AN INVESTIGATION OF THE COGNITIVE PROFILE OF DEAF AND HARD OF HEARING STUDENTS ON THE WECHSLER INTELLIGENCE SCALE FOR CHILDREN-FIFTH EDITION

A DISSERTATION

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

IN THE GRADUATE SCHOOL OF THE

TEXAS WOMAN'S UNIVERSITY

DEPARTMENT OF SPECIAL EDUCATION

COLLEGE OF PROFESSIONAL EDUCATION

BY

LEAH M. ARRINGTON, B.S., M.S.

DENTON, TEXAS

MAY 2018

DEDICATION

This dissertation is dedicated to my mother, Judith C. Rippstein, who led by example and always believed in me. My earliest memory of our time together was when she sat by my side as I struggled to learn to read. She painstakingly listened and worked with me as I read the Dick and Jane books. I remember crying out of frustration because I wanted to do so well; I wanted to make her proud of me. As I struggled in school she never let me take the easy road out, she was there telling me I could do it. When I had self-doubt, she had the words of encouragement. She never let me believe I was limited but rather the sky was the limit. She showed by example the importance to pursue your interest and any age. I thank her for she is a unique individual that knew the most important lesson she could teach was by her example of continual learning.

The completion of this leg of my journey could not have been possible without the support of so many individuals. First and foremost, words are not available to express how deeply grateful I am for my family. My husband has been my biggest cheerleader and he means the world to me; I am eternally grateful that I know this is not temporary. Next to my children, Samuel, Zachary, Matthew, Mikayla, and Isabelle their love and support has never wavered. When I was so close to the end but ready to be done it was my children that would say, “You can’t stop now.” I truly have been blessed with a great family.

ACKNOWLEDGMENTS

I would like to sincerely thank the members of my committee. To Dr. Jane Pemberton, my dissertation chair, thank you for checking in on my progress, your timeless edits, words of encouragement, and your knowledge of the special education field. To Dr. Mary Dell Donelson, the visiting professor on by board as support, thank you for your expertise in the field of assessment. Your knowledge and insight of the low incident population has been invaluable to me both in my research and in my acting profession, thank you. To Dr. Marshall, thank you for working with me to make sense of my complex data and continually answering questions so I could more fully investigate data from my collection. To Dr. Allmen and Dr. Whitworth thank you for supporting this research and the time and effort you have contributed to ensuring this study has met the high standards that have been established at TWU.

Additionally, I would like to thank my employer and colleagues. My employer for giving me the means possible to complete this study. And to my colleagues for everything. They have been much more than a support but rather they have taught me so much in the area of assessment and the value beyond the numbers. They have given me more than I could express, thank you all.

ABSTRACT

LEAH M. ARRINGTON

AN INVESTIGATION OF THE COGNITIVE PROFILE OF DEAF AND HARD OF HEARING STUDENTS ON THE WECHSLER INTELLIGENCE SCALE FOR CHILDREN

MAY 2018

In the academic setting, the measure of intelligence is used to predict the success of learning or to identify possible disabilities due to identified strengths and weaknesses in cognitive processes. The predominant theory of intelligence is the Cattell-Horn-Carroll (CHC) theory in which broad cognitive processes are determined by the measurement of narrow abilities within each broad area of cognition. The *Wechsler Intelligence Scale for Children, Fifth Edition* (WISC-V) is a cognitive tool that provides scores of both the broad and narrow cognitive processes, which can then provide a profile of strengths and weakness to be used for individualized educational planning. The purpose of this study was to determine if a cognitive profile exists on the WISC-V for D/HH students. Furthermore, if the cognitive profile is affected by known dependent variables (amplification, degree of hearing loss, mode of communication).

Participants were first through fifth grade students who had been identified as D/HH and had been administered the WISC-V. A total of 49 students met criteria for the study. In addition to subtests and index scores, the degree of hearing loss, mode of communication, and type of amplification used was recorded.

Results showed that overall the profile of the D/HH student was within the average range established by the WISC-V norms except in the area of Verbal Knowledge (Gc) which was slightly below average. The Vocabulary subtest was also found to be below average. Type of amplification did not appear to significantly impact the profile of the broad or narrow abilities. The degree of hearing loss identified moderate to severe and profound had a significant difference in Gs and Coding. The mode of communication had reported significant differences in NVI, Gv, Gf, and in Visual Puzzles, Matrix Reasoning, and Picture Span subtests.

This study demonstrates that D/HH students perform similarly to the expected norms on the WISC-V verbal and nonverbal indexes. However, the Crystalized Knowledge Index and more specifically Vocabulary subtest are below the expected norms and are important factors when considering educational planning for D/HH students.

TABLE OF CONTENTS

LIST OF TABLES

Table Page

LIST OF FIGURES

CHAPTER I

INTRODUCTION

The interest in human intelligence or ability to acquire and apply knowledge has existed since before the time of Aristotle. Formal assessment of intelligence did not become formalized until the 1900s when Alfred Binet developed an intelligence scale that would help identify students who would have difficulty learning in a general education classroom. Since that time, the understanding of intelligence has evolved to more accurately measure an individual’s intelligence. Cognitive theories, theories that address the processes which an individual assimilates and interrogates knowledge, have driven research to dissect and analyze the subtests on which the single or global score relied (Ortiz & Lella, 2004). As a result, intelligence assessments have been designed to more accurately address and measure specific cognitive processes that contribute to an individual’s overall intelligence (Keith & Reynolds, 2010; Newton & McGrew, 2010).

A pre-dominate cognitive taxonomy theory that unwinds the complex cognitive processes as they relate to academic learning is the operational working of the Cattell-Horn-Carroll (CHC) theory (Claeys, 2013; Flanagan, Ortiz, & Alfonso, 2013; Lynch & Warner, 2012; Newton & McGrew, 2010). The CHC theory includes a three-stratum hierarchy with a general factor (g), 16 broad abilities and over 70 narrow abilities. An analysis of an individual’s cognitive abilities (broad and narrow) can provide a profile of the student’s cognitive assets and/or deficits often referred to as a student’s strengths and/or weaknesses. The use of such a profile is most commonly used in the educational setting to identify specific learning disabilities (SLD) among students who are struggling in school.

Some school districts have adopted the CHC theory through a cross-battery construct of testing as their foundation in identifying cognitive strengths and weaknesses that directly impact a student's learning, as required by the evaluation procedures presented by the Code of Federal Regulation §300.304(c)(6) (see Appendix A for the Federal Determination of Deafness and Hearing Impairment). Significant research supports the use of the CHC theory when evaluating an individual's cognitive abilities to distinguish and explain differences in academic abilities that are not accounted for by the overall *g* factor (Claeys, 2013; Flanagan et al., 2013; Lynch & Warner, 2012; Newton & McGrew, 2010). Research has not only identified typical profiles of students with SLD but also linked specific cognitive processing deficits with specific academic deficits (Cormier, Bultu, McGrew, & Frison, 2016; Flanagan et al., 2013; McGrew & Wendling, 2010; Meisinger, Meisinger, Gregg, & Keith, 2012). This information can support better educational programming with focused, research-based interventions targeting the student's deficit area.

However, the use of the CHC theory is typically limited to the identification of students with SLD, although other students needing individualized education programs might benefit from information that could be obtained through the examination and analysis of cognitive strengths and weaknesses; information that could yield diagnostic and treatment validity. Detterman and Thompson (1997, p. 1083) presented the importance of understanding cognitive abilities and then applying that understanding to develop an individualized educational program:

> …the lack of understanding of the cognitive skills underlying educational interventions is the fundamental problem in the development of special education. Without understanding the full complexity of cognitive abilities, special educational methods can never be special.

For one such low incident but highly diversified population, the deaf and hard of hearing (D/HH), it has been a long journey with many setbacks in discerning their cognitive abilities. For centuries, the fallacy of D/HH lacking in intelligence was the status of the D/HH population. This began as early as when Aristotle when he identified D/HH as “senseless and incapable of reason” and that mindset continued with many philosophers over centuries, supporting such falsehoods (Winzer, 1993). However, a literature review of the intelligence of D/HH by McCay Vernon (2005) provided the turning point to the approach of D/HH cognition being inferior. Vernon directed the way for further understanding of intelligence of D/HH by rectifying key concepts such as cognitive performance process correlates with academic performance in which D/HH could more accurately be measured. Cognitive distributions of D/HH, with no additional disabilities, are similar to their hearing peers in IQ level on performance intelligence tests (Vernon, 2005).

The shift of studies moved from primarily the comparison of D/HH students to hearing students to addressing specific cognitive areas that impact D/HH academic performance. However, a cognitive profile of a D/HH student is an area that appears to have little evidential support. It is understood and supported that a hearing impairment inhibits an individual's language exposure, thus impacting learning. There are a number of studies that address language deficits and the effect on academic performance (Edwards, Figueras, Mellanby, & Langdon, 2010; Thagard, Hilsmier, & Easterbrooks, 2011).

Executive function is a specific process that has been a topic of interest with other processes getting some attention (Beer, Kronenberger, & Pisoni, 2011; Figueras, Edwards, & Langdon, 2008; Sipal & Bayhan, 2011). Yet, the compiling of measurable cognitive processes to create an expected profile of cognitive abilities as they are observed among the D/HH population presents a prominent gap in research. This might be due to the complexity of measuring cognitive processes when significant language limitations are known or due to the lack of available tests normed with the D/HH population (Akamatsu, Mayer, & Hardy-Braz, 2008; Miller, Thomas-Presswood, Metz, & Lukomski, 2015). Although the D/HH is considered a low incident population, it is understood the D/HH population is one that is far from being homogeneous. An expected profile of strengths and weakness could provide a framework that would be valuable diagnostically.

Statement of the Problem

Is there a profile difference, as identified by index scores, among D/HH students compared with the WISC-V norms? When a student receives a Full Individual Evaluation

(FIE), it typically includes some level of cognitive assessment, as in full scale or nonverbal. The scores are reported as standard scores. Analysis of how far the score deviates above or below the mean is documented along with a qualitative descriptor. What the information is used for and how it is applied to educational planning is often unclear. For hearing students, scores are analyzed to identify patterns of strengths and weaknesses among the cognitive processes; then that pattern is linked to the student's academic performance. It is when the pattern deviates from the norm that a specific learning disability is often identified; different patterns assist in identifying specific areas of learning disabilities.

A pattern of strengths and weaknesses is a method for identifying a learning disability, according to IDEIA (2004) and Texas Education Agency (TEA, 2007). There are many studies linking a pattern of cognitive strength and/or weaknesses or a profile to specific academic performance among varying populations (Bergeron & Floyd, 2006; McKnight & Culotta, 2012; Thaler, Bello, & Etcoff, 2012). However, for the low incident populations of D/HH, there are limited studies that exam a pattern of strengths or weakness or establish a cognitive profile for a typically developing D/HH student (Reeseman et al., 2014; Miller et al., 2015).

Additionally, the D/HH population is often misrepresented and misunderstood as 'vanilla' deaf, a student with a hearing loss. However, in addition to the hearing loss, evaluators should consider such variables as to the degree of hearing loss, type or amplification, and mode of communication. These factors impact the access to experiences on all levels which then can directly impact the development of cognitive processes. The construct of this study is to take the information that is obtained and link it to the earlier studies to support the knowledge base of typical profiles of the D/HH population. This information can help determine how the profiles of the D/HH student differ within the D/HH population.

When comparing this study to earlier studies of D/HH cognition, this study approached cognition as a whole, establishing a complete profile from the index scores and subtest scores. In essence, the framework was to establish a general profile as it relates to the established norms. In addition, more importantly, this study was to analyze what effects varying conditions (i.e., mode of communication, degree of hearing loss, and type of amplification) related to D/HH had on the cognitive profile as well as more specific narrow abilities.

Purpose of the Study

The purpose of this study was to identify if cognitive strengths and weakness, as defined by the Cattell-Horn-Carroll (CHC) theory, exist for elementary school age students who are identified as D/HH. Research examining theories of the complete cognitive profile among students who are D/HH tends to focus on two domains of cognition: verbal knowledge as it relates to language acquisition and executive function as it related to academic learning (Hauser, Lukomski, & Hillman, 2008; Marschark & Wauters, 2008; Pisoni et al., 2008; Thagard et al., 2011). This study framed its design around the research-based CHC theory to clearly define cognitive abilities. This study used the Code of Federal Regulations and specifically the Texas Administrative Code definition of auditory impairment (AI) to define students who are D/HH in order to identify cognitive patterns (see Appendix B for Texas State Determination of Auditory Impairment).

Research Questions

1. Is there a profile difference, as identified by index scores, among D/HH students compared with the WISC-V norms?
2. Is there a cognitive profile, CHC subtest patterns and/or index standard scores, difference among D/HH students as it relates to their degree of hearing loss (mild, moderate, severe, profound)?
3. Is there a difference in the cognitive profile, CHC subtest patterns and/or index standard scores, of D/HH students who have a cochlear implant(s), hearing aids, or no amplification?
4. Is there cognitive profile, CHC subtest patterns and/or index standard scores, difference among D/HH student whose primary mode of communication is sign language versus oral language?

Significance of this Study

The significance of this study is to provide additional documentation to current research of D/HH cognition abilities and to begin to establish a complete profile of cognitive abilities of D/HH students. The profile provides information of general cognitive strengths and weaknesses for D/HH students. These predictable patterns of strengths and weakness can then be used to enhance general instruction and allow for more accurately designed individualized education programs and interventions. Additionally, a deviation from the expected profile of strengths and weakness may help identify those D/HH students that might possibly have an additional disability such as learning disability or intellectual disability, thus their needs can be better addressed.

Definitions of Terms

Auditory Impairment (Deaf/Hard of Hearing) (Code of Federal Regulations): "…a hearing impairment that is so severe that the child is impaired in processing linguistic information through hearing, with or without amplification, that adversely affects the child's educational performance" (34 Code of Federal Regulations §300.89(c)(5)) and "…an impairment in hearing, whether permanent or fluctuating, that adversely affects a child's educational performance…" (4 Code of Federal Regulations §300.8 (c)(3)).

Auditory Impairment (Texas Administrative Code): A student with an auditory impairment is one who has been determined to meet the criteria for deafness as stated in 34 CFR, §300.8(c)(3), or for hearing impairment as stated in 34 CFR, §300.8(c)(5). The evaluation data reviewed by the multidisciplinary team in connection with the determination of a student's eligibility based on an auditory impairment must include an otological examination performed by an otolaryngologist or by a licensed medical doctor, with documentation that an otolaryngologist is not reasonably available, and an audiological evaluation performed by a licensed audiologist. The evaluation data must include a description of the implications of the hearing loss for the student's hearing in a variety of circumstances with or without recommended amplification (19 Texas Administrative Code § 89.1040. Eligibility Criteria).

Cattell-Horn-Carroll (CHC) theory: The CHC theory is a theoretical model of intellectual abilities, consisting of a hierarchical, three-stratum model of intelligence.

Cochlear Implant: A device that is surgically implanted into the cochlea to stimulate sound.

Cognitive Aptitude: The specific cognitive ability weakness or deficit that has an established empirical relation to the academic skill weakness or deficit.

Cognitive Area of Strength: A significant positive difference between an index score and the overall performance.

Cognitive Area of Weakness: A significant negative difference between an index score and the overall performance.

Decibel (dB): Is the unit of measure for loudness, or intensity of a sound.

Degree of Hearing Loss: Is the severity of impairment with the following being the qualitative descriptors: mild hearing loss (20-30 dB), moderate hearing loss (30-50 dB), moderately-severe hearing loss (50-70 dB), severe hearing loss (70-90 dB) and profound hearing loss (over 90 dB).

FM System: A personal microphone and receiver. The microphone is used by the teacher and transmits the teacher’s voice to the student’s receiver which is typically directly to the hearing aid or cochlear implant.

Hearing Age: The time when an individual begins receiving auditory input through appropriate amplification.

Hearing Aid: A type of amplification worn in or on the ear to amplify sound.

Hertz (Hz): Is the measure of the frequency or pitch of a sound.

Index Score: A composite of scores.

Intelligence: The ability to acquire and apply knowledge skills.

Nonverbal Index (NVI): NVI examines four of the five primary cognitive domains using six subtests from the *Wechsler Intelligence Scale for Children, Fifth Edition* (WISC-V) that requires no verbal responses. The cognitive domains addressed are Visual-Spatial, Fluid Reasoning, Working Memory, and Processing Speed.

Oral Communication: Is the method of communication that emphasized the acquisition of speech for all communication and discourages sign language.

Pattern of Strengths and Weaknesses (PSW): When a battery of multiple cognitive abilities scores are assessed to determine within an average profile of scores if there is one or more significant cognitive weaknesses or strengths.

Scale Score: A scaled score is a conversion of a student's raw to a standardized scale based on the same mean with a set of standard deviations to allow numerical comparison between student scores. These scaled scores are scores with the mean of 10 and a standard deviation (SD) of 3.

Standard Score: Scores that are based on the same mean with a set of standard deviations to allow for comparison. The standard score reflects how many standard deviations above or below the mean a specific score is. These standard scores are scores with the mean of 100 and standard deviation (SD) of 15. The Qualitative Descriptors that are assigned to each SD is as follows: Extremely High 130 and above; Very High 120-129; High Average 10-119; Average 90-109; Low Average 80-89; Very Low 70-79; and 69 and below Extremely Low.

Total Communication (TC): Is a method of communication that emphasizes the acquisition of language through sign language. Typically sign and speech are presented simultaneously. The Regional Day School used in this study emphasized Signed Exact English (SEE); using exact sign with speech.

CHAPTER II

REVIEW OF LITERATURE

In the preface to the republishing of Vernon's 1965 pivoting literature review, *Fifty Years of Research on the Intelligence of Deaf and Hard-of-Hearing Children: A Review of Literature and Discussion of Implications*, Vernon's findings were described as a "stake through the heart of the established truths" that deaf were intellectually inferior to hearing individuals (Vernon, 2005, p. 225). Aristotle had characterized the deaf as "…in all cases dumb; they can make vocal noises but they cannot speak" they were "senseless and incapable of reason" and "no better than the animals of the forest and unteachable" which remained the perspective for nearly 2,000 years (as cited in Winzer, 1993, p. 18). Vernon (2005) exposed the error in such philosophy in his literature review by identifying several constructs of the intelligence of deaf and hard of hearing (D/HH). Intelligence distributions and the values of performance tests were two of the primary implications reported, which were similar in correlation to verbal tests as it relates to academic performance. Within Vernon's review of intelligence testing of D/HH individuals, the nature of intelligence was not addressed. The value of the performance test and the many limitations in research completed on D/HH intelligence assessment was the focus. Since the time of Vernon's extensive review, the depth of understanding the complex cognitive abilities has greatly improved, as well as how such abilities are assessed (Keith & Reynolds, 2010; Miller et al., 2015; Wood & Dockrell, 2010).

The purpose of this literature review was to identify literature dealing with cognitive profiles of students who are D/HH; to ascertain if there is a unique pattern of strengths and weakness that would be expected among D/HH students. This study was designed to examine aspects of the predetermined cognitive test; global, index, and subtests scores. The purpose of this literature review is to explore the history of intelligence testing and to examine how contemporary perspectives have been used to understand the cognitive abilities and how this all relates to and can be used for the benefit of the D/HH population. It is not to debate the value of analyzing a single score of intelligence versus focusing in on narrow abilities or to find fault in any test as it relates to D/HH assessment.

The Development of Intelligence Testing

Sir Francis Galton's contributions to mental ability based assessment launched the revolution of intelligence testing. Galton is known as the father of psychometrics and it was his philosophy of individual differences that led to the notion that intelligence could be measured (Jensen, 2002; Sattler, 2008). Although much of his research provided null results, it was his use of statistical concepts of regression to the mean and correlation that could identify intelligence as quantifiable and normative distributions (Jensen, 2011; Sattler, 2008). Galton's interests led him towards developing tests related to individual heredity differences, which provided a framework for the measurements of other individual differences such as intelligence. It is important to note that Galton never claimed his test measured intelligence, but rather sensory abilities that measured the extent to which the individual was able to perceive experiences. It was Galton's theory that all information an individual received was obtained through his or her five senses, thus allowing for sound judgments and intelligence. A measurement of an individual's senses was a measurement of the individual's intelligence (Wasserman, 2012).

It was Alfred Binet who recognized complex processes rather than sensory and motor processes yielded more variances among individuals, thus providing better measures of intelligence (Wasserman, 2012). There were several predecessors to Binet's intelligence test. It is generally acknowledged that Binet's work has been the foundation from which modern intelligence tests have emerged. Binet's first normed referenced test came when the French Ministry of Education needed a means to identify children that were required to attend school, under the mandatory education laws, but did not effectively learn in the general education classroom. Binet and Theodore Simon constructed their first practical test, The Binet – Simon Scale, to measure higher mental processes which were reported as a mental age; the mental age was derived from several mental tasks that accumulated into one given score. The test was individually administered with specific guidelines. It included 30 items progressing in difficulty that focused on mental abilities (e.g., language, memory, reasoning, digit span, and psychophysical judgments). Previous tests assessed an individual's senses, physical measurement, or behaviors which were not predictors of intelligence or academic performance (Boake, 2002).

The Binet-Simon Scale was revised in 1908 and 1911 to include more tests that were organized by grade level performance of the average passing student, assessment of additional mental abilities (auditory processing and visual processing), in addition to expanding the use of the test through adulthood (Wasserman & Tulsky, 2005). The test continued to report the student's performance as mental level, age level, or year scale. The Binet-Simon Scale had three revisions and was credited for the inception of an intelligence scale that was efficient and practical. The scales used the combination of several mental assessments to yield a composite score and the statistical method in which to analyze the data but did not render an intelligence quotient (Boake, 2002; Wasserman & Tulsky, 2005; Wechsler, 2014).

In essence, Binet and Simon developed a procedure in which individuals could be measured and categorized as it related to their intellectual abilities. However, four years after its original release, the French government enacted a new law placing the identification of students with special education needs in the hands of physicians, school inspectors, directors, and teachers with no mention of assessing the student. Although the French did not fully benefit from the success of the Binet-Simon Scales, the practicality of measuring intelligence was realized elsewhere in the world, specifically the United States.

The progress of the intelligence test continued with a revision by Yerkes and Bridges that transformed the score report from a year scale to a point scale and was the model for a future intelligence test by Wechsler (Boake, 2002). The second revision came from Terman of Stanford University. Terman et al. revised, extended, standardized, and renamed the Binet-Simon Scale to the Stanford-Binet Intelligence Scale (Wasserman & Tulsky, 2005). Additionally, Terman's revision identified the mental age as an intelligence quotient (IQ). It is this scale, Stanford-Binet Intelligence Scale, which was the dominating intelligence test for decades (Boake, 2002; Wasserman & Tulsky, 2005).

The success of the Binet-Simon Scale and the Stanford-Binet Intelligence Scale empowered the use of such tools to be used for placements according to skill. During World War I, Yerkes and a team of psychologists spearheaded the development of two separate group administered tests, the Army Alpha and Beta *(*Gottfredson & Saklofske, 2009*)*. The Alpha test was constructed for recruits who were literate and fluent in English; the Beta test was performance-based and intended for recruits who were illiterate and non-proficient in English. The separate construct was intended to remove or minimize the lack of formal education/language needed to complete the test, thus providing a more accurate examination of the recruits' abilities versus measuring their formal education level (Gottfredson & Saklofske, 2009; Wasserman & Tulsky, 2005). The success of the Army Alpha and Beta tests encouraged the use of intelligence tests in schools, colleges, industry, and military, broadening the base and purpose of intelligence testing (Wasserman & Tulsky, 2005).

