positively correlated with BRS. A student who presents with a deficit in Gc, Glr, Gs, and Gsm will be more likely to have low achievement scores, as measured by Letter-Word Identification and Reading Fluency. Conversely, a student strong in Gc, Glr, Gs, and Gsm will likely have high achievement scores in Letter-Word Identification and Reading Fluency. The clarification hypotheses examined the broad ability Ga and the narrow ability Ga-Pc and their relationship with BRS. It was hypothesized that Ga and Ga-PC would be positively correlated with BRS. A deficiency in either Ga or Ga-PC would result in a student with low achievement scores, as measured by Letter-Word Identification and Reading Fluency. Conversely, a student strong in either Ga or Ga-PC would have high achievement scores in Letter-Word Identification and Reading Fluency. Regression analysis was utilized to analyze the individual predictive value of Ga and Ga-PC on the BRS measures. For all regression analyses, age, Gc, Glr, Gsm, and Gs were included in the models as controls.

The results of this study confirmed well-established correlations among five broad cognitive factors (Ga, Gc, Glr, Gs, Gsm), one narrow CHC cognitive factor (Ga-PC), and reading achievement, as measured by the Letter-Word Identification and Reading Fluency subtests of the Woodcock-Johnson III. Within the variables of interest, all cognitive skills demonstrated significant positive correlations among one another. Four regression models utilizing the entire sample were created to analyze the predictive values of Ga and Ga-PC on the Letter-Word

Identification and Reading Fluency subtests. For all regression analyses age, Gc, Glr, Gsm, and Gs were included in the models as controls. Letter-Word Identification predicted by Ga found Ga to be predictive to performance; however, control variables Glr and Gsm demonstrated the strongest relations. Letter-Word Identification predicted by Ga-PC also found Ga-PC to be predictive with Glr, Gsm, and age having significance. Reading Fluency performance was not found to be predicted by Ga or Ga-PC. Control variables of Glr, Gs, Gsm, and age were all significant. In both models, Gsm demonstrated the highest predictive value.

Because age was a significant predictor in all models, the whole sample was divided in order to reveal if the results would be different for younger and older students. Creating two groups facilitated further analysis of how different CHC abilities become more or less significant depending on the participant's age. Younger students included study participants ages 5-10 and older students included participants ages 11-15.

Confirmatory Hypothesis 1: Gc (Crystallized Intelligence) Will Be Positively Correlated with Basic Reading Skills

Results yielded a positive correlation between Gc and BRS, as measured by the Letter-Word Identification and Reading Fluency subtests of the Woodcock-Johnson III. Regression analysis examined the influence of Gc on BRS. Gc was found to be significant for older students on the Letter-Word Identification subtest, indicating that Gc may become more impactful as a student ages. Correlations between Gc and BRS skills in this study demonstrated both consistencies and discrepancies with prior reading research. Consistent with this study, Benson (2008) found the influence of Gc on BRS minimal in kindergarten through sixth grade. This may be related to the nature of crystallized abilities, specifically a student’s language and vocabulary development. Becoming a good reader includes the acquisition of a vocabulary of words, over time, that can be recognized in a text. Gc is linked to these necessary word identification skills (Torgesen, 2002). Additionally, older children’s reading strategy skills may be more sophisticated, allowing them to better utilize background knowledge, an important component of Gc.

Confirmatory Hypothesis 2: Glr (Long Term Retrieval) Will Be Positively Correlated with Basic Reading Skills

Results yielded a positive correlation between Glr and BRS, as measured by the Letter-Word Identification and Reading Fluency subtests of the Woodcock-Johnson III. Long-term retrieval ability manifests in efficient storage and later retrieval of information (Schrank, Miller, Wendling, & Woodcock, 2010). Glr encompasses the ability to analyze words based on the sound-symbol organization of written language. This ability to form, store, and efficiently retrieve these letter-sound linkages is important to early reading development (McGrew & Wendling, 2002). When analyzing the sample as a whole, regression analysis indicated Glr to be predictive of performance on both Letter-Word Identification and Reading Fluency.

The effects of Glr varied across age groups. Analysis by group indicates the influence of Glr as the strongest of all predictors for BRS for younger students. However, Glr loses significance for older students. The decline in the impact of Glr with the increase in student age is logical due to decreased reliance on acquisition of sound/symbol relationships for decoding (beginning stages of reading) and represents a move towards automaticity (Schrank et al., 2010). The declining significance of Glr with age is also consistent with existing research.