One of the Alpha and Beta test administrators, a draftee with a psychological background, David Wechsler began fostering essential ideas that would later influence his approach to intelligent assessment. Wechsler's time in service would allow him to draw on the experiences and observations he received as a test administrator. Wechsler developed an understanding of the limits a group administration had, the value of nonverbal components in overall intelligence, and the start of the analysis of a profile. Using the experience he acquired in the service, from other clinic positions, and the influence of some notable colleagues (Spearman, Person, Wells, and Cattel), Wechsler assembled a single battery of co-normed tests, the Wechsler-Bellevue Intelligence Scale (W-B), which surpassed the popularity and use of the Stanford-Binet (Wasserman, 2012).

The W-B was an individually administered test that included 10 subtests with an alternate vocabulary test. The test included a verbal scale and a performance scale and provided a full scale IQ score. From his army experience, Wechsler recognized the verbal and performance tests to be "equally adequate measures of general intelligence, but he emphasized the importance of appraising people in many different modalities as possible," thus it was an important factor to minimize the likelihood of underestimating an individual due to a verbal only assessment (Wasserman, 2012, p. 35). The W-B also introduced the standard score which was based on converting the sum of test scores into a standard score and using a statistical distance from the normative mean in standardized units from each age level (Boake, 2002; Wasserman 2012). This form of scoring changed reporting the IQ as mental age to standard score having the same distribution at each age level.

Although the W-B did not introduce any new subtests, the existing subtests were carefully examined and chosen based on Wechsler's definition of intelligence, appropriateness for age scale versus point scale, and the practical criterion of validation (Wechsler, 1939). Wechsler explained,

> Our aim was not to produce a set of brand new tests but to select, from whatever source available, such a combination of them as would best meet the requirements of an effective adult scale" (Wechsler, 1939, p. 76).

At this point in the history of intelligence testing, the foundation and acceptance of intelligence assessment had been well established. Galton pioneered the way and was credited as the father of psychometrics; Cattel was an advocate for psychology as a science and coined the term mental age; Binet was credited for the first practical intelligence test; Terman revised the Binet-Simon Scale; Goddard translated and popularized the Binet in America; Yerkes with a team developed the Army Alpha and Beta assessments; Scott led the way of applying principles of experimental methodologies; and Wechsler provided a single battery of co-normed tests (Boake, 2002; Carlson, 1993; Gottfredson & Saklofske, 2009; Sattler, 2008; Wasserman, 2012). However, to state that one person or only those individuals or one test propelled intelligence testing to where it is today would be extremely misleading. Many individuals around the world put their ideas and understanding of intelligence into practice. Although they may not have directly worked together it seems as if one psychologist came into contact with another and the tests, ideas, and constructs spread, with each building upon its predecessor.

There are currently multiple intelligence tests published; however, there are six that are commonly used in the educational setting: Differential Ability Scale (DAS), Kaufman Assessment Battery for Children, Second Edition (KABC-II), Reynolds Intellectual Assessment Scales (RIAS), Wechsler Intelligence Scale for Children, Fifth Edition (WISC-V), Stanford-Binet, Fifth Edition (SB-5), and Woodcock-Johnson IV Test of Cognitive Ability (WJ-IV). Due to the significant number of individuals being assessed who have significant language delays or are second language learners, several nonverbal tests or portions of batteries better referred to as language reduced, are used when appropriate. The SB-5, KABC-II, WISC-V, DAS, and RIAS all provide a nonverbal index score through the administration of selected subtests. The WISC series is the most used intelligence assessment (Weiss, Keith, Zhu, & Chen, 2013). The Leiter-3 and Universal Nonverbal Intelligence Test-2 (UNIT2) are two batteries that are performance-based intelligence tests and are specifically identified for use with individuals who have speech, language or hearing impairments. However, both of these tests are limited in cognitive areas assessed. Of the current tests available, the WISC series is the predominant one used to test cognition (Weiss et al., 2013).

Theories Behind the Development of Intellectual Assessment

Initially, intelligence was explained by a single score and was referred to as mental ability, mental age, and later intellectual quotient (IQ). Although early tests examined more than mental abilities, often including sensory and strength of the individual, the net score was developed with the end in mind versus based on empirical finding and theories. However, the early intelligent or mental ability tests laid the foundation for theories of intelligence to cultivate; they guided the evolution of the structure of intelligence theories.

Before presenting the history of intelligence theories, the role of factor analysis must be discussed due to its powerful influence in the understanding and construct of intelligence in the 20th century (Sattler, 2008). Factor analysis is a statistical method used to find trends in large amounts of data that could account for existing inter-correlations. The goal of a factor analysis is “to explain the pattern of inter-correlations by identifying the smallest number of meaningful underlying variables of factors that could account for the observed inter-correlations” (Sattler, 2008, p. 123). Factor analysis is a useful tool for examining relationships between complex concepts such as the subtests that are used to identify one’s intelligence.

In the early years of intelligence assessment, the use of factor analysis allowed for better understanding of what the subtests measured and their relationships to the overall score. With this understanding intelligence theories typically evolved in support of one of two ideas - a general factor or multifactor of intelligence. The general factor supported the idea that intelligence could be explained with one primary factor, called general intelligence, that works in conjunction with special abilities which included theories such as Spearman’s two-factory theory, Vernon’s hierarchical theory, and Carroll’s three-stratum factor analytic theory of cognitive abilities. The multifactor was based on the idea that an individual’s intelligence included a combination of several mental factors which included theories such as Thorndike's multifactor theory, Thurstone's primary mental abilities theory, Guilford's structure of intellect theory, and Cattell and Horn's fluid and crystalized theory of intelligence.

Spearman, being a proponent of factor analysis, discovered shared variances of scores from several closely related mental ability tests leading to the two-factor intelligence model. Establishing the similar performances on different tests fostered Spearman's understanding of the structure of intelligence. Spearman explained performance on intelligence tests by the general factor ('g') which included deductive operations and one additional specific factor ('s') (Sattler, 2008). Due to the correlation between the *g* factor and all aspects of intelligence, this became the numerical expression for an individual's general mental energy, later referred to as general ability or intelligence (Bergeron & Floyd, 2006; Bickley, Keith, & Wolfle, 1995; Spearman, 1927, p.137; Wasserman & Tulsky, 2005). Spearman's theory became known as the two-factory theory, having separated performance into *general factors* and *specific factors*.

The general factors were those that were present across tasks and the specific factors were 'unique' to individual tasks (Wasserman, 2012). However, this single 'g' factor, or IQ, had significant limitations in that some cognitive abilities could be easily over or under represented. Additionally, it provided little information as to why identical IQ scores could produce very different performances among students. With that limitation came controversy as to the acceptance of the 'g' factor. It has taken time and considerable empirical evidence to come to some level of agreement that Spearman's 'g' exists and is evident in current reported intelligence scores. Wechsler Intelligence Scale for Children-V (WISC-V) has the Full Scale IQ (FSIQ); Woodcock-Johnson IV Test of Cognitive Abilities has the General Intellectual Ability (GIA); and Kaufman Assessment Battery for Children- II has Fluid-Crystallized Index (FCI); and Differential Ability Scales (DAS) has the General Conceptual Ability (GCA) all representing the overall general cognitive ability – a single intelligence score (Farmer, Floyd, Reynolds, & Kranzler, 2014; Neisser et al., 1996; Sattler, 2008; Wasserman, 2012).

With Spearman's two factor theory as a foundation, additional theories that addressed the underlying factors of intelligence emerged (Wasserman & Tulsky, 2005; Wasserman, 2012). Thurstone's theory of primary abilities is a theory that rocked the existing explanation of the structure of intelligence and evolved through the development of Thurstone's statistical method to analyze multiple factors. Thurstone multiple factor analysis enabled Thurstone to extract ability factors that were largely separate, independent, and unrelated (Wasserman & Tulsky, 2005; Wasserman, 2012). Thurstone found Spearman's single 'g' limiting and using multiple-factor analysis reported that intelligence was the accumulation of seven independent factors that he identified as *primary abilities*: word fluency, verbal comprehension, spatial visualization, number facility, associative memory, reasoning, and perceptual speed (Thurstone, 1938). The theory of primary abilities not only challenged representing an individual's intelligence with a single score but provided a new perspective on understanding intelligence. It should be noted that although Thurstone's theory identifies with the multifactor intelligence theories research, Thurstone's *primary factors* correlated among themselves suggesting the existence of a factor related to general ability. Thurstone acknowledged the existence of a general factor such as a single score for IQ but recommended reporting a profile of mental abilities describing strengths and weaknesses rather than an IQ score (Sattler, 2008; Wasserman, 2012).

Cattell obtained information on intelligence theories from both sides of the trending theories- single 'g' and multi-factor of intelligence. His professor was Charles Spearman, who used factor analysis to identify a single factor 'g'. Spearman's colleague was E. L. Thorndike, whose intelligence theory was based on a multiple factor model. With influence from both perspectives, Cattell based his theory on his research as well as Thorndike's theory. In 1941, Cattell presented his theory on intelligence by stating the single factor was not enough to explain intelligence, and that evidence existed of influences from educational-cultural opportunities and influences from genetic factors and physiological-neurological functioning (Cattell, 1941). Cattell provided a dichotomous perspective; two separate general factors or the fluid and crystalized theory of intelligence (G*f*-G*c* theory).

Fluid intelligence (Gf) is the general ability to reason, to do so abstractly, in identifying patterns and recognizing relations. Sattler described fluid intelligence as being the nonverbal component that is a "relatively culture-free mental efficiency" (2008, p.225). This intelligence ability is fluid with the ability to change from one situation to the next. In general, it is how an individual problem solves; how they think, generalize, and adapt to new situations. For Cattell, Gf was an indispensable capacity factor because it defined the ability to acquire and apply knowledge and crystallized intelligence (Wasserman & Tulsky, 2005).

Crystallized Intelligence (Gc) is the ability to acquire and access skills and knowledge which are dependent on education and acculturation. This intelligence factor is dependent on exposure to culture, education, and language. Additionally, it is manifested in known situations and with known material.

After reanalyzing Cattell's data, Horn, a student of Cattell's, expanded Cattell's dichotomous model to include several additional abilities until the model developed into a 10 factor model (Flanagan et al., 2013). The once Gf-Gc theory had become known under several names: Expanded Gf-Gc theory, Cattell-Horn Gf-Gc theory, and *modern* Gf-Gc theory. This new perspective included the following 10 factors: fluid intelligence (Gf), crystallized intelligence (Gc), visual processing (Gv), short-term acquisition and retrieval (Gsm), long-term storage and retrieval (Glr), processing speed (Gs), auditory processing (Ga), quantitative ability (Gq), decision speed (Gt), and reading/writing ability (Grw). Cattell and Horn's expanded theory is fluid and has been revised several times but the key factors, fluid and crystallized intelligence factors, have remained steadfast and intact.

Carroll, who was influenced by Thurstone's theory of primary abilities, completed an extensive meta-analysis study on more than 460 studies. Using factory analysis Carroll identified a hierarchical organization of intelligence with a three-stratum model and described his three-stratum theory as

> …an expansion and extension of previous theories. It specifies what kind of individual differences in cognitive abilities exist and how those kinds of individual differences are related to one another. It proposes that there are a fairly large number of distinct differences in cognitive ability and that the relationships among them can be derived by classifying them into three different strata: stratum I, 'narrow' abilities: stratum II, 'broad' abilities: and stratum III, consisting of a single 'general' ability (Carroll, 2005, p. 69).

Carroll's three-stratum theory asserts most intelligence abilities can be classified and categorized into a one of three stratum – stratum I, stratum II, and stratum III, with stratum III being the highest. Stratum III consists of the general factor or 'g' which is consistent with Spearman's g factor. Stratum II includes "broad" factors is such as fluid intelligence, crystallized intelligence, general memory and learning, broad visual perception, broad auditory perception, broad retrieval ability, broad cognitive speediness, and processing speed. Stratum I includes fairly specific narrow abilities, more than 65. The factors were placed into stratum level in accordance to the perceived breadth or narrowness of each factor (Carroll, 2005).

Where previous theories of intelligence were used to explain existing intelligence assessment; the Gf-Gc was the first model used in developing a test. Richard Woodcock used the Gf-Gc theory as a model for the revision of the original Woodcock-Johnson

Psycho-Educational Battery (Keith & Reynolds, 2010). This was the first step in taking the intelligence theory into practice.

The Gf-Gc theory and three-stratum theory have much in common with the only major difference being the Three-stratum theory acknowledging a general factor. Other minor differences are the placements of a few of the factors, thus identifying them as slightly different but acknowledging their existence and relevance. Both theories provided a hierarchical structure, varying levels of breadth with several of the factors similarly defined (Pohlman, 2008). The merger of the two theories is not surprising and provided a well-defined structure of intelligence. This "integrated" Gf-Gc theory is the leading cognitive taxonomy theory used today in the educational setting and is known as the Cattell-Horn-Carroll (CHC) theory of cognitive abilities.

In the past two decades, there has been extensive research completed to examine standardized data from existing cognitive tests, identifying and supporting the CHC abilities (Kamphaus, Winsor, Rowe, & Kim, 2012; Keith & Reynolds, 2010; Flanagan et al., 2013; Schneider & McGrew, 2012). Keith and Reynolds (2010, p. 647) reported in their factor-analysis of seven different intelligence batteries, "CHC theory appears to be a valid foundation on which to build the current and next generation of intelligence tests." It has become the foundation that provides a working road map of the understanding of human cognition. It provides a means to organize research and practice. The CHC framework is "an open-ended empirical theory to which future tests of yet unmeasured or unknown abilities could possibly result in additional factors at one or more levels in

Carroll's hierarchy" (Jensen, 2004, p. 5). Over the last several decades and significant research, there have been refinements and extensions to the CHC theory (Keith & Reynolds, 2010). Currently, for the practitioner, the CHC theory is a guide and a reference to the current understanding of the cognitive process.

Current CHC and its Relation to a Profile of Strengths and Weaknesses

According to Flanagan et al. (2013), the current contemporary CHC theory has transitioned from a 10-factor model to a 16-factor model with over 80 narrow abilities. The previous 10 broad abilities being identified as: fluid reasoning (Gf), crystalized intelligence (Gc), quantitative knowledge (Gq), visual processing (Gv), auditory processing (Ga), short-term memory (Gsm), long-term storage and retrieval (Glr), processing speed (Gs), reaction and decision speed (Gt), reading and writing (Grw) and the six added broad areas are: psychomotor speed (Gsp), domain-specific knowledge (Gkn), olfactory abilities (Go), tactile abilities (Gh), kinesthetic abilities (Gk), and psychomotor abilities (Gp). Although the six newer broad abilities are part of an individual's complete intelligence, they have not been identified as contributing to academic performance, thus are not typically found in current intelligence tests (Flanagan et al., 2013). Major intelligence tests address 5-7 broad areas which are subdivided into narrow abilities, totaling approximately 35 to 40 narrow abilities. Flanagan et al. (2013), define the seven broad abilities (see Appendix C):

Fluid Reasoning (Gf). The deliberate but flexible control of attention to solve novel, on the spot problems that cannot be performed by relying exclusively on previously learned habits, schemas, and scripts

Crystalized Intelligence (Gc). The depth and breadth and of knowledge and skills that are valued by one's culture

Visual Processing (Gv). The ability to make use of stimulated mental imagery (often in conjunction with currently perceived images) to solve problems

Short-Term Memory (Gsm). The ability to encode, maintain, and manipulate information over periods of time measured in minutes, hours, days, and years

Long-Term Storage and Retrieval (Glr). The ability to store, consolidate, and retrieve information over periods of time measured in minutes, hours, days, and years

Processing Speed (Gs). The ability to perform simple, repetitive cognitive tasks quickly and fluently

Auditory Processing (Ga). The ability to detect and process meaningful nonverbal information in sound (p. 17)

These seven identified broad abilities provide a framework in which practitioners may rely on to improve the validity and interpretation of the cognitive assessment. Flanagan et al., (2013) reported research for more than a decade that supports the CHC theory as a valid method to use in test interpretation, in which cognitive abilities are linked to academic skills

It is currently the trend, which is backed by empirical research, to identify construct-relevant clusters/indexes that measure those areas of interest when identifying individuals with learning disabilities (Flanagan et al., 2013; Newton & McGrew, 2010). The relationship between specific cognitive abilities and specific academic skills (i.e., reading, writing, and math achievement) provides a predictable manner in which to identify plausible explanations as to specific academic performances. This methodology of examining a pattern of strengths and weaknesses in a cognitive profile is typically used in the identification of specific learning disabilities among students with poor academic performance. It is by identifying a linked cognitive deficit to an area of poor academic performance and eliminating exclusionary factors that a student is identified as having a learning disability.

This awareness of cognitive strengths and weaknesses can be employed for more than the identification of students with specific learning disabilities. By creating a profile on how a student thinks, processes, stores, retrieves, and analyzes information, the profile will provide working information to create a more individualized education plan (Fiorello & Primerano, 2005). In essence, the CHC theory provides the blueprint that helps identify an individual's cognitive processes profile or a pattern of strengths and weaknesses within their cognitive processing structure. The profile, in turn, provides information to be organized and interpreted as it relates to academic abilities and areas where interventions might be warranted (Farmer et al., 2014; Pohlman, 2008).

Although research supports the *g* or overall IQ score as a predictor of academic performance, it does not provide much information on areas of strength or weakness for an individual (Carroll, 1997; Farmer et al., 2014). Watkins stated in 2003, "…the speculation that the variability or profile of an individual's scaled score across the subtests of an intelligence test has meaning beyond that provided by IQ measures" (p.18). Wechsler supported the idea of an intelligence profile analysis when assisting in the development of the Army Alpha/Beta subtests and again when having two distinctive Verbal and Performance intelligence indexes; emphasizing analyzing people "in as many different modalities as possible" (Wasserman, 2012; Wechsler, Doppelt, & Lennon, 1975, p. 55). Carroll (2005; 2012) likewise expressed the need to portray the student in a profile rather than a single score. Understanding the whole intelligence (the *g*) can allow for meaningful interpretations of the parts (broad and narrow abilities identified in CHC theory).

Sattler (2008) explained that a cognitive profile analysis can provide information beyond the information provided by a full scale IQ score. Profiles can provide information in regard to relations between scaled scores and indexes as well as comparing scores to the norm group (interindividual comparison) or comparing scores within his or her unique profile (intraindividual comparison). Regardless of which profile analysis is used, the goal is to identify underlying abilities that emerge from the student's unique profile in order to identify possible strengths and weakness that will inform educators how to better develop educational strategies. Sattler (2008) identified the value in profile analysis but also cautioned in viewing the profile in isolation, rather expressing the use of background information to collaborate findings.

Brief History of D/HH IQ Assessment

> The handicap of deafness is such as to make a deaf person, particularly if uneducated, very different from a hearing individual. Deafness isolates him very much from the world in general, because he lacks the easy and quick method of communication between man and man afforded by speech. The deaf have, thus, always been looked upon as peculiar. (Pintner, 1923, p. 312)

One of the greatest challenges in assessing the intelligence of the D/HH has been the language barrier presented in the available forms of assessment. From as early as the 1900s, it was recognized that language factor was a barrier and would lead to the misrepresentation of D/HH intelligence. Pintner and Paterson (1915) completed a study, for theoretical purposes, using the Binet-Simon Scale to determine what use this scale would be with D/HH students. Results from this test indicated that on average the deaf child was four and a half years delayed (Pintner, 1923). Pintner and Paterson concluded the test presented a significant language barrier and thus could not be readily applied to the deaf. In the study, Pintner and Paterson described using written language, manual alphabet, sign language, and oral methods to work around the communication barrier, but responses were evident that the students did not understand what was being requested from them indicating they were unable to understand the English language. Pintner and Paterson wrote, the "…comprehension of our language is one of the greatest difficulties that the deaf child has to overcome…" (1915, p. 203). It was from this study that the recommendation for performance-based tests for D/HH emerged and the awareness of the current IQ tests were measuring language deprivation rather than the intelligence of D/HH individuals (Vernon, 2005).

Pintner (1917) continued to study the intelligence of D/HH individuals and in a well-publicized study that examined the immediate memory of D/HH individuals compared to their hearing peers; he, along with Paterson, reported that the median memory span of a D/HH child never reached that of a 7-year-old hearing child. The lack of auditory experience was the mental process in which they accredited the lower performance. It was explained that for hearing children it was primarily a twofold process: auditory images and inner tactual sensations; whereas for the D/HH it was a memorization and recall with only visual input. The conclusion was that auditory experience assisted in the visual memory.

Up to this point, most of the intelligence tests examined abstract thinking primarily through verbal input, thus requiring an understanding of the English language. Pintner reported that "general" intelligence was too vague and that non-verbal material could be used to measure a different aspect of intelligence. Pintner continued his interest in nonverbal intelligence measures with the development of the Pintner Non-language Test. At the time his test was developed, the Army Beta Test and Thorndike Group Test without Language were two other tests available that did not presuppose the individual could read or write the English language. Results from a study using the Pintner Non-

Language Test concluded that correlation between non-verbal and verbal test was poor but each test examined different aspects of intelligence, thus should not be ignored (Pintner, 1924). Additionally, when the language factor was eliminated the D/HH presented nearer to normal intelligence, although it was still much below that of their hearing peers, approximately 2 years. Pintner also reported, “As we broaden our concept of intelligence, we must broaden our criterion of intelligence” thus has been the pursuit of understanding not only intelligence as a whole but the underpinning of D/HH intelligence (Pintner, 1924, p. 483).

In a review of 50 comparative studies, Vernon (2005) reported the first study to identify D/HH students having average intelligence equal to their hearing peers, completed by Drever and Collins in 1928. Following Drever and Collin’s published results several other studies followed which supported their findings that the D/HH were almost equal in mental abilities (Myklebust, 1948; Peterson & Williams, 1930; Pintner & Lev, 1939).

Around the mid-20th century, Myklebust reviewed the works that had accumulated and concluded D/HH were not less intelligent but rather required less abstract and more concrete thinking (Moores, 2001). It was the idea that because one of the senses (audition) in the deaf functioned differently then their thinking would be different as well; it was a qualitative difference. Myklebust reported the D/HH were quantitatively equal to the hearing but qualitatively they were inferior (Moores, 2001). In essence, D/HH were able to think more concrete than previously recognized but they still were identified as being inferior when it came to abstract thinking. Myklebust reported that D/HH individuals learned and processed information differently than their hearing peers, thus their development would proceed on a different path. Marschark & Hauser (2008b) explained Myklebust's philosophy in his statement,

> …Myklebust presents what are some self-evident truths: That most deaf children will experience a more limited world than hearing children, that their interactions with the world will involve somewhat different rules and constraints, and that these differences will have a variety of significant implications for the psychological development of deaf children (p. 440-441).

The philosophy that D/HH needed concrete information to learn and that their intelligence was based on concrete information existed for an extended period of time; although it was an improvement over being thought of as significantly below hearing peers it was still limiting.

In the 1960s Rosenstein (1961), Furth (1964), and Vernon (2005) examined previous studies related to D/HH intelligence. Although each addressed their analysis of previous research slightly different they each arrived at the conclusion that the D/HH children function about the same as hearing children on performance tests.

Rosenstein (1961) examined several studies that assessed the perceptual and conceptual abilities and their relation to language development among D/HH children. Rosenstein reported that the primary issue that had led to inconsistent reported findings had to do with labeling or the definition of perceptual and conceptual tasks. When

Rosenstein reported on these language development studies, he found when the linguistic factors were within the D/HH students' language experience, there was no difference in conceptual performance.

Whereas Furth (1964) examined more than 35 studies that measured the performance of D/HH on nonverbal intelligent tests; however, his purpose was to better understand the impact of language on cognition. He reportedly found that language does not influence intellectual development but rather the lack of general experiences may have a profoundly negative impact. Furth (1964) stated, "A hearing child through language may simply have more opportunity to interact with or meet the environment. Language thus affords opportunity for more experience but is not considered a primary or necessary factor in developing intellective habits" (p. 161). In an earlier study by Furth (1961), he concluded that language was not a prerequisite for abstract thinking or generalization, although language did increased efficiency.

A short time later, Vernon (2005) examined approximately 50 comparative studies reporting, "…when there are no complicating multiple handicaps, the deaf and hard-of-hearing function at approximately the same IQ level on performance intelligence tests as do the hearing" (p. 229). His purpose was to address the misconception that deafness is associated with the lack of intelligence through a critical review of the current studies. In addition to reporting D/HH function approximately at the same level as their hearing peers on performance test, Vernon provided awareness to common errors such as test selection and administrating errors. His conclusion also supported Furth's notion that on performance tests, cognitive function may not depend on the level of language development (Vernon, 1972; Vernon, 2005).

At this point, there has developed a consensus that on performance tests the D/HH intelligence is no different than their hearing peers. However, due to documented poor performance in school and lack of expected progress, the understanding of D/HH intelligence has just begun (Marschark & Hauser, 2008b; Marschark & Knoors, 2012; Qi & Mitchell, 2011). As Hauser and Marschark (2008b) so eloquently stated:

> Hearing loss might 'deprive the organism of some of the material resources from which the mind develops,' but our inherent resilience ensures that we will take advantage of other resources. The result this is not a state of deficiency, but one of difference – a difference that has not yet received much attention in educational research and practice (p. 454).

CHC and D/HH

Although there has not been a study located specifically examining the profile of D/HH intelligence as it relates to the CHC abilities, there have been many studies that examined cognitive areas that correspond with the CHC defined abilities as related to language or some area of academic performance (Castellanos et al., 2015; Edwards et al., 2010; Marschark, Morris, Lukomski, Borgna, & Convertino, 2013). In reviewing current studies, an understanding of what might be expected when examining the D/HH cognitive profile can emerge. Many of the studies reviewed overlap and provide information in more than one area of cognition (Castellanos et al., 2015; Hamilton, 2011;

López-Crespo, Daza, & Mendez-López, 2012; Marschark, Sarchet, & Trani, 2016). For the purpose of this paper, only those areas to be addressed in this study will be reviewed: verbal comprehension (Gc); visual-spatial (Gv), fluid reasoning (Gf), working memory (Gsm), and processing speed (Gs).

The issue of language is one of the most difficult issues when examining cognition in D/HH populations; one must always be critical as to what the test is truly measuring – language or an area of cognition. Measures of verbal comprehension (Gc) and working memory (Gsm) have consistently indicated lower performance for the D/HH (Burkholder & Pisoni, 2003; Geers & Sedey, 2011). Verbal comprehension is the area where the breadth and depth of knowledge is measured and is typically received through auditory means since birth and enhanced by formal education and learning experiences (Flanagan et al., 2013). Although the D/HH do not have equal access to this auditory input, it is an area that should not be neglected, as Akamatsu et al. (2008) explained, "…it is critical to focus on verbal abilities, as they are central to gaining an understanding of how well any learner can use language to 'do school'" (p.134). And "…nonverbal IQ, even as the best estimate of *g*, does not say it all. Information is missing" (Akamatsu et al., 2008, p. 144).

Studies that have examined D/HH on one or more of the narrow abilities identified under G*c* (i.e., language development, lexical development, listening ability, communication ability, oral production and fluency, and grammatical sensitivity) have reported, that D/HH students perform below their hearing peers (Edwards et al., 2010;

Lederberg, Schick, & Spencer, 2012; Takahashi, Isaka, Yamamoto, & Nakamura, 2017). These findings are not surprising due to verbal knowledge being primarily acquired through auditory means and language development. In addition, D/HH students often have a hearing age below their actual age which reflects in their delayed language development.

A study by Edwards et al. (2010) examined the verbal and spatial analogical reasoning and the role of grammar and vocabulary in language. In a group of 69 participants (22 D/HH with CI, 25 D/HH with hearing aids, and 22 hearing students), comparison results indicated in terms of vocabulary and grammar, D/HH students performed lower than their hearing peers but no difference was reported when the D/HH population was compared internally – hearing aid users versus CI users. The verbal and spatial analogical reasoning portion of the study reported D/HH performed remarkably lower than their hearing peers on the verbal analogical reasoning. Examining just the D/HH performance, there was a difference in the verbal versus the spatial reasoning, which was not found in the hearing population. Poor performance on verbal tasks is not unexpected, especially when they are being compared to their hearing peers. In fact, on "simple items," the D/HH students performed similarly to their hearing peers but when the tasks became complex their performance fell dramatically. Interestingly, Edwards et al. (2010) found "…performance of the deaf children closely resembled that of younger hearing children…" (p. 196); which findings are supported by other studies (Moores, 2001; Takahashi et al., 2017). The conclusion of this study indicated that the weakness in verbal comprehension lies with insufficient knowledge, which results in the lack of understanding vocabulary and complex language structures.

Another study that addressed verbal reasoning skills compared hearing students to D/HH with CI or hearing aids. This study addressed grammar and vocabulary that reported language development predicted performance on tasks that required verbal analogical reasoning. The study examined verbal reasoning skill differences between D/HH with bilateral and unilateral cochlear implants (CI) and reported the bilateral CI individuals scored higher than those who were unilaterally implanted (Jacobs et al., 2016). This finding supports the long-standing hypothesis that an increased access to spoken language assists in the verbal comprehension development (Leigh, 2008; Marschark & Hauser, 2008a).

A study in Japan examined the differences between 207 deaf students and 425 hearing students related to vocabulary and grammar (Takahashi et al., 2017). Findings reported by Takahashi et al. supported previous findings; D/HH students develop grammatical knowledge in developmental sequential order as hearing students and that insufficient knowledge prevents understanding of language. In addition to supporting previous findings, Takahashi et al. provided an interesting perspective from an individual who experienced her hearing loss in her infancy. The D/HH "…feel weak in processing verbal information sequentially; they find it easier to retrieve the meanings of words than to process the relationships between words while reading" (Takahashi et al., 2017, p. 100).

Although information from the assessment of verbal comprehension of the D/HH student can provide informative information on the language development of the student, many of the test manuals provide a word of caution when assessing students that have limited language exposure or proficiency. In fact, most of the predominate tests used today are not normed with D/HH students. The WISC-V recently released a technical report in which it stated, “Given the heavy English demand, the Verbal Comprehension Index (VIC) and Full Scale IQ (FSIQ) composite scores are not to be considered valid scores with certain deaf and hard of hearing individuals…” (Day, Adam-Costa, & Raiford, 2015, p. 3)

The next area with significant research is D/HH Working Memory (G*sm*), which is the ability to hold information while at the same time using that information to complete a task. Because working memory has been tied to academic performance and learning and the D/HH often perform poorly in school, research has closely examined different aspects of the D/HH working memory (Dang, Braeken, Colom, Feerer, & Liu, 2014; Moores, 2001). Research on D/HH memory functions is widespread, but ultimately arrives at a consensus that D/HH perform below their hearing peers when verbal coding is required and about the same with visual-spatial memory when verbal coding is not measured (Marschark et al., 2016; Pisoni & Cleary, 2003).

Hamilton (2011) provided a review of the memory skills of the D/HH as it pertains to learning; he reviewed many studies using their findings to identify implications and applications for the D/HH population. Sequential memory was identified as an area with limitation for the D/HH. Their lack of strategies for processing sequential information may account for deficits in their working memory, as well as their language comprehension (Hamilton, 2011; Marschark & Wauters, 2008).

A recent study specifically addressed working memory in regard to hearing status and the use of sign language. Marschark et al. (2016) examined 85 D/HH college students and 67 hearing college students' memory through assessment of several complex memory tasks. Marschark et al. (2016) noted that at the time, no other study had examined or used participants that varied in sign language abilities or variance in amplification (CI users and nonusers). By categorizing the D/HH down into smaller participant groups, additional information was obtained. Results published indicated regardless of hearing thresholds or mode of communication, there did not appear to be an advantage or a rise in scores in either the verbal or visual-spatial memory tasks among the D/HH.

Marshall et al.'s (2015) investigation on non-verbal working memory concluded there is no difference in D/HH and hearing students but included the disclaimer that it depended on the task. Because this study identified the participants as hearing, native signers, and signers, they were able to more specifically identify factors of working memory related to the unique populations of the D/HH. Although the D/HH, in general, scored below their hearing peers, the native signers performed better than the non-native signers, suggesting the impacted language experience, not the deafness was the more relevant factor (Marshall et al., 2015).

Closely related to the working memory is processing speed, which is the ability to move information through the processing system and how efficient tasks are executed (Dehn, 2008). A review of recent studies produced no study that specifically examined processing speed without additionally linking the processing with some aspect of language and/or reading. These studies indicated that processing speed deficits have a negative impact on reading and writing acquisition.

Because D/HH often rely primarily on visual input for language/communication it is assumed their visual-spatial abilities must be above that of their hearing peers, often referring to D/HH as *visual learners* (Marschark & Hauser, 2012). However, the visual-spatial (Gv) area of cognition relies on more than just the visual component, but rather the ability to critically visually examine, identifying important elements and stimuli, and being able to take parts to create a whole. It is not a matter if the student takes in information visually but how they process visual information.

Marschark et al. (2017) examined the performance of D/HH students on visual-spatial tasks from two different instruments comparing the performance of D/HH that signed or used spoken language and hearing peers. Findings indicated that the D/HH have no advantage over hearing individuals in visual-spatial skills; in essence D/HH do not outperform the hearing on visual-spatial tasks, but rather they appeared to perform about the same as a whole and on some task the hearing outperformed the D/HH (Marschark et al., 2017). A comparable study earlier reported similar results with the addition to the performance outcomes appeared to be linked to the D/HH's proficiency in their preferred mode of communication; it did not appear to matter which mode of communication (Marschark et al., 2015). In essence, if the student was proficient in their preferred mode of communication then their visual-spatial performance tended to be better. Additionally, Marschark et al. (2015) stated D/HH individuals "…may utilize somewhat different cognitive abilities in dealing with the same (apparently) visual-spatial tasks" (p. 326).

A past study that specifically investigated if deafness enhanced visual-spatial cognition abilities found that deafness itself did not appear to cause an enhancement in visual-spatial tasks but added that early exposure to a sign language might be an important factor (Parasnis, Samar, Bettgerm, & Sathe, 1996). Parasnis et al. reasoned sign language at an early age would develop a linguistic structure to visual-spatial information. However, Marschark et al. (2015) concluded performance was not so much linked to sign language as it was to the individual proficiency in their preferred mode of communication.

Fluid reasoning (Gf), which is the ability to solve unfamiliar problems using induction, general sequential reasoning, and quantitative reasoning with flexibility without relying on previously learned information typically is measured through performance and is viewed as a more reliable source for estimating D/HH cognition (Akamatsu et al., 2008; Vernon, 2005). In a review of literature, the D/HH's fluid reasoning as an isolated dependent variable was not found. However, components of fluid reasoning were found in studies that examined some form of nonverbal intelligence or addressed some area of reasoning (Akamatsu et al., 2008; Edwards et al., 2010).

Bandurski and Galkowski (2004) investigated the development of analogical reasoning involving relations of opposite, part-whole, causality, class membership, and opposite with the purpose of better understanding the early influences of sign communication on conceptual and mental development. Studies were consistent with previous related findings, in that the performance was linked to language but no specific fluid reasoning study for D/HH students was found (Castellanos et al., 2015; Marschark et al., 2015). A technical report for the WISC-V reported no significant mean difference between D/HH and the control group on the Fluid Reason Index (Adam-Costa, Day, & Raiford, 2016).

Like fluid reasoning, research on the processing speed (Gs) of the D/HH in isolation was not found in current research, other than in factor invariance, reliance, and validity on different editions of the WISC. A factor invariance on the WISC-III indicated D/HH had deficits in their proceeding speed index scores (Maller & Ferron, 1997). A more recent study examining the reliability and validity of the WISC-IV among D/HH reported "because the split-half reliability method is not a proper estimate of reliability for speed task," no reliability was reported (Krouse & Braden, 2011, p. 242). However, the reported Processing Speed Index mean fell within the average range.

Wechsler Intelligence Scales for Children, Fifth Edition (WISC-V)

The WISC-V is the most recent revision on the Wechsler Intelligence Scale for Children, released in 2014. The WISC-V is a battery of tests used for children between the ages of 7 to 16 to measure cognitive abilities that have incorporated "new research on intelligence, cognitive development, neurodevelopment, cognitive neuroscience, and processes important to learning" (Wechsler, 2014, p. 6). The WISC-V provides four scales (Full Scale, Primary Index Scales, Ancillary Index Scales, and Complementary Index Scales) for varying interpreting purposes (Wechsler, 2014) (see Appendix D for Test Framework and Appendix E for Primary Index Scales correlation to CHC broad and narrow abilities).

The Full Scale IQ (FSIQ) identifies a general intelligence *g*. The FSIQ is obtained from a composite score from seven of the primary subtests, the first seven in the battery (Block Design [BD], Similarities [SI], Matrix Reasoning [MR], Digit Span [DS], Coding [CD], Vocabulary [VO], and Figure Weights [FW]). There are three additional primary subtests (Visual Puzzles [VP], Picture Span [PS], and Symbol Search [SS]) used to complete the five primary index scores which are the broad abilities (verbal comprehension [VC], visual spatial [VS], fluid reasoning [FR], working memory [WM], and processing speed [PS]). These additional primary subtests can be used to provide substitutions for the FSIQ only and/or provided needed data for the Ancillary Index Scores (quantitative reasoning, auditory working memory, nonverbal, general ability, and cognitive proficiency). This revision of the WISC also includes several expanded composite scores which can be used for different interpreting purposes which the FISQ "cannot or should not be derived" (Wechsler, 2014, p. 15) (see Appendix E for Subtest, Abbreviations, Score Types, and Categories).

The Primary Index Scales includes Verbal Comprehension Index (VCI), Visual-Spatial Index (VSI), Fluid Reasoning Index (FRI), Working Memory Index (WMI), and

Processing Speed Index (SPI). The instructional manual for the WISC-V provides the following information for the five indexes and subtests which are measures of narrow abilities (Wechsler, 2014, p.7-12 & 157-159) (see Appendix F)

1. Verbal Comprehension Index (VCI) measures the student's ability to access and apply acquired word knowledge (requires verbal concept formation, reasoning, and expression).

   Similarities – measures verbal concept formation and abstract reasoning and additionally involves crystalized intelligence, word knowledge, cognitive flexibility, auditory comprehension, long-term memory, associative and categorical thinking, distinction between nonessential and essential features, and verbal expression.

   Vocabulary – measures word knowledge and verbal concept formation and additionally involves crystalized intelligence, fund of knowledge, learning ability, verbal expression, long-term memory, and degree of vocabulary development.

2. Visual-Spatial Index (VSI) measures the student's ability to evaluate visual details and to understand spatial relationships to construct geometric designs from a model (requires visual-spatial reasoning, integration and synthesis of part-whole relationships, attentiveness to visual detail, and visual motor integration).

Block Design – measures the ability to analyze and synthesize abstract visual stimuli and additionally involves nonverbal concepts formation and reasoning, broad visual intelligence, visual perception and organization, simultaneous processing, visual-motor coordination, learning, and the ability to separate figure-ground in visual stimuli.

Visual Puzzles – measures mental, non-motor construction ability, which requires visual and spatial reasoning, mental rotation, visual working memory, understanding part-whole relationships, and the ability to analyze and synthesize abstract visual stimuli.

3. Fluid Reasoning Index (FRI) measures the student's ability to detect the underlying conceptual relationship among visual objects and use reasoning to identify and apply rules (requires inductive and quantitative reasoning, broad visual intelligence, simultaneous processing, and abstract thinking).

   Matrix Reasoning – measures the fluid intelligence, broad visual intelligence, classification and spatial ability, knowledge of part-whole relationships, and simultaneous processing and additionally involves attention to visual detail and working memory.

   Figure Weights – measures quantitative fluid reasoning and induction and additionally involves some working memory.

4. Working Memory Index (WMI) measures the student's ability to register, maintain, and manipulate visual and auditory information in conscious

awareness (requires attention, auditory and visual discrimination, and concentration).

Digit Span- measures working memory and mental manipulation and additionally involves increasing cognitive complexity demands.

Picture Span – measures visual working memory and working memory capacity and additionally involves attention, visual processing, visual immediate memory, and response inhibition.

5. Processing Speed Index (PSI) measures a student's speed and accuracy of visual identification, decision making, and decision implementation (requires visual scanning, visual discrimination, short-term visual memory, visual motor coordination, and concentration).

   Coding – measures processing speed and additionally involves short-term visual memory, procedural and incidental learning ability, psychomotor-speed, visual perception, visual-motor coordination, visual scanning ability, cognitive flexibility, attention, concentration, and motivation.

   Symbol Search – measures visual-perceptual and decision speed and additionally involves short-term visual memory, visual-motor coordination, inhibitory control, visual discrimination, psychomotor speed, sustained attention, and concentration.

These indexes correlate with the CHC abilities and provide a comprehensive description and evaluation of intellectual abilities (see Table 3 for Primary Index Scales correlation to CHC broad and narrow abilities).

The Nonverbal Index (NVI) is an ancillary scale which provides additional information about the student's cognitive abilities and processes using a combination of language reduced subtests. The NVI is obtained from six primary subtests that do not require expressive responses (Block Design [BD], Visual Puzzles [VP], Matrix Reasoning [MR], Figure Weights [FW], Picture Span [PS]. And Coding [CD]. The NVI utilizes subtests from more than one cognitive domain and thus provides a more generalized overall ability than individual index scores such as VSI and FRI. The NVI "provides a useful estimate of overall ability for children who are deaf or hard of hearing…" (Wechsler, 2014, p. 34). It is important to note that this nonverbal index means expressive responses were eliminated and the language demands were reduced but not eliminated.

The WISC-V provides standard scores based on a mean of a 100 and a standard deviation of 15, thus 85 and 115 are respectively 1 SD from the mean. The scaled scores are based on a mean of 10 and a standard deviation of 3, thus 7 and 13 are 1 standard deviation from the mean. Also, qualitative descriptors, age equivalents, pairwise differences, and statistical differences in scores are provided. An individual's intra-individual strengths and weaknesses can be examined by using an estimate of overall ability across different primary indexes. Furthermore, a profile can be constructed from the student's score patterns on the composite scores and/or primary subtests. This profile can then be used to describe the student's strengths and weaknesses allowing for more meaningful information to assist in developing an individualized education plan.

Although the WISC-V provides rich, descriptive information on a student's intellectual process, the WISC-V Technical and Interpretative Manual cautions several times to not use the intellectual scores alone but as a guide with additional data collected by the examiner. The manual's introduction states: "The task of assessing an individual's intelligence involves more than simply obtaining his or her score on measures of intelligence" (Wechsler, 2014, p. 8). And later in the Interpretive Considerations chapter, it states:

> Results from the WISC-V provide important information regarding a child's cognitive abilities, but they should never be interpreted in isolation. Item responses and scores provide qualitative and quantitative information …A pattern of test scores may be helpful to evaluate cognitive strengths and weaknesses…the practitioner should evaluate results within the context of the referral question or purpose of the evaluation (Wechsler, 2014, p. 149).

And again, in the summary of the final chapter of the WISC-V test manual, it states, test scores are but one source that a professional examiner "uses to develop a well-integrated and comprehensive psychological portrait of the student examined" (Wechsler, 2014, p. 186).

WISC-V with the D/HH Populations

In 2015, Day et al. published a technical report that examined the testing of D/HH students and the WISC-V. This technical report provided considerations for administration, communication, and interpretations of the WISC-V among D/HH. They caution that an understanding of modification of standardize testing procedures may compromise reliability and validity. Additionally, it is important the examiner has an understanding and takes into consideration the onset of hearing loss, modes of communication, early language access, degree of hearing loss, use of technology, and co-morbid conditions.

The technical report additionally provides appropriateness ratings and modification considerations for children who are D/HH for each subtest as it relates to the given mode of communication. The subtests for the Nonverbal Index (Block Design [BD], Visual Puzzles [VP], Matrix Reasoning [MR], Figure Weights [FW], Coding [CD], and Symbol Search [SS]) all can be administered with little to no modifications; however, BD, VP, FW, CD, and SS are timed and may affect performance and interpretation. The additional primary subtests necessary for FSIQ (Similarities [SI], Vocabulary [VC], and Digit Span [DS]) can be administrated orally with caveats to pronunciation/auditory detection demands on the student; and with notation the DS "modification by modality may alter the task demand or introduce construct irrelevant variance" (Day et al., 2015, p. 7). When signing the SI and VC subtests the modality modification alters the demands, thus making administration problematic and interpretation may be difficult (i.e., Signs often relate to the meaning of the word, thus instead of signing a word it might require the examiner to fingerspell the word, thus the tests firsts measures if the student can read the fingerspelled word). When signing DS, the modality modification alters the task demand and thus makes it difficult to interpret. See Appendix G for identification of appropriateness ratings and modification considerations by mode of communication.

A later report from Adam-Costa, Day, and Raiford (2016) provided information from a group study of D/HH students who use oral language as their mode of communication and have some type of amplification on the WISC-V. Results reported as only the Working Memory Index was significantly different from the hearing group. The FSIQ and the Nonverbal Index for the control group were slightly higher than the mean. On subtests that will be used in this study, only one was identified as significantly lower for D/HH (Digit Span). Adam-Costa et al. (2016) concluded their study by reiterating their findings are consistent with previous findings across index scores, which it is not by coincidence.

Summary

The study of intelligence has fascinated philosophers and psychologists for centuries. Extensive studies and research have allowed for cognitive theories to unfold and evolve. This in-depth understanding has allowed for better planning by educators to address cognitive weaknesses that impact academic performances. It is by addressing an individual's cognitive weaknesses and using their cognitive strengths to promote learning that has set the bar for identifying and addressing academic learning difficulties.

However, not all populations have a completed roadmap of cognitive understanding, thus do not benefit from such a philosophy.

The D/HH population is one such population that has been addressed for centuries but the many dependent variables that play an active role in their learning have been much more difficult to separate. The understanding of the underpinnings of the D/HH cognition is still being revealed with the depth and breadth of the complexity still unraveling. Because of the lack of auditory input many have addressed verbal development or the impact of auditory input. The lack of auditory input impacts some aspects of intelligence, but to stop there or to assume their intelligence is less, is selling the D/HH population short. Yet, studies on a complete cognitive profile of the D/HH exist only in pieces. Although the D/HH population is far from homogeneous, an understanding of expected cognitive ability ranges would allow identifying strengths and weaknesses, especially when abilities fall outside the expected range. In essence, understanding expected cognitive functioning of D/HH population will allow for better educational planning.