Other researchers have found that the significance of Glr tended to decline with age as other abilities became more important (Evans et al., 2001; McGrew & Wendling, 2010).

Confirmatory Hypothesis 3: Gs (Processing Speed) Will Be Positively Correlated with Basic Reading Skills

Results yielded a positive correlation between Gs and BRS, as measured by the Letter-Word Identification and Reading Fluency subtests of the Woodcock-Johnson III. Current research on processing speed, the ability to perform simple cognitive tasks quickly, has some mixed findings. Vanderwood et al. (2002) found no relationship between Gs and BRS. Benson (2008) found increased significance of Gs on BRS with age. The results of this study may explain some of the discrepancy in the research. In the present study, when analyzing the sample as a whole, regression analysis indicated Gs to be predictive of performance on Reading Fluency, but not on Letter-Word Identification. It is noteworthy that Vanderwood et al. (2002) did not include a fluency measure in their research. Benson (2008), using a model similar to Vanderwood and colleagues, included a fluency variable, as did this present study. Present study analysis by group indicates Gs as the strongest predictor for Reading Fluency in older students. No significance was demonstrated between Gs and Reading Fluency in younger students. This finding shows an increase in the relationship between Gs and BRS with age. The emergence of significance for Gs in older students may be attributable to the decline in Glr as automaticity and other speed and fluency constructs begin to take precedence.

Confirmatory Hypothesis 4: Gsm (Short Term Memory) Will Be Positively Correlated with Basic Reading Skills

Results yielded a positive correlation between Gsm and BRS, as measured by the Letter-Word Identification and Reading Fluency subtests of the Woodcock-Johnson III. Gsm ability refers to tasks involving storage and minimal processing of information (Schrank et al., 2010). Relationships between Gsm and the BRS measures in this study demonstrate consistencies with prior reading research. Regression analysis analyzed the predictive value of Gsm on BRS. Gsm was found to be significant across age groups on both Letter-Word Identification and Reading Fluency. These findings support existing research, which has demonstrated the significant relationship between Gsm and reading achievement (Evans et al., 2001; Schrank et al., 2010).

Clarification Hypothesis 1: Ga (Auditory Processing) Will Be Positively Correlated with Basic Reading Skills

Auditory processing has been defined as the ability to process and detect meaningful nonverbal information in sound (Schneider & McGrew, 2012). The cognitive abilities needed to discriminate, analyze, synthesize, and manipulate sound are subsumed under Ga (Schrank et al., 2010). In the present study, Pearson’s correlation analysis yielded a positive correlation with a medium effect size between Ga and BRS. However, regression analysis demonstrated little individual predictive value of Ga on BRS performance. Ga was significant for Letter-Word Identification when analyzing the whole sample; this relationship was lost when analyzing the sample by age groups. Ga was not significant for either younger or older students on either BRS measure. This result is important, as research regarding Ga is conflicting. Some prior research has identified Ga as significantly related to reading achievement (Garcia & Stafford, 2000; Schrank, 2010; Vanderwood et al., 2002). There have also been detractors. Specifically, Benson (2008) found no relationship between Ga and BRS when using a W-J III ACH basic reading skills cluster that included Letter-Word Identification (accurately identifying familiar words) and Word Attack (phonological decoding of unfamiliar words).

Additional research has contradicted the Ga/BRS relationship (McGrew & Wendling, 2010). This discrepancy in the research may be due to differences in the operationalization of Ga. Some studies that purported to measure Ga were, in reality, measuring Ga-PC. For instance, Garcia and Stafford (2000) and Vanderwood et al., (2002) used Sound Blending and Incomplete Words, which are tests of narrow Ga-PC (Garcia & Stafford, 2000; Vanderwood et al., 2002). Both of these subtests measure factors related to Phonetic Coding; by contrast, broad Ga includes other narrow abilities related to attending to sound, discriminating speech from noise, and analyzing and synthesizing speech patterns (Ga subsumes narrow cognitive abilities, such as Phonetic Coding). The W-J III cognitive cluster for Ga used in this study included the subtest of Sound Blending (a form of Ga-PC) and Auditory Attention (a measure of speech-sound discrimination and resistance to auditory-stimulus distortion). The present findings offer support to the position that the broad ability of Ga may not play the important role in reading abilities as once thought. A future emphasis on more narrow abilities may be warranted.