CHAPTER III

METHODOLOGY

Overview

The purpose of this study was to identify if a cognitive profile of D/HH students existed on the Wechsler Intelligence Scale for Children-Fifth Edition (WISC-V) using cognitive abilities as explained by the CHC theory and if that profile differed from their hearing peers. Although the CHC theory is typically used when identifying specific learning disabilities, it was used in this study to identify a cognitive profile of students who are D/HH. This study also further examined if a profile differed among the D/HH when taking into account degree of hearing loss (mild, moderate, severe, or profound), type of amplification used (no amplification, hearing aid(s), or cochlear implant(s)), and the mode of communication used by the individual (sign language or total communication). Students who met state eligibility criteria for an auditory impairment (deaf or hard of hearing) and were enrolled in the Regional Day School Program for the Deaf were considered for this study. This chapter addresses participants, the type and process of data collection, and the data analysis used for this study.

Participants

The study began with 62 participants; however, 6 were eliminated due to being identified as having an additional disability and 12 were eliminated due to not having been administered the WISC-V. This study identified 43 qualifying participants (25 males/18 females) between the ages 6 and 11 years of age and between first through fifth grades from a large (53,000+ students) school district in Texas that has a Regional Day School Program for the Deaf (RDSPD). All the participants had been identified as students with an auditory impairment as defined in the Texas Administrative Code. The required documents for and AI identification included an ontological report from a medical physician, an audiological report from an audiologist, and a communication report from a speech and language pathologist.

This study required that other than speech impairment, the student does not have any additional identified disabilities. Additional criteria for this study required the student had to have been administered the WISC-V between 2014 and early 2017 with either a FSIQ or Nonverbal (NVI) standard score reported. Students who utilized oral language as their primary mode of communication were given all 10 subtests and the FSIQ and NVI were reported. Students who use total communication (oral language with accompanying sign language) as their primary mode of communication were administered the five subtests required for a NVI standard score.

The sample collected is a sample of convenience including all students from the RDSPD in the large school district that met the established criteria. Because these students attended a RDSPD some factors that can lead to variability in outcomes were better controlled such as: students had regular hearing monitored by an audiologist as recommended in the Audiological Evaluation – Part B of the Full and Individual

Evaluation, received speech and language therapy as recommended in the Communication report – Part C of the Full and Individual Evaluation, are provided specialized supports and services by certified teachers of the deaf, classroom amplification (for those with implication devices), and smaller class sizes.

Instrumentation

The WISC-IV was developed to be used for the assessment of intellectual functioning using a FSIQ standard score and/or NVI standard score.

The FSIQ requires the following subtests: Block Design, Similarities, Matrix Reasoning, Digit Span, Coding, Vocabulary, and Figure Weights. Using the subtests required for the FSIQ, the cognitive skills of Verbal Comprehension and Fluid Reasoning were reported. The administration of three additional subtests (Visual Puzzles, Picture Span, and Symbol Search) the cognitive skills of visual-spatial, working memory, and processing speed were reported.

The NVI required the following subtests: Block Design, Matrix Reasoning, Coding, Figure Weights, and Picture Span. Using the subtests required for the NVI, the cognitive skills of Visual Spatial and Fluid Reasoning were reported. The administration of one subtest (Symbol Search) the cognitive skills of processing speed was reported as well.

Tests were administered in the students' primary mode of communication by the same examiner. Sign Language was used for test administration for those students using total communication. The additional accommodation of an FM system was used when dictated by the student's Individualized Education Program (IEP) at the time of the assessment.

Data Collection

A proposal to conduct the study was submitted to the school district's Executive Director of Special Education, the Coordinator of the Regional Day School Program for the Deaf, and the school district's Research Review Committee (RRC) which is housed in the Department of Assessment & Accountability. Additionally, a one on one meeting with the Executive Director of Special Education was completed. When approval was received from the district, Texas Woman's Institutional Review Board and dissertation committee, data collection was initiated. The research approval letter is on file with the IRB office at Texas Woman's University (see Appendix H).

The Deaf Education Coordinator for the RDSPD selected a professional educator to access the student information of the participants that met the required criteria and compile the requested information. The required criteria included: gender, grade level, age when tests were administered, mode of communication, type of hearing amplification used, and degree of hearing loss, specific index scores, and subtests scaled scores from the WISC-V.

The selected professional recorded requested information on a data collection sheet. No identifying information was collected. Identifying information included but was not limited to the student's name, student school identification number, address, parent's name, name of school, and teacher's name. Each participant was assigned a sequential identification number. All data collected was placed in a large envelope and delivered to the deaf education coordinator of that RDSPD. The coordinator reviewed the documents collected to ensure no identifying information was recorded. The coordinator then notified the researcher that the information had been collected and available for the researcher.

Data was collected from each identified student's Full Individual Evaluation (FIE) which is electronically stored on a campus-wide electronic system. If by chance the FIE was not properly uploaded to the storage system then data was collected from the hard copy which is located on the Regional Day School campus. The FIE included the written report as well as the otological, audiological, and communication reports. Individual reports were accessed using a secure, password protected, electronic program.

The data collection document was designed to record all areas of interest in this study (see Appendix I). Data was collected and stored electronically. The student information consisted of gender, age when tests were administered, grade, type of hearing loss (mild, moderate, severe, profound), type of amplification (no amplification, hearing aid(s), cochlear implant(s)), and mode of communication (sign language, total communication). Cognitive test scores from the WISC-V included the standard scores of the five primary composite scales (Verbal Comprehension Index, Visual Spatial Index, Fluid Reasoning Index, Working Memory Index, and Processing Speed Index), the subtests scaled scores which comprised these indexes, the FSIQ scale, and the NVI scale. Data was not available in all areas for all student as far as the assessment scores are concerned. Students that are identified with a hearing loss and use sign language as their primary mode of communication are not typically administered all subtests, all available data were collected.

Data

The researcher used the participant's age and grade level when tested, both of which are reported in the FIE. Independent variables consisted of:

- Verbal Comprehension (Gc)
- Visual-Spatial (Gv)
- Fluid Reasoning (Gf)
- Working Memory (Gsm)
- Processing Speed (Gs)
- Full Scale IQ (FISQ)
- Nonverbal Index (NVI)

Dependent variables for this study included:

- Degree of hearing loss (mild, moderate, severe, profound)
- Type of amplification (no amplification, hearing aid(s), cochlear implant(s))
- Mode of communication (sign language, total communication)

Research Design (Analysis of Data)

An ex-post facto/correlational design using convenience sampling was used as the method of statistical analysis. A correlation study examines how a set of variables relate without implying cause and effect. To determine the relationship between the five 'g' factors a Canonical correlation analysis was used to explore the relationship between the variables. The 'g' factors were the dependent variables. The independent variables in this study were the diagnosed auditory impairment or degree of hearing loss (mild, moderate, severe, profound), type of amplification (no amplification, hearing aid(s), or cochlear implant(s)), and mode of communication (total communication or oral). Because this study had two types of variables, between-subject variables and within subject variables, a mixed ANOVA was used to provide an analysis of the mean differences among and between the several means. The *p*-value was set at the .05 level.

Research Question 1: Is there a profile difference, as identified by index scores, among D/HH students compared with the WISC-V norms? Research Question 1 was analyzed through the descriptive statistics, means, and standard deviations, and using independent variables. A Pearson correlation was completed to determine if standard/scaled scores from the D/HH student performance correlated with the standard/scaled scores reported by the WISC-V norms. The strength of the correlation and the significance was at either the $p < .01$ or $p < .05$ level.

Research Question 2: Is there a cognitive profile, CHC subtest patterns and/or index standard scores, difference among D/HH students as it relates to their degree of hearing loss (mild, moderate, severe, profound)? Research Question 2 was analyzed through descriptive statistics, means, and standard deviations, and using independent variables. Canonical correlation analysis was completed to explore the relationship between the latent variables and direct variables; the mixed ANOVA to observe differences between the independent variables.

Research Question 3: Is there a difference in the cognitive profile, CHC subtest patterns and/or index standard scores, of D/HH students who have a cochlear implant(s), hearing aids, or no amplification? Research Question 3 was analyzed through descriptive statistics, means, and standard deviations, and using independent variables. Canonical correlation analysis was completed to explore the relationship between the latent variables and direct variables; the mixed ANOVA to observe differences between the independent variables.

Research Question 4: Is there cognitive profile, CHC subtest patterns and/or index standard scores, difference among D/HH student whose primary mode of communication is sign language versus oral language? Research Question 4 was analyzed through descriptive statistics, means, and standard deviations, and using independent variables. Canonical correlation analysis was completed to explore the relationship between the latent variables and direct variables; the mixed ANOVA to observe differences between the independent variables.

CHAPTER IV

RESULTS

The purpose of this study was to determine if a cognitive profile existed, according to the index scores of the WISC-V, that differed from the reported norms among first through fifth grade D/HH students. The profile was to be identified by the CHC theory based patterns using the index and subtest scores. The research also identified if any independent known variable (i.e., type of amplification, degree of hearing loss, mode of communication) provided a difference in the cognitive profile.

Descriptive Analysis

A total of 49 students were included in the analysis, but 6 did not meet criteria, resulting in a total of 43 participants. A little over half of the students were male (51.0%) (see Table 4.1). The age of the students was between 6 and 11 years of age, with the largest group (49%) being 8 years of age (see Table 4.2). Other age groups included 10 and 11 years of age having 12.2 % each, 6 years of age having 6.1%, and the 7 and 9 years of age having 4.1 % each. The students were between 1st and 5th grade (see Table 4.3). The largest group were the 3rd grades at 40.8% followed by 5th grade with 18.4% and 2nd grade with 16.3%. Both the 1st and 4th grades had 6.1%. Grade identification was not available for six participants.

Table 4.1

Frequency and Percentage of Gender

	Female	Male	Missing Data	Total
N	18	25	6	49
Percent	36.7	51.0	12.2	100.0

Table 4.2

Frequency and Percentage of Age

Age	N	Percent
6	3	6.1
7	2	4.1
8	24	49.0
9	2	4.1
10	6	12.2
11	6	12.2
Missing Data	6	12.2
Total	49	100.0

Table 4.3

Frequency and Percentage of Grade

Grade	N	Percent
1	3	6.1
2	8	16.3
3	20	40.8
4	3	6.1
5	9	18.4
Missing Data	6	12.2
Total	49	100.0

The type of hearing loss was identified as conductive, neural, neuropathy, and sensorineural and obtained from the ontological reported provided by a medical physician (see Table 4.4). Eight ontological reports did not provide this information (16.3%). A sensorineural hearing loss occurred the most frequently at 75.5%. The other three categories were relatively small: conductive at 4.1%, neural and neuropathy both at 2.0% of the participants.

Table 4.4

Frequency and Percentage of Type of Hearing Loss

Type of Hearing Loss	N	Percent
conductive	2	4.1
neural	1	2.0
neuropathy	1	2.0
sensorineural	37	75.5
Missing Data	8	16.3
Total	49	100.0

The degree of hearing loss (mild, moderate, severe, profound) was identified according to the student's ontological or audiological report. As reported in Table 4.5, students' hearing loss descriptions included more than mild, moderate, severe, and profound. One participant (2.0%) that was included in the study did not have the degree of hearing loss provided but was identified as having neuropathy. The largest identified group were those with a profound hearing loss at 34.7%. Students' with a moderate-severe or severe-profound hearing loss were each represented by 18.4%. Additionally, the two categories, moderate-profound and severe hearing loss each were represented by

4.1%. The remaining groups (mild, mild-profound, moderate, and neuropathy) each were compile of 2.0% of the participants.

Table 4.5

Frequency and Percentage of Degree of Hearing Loss

Degree of Hearing Loss	N	Percent
Mild	1	2.0
Mild-Profound	1	2.0
Moderate	1	2.0
Moderate-Profound	2	4.1
Moderate-Severe	9	18.4
Profound	17	34.7
Severe	2	4.1
Severe-Profound	9	18.4
Missing Data	7	14.3
Total	49	100.0

Amplification was identified through the audiological reports and was separated into three categories: implanted, hearing aids, no amplification. The greatest percent of participants were implanted (46.9%) whereas 32.7% used hearing aids, and 4.1% used no amplification at all (see Table 4.6).

Table 4.6

Frequency and Percentage of Type of Amplification

Type of Amplification	N	Percent
Mixed	2	4.1
Implant	23	46.9

(continued)

Table 4.6

Frequency and Percentage of Type of Amplification (continue)

Type of Amplification	N	Percent
Hearing aid	16	32.7
None	2	4.1
Missing data	6	12.2
Total	49	100.0

Mode of communication was identified as total communication or oral language. Total communication consisted of a manual sign language parallel to verbal language. Of the participants meeting criteria, 34% used total communication for their mode of communication and 26% used oral communication alone (see Table 4.7).

Table 4.7

Frequency of Percentage and Mode of Communication

Mode of Communication	N	Percent
Total Communication	17	34.7
Oral	26	53.1
Missing Data	6	12.2
Total	49	100.0

When analyzing the D/HH participants, without any identifying dependent variables, their scores were within the average range as established by WISC-V except, for Gs (M = 97.07, SD = 15.525), Gsm (M = 97.07, SD = 15.525), and Vocabulary (M = 5.56, SD = 2.642). However, the FSIQ (M = 90.15, SD = 12.678) and NVI (M = 95.59, SD = 13.766) remained within the average range (see Table 4.8), with nonverbal being higher. Gsm was within the low average range and Gc and Vocabulary were within the below average range.

Table 4.8

Total Mean and Standard Deviation for Full Scale, Indexes, and Subtests

	N	Mean	SD
FSIQ	34	90.15	12.678
Nonverbal	41	95.59	13.766
Gc	34	81.68	13.395
Gv	43	97.56	13.607
Gf	43	99.33	13.300
Gsm	34	87.50	13.979
Gs	43	97.07	15.525
Similarities	34	7.71	2.866
Vocabulary	34	5.56	2.642
Block Design	43	9.21	2.642
Visual Puzzles	43	9.86	2.892
Matrix Reasoning	43	9.93	3.003
Figure Weights	43	9.86	2.019
Digit Span	34	7.29	2.747
Picture Span	43	7.98	3.059
Coding	43	9.42	3.065
Symbol Search	43	9.70	3.481

Primary Analysis

The dependent variables were submitted to univariate and multivariate analysis of variance for differences due to the independent variables type of amplification, degree of hearing loss, and mode of communication. Findings were as follows for each independent variable.

Research Question One – Profile

A profile analysis was conducted in order to compare the D/HH participants to the WISC-V reported norms. In this study, the comparisons analyzed Full Scale, Indexes, and Subtests scores to the WISC-V norm standard score of 100 with a standard deviation of 15 and a norm scaled score of 10 with a standard deviation of 3. There were 34 participants contributing to the FISQ, Gc, and Gsm scores, 41 participants contributing to the Nonverbal Index, and 43 participants contributing to the Gf, Gv, and Gs. On the Full Scales and Indexes the FSIQ (M = 90.15, SD = 12.678), NVI (M = 95.59, SD = 13.766), Gc (M = 81.68, SD = 13.395), and Gsm (M = 87.50, SD = 13.979) were identified as having a significant difference from the WISC-V norm of 100. Only the Gc was more than one standard deviation below the mean of 100 (see Tables 4.9 and 4.10).

The subtests, Similarities, Vocabulary, and Digit Span had 34 participants. On the subtests Block Design, Visual-Spatial, Matrix Reasoning, Figure Weights, Coding, and Symbol Search there were 43 participants. The subtests, Similarities (M = 7.71, SD = 2.866), Vocabulary (M = 5.56, SD = 2.642), Digit Span (M = 7.29, SD = 2.747), and Picture Span (M = 7.98, SD = 3.059) had a significant difference from the WISC-V norm of 10. Block Design (M = 9.21, SD = 2.642) was identified as approaching significance (see Table 4.11).

The pattern of the mean index scores for the D/HH participants, from highest to lowest was: Gf > Gv > Gs > Gsm > Gc with the Gsm in the low average range and Gc in the below average range. The subtest, from highest to lowest was: Similarities > Matrix

Reasoning > Visual-Spatial and Figure Weights >Symbol Search > Coding > Block Design > Picture Span > Digit Span > Vocabulary with Picture Span and Digit Span being within the low average range and Vocabulary being below average. Overall the FSIQ and NVI were both found to be in the average range with the Nonverbal IQ being higher.

Table 4.9

Mean and Standard Deviation of Full Scale and Indexes

	N	Mean	*SD*
FSIQ	34	90.15	12.678
Nonverbal	41	95.59	13.766
Gc	34	81.68	13.395
Gv	43	97.56	13.607
Gf	43	99.33	13.300
Gsm	34	87.50	13.979
Gs	43	97.07	15.525

Table 4.10

One-Sample Test of Significant Differences in Full Scale and Indexes

	t	df	Sig. (2-tailed)
FSIQ	-4.532	33	.001
Nonverbal	-2.053	40	.047
Gc	-7.976	33	.001
Gv	-1.177	42	.246
Gf	-.333	42	.741
Gsm	-5.214	33	.001
Gs	-1.238	42	.223

Note. Test Value = 100

Table 4.11

Mean and Standard Deviation of Subtests

	N	Mean	*SD*
Similarities	34	7.71	2.866
Vocabulary	34	5.56	2.642
Block Design	43	9.21	2.642
Visual Puzzles	43	9.86	2.892
Matrix Reasoning	43	9.93	3.003
Figure Weights	43	9.86	2.019
Digit Span	34	7.29	2.747
Picture Span	43	7.98	3.059
Coding	43	9.42	3.065
Symbol Search	43	9.70	3.481

Table 4.12

One-Sample Test of Significant Differences in Subtests

	t	df	Sig. (2-tailed)
Similarities	-4.667	33	.000
Vocabulary	-9.801	33	.001
Block Design	-1.963	42	.056
Visual Puzzles	-.316	42	.753
Matrix Reasoning	-.152	42	.880
Figure Weights	-0.453	42	.653
Digit Span	-5.743	33	.001
Picture Span	-4.337	42	.001
Coding	-1.244	42	.220
Symbol Search	-0.569	42	.572

Note. Test Value = 10

Research Question Two – Degree of Loss

The second research question examined the impact the degree of hearing loss had on the D/HH profile. Overall differences were found to be significant, and four variables were separately significant (see Table 4.13). Groups differed as follows (see Table 4.14): nonverbal showed moderate-severe (*M* = 101.00, *SD* = 9.055) and profound (*M* = 103.17, *SD* = 10.205) to be higher than the other groups; Gs (*M* = 73.00, *SD* = 5.657), coding (*M* = 6.50, *SD* = 2.121), and symbol search (*M* = 4.00, *SD* = .000) identified severe to be lower than the other groups.

The attention for the post-hoc inspection was restricted to groups with more than one participant. Groups with one participant include mild, mild-profound, moderate, and moderate-profound.

Other than Gc (Verbal Comprehension Index and Similarities subtest) participants with moderate-severe and profound hearing losses had average mean scores on all indexes and subtests. The participants with severe hearing losses has lower mean scores in all areas when compared to the hearing losses that were measured.

Table 4.13

Multivariate and Univariate Analysis of Variance for Degree of Hearing Loss

		Multivariate Tests[a]				
		Value	F	Hypothesis df	Error df	Sig.
Loss	Pillai's Trace	4.372	1.272	119.000	91.000	.114
	Wilks' Lambda	.000	3.532	119.000	55.604	.000
	Hotelling's Trace	1358.908	60.360	119.000	37.000	.000
	Roy's Largest Root	1334.812	1020.738[b]	17.000	13.000	.000
Loss	FSIQ	1594.634	7	227.805	2.119	.082
	Nonverbal	1761.387	7	251.627	2.649	.037
	Gc	1267.555	7	181.079	1.068	.414
	Gv	1314.176	7	187.739	1.248	.318

(continued)

Table 4.13

Multivariate and Univariate Analysis of Variance for Degree of Hearing Loss (continued)

	Multivariate Tests[a]					
	Value	F	Hypothesis df	Error df	Sig.	Value
Loss	Gf	979.329	7	139.904	.981	.469
	Gsm	674.132	7	96.305	.493	.830
	Gs	3625.096	7	517.871	4.664	.002
	Similarities	49.061	7	7.009	.800	.595
	Vocabulary	32.570	7	4.653	.664	.700
	Block Design	39.963	7	5.709	.940	.496
	Visual Puzzles	44.510	7	6.359	.921	.509
	Matrix Reasoning	46.313	7	6.616	.812	.587
	Figure Weights	25.770	7	3.681	1.062	.418
	Digit Span	46.874	7	6.696	1.167	.359
	Picture Span	24.441	7	3.492	.351	.921
	Coding	150.073	7	21.439	4.661	.002
	Symbol Search	164.657	7	23.522	3.160	.017

Table 4.64

Mean and Standard Deviation for Full Scale, Indexes, and Subtest by Degree of Hearing

	Degree of Hearing Loss	Mean	*SD*	N
FSIQ	Mild	64.00	.	1
	Mild-Profound	77.00	.	1
	Moderate	103.00	.	1
	Moderate-Profound	89.00	.	1
	Moderate-Severe	94.00	7.958	7
	Profound	91.50	12.486	12
	Severe	75.50	2.121	2
	Severe-Profound	91.83	8.635	6
	Total	90.03	11.643	31
Nonverbal	Mild	71.00	.	1

(continued)

Table 4.74

Mean and Standard Deviation for Full Scale, Indexes, and Subtest by Degree of Hearing (continued)

	Degree of Hearing Loss	Mean	*SD*	N
Nonverbal	Mild-Profound	90.00	.	1
	Moderate	111.00	.	1
	Moderate-Profound	97.00	.	1
	Moderate-Severe	101.00	9.055	7
	Profound	103.17	10.205	12
	Severe	83.00	9.899	2
	Severe-Profound	99.67	9.480	6
	Total	99.29	11.469	31
Gc	Mild	68.00	.	1
	Mild-Profound	68.00	.	1
	Moderate	100.00	.	1
	Moderate-Profound	68.00	.	1
	Moderate-Severe	83.71	5.057	7
	Profound	79.83	16.623	12
	Severe	73.00	4.243	2
	Severe-Profound	86.83	11.720	6
	Total	81.13	13.122	31
Gv	Mild	81.00	.	1
	Mild-Profound	97.00	.	1
	Moderate	118.00	.	1
	Moderate-Profound	92.00	.	1
	Moderate-Severe	104.71		
	Profound	102.421	.7111.856	7
	Severe	87.00	25.456	2
	Severe-Profound	99.17	15.497	6
	Total	100.61	12.614	31
Gf	Mild	79.00	-	1
	Mild-Profound	94.00	-	1
	Moderate	107.00	-	1
	Moderate-Profound	106.00	-	1
	Moderate-Severe	105.57	8.904	7
	Profound	102.83	14.295	12
	Severe	91.00	4.243	2
	Severe-Profound	103.00	10.392	6
	Total	101.90	11.917	31
Gsm	Mild	76.00	-	1
	Mild-Profound	76.00	-	1

(continued)

Table 4.84

Mean and Standard Deviation for Full Scale, Indexes, and Subtest by Degree of Hearing (continued)