Clarification Hypothesis 2: Ga-PC (Auditory Processing-Phonetic Coding) Will Be Positively Correlated with Basic Reading Skills

Results indicate a positive correlation among Ga-PC and both Letter-Word Identification and Reading Fluency. Phonological awareness, a narrow ability within Ga, is the ability to hear phonemes distinctly. Students with poor Ga-PC ability will have difficulty hearing the internal structure of sounds in words (Schneider & McGrew, 2012). The impact of Ga-PC on early reading skill acquisition has been extensively documented over various studies (Evans et al., 2001; McGrew & Wendling, 2010; Shaywitz et al., 2008; Schrank et al., 2001). Abilities associated with the perception and manipulations of units of sound (Phonetic Coding) have demonstrated significant effects on decoding skills (Floyd et al., 2007). The findings of this study support the contribution that Ga-PC makes to reading achievement remains critical to reading success. The results of this study also confirm that the impact of Ga-PC exceeds early skill development and can be influential well beyond grade school. Results demonstrated strong relations with BRS skills from ages 5-10, but Ga-PC continued to demonstrate an increase in relations with Letter-Word Identification throughout the period of analysis.

Limitations and Future Studies

One limitation to this study is that the W-J III ACH Basic Reading Skills cluster combines the subtests Letter-Word Identification and Word Attack. Due to the sample utilized for this study being one of convenience and comprised of archival data, data were not available on subtests that were supplemental to the W-J III ACH standard battery. Word Attack is a supplemental measure rendering scores unavailable for the analysis for this study.

BRS primarily cover decoding and word recognition (McGrew & Wendling, 2010). Reading Fluency requires decoding and recognizing words quickly and is included with Letter-Word Identification and Passage Comprehension (identifying a key word that makes sense in the context of a written passage) in the W-J III ACH Broad Reading Cluster. However, Reading Fluency, as measured by the W-J III ACH, is not a pure measure of BRS. The subtest requirement to answer yes or no after reading a sentence implies comprehension—a skill independent from decoding and potentially influenced by different cognitive abilities. Letter-Word Identification entails less complex reading skills, whereas the Reading Fluency subtest requires both BRS and understanding of the sentence, a higher-level ability (Mather & Woodcock, 2001).

A second limitation is that these results apply to groups, not individual assessment. In other words, knowing that a particular student has specific cognitive strengths and weaknesses may not necessarily indicate a need for remediation or intervention. This study confirms much of the existing research regarding empirical relationships between cognitive abilities and academic performance. However, on the individual level, there is complexity to the cognitive processes involved in academic tasks (Decker, Hale, & Flanagan, 2013). Even after determining the strengths and weaknesses of students’ cognitive and academic profiles, one must still determine if the information will lead to educationally meaningful decisions for individual students?

Proponents of PSW argue that assessments of strengths and weaknesses exceed identification of the disability to inform intervention and individualize educational strategies (Decker et al., 2013). Decker et al. (2013) argued for a growing body of research demonstrating positive effects of intervention on cognitive processes. Some research does show a direct impact on academic achievement through cognitive intervention. For example, Dahlin (2011) demonstrated that training in working memory (Gsm) improved reading comprehension. However, research linking improved cognitive processes to increased academic achievement is limited. Miciak et al. (2016) concluded that information related to a student’s cognitive profile is not useful in predicting favorable responses to intervention. Study authors do acknowledge that the study did not address whether information on cognitive profiles could be “utilized to formulate better or more effective intervention plans” (Miciak et al., 2016, p. 907). Further research should address these issues.

Despite its limitations, the current study is one of the few that examined a real clinical population, rather than a standardized sample. Within a clinical population, this study established that the broad ability of Ga was not related to BRS. Focusing assessment and intervention on the narrow ability of Ga-PC may more accurately identify and intervene for students with reading difficulties. The NRP (2000) completed a meta-analysis of research regarding the benefits of phonemic awareness instruction and found significant improvement not just in phonological awareness, but in reading outcomes as well.

Phonological processing increased in association with reading achievement among older students referred for evaluations. Older students encountered more classroom reading demands and less reading instruction. It is hypothesized that older, struggling students have not received interventions to address phonological processing skills, which has exacerbated reading problems. Research has demonstrated that phonic awareness intervention was beneficial for all students; however, effect sizes were greater for beginning readers than for older, disabled readers (NRP, 2000). Taken together, the present results reaffirm the necessity for early intervention in the area of phonological processing.

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