	Degree of Hearing Loss	Mean	*SD*	N
Gsm	Moderate	94.00	-	1
	Moderate-Profound	91.00	-	1
	Moderate-Severe	89.00	13.528	7
	Profound	90.42	13.925	12
	Severe	77.50	2.121	2
	Severe-Profound	85.00	15.837	6
	Total	87.42	13.119	31
Gs	Mild	63.00	-	1
	Mild-Profound	80.00	-	1
	Moderate	105.00	-	1
	Moderate-Profound	100.00	-	1
	Moderate-Severe	103.29	7.889	7
	Profound	104.42	11.147	12
	Severe	7300	5.657	2
	Severe-Profound	103.33	12.501	6
	Total	99.68	14.351	31
Similarities	Mild	5.00	-	1
	Mild-Profound	5.00	-	1
	Moderate	1.00	-	1
	Moderate-Profound	7.00	7.071	1
	Moderate-Severe	8.25	1.389	7
	Profound	7.33	3.284	12
	Severe	6.00	1.414	2
	Severe-Profound	9.17	2.639	6
	Total	7.76	-2.894	31
Vocabulary	Mild	3.00	-	1
	Mild-Profound	3.00	-	1
	Moderate	9.00	-	1
	Moderate-Profound	6.00	-	1
	Moderate-Severe	5.89	1.069	7
	Profound	5.25	3.441	12
	Severe	4.00	.000	2
	Severe-Profound	6.00	2.191	6
	Total	5.45	2.541	31
Block Design	Mild	6.00	-	1

(continued)

Table 4.14

Mean and Standard Deviation for Full Scale, Indexes, and Subtest by Degree of Hearing (continued)

	Degree of Hearing Loss	Mean	*SD*	N
Block Design	Mild-Profound	9.00	-	1
	Moderate	12.00	-	1
	Moderate-Profound	8.00	-	1
	Moderate-Severe	10.43	2.440	7
	Profound	9.67	2.060	12
	Severe	7.00	4.243	2
	Severe-Profound	9.67	2.805	6
	Total	9.55	2.447	31
Visual Puzzles	Mild	7.00	-	1
	Mild-Profound	10.00	-	1
	Moderate	14.00	-	1
	Moderate-Profound	9.00	-	1
	Moderate-Severe	11.29		7
	Profound	11.08		12
	Severe	8.50	4.950	2
	Severe-Profound	10.00	2.966	6
	Total	10.61	2.604	31
Matrix Reasoning	Mild	6.00	-	
	Mild-Profound	8.00	-	1
	Moderate	12.00	-	1
	Moderate-Profound	9.00	-	1
	Moderate-Severe	11.29	1.704	7
	Profound	10.67	3.846	12
	Severe	8.50	0.707	2
	Severe-Profound	11.17	1.169	6
	Total	10.52	2.791	31
Figure Weights	Mild	7.00	-	1
	Mild-Profound	10.00	-	1
	Moderate	10.00	-	1
	Moderate-Profound	13.00	-	1
	Moderate-Severe	10.57	1.813	7
	Profound	10.33	1.497	12
	Severe	8.50	2.121	2
	Severe-Profound	9.83	2.483	6
	Total	10.13	1.875	31

(continue)

Table 4.14

Mean and Standard Deviation for Full Scale, Indexes, and Subtest by Degree of Hearing (continued)

	Degree of Hearing Loss	Mean	*SD*	N
Digit Span	Mild	4.00	-	1
	Mild-Profound	5.00	-	1
	Moderate	8.00	-	1
	Moderate-Profound	10.00	-	1
	Moderate-Severe	8.43	2.070	7
	Profound	7.42	2.429	12
	Severe	5.50	0.707	2
	Severe-Profound	6.17	2.858	6
	Total	7.19	2.442	31
Coding	Mild	1.00	-	1
	Mild-Profound	8.00	-	1
	Moderate	14.00	-	1
	Moderate-Profound	12.00	-	1
	Moderate-Severe	9.57	2.299	7
	Profound	11.25	1.960	12
	Severe	6.50	2.121	2
	Severe-Profound	10.33	2.338	6
	Total	10.06	2.920	31
Symbol Search	Mild	6.00	-	1
	Mild-Profound	5.00	-	1
	Moderate	15.00	-	1
	Moderate-Profound	8.00	-	1
	Moderate-Severe	11.57	2.299	7
	Profound	10.33	2.995	12
	Severe	4.00	.000	2
	Severe-Profound	10.83	2.858	6
	Total	10.06	3.346	31

Research Question Three – Type of Amplification

Research Question 3 was examined through the use of a multivariate test to analyze if there were differences in test performance between the types

of amplification used. Results demonstrated no overall significant mean differences between the types of amplification although three variables approached significance and warrant further analysis – Gv, Gs, and Coding (see Table 4.15). Those variables that approached significance were among the cochlear implant group who scored lower on Gv (M = 97.44, SD = 11.126) and higher on Gs (M = 102.94, SD = 12.558) and coding (M = 10.78, SD = 2.557) than the group who used hearing aids (see Table 4.16).

Table 4.15

Multivariate and Univariate Analysis of Variance for Type of Amplification

Multivariate Tests[a]						
Effect		Value	F	Hypothesis df	Error df	Sig.
ha	Pillai's Trace	.601	1.239	17.000	14.000	.346
	Wilks' Lambda	.399	1.239	17.000	14.000	.346
	Hotelling's	1.505	1.239	17.000	14.000	.346
	Roy's	1.505	1.239	17.000	14.000	.346
ha	FSIQ	60.071	1	60.071	.432	.516
	Nonverbal	45.240	1	45.240	.343	.562
	Gc	85.429	1	85.429	.493	.488
	Gv	449.556	1	449.556	3.106	.088
	Gf	55.335	1	55.335	.384	.540
	Gsm	236.846	1	236.846	1.422	.242
	Gs	561.556	1	561.556	2.905	.099
	Similarities	3.754	1	3.754	.457	.504
	Vocabulary	2.294	1	2.294	.349	.559
	Block Design	15.716	1	15.716	2.872	.100
	Visual Puzzles	14.846	1	14.846	2.339	.137
	Matrix Reasoning	4.108	1	4.108	.510	.481
	Figure Weights	.389	1	.389	.111	.741
	Digit Span	.389	1	.389	.064	.802
	Picture Span	21.050	1	21.050	2.712	.110
	Coding	26.929	1	26.929	3.394	.075
	Symbol Search	3.175	1	3.175	.283	.599

Table 4.16

Mean and Standard Deviation for Type of Amplification

	Type of Amplification	Mean	*SD*	N
FISQ	HA	90.83	11.597	
	Total	88.07	12.041	32
Nonverbal	CI	89.63	11.683	18
	HA	100.11	10.862	14
	Total	97.71	12.238	32
Gc	CI	99.06	11.356	18
	HA	82.22	14.727	14
	Total	78.93	10.788	32
Gv	CI	80.78	13.058	18
	HA	97.44	11.126	14
	Total	105.00	13.121	32
Gf	CI	100.75	12.433	18
	HA	102.72	13.389	14
	Total	100.07	9.895	32
Gsm	CI	101.56	11.881	18
	HA	89.56	13.891	14
	Total	84.07	11.486	32
Gs	CI	87.16	12.992	18
	HA	102.94	12.558	14
	Total	94.50	15.486	32
Similarities	CI	99.25	14.323	18
	HA	7.83	3.092	14
	Total	7.14	2.538	32
Vocabulary	CI	7.53	2.840	18
	HA	5.61	3.051	14
	Total	5.07	1.730	32
Block Design	CI	5.38	2.537	18
	HA	8.94	2.209	14
	Total	10.36	2.499	32
Visual Puzzles	CI	9.56	2.409	18
	HA	11.43	2.793	14
	Total	10.66	2.573	32
Matrix Reasoning	CI	10.72	3.322	18
	HA	10.00	2.038	14

(continued)

Table 4.16

Mean and Standard Deviation for Type of Amplification (continued)

	Type of Amplification	Mean	*SD*	N
Matrix Reasoning	Total	10.41	2.815	32
Figure Weights	CI	10.22	1.957	18
	HA	10.00	1.754	14
	Total	10.13	1.845	32
Digit Span	CI	7.22	2.602	18
	HA	7.00	2.287	14
	Total	7.13	2.433	32
Picture Span	CI	9.28	2.845	18
	HA	7.64	2.706	14
	Total	8.56	2.862	32
Coding	CI	10.73	2.557	18
	HA	8.93	3.125	14
	Total	9.97	2.924	32
Symbol Search	CI	10.28	3.159	18
	HA	9.64	3.586	14
	Total	10.00	3.312	32

Note. CI = cochlear implant, HA = hearing aid.

Research Question Four – Mode of Communication

The final research question was designed to analyze the profile difference when mode of communication is taken into account. This was complete by measuring the variance across samples using the Levene's test on the identified means. On all scores (full scale, indexes, and subtests) the oral participants had higher scores than the total communication participants although only five dependent variables reported significant differences. The nonverbal (M = 100.46, SD = 13.531), Gv (M = 101.00, SD = 13.816), Gf (M =103.15, SD = 13.916), visual-spatial (M = 1073, SD = 2.836), matrix reasoning

(M = 10.81, SD = 3.225), and picture span (M = 8.81, SD = 3.112) had significant differences between modes.

Table 4.17

Mean and Standard Deviation for Mode of Communication

	Mode	N	Mean	*SD*
FSIQ	Total	8	85.25	7.649
	Oral	26	91.65	13.629
Nonverbal	Total	17	88.71	13.531
	Oral	24	100.46	11.935
Gc	Total	8	74.38	7.577
	Oral	26	83.92	14.088
Gv	Total	17	92.29	11.794
	Oral	26	101.00	13.816
Gf	Total	17	93.47	10.075
	Oral	26	103.15	13.916
Gsm	Total	8	83.00	10.836
	Oral	26	88.88	14.717
Gs	Total	17	96.41	17.829
	Oral	26	97.50	14.177
Similarities	Total	8	6.25	1.832
	Oral	26	8.15	3.003
Vocabulary	Total	8	4.25	1.282
	Oral	26	5.96	2.835
Block Design	Total	17	8.71	2.756
	Oral	26	9.54	2.565
Visual Puzzles	Total	17	8.53	2.503
	Oral	26	10.73	2.836
Matrix Reasoning	Total	17	8.59	2.063
	Oral	26	10.81	3.225
Figure Weights	Total	17	9.24	1.821
	Oral	26	10.27	2.070

(continued)

Table 4.17

Mean and Standard Deviation for Mode of Communication (continued)

	Mode	N	Mean	*SD*
Digit Span	Total	8	6.75	2.121
	Oral	26	7.46	2.929
Picture Span	Total	17	6.71	2.568
	Oral	26	8.81	3.112
Coding	Total	17	8.71	3.037
	Oral	26	9.88	3.051
Symbol Search	Total	17	9.94	3.881
	Oral	26	9.54	3.265

Table 4.18

Independent Sample Test for Mode of Communication

		Levene's Test for Equality of Variances		t-test for Equality of Means		
		F	Sig.	t	df	Sig. (2-tailed)
FSIQ	Equal variances assumed	3.088	.088	-1.260	32	.217
Nonverbal	Equal variances assumed	.336	.565	-2.939	39	.006
Gc	Equal variances assumed	3.371	.076	-1.824	32	.077
Gv	Equal variances assumed	.834	.366	-2.137	41	.039
Gf	Equal variances assumed	1.094	.302	-2.472	41	.018
Gsm	Equal variances assumed	1.053	.312	-1.043	32	.305
Gs	Equal variances assumed	.699	.408	-.222	41	.825
Similarities	Equal variances assumed	3.126	.087	-1.688	32	.101

(continued)

Table 4.18

Independent Sample Test for Mode of Communication (continued)

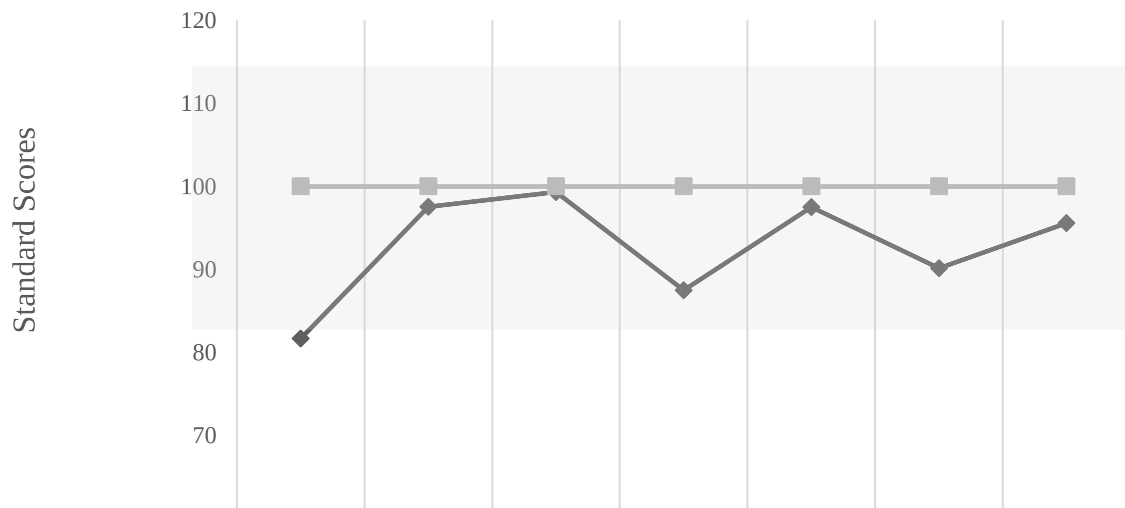
		Levene's Test for Equality of Variances		t-test for Equality of Means		
		F	Sig.	t	df	Sig. (2-tailed)
Similarities	Equal variances assumed	3.126	.087	-1.688	32	.101
Vocabulary	Equal variances assumed	3.375	.075	-1.643	32	.110
Block Design	Equal variances assumed	.000	.997	-1.011	41	.318
Visual Puzzles	Equal variances assumed	.345	.560	-2.603	41	.013
Matrix Reasoning	Equal variances assumed	2.429	.127	-2.515	41	.016
Figure Weights	Equal variances assumed	.023	.879	-1.677	41	.101
Digit Span	Equal variances assumed	.734	.398	-.635	32	.530
Picture Span	Equal variances assumed	1.465	.233	-2.314	41	.026
Coding	Equal variances assumed	.007	.933	-1.241	41	.222
Symbol Search	Equal variances assumed	.293	.591	.367	41	.715

Results Summary

In summary, the profile of the D/HH participants indicated some significant difference when compared to the norms from WISC-V. With and without independent variables accounted for the D/HH profile presented a below average mean in Gc Index and low average mean in Gsm. No significant differences were found in Gc Index among the independent variables. Performance with each variable could be described on the Gc as follows amplification: CI > hearing aids; degree of hearing loss: severe-profound >

profound > severe > moderate-severe; and mode of communication: oral > total communication (see Figure 1).

One of the subtests under Gc, Vocabulary, and Similarities, also presented a significant difference in the profile but did not present a significant difference among the variables. Both the Vocabulary and Similarities subtests are described as follows amplification: CI > hearing aids; degree of hearing loss: severe-profound > moderate-severe > profound > severe; and mode of communication: oral > total communication (see Figure 2).



	Gc	Gv	Gf	Gsm	Gsm	FSIQ	NVI
D/HH	81.68	97.56	99.33	87.5	97.5	90.15	95.59
WISC-V Norm	100	100	100	100	100	100	100

Figure 1. Mean performance of D/HH participants and standard score norm of 100 (gray area being the average range) on the WISC-V on the FSIQ, NVI, and Indexes.

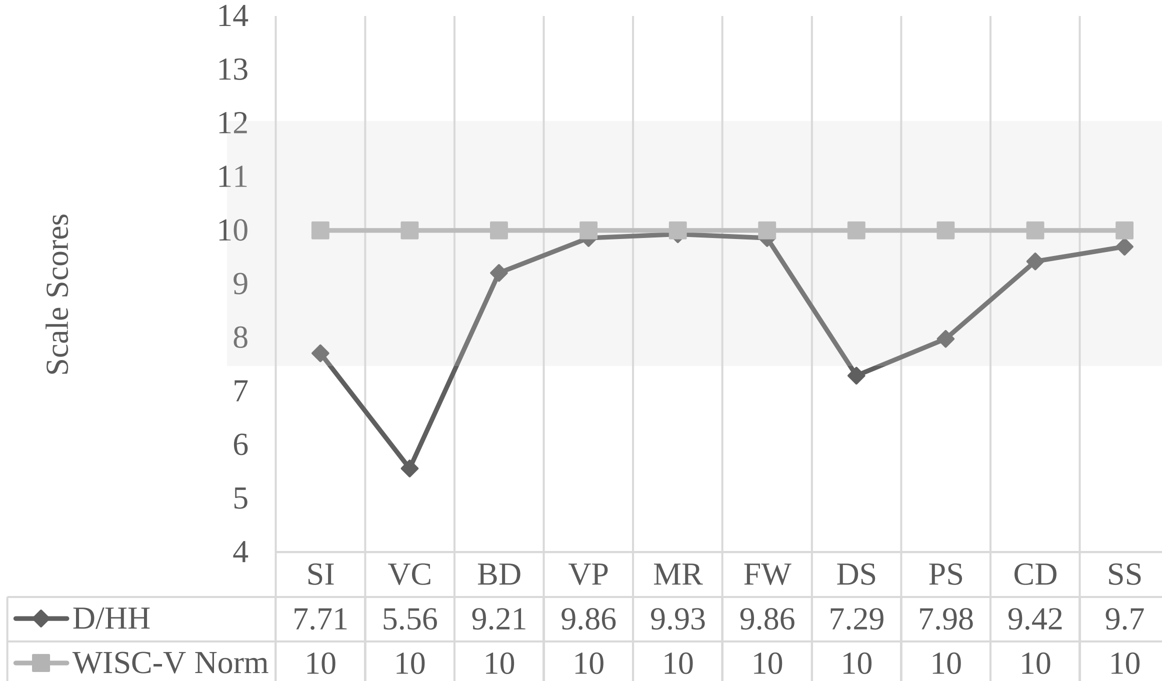
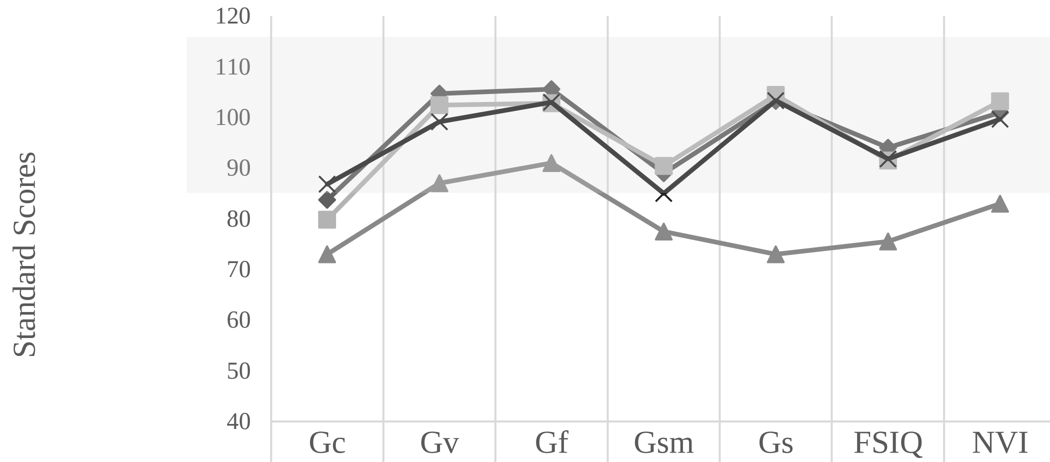


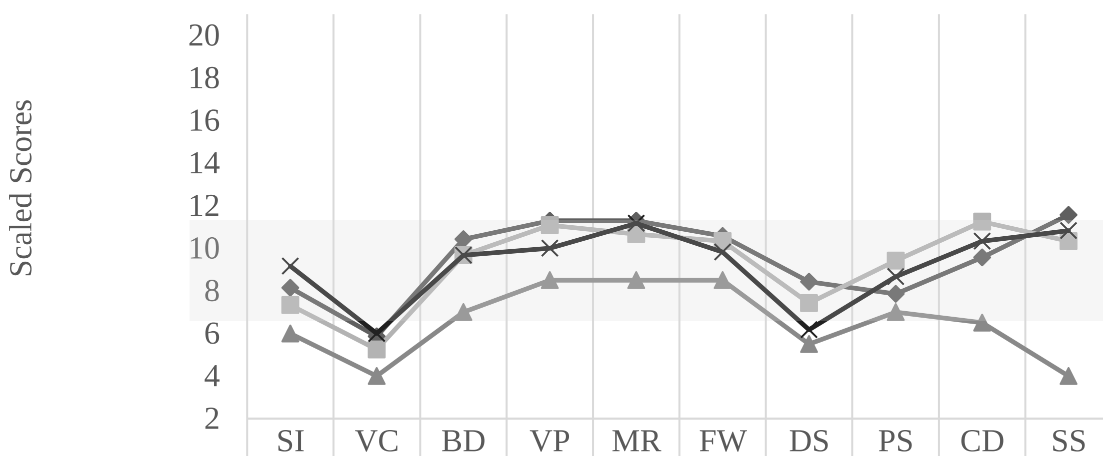
Figure 2. Mean performance of D/HH participants and standard score norm of 10 on the WISC-V subtests.

Although not all participants or descriptors were represented when analyzing the degree of hearing loss several significant differences were identified. Participants with moderate to severe and profound hearing loss presented a difference in higher means in Gs (see Figure 3). Participants with a severe hearing loss had a significant difference in the Gs, Coding, and Symbol Search subtests which demonstrated below average means (see Figure 4). Additionally, participants with a severe hearing loss had lower means than the other participants in all measured areas.



	Gc	Gv	Gf	Gsm	Gs	FSIQ	NVI
Moderate-Severe	83.71	104.71	105.57	89	103.23	94	101
Profound	79.83	102.42	102.83	90.42	104.42	91.5	103.17
Severe	73	87	91	77.5	73	75.5	83
Severe-Profound	86.83	99.17	103	85	103.33	91.83	99.67

Figure 3. Mean performance of D/HH participants according to degree of hearing loss on the FSIQ, NVI, and Indexes.

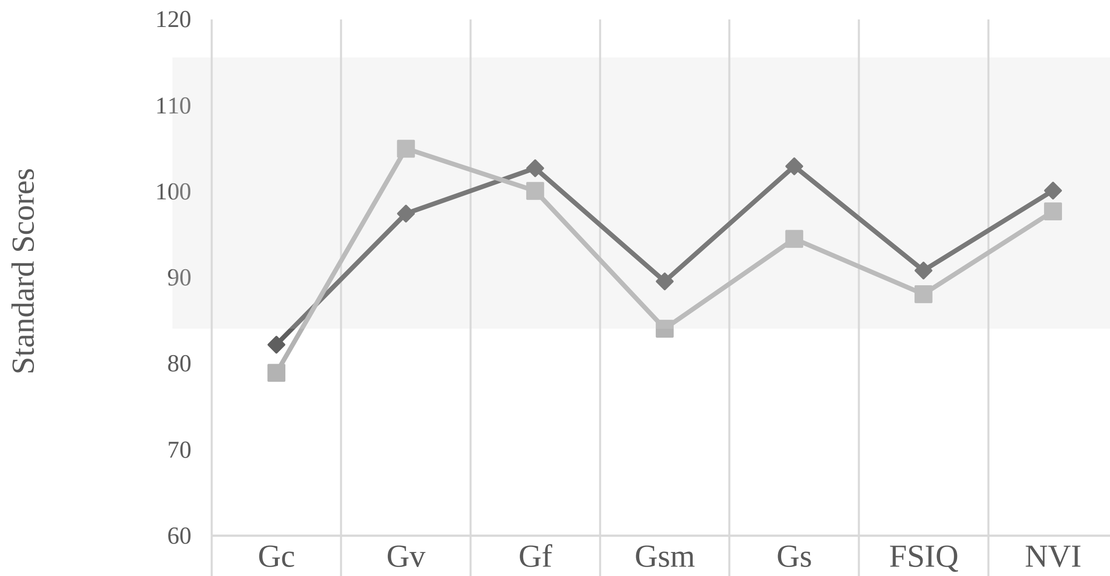


	SI	VC	BD	VP	MR	FW	DS	PS	CD	SS
Moderate-Severe	8.14	5.86	10.43	11.29	11.29	10.57	8.43	7.86	9.57	11.57
Profound	7.33	5.25	9.67	11.08	10.67	10.33	7.42	9.42	11.25	10.33
Severe	6	4	7	8.5	8.5	8.5	5.5	7	6.5	4
Severe-Profound	9.17	6	9.67	10	11.17	9.83	6.17	8.67	10.33	10.83

Figure 4. Mean performance of D/HH participants according to degree of hearing loss on WISC-V subtests.

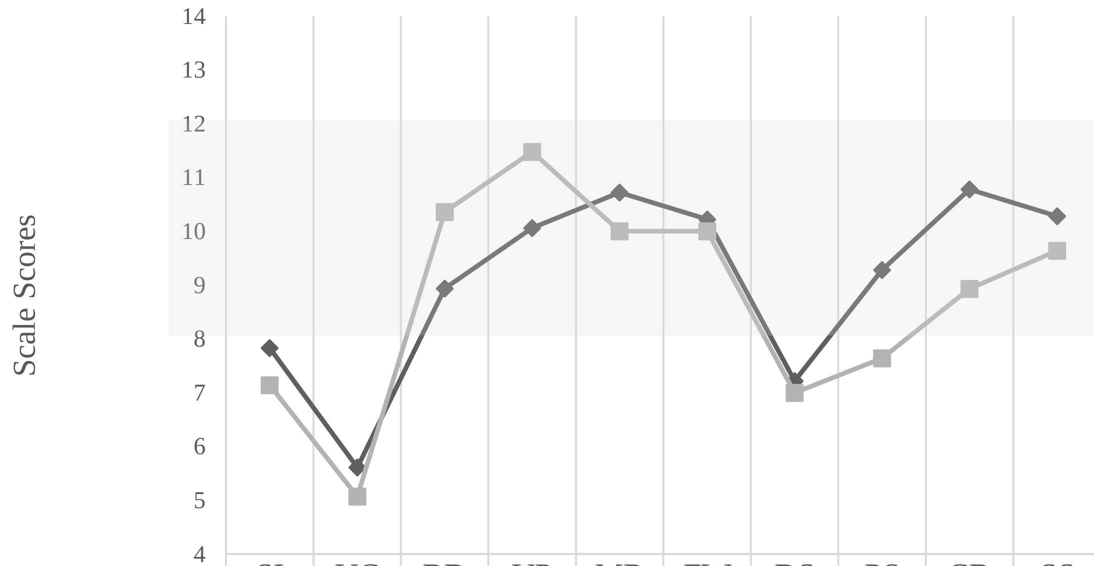
The independent variable, amplification did not appear to have any significant differences; although two were approaching the means were still within the average range. The participants with CI(s) performed the highest in all measured areas regardless to mode of communication or the degree of hearing loss (see Figure 5 and 6).

Figure 5. Mean performance of D/HH participants according to type of amplification on the FSIQ, NVI, and Indexes.



	Gc	Gv	Gf	Gsm	Gs	FSIQ	NVI
Cochlear Implant	82.22	97.44	102.72	89.56	102.94	90.83	100.11
Hearing Aids	78.93	105	100.07	84.07	94.5	88.07	97.71

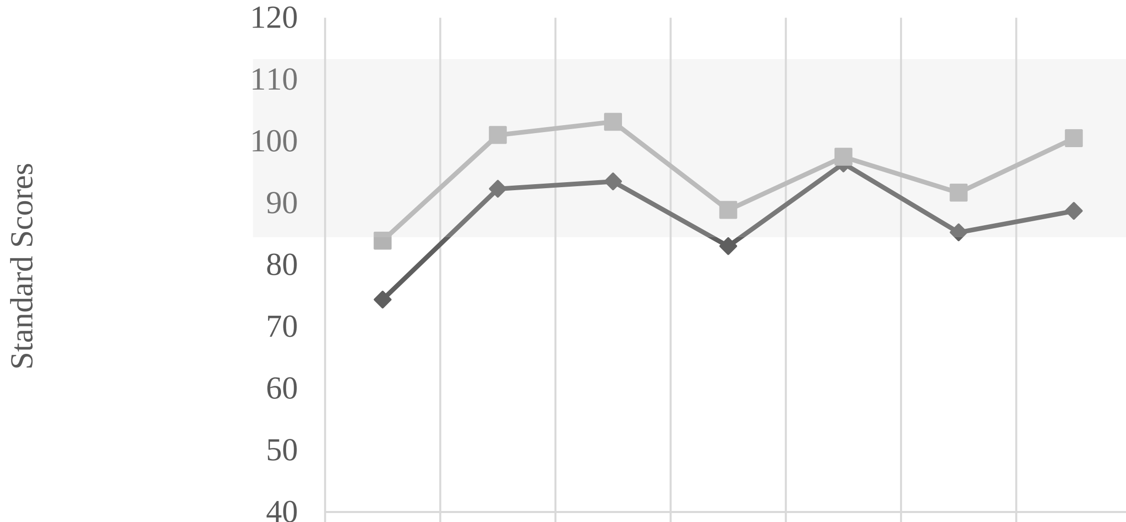
Figure 5. Mean performance of D/HH participants according to type of amplification on the FSIQ, NVI, and Indexes.



	SI	VC	BD	VP	MR	FW	DS	PS	CD	SS
Cochlear Implant	7.83	5.61	8.94	10.06	10.72	10.22	7.22	9.28	10.78	10.28
Hearing Aids	7.14	5.07	10.36	11.48	10	10	7	7.64	8.93	9.64

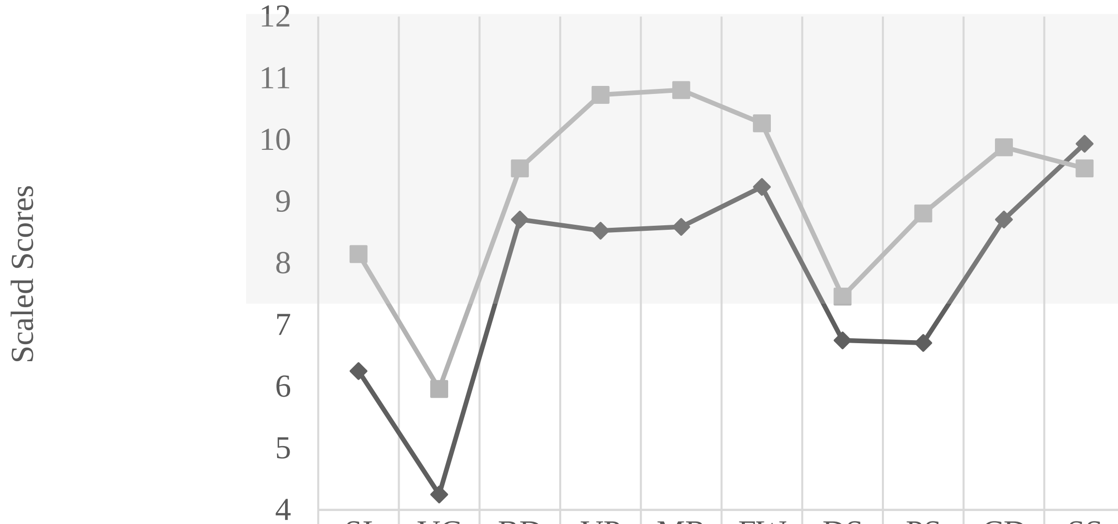
Figure 6. Mean performance of D/HH participants according to type of amplification on WISC-V subtests.

The independent variable, mode of communication indicated five dependent variables with significant differences – NVI, visual spatial, matrix reasoning, and picture span (see Figure 7 and 8). Furthermore, the oral participants had overall higher means on in all areas measured, although not all were identified as significant.



	Gc	Gv	Gf	Gsm	Gs	FSIQ	NVI
Total Communication	74.38	92.29	93.47	83	96.41	85.25	88.71
Oral	83.92	101	103.15	88.88	97.5	91.65	100.46

Figure 7. Mean performance of D/HH participants according to mode of communication on the FSIQ, NVI, and Indexes.



	SI	VC	BD	VP	MR	FW	DS	PS	CD	SS
Total Communication	6.25	4.25	8.71	8.53	8.59	9.24	6.75	6.71	8.71	9.94
Oral	8.15	5.96	9.54	10.73	10.81	10.27	7.46	8.81	9.88	9.54

Figure 8. Mean performance of D/HH participants according to mode of communication on WISC-V subtests.

CHAPTER V

DISCUSSION

Profiles are currently used in the identification of subgroups within specific learning disabilities due to patterns of strengths and weaknesses of cognitive processes as it relates to academic performance (Flanagan et al., 2013). This same idea, identifying a profile and determining a pattern of strengths and weaknesses, will assist in understanding and identifying unusual weaknesses among the D/HH population, thus providing information for more appropriate interventions and educational planning (Akamatsu et al., 2008).

The primary goal of this study was to identify the CHC theory based profiles of D/HH students to better assist in their educational planning. First, the identification of an overall profile of D/HH students without any comorbid disabilities was analyzed and then compared to the normed standards of the WISC-V for significant differences. Additional analysis was completed on known variables such as hearing loss (mild, moderate, severe, profound), type of amplification used (CI(s), hearing aid(s), no amplification), and mode of communication (total communication or oral), to identify any possible significant differences within the variables related to the profile. The summary of this study discusses the identified profiles and differences among the variables providing possible explanations for the reported significant differences.

In discussing the results, it is important to remember that although there was a total of 49 participants from which data were collected 6 did not meet criteria.

Additionally, not all participants contributed data to every area of measurement due to some measurements being deemed not appropriate for that participant by the assessor.

The reported overall IQ, both FSIQ and NVI, indicated that the D/HH have cognitive abilities that fall within the average range, just as Vernon's (2005) critical review of approximately 50 D/HH cognitive studies reported. Although the FSIQ and NVI scores were within the average range they were slightly lower than the mean of the norm which supports previous studies (Krivitsko, Mcintosh, Rothlisberg, & Finch, 2004; Marschark & Knoors, 2012; Myklebust, 1948; Marschark & Hauser, 2008b; Qi & Mitchell, 2011). The NVI was slightly higher than the Full Scale IQ which also has been previously reported (Akamatsu, Musselman, & Zweiebel, 2000; Remine, Brown, Care, & Rickards, 2007). Additionally, the profile identified indicated some cognitive ability differences which were outside of the established average ranges. The primary cognitive area identified as significantly different was Gc with Vocabulary, Digit Span, and Picture Span subtests being reported with significant differences as well. The identified significant differences negatively impacted the cognitive profile as they were within the low average to below average.

Previous research on specific broad and narrow cognitive abilities indicate some areas of weakness for the D/HH population, specifically in language development (verbal comprehension) and working memory (short-term memory) (Castellanos et al., 2015; Marschark & Hauser, 2008a; Marschark et al., 2013; Marshall et al., 2015). In this study, the profile results replicate previous research on D/HH students demonstrating lower scores on tasks that required word knowledge and acquisition (Akamatsu et al., 2008; Adam-Costa et al., 2016). Verbal comprehension (Gc) was found to be below average for the D/HH participants before taking into account any of the independent variables. When the independent variables were added to the equation there were no significant difference among any of the variables, indicating Gc is a weakness for the D/HH participants as a whole.

The results from deeper analysis of the D/HH profile revealed three subtests were identified as significantly different. The lowest performance was on the Vocabulary subtest which measures a narrow ability under Gc. Gc measures the student's ability to acquire, access, and express word knowledge, more specifically the Vocabulary subtest examines the student's ability to retrieve verbal descriptions that appropriately define a stimulus word which indicates their understanding of the stimulus word. The D/HH participants performed below average on the Vocabulary subtest, regardless to which variables were considered thus indicating a weakness for the D/HH as a whole. This finding is supported by significant research in which language development is investigated among the D/HH populations (Lederberg et.al, 2012; Marschark & Knoors, 2012; Remine et al., 2007; Takahashi et al., 2017). The low Vocabulary score may be explained by the limited and/or delayed development of language resulting in poor word knowledge and thus contributing to difficulties with verbal expressions. The Vocabulary subtest requires retrieval of familiar description; retrieval indicates input has previously been received and stored but because language is often delayed sometimes significantly the limited vocabulary may be insufficient to verbally express understanding.

Although the D/HH participants demonstrated difficulties retrieving words to define a word stimulus it is interesting to note that performance on the second subtest (Similarities) used to determine the Verbal Comprehension Index fell well within the average range. The Similarities subtest measures the same narrow ability as Vocabulary but some of the cognitive demands required for successful performance differed slightly. The Similarities subtest required generating novel verbal content not retrieval of exact verbal content, in other words, the student could create their response from words they know and are familiar with (Wechsler, 2014). Furthermore, responses on the Similarities subtest could be much shorter, requiring less cognitive pull. It was interesting, the D/HH participants could better demonstrate breadth and depth of knowledge when given a large berth to respond versus needing exact, extensive responses.

The other two subtests that presented a significant difference were Digit Span and Picture Span. Digit Span and Picture Span are two subtests used to measure a student's working memory cognitive abilities (Gsm). Working Memory requires attention, concentration, visual and auditory discrimination to register, maintain, and manipulate of visual and auditory information (Wechsler, 2014). This study reported the overall Working Memory Index to be within the low average range and did not present a significant difference; however, the two subtests means were identified as low average and did present a significant difference. Although the scores were low average the two subtests did indicate a cohesive performance on both tasks with Picture Span being slightly higher than Digit Span (SP M = 7.98 > DS M = 7.29). These cohesive scores indicate a Working Memory that performs slightly below expectation but is relatively even whether it is a free recall paradigm or recognition paradigm. In general, Working Memory in the D/HH population has been reported to be below that of their hearing peers (Adam-Costa et al., 2016; Hauser & Marschark, 2008a).

Even though in this study Gsm was not found to have a significant difference, it was identified as being compromised; this is to be expected in light of some of the recent research related to D/HH Working Memory linked to language deficits (Arfé, Rossi, & Sicoli, 2015; López-Crespo et al., 2012; Marshall et al., 2015). In a comparison study, Marshall et al.'s (2015), appears to have clarified the impact language experiences have on Working Memory by investigating a group of D/HH that was identified as either native signers or non-native signers. Marshall et al.'s (2015) study was intended to examine language experiences versus deafness *per se* as these variables relate to the Working Memory process. Findings supported and clarified previous findings that language experiences directly impact working memory. In fact, language has a much broader effect on developing cognitive skills which research has just begun to scratch the surface (Marshall et al., 2015).

When considering the impact the independent variables had on the cognitive profile results indicated the degree of hearing loss and mode of communication had significant differences; amplification had no significant difference although several were identified as approaching significant.

The degree of hearing loss dictates the level of sounds that an individual can hear. In this study, the milder losses were not included due to the sample sizes being one. The moderate to profound ranges were measured; a moderate loss means conversation may not be heard and a profound loss would have almost no auditory input. Most of the participants (75%) have a sensorineural hearing loss which is permanent but can be improved with amplification. The participants with a severe hearing loss had a lower Processing Speed Index (Gs) score which was also reflected in lower performance on the two subtests under Gs, Coding and Symbol Search. Performance on these two subtests were cohesive among those with severe hearing loss which indicates difficulties with associate learning, visual scanning, and discrimination (Wechsler, 2014). The Gs is used to measure the speed and accuracy of visual information and requires visual scanning, visual discrimination, short-term visual memory, visual motor coordination, and concentration (Wechsler, 2014). The low Gs score may be attributed to the required performance of the short-term visual memory which has been found to be lower in the D/HH populations (López-Crespo et al., 2012). However, in the case of this study, it is more likely due to lower cognitive abilities, as the participants with a severe hearing loss had the lowest score in all the measured indexes and subtests. Whereas the with the moderate to severe and profound hearing loss participants had a significant difference in the Nonverbal Index and scored within the average range on all measured indexes and subtests other than those related to Gc.

The participants' mode of communication appears to have impacted the cognitive profile in the NVI, indexes, and subtests. While all measured scores were higher for the oral participants only NVI, Gv (including subtest Visual Puzzles), Gf (including subtest Matrix Reasoning), and the Picture Span subtest presented significant differences. The areas identified as significantly different are nonverbal by nature of the required task, however, the cognitive processes used to complete each task in this incident require some type and level of reasoning that is language based. When examining the mode of communication, the question has to be then, when and what level of language are the participants receiving. Although it is clear oral participants performed much better, it is difficult to determine if the difference is due to the mode of communication or language development.

The type of amplification did not appear to present any significant difference in the cognitive profile. Although there were some areas that were approaching significance it is difficult to identify amplification as the key factor in the slight score difference. When examining the indexes and subtests where approaching significance appeared, the cognitive demands did not appear to have any correlation to the type of amplification. Students with CI performed better in Gs and on the Coding subtest; both the index and subtest are related to speed in which repetitive cognitive tasks are performed (Flanagan et al., 2013). The tasks are visual in nature so the explanation as to the CI increasing performance is unlikely but rather it might have a been an area of strength for them. When Gs is observed without out variables it falls within the average range this is what can be expected from D/HH population. Again, the lower Gv cannot be explained by change in amplification; as the task are nonverbal by nature and require visual imagery to solve problems which require some level of organization and language (Flanagan et al., 2013). The higher performance by participants with CI(s) could be contributed to their access to sound and spoken language (Jacobs et al., 2016; Leigh, 2008). Furthermore, participants with Cis performed slightly higher than those with hearing aids in all indexes areas except Gv.

Implications for Future Research

Continued research is needed to examine the relationship between cognitive abilities and academic performance as it relates to the D/HH populations with and without any comorbid disabilities. The understanding of D/HH cognitive profiles is needed in order to identify a typical profile versus a profile that has outliers and could indicate additional or alternative educational planning is needed. By identifying and understanding outliers, a pattern of strengths and weaknesses can be established and more accurate information will be present to more completely identify the D/HH student's disabilities and provide the information needed for the teacher to more appropriately design an educational plan. Additionally, research is needed to better understand the impact independent variables have on the cognitive development of D/HH students and when and where interventions could occur to lessen the impact of these variables.

Limitations

This study did not control for several language factors that might have had an impact on the results. The study did not address the language that was spoken at home. For D/HH students that sign and their parents do not know sign results in fewer language opportunities and thus lower language scores would be expected. Additionally, if the student uses oral language at school and at home their parents speak a language other than English, the language opportunities have not lessened but changed in nature. Lastly, students that come from another country and are not exposed to oral or signed English are only administered the nonverbal portion of the assessment however culture difference may impact performance.

Other factors that were not controlled relate to hearing loss including the age and cause of the hearing loss and the age the hearing loss was identified. Although students may have the same hearing loss, if they were identified later it would mean delayed interventions.

The educational placement was not a factor that was controlled. Although the participants were all on the same campus their educational placements could differ from self-contained total communication to complete inclusion.

Lastly, the small population size limited the results of this study. In some independent variable analysis, not all variables were represented due to the participant count being one individual thus their descriptive independent variable was not examined for significance. If the sample population had been larger additional differences in the profile might have been identified or stronger significant differences might have been reported.

Conclusion

Findings in this study support four main conclusions: (a) the D/HH's Full Scale IQ and Nonverbal Index on the WISC-V fall within the average range according to the established norms; (b) the Gc in the D/HH cognitive profile is below the expected norm regardless to the type of amplification used, the degree of hearing loss, or mode of communication used; (c) although there was not a reported significant difference, the Gsm is within the low average range of the expected norms and is an area where more understanding is needed; and (d) increased access to language experiences appear to be the greatest factor in overall cognitive performance. Although the cognitive process can be categorized as verbal and nonverbal, language appears to indirectly impact nonverbal performance.

Although this study has data to support the identified conclusions, it is important that educators remember that when working with the D/HH population there are often other significant variables contributing to or affecting communication or learning. Being deaf in itself is complex with explanations; yet to be fully understood, research has only begun to scratch the surface of understanding the impact or changes delayed or no auditory input has on cognitive processing.

REFERENCES

Adam-Costa, E. B, Day, L. A., & Raiford (2016). *Wisc-v special group study: children with hearing differences who utilize spoken language and have assistive technology* (Report No. 4). New Jersey: Pearson Education.

Akamatsu, C. T., Mayer, C., & Hardy-Braz, S. (2008). Why considerations of verbal aptitude are important in educating deaf and hard-of-hearing students. In: M. Marschark & P. C. Hauser (Eds), *Deaf Cognition Foundation and Outcomes* (pp. 131-169). New York: Oxford University Press.

Akamatsu, C. T., Musselman, C., & Zwiebel, A. (2000). Nature versus nurture in the development of cognition in deaf people. In P. E. Spencer, C. J. Erling & M. Marschark (Eds.), *The deaf child in the family and at school: Essays in honor of Kathryn P. Meadow-Orlans* (pp. 255-274). Mahwah, NJ: Lawrence Eribaum Associates Publishers.

Arfé, B., Rossi, C., & Sicoli, S. (2015). The contribution of verbal working memory to deaf children's oral written production. *Journal of Deaf Studies and Deaf Education*, *20*(3), 203-214.

Bandurski, M. & Galkowski, T. (2004). The development of analogical reasoning in deaf children and their parents' communication mode. *The Journal of Deaf Studies and Deaf Education, 9*(2), 153-175.

Beer, J., Kronenberger, W. G., & Pisoni, D. B. (2011). Executive function in everyday life: implications for young cochlear implant users. *Cochlear Implants International, 12*(1), 89-91.

Bergeron, R. & Floyd, R. G. (2006). Broad cognitive abilities of children with mental retardation: an analysis of group and individual profiles. *American Journal of Mental Retardation*, *111*(6), 417-432.

Bickley, P., Keith, T., & Wolfle, L. (1995). The three-stratum theory of cognitive abilities: test of the structure of intelligence across the life span. *Intelligence, 20*(3), 309-327.

Boake, C. (2002). From the binet-simon to the wechsler-bellevue: tracing the history of intelligence testing. *Journal of Clinical and Experience Neuropsychology, 24*(3), 383-405.

Burkholder, R. A. & Pisoni, D. B. (2003). Speech timing and working memory in profound deaf children after cochlear implantation. *Journal of Experimental Child Psychology*, *85*(1), 63-88.

Carlson, J. (1993). Army alpha, army brass, and the search for army intelligence. Chicago, IL: The University of Chicago Press.

Carroll, J. B. (1997). Psychometrics, intelligence, and public perception. *Intelligence, 24*(1), 25-52.

Carroll, J. (2012). The three-stratum theory of cognitive abilities. In D. P. Flanagan & P. L. Harrison (Eds.), *Contemporary intellectual assessment: theories, tests, and issues, second edition* (3rd ed., 883-890). New York, NY: The Guilford Press.

Carroll, J. (2005). The three-stratum theory of cognitive abilities. In D. P. Flanagan & P. L. Harrison (Eds.), *Contemporary intellectual assessment: theories, test, and issues, second edition* (2nd ed., 69-76). New York, NY: The Guilford Press.

Castellanos, I., Kronenberger, W. G., Beer, J., Colson, B. G., Henning, S. C., Ditmats, A. & Pisoni, D. B. (2015). Concept formation skills in long-term cochlear implant users. *Deaf Studies and Deaf Education, 20*(1), 27-40.

Cattell, R. B. (1941). A culture-free intelligence test: II. evaluation of culture influence on test performance. *Journal of Educational Psychology*. *32*(2), 21-100.

Claeys, J. (2013). Theory and research: the nexus of clinical inference. *Journal of Psychoeducational Assessment, 31*(2), 170-174.

Cormier, D. C., Bulut, O., McGrew, K. S., & Frison, J. (2016). The role of cattell-horn carroll (chc) cognitive abilities in predicting writing achievement during the school-age years. *Psychology in the Schools, 53*(8), 787-803.

Dang, C., Braeken, J., Colom, R., Ferrer, E., & Liu, C. (2014). Why is working memory related to intelligence? different contributions from storage and processing. *Memory, 22*(4), 426-441.

Day, L. A., Adam-Costa, E. B., & Raiford, S. E. (2015). *Testing children who are deaf or hard of Hearing* (Report No. 2). New Jersey: Pearson Education.

Dehn, M. J. (2008). *Working memory and academic learning assessment and intervention*. New Jersey: John Wiley & Sons, Inc.

Detterman, D. K., & Thompson, L. A. (1997). What is so special about special education.

American Psychologist, 52(10), 1082-1090.

Edwards, L., Figueras, B., Mellanby, J., & Langdon, D. (2010). Verbal and spatial analogical reasoning in deaf and hearing children the role grammar and vocabulary. *Journal of Deaf Studies and Deaf Education, 16*(2), 189-196.

Farmer, R. L., Floyd, R. G., Reynolds, M. R., & Kranzler, J. H. (2014). Iqs are very strong but imperfect indicators of psychometric g: results from joint confirmatory factor analysis. *Psychology in the Schools, 51*(8), 801-813.

Figueras, B., Edwards, L., & Langdon, D. (2008). Executive function and language in deaf children. *Journal of Deaf Studies and Deaf Education, 13*(3), 262-377.

Fiorello, C. A. & Primerano, D. (2005). Research into practice: cattell-horn-carroll assessment in practice: eligibility and program development issues. *Psychology, 45*(5), 525-536.

Flanagan, D. P., Ortiz, S. O., & Alfonso, V. C. (2013). *Essentials of cross-battery assessment, third edition*. Hoboken, New Jersey: John Wiley & Sons, Inc.

Furth, H. G. (1961). The influence of language on the development of concept formation in deaf children. *Journal of Abnormal and Social Psychology, 63*(2), 386-389.

Furth, H. G. (1964). Research with the deaf: implications for language and cognition. *Psychological Bulletin, 62*(3), 145-164.

Geers, A. E. & Sedey, A. L. (2011). Language and verbal reasoning skill in adolescents and 10 or more years of cochlear implant experiences. *Ear and Hearing, 31*9(1 Suppl), 39S-48S.

Gottfredson, L. & Saklofske, D. H. (2009). Intelligence: foundations and issues in assessment. *Canadian Psychology*, *50*(3), 183-195.

Hamilton, H. (2011). Memory skills of deaf learners: implications and applications. *American Annals of the Deaf*, *156*(4), 402-423.

Hauser, P. C., Lukomski, J., & Hillman, T. (2008). Development of deaf and hard-of hearing students' executive function. In: M. Marschark & P. C. Hauser (Eds.), *Deaf cognition foundation and outcomes* (pp. 286-308). New York: Oxford University Press.

Individuals with Disability Education Improvement Act (IDEIA) of 2004, Public L. No. 108-446, 34 Code of Federal Regulations § 300.8 (2004). Retrieved from: https://framework.esc18.net/display/Webforms/ESC18-FW-Summary.aspx?FID=134&DT=G&LID=en

Jacobs, E., Langereis, M. C., Frijns, J. H., Free, R. H. M., Goedegebure, A., Smits, C., Stokroos, R. J., Ariens-Meijer, S. A. M., Mylanus, E. A. M., & Vermeulen, A. M. (2016). Benefits of simultaneous bilateral cochlear implantation on verbal reasoning skills in prelingually deaf children. *Research in Developmental Disabilities*, *58*(2016), 104-113.

Jensen, A. R. (2011). The theory of intelligence and its measurement. *Intelligence, 39*(4), 171-177.

Jensen, A. R. (2004). Obituary – john carroll. *Intelligence, 32*(10), 1-5.

Jensen, A. R. (2002). Galton's legacy to research on intelligence. *Journal of Biosocial*

Science, 34(4), 145-72.

Kamphaus, R. W., Winsor, A. P., Rowe, E. W., & Kim, S. (2012). A history of intelligence test interpretation. In Flanagan, D. P. & Harrison, P. L. (Eds.), *Contemporary intellectual assessment: theories, test, and issues, second edition* (3-22). New York, NY: The Guilford Press.

Keith, T. Z. & Reynolds, M. R. (2010). Cattell-horn-carroll abilities and cognitive tests: what we've learned from 20 years of research. *Psychology in Schools, 47*(7) 635-650.

Krivitsko, E. C., Mcintosh, D. E., Rothlisberg, B., & Finch, H. (2004). Profile analysis of deaf children using the universal nonverbal intelligence test. *Journal of Psychoeducational Assessment*, *22*(4) 338-350.

Krouse, H. E. & Braden, J. P. (2011). The reliability and validity of wisc-iv scores with deaf and hard-of-hearing children. *Journal of Psychoeducational Assessment, 29* (3), 238-248.

Lederberg, A. R., Schick, B., & Spencer, P. E. (2012). Language and literacy development of deaf and hard-of-hearing children: successes and challenges. *Developmental Psychology*, *49*(1), 15-30.

Leigh, G. (2008). Changing parameters in deafness and deaf education. In: M. Marschark & P. C. Hauser (Eds.), *Deaf cognition foundation and outcomes* (pp. 24-101). New York: Oxford University Press.

López-Crespo, G. Daza, M. T., & Méndez-López, M. (2012). Visual working memory in deaf children with diverse communication modes: improvement by differential outcomes. *Research in Developmental Disabilities, 33*(2), 362-368.

Lynch, S. A. & Warner, L. (2012). A new theoretical perspective of cognitive abilities. *Childhood Education, 88*(6), 347-353.

Maller, S. J. & Ferron, J. (1997). Wisc-iii factor invariance across deaf and standardization samples. *Educational and Psychological Measures, 57*(6), 987-994.

Marschark, M. & Hauser, P. C. (2012). *How deaf children learn*. New York, NY: Oxford University Press.

Marschark, M. & Hauser, P. C. (2008a). Cognitive underpinnings of learning by deaf and hard-of hearing students. In: M. Marschark & P. C. Hauser (Eds.), *Deaf cognition foundation and outcomes* (pp. 3-23). New York: Oxford University Press.

Marschark, M. & Hauser, P. C. (2008b). What we know and what we don't know about cognition and deaf learners. In: M. Marschark & P. C. Hauser (Eds.), *Deaf cognition foundation and outcomes* (pp. 439-458). New York: Oxford University Press.

Marschark, M. & Knoors, H. (2012). Educating deaf children: language, cognition, and learning. *Deafness & Education International, 14*(3), 136-160.

Marschark, M., Morris, C., Lukomski, J., Borgna, G., & Convertino, C. (2013). Are deaf students visual learners? *Learning and Individual Differences, 25*(June 2013), 165-162.

Marschark, M., Paivio, A., Spencer, L. J., Durkin, A., Borgna, G., Convertino, C., & Machmer, E. (2017). Don't assume deaf students are visual learners. *Journal of Developmental and Physical Disabilities, 29*(1), 153-171.

Marschark, M., Sarchet, T., & Trani, A. (2016). Effects of hearing status and sign language use on working memory. *Journal of Deaf Studies and Deaf Education, 21*(2), 148-155.

Marschark, M., Spencer, L., Durkin, A., Borgna, G., Convertino, C., Machmer, E., Kronenberger, W. G., & Trani, A. (2015). Understanding language, hearing status, and visual-spatial skills. *Journals of Deaf Studies and Deaf Education, 20*(4), 310-330.

Marschark, M. & Wauters, I. (2008). Language comprehension and learning by deaf students. In: M. Marschark & P.C. Hauser (Eds.) *Deaf cognition foundation and outcomes* (pp. 309-350). New York: Oxford University Press.

Marshall, C., Jones, A., Denmark, T., Mason, K., Atkinson, J., Botting, N., & Morgan, G. (2015). Deaf children's non-verbal working memory is impacted by their language experience. *Frontiers in Psychology*, *6*(*527*), 1-12.

McGrew, K. S. (2009). Cattell-horn-carroll (chc) broad and narrow cognitive ability definitions. Retrieved from http://www.iapsych.com/articles/chcdefs031109.pdf

McGrew, K. S. & Wendling, B., J. (2010). Cattell-horn-carroll cognitive-achievement relations: what we have learned from the past 20 years of research. *Psychology in the Schools, 4*(7), 651-675.

McKnight, M. E. & Culotta, V. P. (2012). Comparing neuropsychological profiles between girls with asperger's disorder and girls with learning disabilities. *Focus on Autism and Other Developmental Disabilities*, 27(4), 247-253.

Meisinger, R. F., Meisinger, E., Gregg, N., & Keith, T. (2012). An explanation of reading comprehension across development using models from cattell-horn-carroll theory: support for integrative models of reading. *Psychology in Schools, 49*(8), 725-743.

Miller, M. S., Thomas-Presswood, T. N., Metz, K., & Lukomski, J. (2015). *Psychological and psychoeducational assessment of deaf and hard of hearing children and adolescents.* Washington, D.C.: Gallaudet University Press.

Moores, D. F. (2001). *Educating the deaf psychology, principles, and practices*. NY: Houghton Mifflin Company.

Myklebust, H. R. (1948). Clinical psychology and children with impaired hearing, *Volta Review, 50*(90), 55-60, 90.

Neisser, U., Boodoo, G., Bouchard, T., Boykin, W., Brody, N., Ceci, S., Halpern, D., Loehlin, J., Perloff, R., Sternberg, R., & Urbina, S. (1996). Intelligence: knowns and unknowns. *American Psychologist, 51*(2), 77-101.

Newton, J. H. & McGrew, K. S. (2010). Introduction to the special issue: current research in cattell-horn-carroll-based assessment. *Psychology in the Schools, 47*(4), 621 634.

Ortiz, S. O. & Lella, S. A. (2004). Intellectual assessment and cognitive abilities: basics for parents and educators. In: A. Canter, L. Paige, M. Ruth, I. Romero, & S. Carrol (Eds.), *Helping children and home and school II: handouts for family and educators*. Bethesda, MD: National Association of School Psychologist.

Parasnis, I., Samar, V. J., Bettger, J. G., & Sathe, K. (1996). Does deafness lead to enhancement of visual spatial cognition in children? negative evidence from deaf nonsigners. *Journal of Deaf Studies and Deaf Education, 1*(2), 145-152.

Peterson, E. G. & Williams, J. M. (1930). Intelligence of deaf children as measured by drawings. *American Annuals of the Deaf. 75*(4), 273-290.

Pintner, R. (1923). *Intelligence testing methods and results*. New York, NY: Henry Holt and Company. Retrieved from: https://archive.org/stream/intelligencetest00rudo#page/n0/mode/2up

Pintner, R. & Lev, J. (1939). A study of the intelligence of the hard-of-hearing school child. *Journal of Genetic Psychology, 55*(1), 31-48.

Pintner, R. & Paterson, D. G. (1917). A comparison of deaf and hearing children in visual memory for digits. *Journal of Experimental Psychology, 2*(1), 76-88.

Pintner, R. & Paterson, D. G. (1915). The binet scale and the deaf child. *The Journal of Educational Psychology, 6*(4), 201-210.

Pisoni, D. B. & Cleary, M. (2003). Measures of working memory span and verbal rehearsal speed in deaf children after cochlear implants. *Ear & Hearing, 24*(1 Suppl), 106S-20S.

Pisoni, D. B., Conway, C. M., Kronenberger, W. G., Horn, D. L., Karpicke, J., & Henning, S. C. (2008). Efficacy and effectiveness of cochlear implants in deaf children. In: M. Marschark & P. C. Hauser (Eds.) *Deaf cognition foundation and outcomes* (pp. 52-101). New York: Oxford University Press.

Pohlman, C. (2008). *Revealing minds assessing to understand and support struggling learners*. San Francisco, CA: Jossey-Bass.

Qi, S. & Mitchell, R. E. (2012). Large-scale academic achievement testing of deaf and hard-of hearing students: past, present, and future. *Journal of Deaf Studies and Deaf Education, 17*(1), 1-18.

Reeseman, J. H., Day, L. A., Szymanski, C. A., Hughes-Wheatland, R., Witkin, G. A., Kalback, S. R., & Brice, P. J. (2014). Review of intellectual assessment measures for children who are deaf or hard of hearing. *Rehabilitation Psychology, 59*(1), 99-106.

Remine, M. D., Brown, P. M., Care, E., & Rickards, F. (2007). The relationship between spoken language ability and intelligence test performance of deaf children and adolescents. *Deafness and Education International, 9*(3), 147-164.

Rosenstein, J. (1961). Perception, cognition and language in deaf children. *Exceptional Children*, *27*(5), 276-284.

Sattler, J. M. (2008). *Assessment of children cognitive foundations*. San Diego, California: Jerome M. Sattler, Publishing, Inc.

Schneider, W. J. & McGrew, K. S. (2012). The cattell-horn-carroll model of intelligence.

In Flanagan, D. P. & Harrison, P. L. (Eds.), *Contemporary intellectual assessment: theories, test, and issues, third edition* (pp. 3-55). New York, NY: The Guilford Press.

Sipal, R. F. & Bayhan P. (2011). Do deaf children delay in their executive functioning due to their delayed language abilities? *Psychology, 2*(7), 737-742.

Spearman, C. (1927). *The abilities of man their nature and measurement*. London: Macmillan and Co. Limited. Retrieved from: https://archive.org/details/abilitiesofman031969mbp

Takahashi, N., Isaka, Y., Yamamoto, T., & Nakamura, T. (2017). Vocabulary and grammar differences between deaf and hearing students. *Journal of Deaf Studies and Deaf Education, 22*(1), 88-104.

Texas Education Agency, 19 Texas Administrative Code § 89.1040 (2007). Retrieved from: https://framework.esc18.net/display/Webforms/ESC18-FW-Summary.aspx?FID=134&DT=G&LID=en

Thagard, E. K., Hilsmier, A. S., Easterbrooks, S. R., (2011). Pragmatic language in deaf and hard of hearing students: correlation with success in general education. *American Annals of the Deaf, 155*(5), 526-534.

Thaler, N. S., Bello, D. T., & Etcoff, L. M. (2012). Wisc-iv profiles are associated with differences in symptomatology and outcome in children with adhd. *Journal of Attention Disorders, 17*(4), 291-301.

Thurstone, L. L. (1938). *Primary mental abilities*. Chicago: University of Chicago Press.

Vernon, M. (2005). 10th anniversary classics fifty years of research on the intelligence of deaf and hard-of-hearing children: a review of literature and discussion of implications. *The Journal of Deaf Studies and Deaf Education*, *10*(3), 225-231.

Vernon, M. (1972). Language development relationships to cognition, affectivity and intelligence. *The Canadian Psychologist*, *13*(4), 360-374.

Wasserman, J. (2012). A history of intelligence assessment: the unfinished tapestry. In Flanagan, D. P. & Harrison, P. L. (Eds.), *Contemporary intellectual assessment: theories, test, and issues, third edition* (pp. 3-55). New York, NY: The Guilford Press.

Wasserman, J. & Tulsky, D. (2005). A history of intelligence assessment. In Flanagan, D. & Harrison, P. (Eds.), *Contemporary intellectual assessment: theories, test, and issues, second edition* (pp. 3-22). New York, NY: The Guilford Press.

Watkins, M. W. (2003). Iq subtest analysis: clinical acumen or clinical illusion? *The Scientific Review of Mental Health Practice, 2*(2), 118-141.

Wechsler, D. (2014). *Wisc-iv intelligence scale for children-fifth edition technical and interpretive manual*. Bloomington, MN: Pearson, Inc.

Wechsler, D. (1939). *The measurement of adult intelligence*. Baltimore: Williams & Wilkins. Retrieved from: https://archive.org/details/measurementofadu001469mbp

Wechsler, D., Doppelt, J. E., & Lennon, R. T. (1975). A conversation with david wechsler (unpublished transcript of interview). San Antonio, TX: The Psychological Corporation.

Weiss, L. G., Keith, T. Z., Zhu, J., & Chen, H. (2013). Wais-iv and clinical validation of the four- and five- factor interpretative approaches. *Journal of Psychoeducational Assessment. 31*(2), 94-113.

Winzer, M. (1993). *The history of special education: from isolation to integration, first edition.* Washington, D.C.: Gallaudet University Press.

Wood, N. & Dockrell, J. (2010). Psychological assessment procedures for assessing deaf or hard-of-hearing children. *Educational and Child Psychology*. *27*(2), 11-22.

APPENDIX A

FEDERAL DETERMINATION OF DEAFNESS AND HEARING IMPAIRMENT

34 Code of Federal Regulations § 300.8 Child with a disability.

. . .
© *Definitions of disability terms*. The terms used in this definition of a child with a disability are defined as follows:

. . .

(3) *Deafness* means a hearing impairment that is so severe that the child is impaired in processing linguistic information through hearing, with or without amplification, that adversely affects a child's educational performance.

. . .

Last Amended: 82 FR 31912, July 11, 2017
Entered: July 24, 2017

34 Code of Federal Regulations § 300.8 Child with a disability.

. . .
© *Definitions of disability terms*. The terms used in this definition of a child with a disability are defined as follows:

. . .

(5) *Hearing impairment* means an impairment in hearing, whether permanent or fluctuating, that adversely affects a child's educational performance but that is not included under the definition of deafness in this section.

. . .

Last Amended: 82 FR 31912, July 11, 2017
Entered: July 24, 2017

SOURCE: The Legal Framework for Child-Centered Special Education Process retrieved from: https://framework.esc18.net/display/Webforms/ESC18-FW-Summary.aspx?FID=134&DT=G&LID=en

APPENDIX B

TEXAS STATE DETERMINATION OF AUDITORY IMPAIRMENT

19 Texas Administrative Code § 89.1040. Eligibility Criteria.

. . .

©Eligibility definitions.

. . .

(3) Auditory impairment. A student with an auditory impairment is one who has been determined to meet the criteria for deafness as stated in 34 CFR, §300.8©(3), or for hearing impairment as stated in 34 CFR, §300.8©(5). The evaluation data reviewed by the multidisciplinary team in connection with the determination of a student's eligibility based on an auditory impairment must include an 117ntological examination performed by an otolaryngologist or by a licensed medical doctor, with documentation that an otolaryngologist is not reasonably available, and an audiological evaluation performed by a licensed audiologist. The evaluation data must include a description of the implications of the hearing loss for the student's hearing in a variety of circumstances with or without recommended amplification.

. . .

Last Amended: February 15, 2018, 43 TexReg 763
Entered: March 5, 2018

SOURCE: The Legal Framework for Child-Centered Special Education Process retrieved from: https://framework.esc18.net/display/Webforms/ESC18-FW-Summary.aspx?FID=134&DT=G&LID=en

APPENDIX C

CATTELL-HORN-CARROLL (CHC) BROAD AND NARROW COGNITIVE ABILITY DEFINITIONS

A complete list of broad and narrow cognitive ability definitions. The broad and narrow abilities used in this study are bolded.

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

(3rd draft; 3-11-09; Kevin McGrew)

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. Inductive and deductive reasoning are generally considered the hallmark indicators of Gf. Gf has been linked to cognitive complexity which is typically defined as the greater use of a wide and diverse array of elementary cognitive processes during performance. Historically is often referred to as fluid intelligence.

General Sequential (deductive) Reasoning (RG): Ability to start with stated assertions (rules, premises, or conditions) and to engage in one or more steps leading to a problem solution. The processes are deductive as evidenced in the ability to reason and draw conclusions from given general conditions or premises to the specific. Often known as hypothetico-deductive reasoning.

Induction (I): Ability to discover the underlying characteristic (e.g., rule, concept, principle, process, trend, class membership) that underlies a specific problem or a set of observations, or to apply a previously learned rule to the problem. Reasoning from specific cases or observations to general rules or broad generalizations. Often requires the ability to combine separate pieces of information in the formation of inferences, rules, hypotheses, or conclusions.

Quantitative Reasoning (RQ): Ability to inductively (I) and/or deductively (RG) reason with concepts involving mathematical relations and properties.

Piagetian Reasoning (RP): Ability to demonstrate the acquisition and application (in the form of logical thinking) of cognitive concepts as defined by Piaget's developmental cognitive theory. These concepts include seriation (organizing material into an orderly series that facilitates understanding of relations between events), conservation (awareness that physical quantities do not change in amount when altered in appearance), classification (ability to organize materials that possess similar characteristics into categories), etc.

Speed of Reasoning (RE): Speed or fluency in performing reasoning tasks (e.g., quickness in generating as many possible rules, solutions, etc., to a problem) in a limited time. Also listed under Gs.

Comprehension-Knowledge (Gc): The knowledge of the culture that is incorporated by individuals I a process of acculturation. Gc is typically described as 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. Gc is primarily a store of verbal or language-based declarative (knowing what) and procedural (knowing how) knowledge acquired through the investment of other abilities during formal and informal educational and general life experiences. Historically is often referred to as crystallized intelligence.

Language Development (LD): General development or understanding and application of words, sentences, and paragraphs (not requiring reading) in spoken native language skills to express or communicate a thought or feeling.

Lexical Knowledge (VL): Extent of vocabulary (nouns, verbs, or adjectives) that can be understood in terms of correct word (semantic) meanings. Although evidence indicates that vocabulary knowledge is a separable component from LD, it is often difficult to disentangle these two highly connected and corrected abilities in research studies.

Listening Ability (LS): Ability to listen and understand the meaning of oral communications (spoken words, phrases, sentences, and paragraphs). The ability to receive and understand spoken information. CHC broad and narrow cognitive ability definitions "working draft" 3-11-09; Kevin McGrew

General (verbal) Information (K0): Range of general stored knowledge (primarily verbal).

Information about Culture (K2): Range of stored general cultural knowledge (e.g., music, art, literature).

Communication Ability (CM): Ability to speak in "real life" situations (e.g., conversation, lecture, group participation) in a manner that transmits ideas, thoughts, or feelings to one or more individuals.

Oral Production and Fluency (OP): More specific or narrow oral communication skills than reflected by CM. Poorly defined by current research.

Grammatical Sensitivity (MY): Knowledge or awareness of the distinctive features and structural principles of a native language that allows for the construction of words (morphology) and sentences (syntax). Not the skill in applying this knowledge.

Foreign Language Proficiency (KL): Similar to Language Development but for a foreign language.

Foreign Language Aptitude (LA): Rate and ease of learning a new language.

General (domain-specific) knowledge (Gkn): The breadth, depth and mastery of a person's acquired knowledge in a specialized (demarcated) subject matter or discipline domains that typically do not represent the general universal experiences of individuals in a culture (Gc). Gkn reflects deep specialized knowledge domains developed through intensive systematic practice and training (over an extended period of time) and the maintenance of the knowledge base through regular practice and motivated effort (a.k.a., expertise).

Knowledge of English a Second Language (KE): Degree of knowledge of English as a second language.

Knowledge of Signing (KF): Knowledge of finger-spelling and signing (e.g., ASL) used in communication with the deaf or hard of hearing.

Skill in Lip-reading (LP): Competence in ability to understand communication from others by watching the movement of their mouths and expressions (lip reading). Also known as speech reading.

Geography Achievement (A5): Range of geography knowledge (e.g., capitals of countries).

General Science Information (K1): Range of stored scientific knowledge (e.g., biology, physics, engineering, mechanics, electronics).

Mechanical Knowledge (MK): Knowledge about the function, terminology and operation of ordinary tools, machines, and equipment. Since these factors were identified in research prior to the information/technology explosion, it is unknown if this ability generalizes to the use of modern technology (e.g., faxes, computers, internet).

Knowledge of Behavioral Content (BC): Knowledge or sensitivity to nonverbal human communication/interaction systems (beyond understanding sounds and words; e.g., facial expressions and gestures) that communicate feelings, emotions, and intentions, most likely in a culturally patterned style.

Visual Processing (Gv): The ability to generate, store, retrieve, and transform visual images and sensations. Gv abilities are typically measured by tasks (viz., figural or geometric stimuli) that require the perception and transformation of visual shapes, forms, or images and/or tasks that require maintaining spatial orientation with regard to objects that may change or move through space.

> **Visualization** (Vz): The ability to apprehend a spatial form, object, or scene and match it with another spatial object, form, or scene with the requirement to rotate it (one or more times) in two or three dimensions. Requires the ability to mentally imagine, manipulate or transform objects or visual patterns (without regard to speed of responding) and to "see" (predict) how they would appear under altered conditions (e.g., parts are moved or rearranged). Differs from Spatial Relations (SR) primarily by a deemphasis on fluency.
>
> Spatial Relations (SR): Ability to rapidly perceive and manipulate (mental rotation, transformations, reflection, etc.) visual patterns or to maintain orientation with respect to objects in space. SR may require the identification of an object when viewed from different angles or positions.
>
> Closure Speed (CS): Ability to quickly identify a familiar meaningful visual object from incomplete (e.g., vague, partially obscured, disconnected) visual stimuli, without knowing in advance what the object is. The target object is assumed to be represented in the person's long-term memory store. The ability to "fill in" unseen or missing parts in a disparate perceptual field and form a single percept.
>
> Flexibility of Closure (CF): Ability to identify a visual figure or pattern embedded in a complex distracting or disguised visual pattern or array, when knowing in advance what the pattern is. Recognition of, yet the ability to ignore, distracting background stimuli is part of the ability.
>
> Visual Memory (MV): Ability to form and store a mental representation or image of a visual shape or configuration (typically during a brief study period), over at least a few seconds, and then recognize or recall it later (during the test phase).
>
> Spatial Scanning (SS): Ability to quickly and accurately survey (visually explore) a wide or complicated spatial field or pattern and identify a particular configuration (path) through the visual field. Usually requires visually following the indicated route or path through the visual field.

Serial Perceptual Integration (PI): Ability to identify (and typically name) a pictorial or visual pattern when parts of the pattern are presented rapidly in serial order (e.g., portions of a line drawing of a dog are passed in sequence through a small “window”).

Length Estimation (LE): Ability to accurately estimate or compare visual lengths or distances without the aid of measurement instruments. Perceptual Illusions (IL): The ability to resist being affected by the illusory perceptual aspects of geometric figures (i.e., not forming a mistaken perception in response to some characteristic of the stimuli). May best be thought of as a person’s “response tendency” to resist perceptual illusions.

Perceptual Alternations (PN): Consistency in the rate of alternating between different visual perceptions.

Imagery (IM): Ability to mentally depict (encode) and/or manipulate an object, idea, event or impression (that is not present) in the form of an abstract spatial form. Separate IM level and rate (fluency) factors have been suggested.

Auditory Processing (Ga): Abilities that depend on sound as input and on the functioning of our hearing apparatus. A key characteristic is the extent an individual can cognitively control (i.e., handle the competition between signal and noise) the perception of auditory information. The Ga domain circumscribes a wide range of abilities involved in the interpretation and organization of sounds, such as discriminating patterns in sounds and musical structure (often under background noise and/or distorting conditions) and the ability to analyze, manipulate, comprehend and synthesize sound elements, groups of sounds, or sound patterns.

Phonetic Coding (PC): Ability to code, process, and be sensitive to nuances in phonemic information (speech sounds) in short-term memory. Includes the ability to identify, isolate, blend, or transform sounds of speech. Frequently referred to as phonological or phonemic awareness.

Speech Sound Discrimination (US): Ability to detect and discriminate differences in phonemes or speech sounds under conditions of little or no distraction or distortion.

Resistance to Auditory Stimulus Distortion (UR): Ability to overcome the effects of distortion or distraction when listening to and understanding speech and language. It is often difficult to separate UR from US in research studies.

Memory for Sound Patterns (UM): Ability to retain (on a short-term basis) auditory events such as tones, tonal patterns, and voices.

General Sound Discrimination (U3): Ability to discriminate tones, tone patterns, or musical materials with regard to their fundamental attributes (i.e., pitch, intensity, duration, and rhythm).

Temporal Tracking (UK): Ability to mentally track auditory temporal (sequential) events so as to be able to count, anticipate or rearrange them (e.g., reorder a set of musical tones). According to Stankov (2000), UK may represent the first recognition of the ability (Stankov & Horn, 1980) that is now interpreted as working memory (MW).

Musical Discrimination and Judgment (U1 U9): Ability to discriminate and judge tonal patterns in music with respect to melodic, harmonic, and expressive aspects (phrasing, tempo, harmonic complexity, intensity variations).

Maintaining and Judging Rhythm (U8): Ability to recognize and maintain a musical beat.

Sound-Intensity/Duration Discrimination (U6): Ability to discriminate sound intensities and to be sensitive to the temporal/rhythmic aspects of tonal patterns.

Sound-Frequency Discrimination (U5): Ability to discriminate frequency attributes (pitch and timbre) of tones.

Hearing and Speech Threshold Factors (UA UT UU): Ability to hear pitch and varying sound frequencies.

Absolute Pitch (UP): Ability to perfectly identify the pitch of tones.

Sound Localization (UL): Ability to localize heard sounds in space.

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). A limited-capacity system that loses information quickly through the decay of memory traces, unless an individual activates other cognitive resources to maintain the information in immediate awareness.

Memory Span (MS): Ability to attend to, register, and immediately recall (after only one presentation) temporally ordered elements and then reproduce the series of elements in correct order.

Working Memory (MW): Ability to temporarily store and perform a set of cognitive operations on information that requires divided attention and the management of the limited capacity resources of shortterm memory. Is largely recognized to be the mind's "scratchpad" and consists of up to four subcomponents. The phonological or articulatory loop processes auditory-linguistic information while the visuo-spatial sketch/scratchpad is the temporary buffer for visually processed information. The central executive mechanism coordinates and manages the activities and processes in working memory. The most recent component added to the model is the episodic buffer. Recent research (see McGrew, 2005) suggests that MW is not of the same nature as the other 60+ narrow factor-based trait-like individual difference constructs included in this table. MW is a theoretically developed construct (proposed to explain memory findings from experimental research) and not a label for an individual-differences type factor. MW is retained in the current CHC taxonomy table as a reminder of the importance of this construct in understanding new learning and performance of complex cognitive tasks (see McGrew, 2005).

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. Memory consolidation and retrieval can be measured in terms of information stored for minutes, hours, weeks, or longer. Some Glr narrow abilities have been prominent in creativity research (e.g., production, ideational fluency, or associative fluency).

Associative Memory (MA): Ability to recall one part of a previously learned but unrelated pair of items (that may or may not be meaningfully linked) when the other part is presented (e.g., paired-associative learning).

Meaningful Memory (MM): Ability to note, retain, and recall information (set of items or ideas) where there is a meaningful relation between the bits of information, the information comprises a meaningful story or connected discourse, or the information relates to existing contents of memory.

Free Recall Memory (M6): Ability to recall (without associations) as many unrelated items as possible, in any order, after a large collection of items is presented (each item presented singly). Requires the ability to encode a "superspan collection of material" (Carroll, 1993, p. 277) that cannot be kept active in short-term or working memory.

Ideational Fluency (FI): Ability to rapidly produce a series of ideas, words, or phrases related to a specific condition or object. Quantity, not quality or response originality is emphasized. The ability to think of a large number of different responses when a prescribed task requires the generation of numerous responses. The ability to call up ideas.

Associational Fluency (FA): A highly specific ability to rapidly produce a series of words or phrases associated in meaning (semantically associated; or some other common semantic property) when given a word or concept with a restricted area of meaning. In contrast to

Ideational Fluency (FI), quality rather quantity of production is emphasized.

Expressional Fluency (FE): Ability to rapidly think of and organize words or phrases into meaningful complex ideas under general or more specific cued conditions. Requires the production of connected discourse in contrast to the production of isolated words (e.g., FA FW). Differs from FI in the requirement to rephrase given ideas rather than generating new ideas. The ability to produce different ways of saying much the same thing.

Naming Facility (NA): Ability to rapidly produce accepted names for concepts or things when presented with the thing itself or a picture of it (or cued in some other appropriate way). The naming responses must be in an individual's long-term memory store (i.e., objects or things to be named have names that are very familiar to the individual). In contemporary reading research this ability is called rapid automatic naming (RAN).

Word Fluency (FW): Ability to rapidly produce isolated words that have specific phonemic, structural, or orthographic characteristics (independent of word meanings). Has been mentioned as possibly being related to the "tip-of-the-tongue" phenomenon (e.g., word finding difficulties) (Carroll, 1993). One of the first fluency abilities identified (Eckstrom et al., 1979).

Figural Fluency (FF): Ability to rapidly draw or sketch as many things (or elaborations) as possible when presented with a non-meaningful visual stimulus (e.g., set of unique visual elements). Quantity is emphasized over quality or uniqueness.

Figural Flexibility (FX): Ability to rapidly change set and try-out a variety of approaches to solutions for figural problems that have several stated criteria. Fluency in successfully dealing with figural tasks that require a variety of problem solving approaches.

Sensitivity to Problems (SP): Ability to rapidly think of a number of alternative solutions to practical problems (e.g., what can people do to stay healthy?). More broadly may be considered the "ability to imagine problems associated with function or change of function of objects and to suggest ways to deal with these problems" Royce (1973). Requires the recognition of the existence of a problem.

Creativity (FO): Ability to rapidly produce unusual, original, clever, divergent, or uncommon responses (expressions, interpretations) to a given topic, situation, or task. The ability to invent unique solutions to problems or to develop innovative methods for situations where a standard operating procedure does not apply. Following a new and unique path to a problem solution. FO differs from FI in that FO focuses on the quality of creative responses while FI focuses on an individual's ability to think of a large number of different responses. Learning Abilities (L1): General learning ability rate. Poorly defined by existing research.

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

Perceptual Speed (P): Ability to rapidly and accurately search, compare (for visual similarities or differences) and identify visual elements presented side-by-side or separated in a visual field. Recent research (Ackerman et al., 2002; Ackerman & Cianciolo, 2000; Ackerman & Kanfer, 1993; see McGrew, 2005) suggests P may be an intermediate stratum ability (between narrow and broad) defined by four narrow sub-abilities: (1) Pattern Recognition (Ppr)—the ability to quickly recognize simple visual patterns; (2) Scanning (Ps)—ability to scan, compare, and look up visual stimuli; (3) Memory (Pm)—ability to perform visual perceptual speed tasks that place significant demands on immediate short-term memory, and (d) Complex (Pc)—ability to perform visual pattern recognition tasks that impose additional cognitive demands such as spatial visualization, estimating and interpolating, and heightened memory span loads.

Rate-of-Test-Taking (R9): Ability to rapidly perform tests which are relatively easy or over-learned (require very simple decisions). This ability is not associated with any particular type of test content or stimuli. May be similar to a higher-order "psychometric time" factor (Roberts & Stankov, 1998; Stankov, CHC broad and narrow cognitive ability definitions "working draft" 3-11-09; Kevin McGrew 2000). Recent research has suggested that R9 may better be classified as an intermediate (between narrow and broad strata) ability that subsumes most all psychometric speeded measures (see McGrew, 2005).

Number Facility (N): Ability to rapidly perform basic arithmetic (i.e., add, subtract, multiply, divide) and accurately manipulate numbers quickly. N does not involve understanding or organizing mathematical problems and is not a major component of mathematical/quantitative reasoning or higher mathematical skills.

Speed of Reasoning (RE): Speed or fluency in performing reasoning tasks (e.g., quickness in generating as many possible rules, solutions, etc., to a problem) in a limited time. Also listed under Gf.

Reading Speed (fluency) (RS): Ability to silently read and comprehend connected text (e.g., a series of short sentences; a passage) rapidly and automatically (with little conscious attention to the mechanics of reading). Also listed under Grw.

Writing Speed (fluency) (WS): Ability to correctly copy words or sentences repeatedly, or writing words, sentences, or paragraphs, as quickly as possible. Also listed under Grw and Gps.

Reaction and Decision Speed (Gt): The ability to make elementary decisions and/or responses (simple reaction time) or one of several elementary decisions and/or responses (complex reaction time) at the onset of simple stimuli. Gt is typically measured by chronometric measures of reaction and inspection time.

Simple Reaction Time (R1): Reaction time (in milliseconds) to the onset of a single stimulus (visual or auditory) that is presented at a particular point of time. R1 frequently is divided into the phases of decision time (DT; the time to decide to make a response and the finger leaves a home button) and movement time (MT; the time to move finger from the home button to another button where the response is physically made and recorded).

Choice Reaction Time (R2): Reaction time (in milliseconds) to the onset of one of two or more alternative stimuli, depending on which alternative is signaled. Similar to R1, can be decomposed into DT and MT. A frequently used experimental method for measuring R2 is the Hick paradigm.

Semantic Processing Speed (R4): Reaction time (in milliseconds) when a decision requires some encoding and mental manipulation of the stimulus content.

Mental Comparison Speed (R7): Reaction time (in milliseconds) where stimuli must be compared for a particular characteristic or attribute.

Inspection Time (IT): The ability to quickly (in milliseconds) detect change or discriminate between alternatives in a very briefly displayed stimulus (e.g., two different sized vertical lines joined horizontally across the top).

Psychomotor Speed (Gps): The ability to rapidly and fluently perform physical body motor movements (e.g., movement of fingers, hands, legs, etc.) largely independent of cognitive control.

Speed of Limb Movement (R3): The ability to make rapid specific or discrete motor movements of the arms or legs (measured after the movement is initiated). Accuracy is not important.

Writing Speed (fluency) (WS): The ability to copy correctly words or sentences repeatedly, or writing words, sentences, or paragraphs, as quickly as possible. Also listed under Grw and Gps.

Speed of Articulation (PT): Ability to rapidly perform successive articulations with the speech musculature.

Movement Time (MT): Recent research (see summaries by Deary, 2003; Nettelbeck, 2003; also see McGrew, 2005) suggests MT may be an intermediate stratum ability (between narrow and broad strata) that represents the second phase of reaction time as measured by various elementary cognitive tasks (ECTs). The time taken to physically move a body part (e.g., a finger) to make the required response is movement time (MT). MT may also measure the speed of finger, limb, or multi-limb movements or vocal articulation (diadochokinesis; Greek for "successive movements") (Carroll, 1993; Stankov, 2000) and is also listed under Gt.

Quantitative Knowledge (Gq): The breadth and depth of a person's acquired store of declarative and procedural quantitative or numerical knowledge. Gq is largely acquired through the investment of other abilities primarily during formal educational experiences. Gq represents an individual's store of acquired mathematical knowledge, not reasoning with this knowledge. Factor analysis research has been limited in this domain and other Gq narrow abilities most likely exist (e.g., dimensions of early number sense or literacy).

Mathematical Knowledge (KM): Range of general knowledge about mathematics. Not the performance of mathematical operations or the solving of math problems.

Mathematical Achievement (A3): Measured (tested) mathematics achievement.

Reading and Writing (Grw): The breadth and depth of a person's acquired store of declarative and procedural reading and writing skills and knowledge. Grw includes both basic skills (e.g., reading and spelling of single words) and the ability to read and write complex connected discourse (e.g., reading comprehension and the ability to write a story).

Reading Decoding (RD): Ability to recognize and decode words or pseudowords in reading using a number of sub-abilities (e.g., grapheme encoding, perceiving multi-letter units, and phonemic contrasts, etc.)

Reading Comprehension (RC): Ability to attain meaning (comprehend and understand) connected discourse during reading.

Verbal (printed) Language Comprehension (V): General development, or the understanding of words, sentences, and paragraphs in native language, as measured by reading vocabulary and reading comprehension tests. Does not involve writing, listening to, or understanding spoken information.

Cloze Ability (CZ): Ability to read and supply missing words (that have been systematically deleted) from prose passages. Correct answers can only be supplied if the person understands (comprehends) the meaning of the passage.

Spelling Ability (SG): Ability to form words with the correct letters in accepted order (spelling).

Writing Ability (WA): Ability to communicate information and ideas in written form so that others can understand (with clarity of thought, organization, and good sentence structure). Is a broad ability that involves a number of other writing sub-skills (e.g., knowledge of grammar, the meaning of words, and how to organize sentences or paragraphs).

English Usage Knowledge (EU): Knowledge of the "mechanics" (capitalization, punctuation, usage, and spelling) of written and spoken English language discourse.

Reading Speed (fluency) (RS): Ability to silently read and comprehend connected text (e.g., a series of short sentences; a passage) rapidly and automatically (with little conscious attention to the mechanics of reading). Also listed under Gs.

Writing Speed (fluency) (WS): Ability to copy words or sentences repeatedly, or writing words, sentences, or paragraphs, as quickly as possible. Also listed under Gs and Gps.

Psychomotor Abilities (Gp): The ability to perform physical body motor movements (e.g., movement of fingers, hands, legs, etc) with precision, coordination, or strength. Movement or motor behaviors are typically the result of mental activity.

Static Strength (P3): The ability to exert muscular force to move (push, lift, pull) a relatively heavy or immobile object.

Multilimb Coordination (P6): The ability to make quick specific or discrete motor movements of the arms or legs (measured after the movement is initiated). Accuracy is not relevant.

Finger Dexterity (P2): The ability to make precisely coordinated movements of the fingers (with or without the manipulation of objects).

Manual Dexterity (P1): Ability to make precisely coordinated movements of a hand, or a hand and the attached arm.

Arm-hand Steadiness (P7): The ability to precisely and skillfully coordinate arm-hand positioning in space.

Control Precision (P8): The ability to exert precise control over muscle movements, typically in response to environmental feedback (e.g., changes in speed or position of object being manipulated).

Aiming (AI): The ability to precisely and fluently execute a sequence of eye-hand coordination movements for positioning purposes.

Gross Body Equilibrium (P4): The ability to maintain the body in an upright position in space or regain balance after balance has been disturbed.

Olfactory Abilities (Go): Abilities that depend on sensory receptors of the main olfactory system (nasal chambers). The cognitive and perceptual aspects of this domain have not yet been widely investigated.

Olfactory Memory (OM): Memory for odors (smells).

Olfactory Sensitivity (OS): Sensitivity to different odors (smells).

Tactile Abilities (Gh): Abilities involved in the perception and judging of sensations that are received through tactile (touch) sensory receptors. Includes abilities involved in the judgment of thermal stimulation, spatial stimulation, or patterns imposed on the skin. The cognitive and perceptual aspects of this domain have not yet been widely investigated.

> Tactile Sensitivity (TS): The ability to detect and make fine discriminations of pressure on the surface of the skin.

Kinesthetic abilities (Gk): Abilities that depend on sensory receptors that detect bodily position, weight, or movement of the muscles, tendons, and joints. Abilities involved in the process of controlling and coordinating body movements, including walking, talking, facial expressions, gestures and posture. The cognitive and perceptual aspects of this domain have not yet been widely investigated.

> Kinesthetic Sensitivity (KS): The ability to detect, or be aware, of movements of the body or body parts, including the movement of upper body limbs (arms) and the ability to recognize a path the body previously explored without the aid visual input (blindfolded)

(McGrew, 2009).

APPENDIX D.

TEST FRAMEWORK

Test Framework Secondary (Wechsler, 2014, p.22)

Verbal Comprehension	**Visual Spatial**	**Fluid Reasoning**	**Working Memory**	**Processing Speed**
Similarities	*Block Design*	*Matrix Reasoning*	*Digit Span*	*Coding*
Vocabulary	*Visual Puzzles*	Figure Weights	Picture Span	Symbol Search
*Information			*Letter-Number Sequencing	*Cancelation
*Comprehension		*Picture Concepts		
		*Arithmetic		

Italicized notes Primary subtests for FSIQ
*notes Secondary subtests

Full Scale

Primary Index Scales

Verbal Comprehension	**Visual Spatial**	**Fluid Reasoning**	**Working Memory**	**Processing Speed**
Similarities	*Block Design*	*Matrix Reasoning*	*Digit Span*	*Coding*
Vocabulary	*Visual Puzzles*		Picture Span	Symbol Search

Ancillary Index Scale

Quantitative Reasoning	**Auditory Working Memory**	**Nonverbal**	**General Ability**	**Cognitive Proficiency**
Figure Weights	Digit Span	Block Design	Similarities	Digit Span
Arithmetic	Letter-Number Sequencing	Visual Puzzles	Vocabulary	Picture Span
		Matrix Reasoning	Block Design	Coding
		Figure Weights	Matrix Reasoning	Symbol Search
		Picture Span	Figure Weights	
		Coding		

Complementary Index Scales

Naming Speed	**Symbol Translation**	**Storage and Retrieval**

Naming Speed Literacy Naming Speed Quantity	Immediate Symbol Translation Delayed Symbol Translation Recognition Symbol Translation	Naming Speed Index Symbol Translation Index

APPENDIX E

SUBTEST ABBREVIATIONS, SCORE TYPES, AND CATEGORIES

Subtest Abbreviations, Score Types, and Categories (Wechsler 2014, p. 15)

Subtest	Abbreviation	Score Type	Category
Block Design	BD	Scaled	Primary (FSIQ)
Similarities	SI	Scaled	Primary (FSIQ)
Matrix Reasoning	MR	Scaled	Primary (FSIQ)
Digit Span	DS	Scaled	Primary (FSIQ)
Coding	CD	Scaled	Primary (FSIQ)
Vocabulary	VO	Scaled	Primary (FSIQ)
Figure Weights	FW	Scaled	Primary (FSIQ)
Visual Puzzles	VP	Scaled	Primary
Picture Span	PS	Scaled	Primary
Symbol Search	SS	Scaled	Primary
Information	IN	Scaled	Secondary
Picture Concepts	PC	Scaled	Secondary
Letter-Number Sequencing	LN	Scaled	Secondary
Cancellation	CA	Scaled	Secondary
Comprehension	CO	Scaled	Secondary
Arithmetic	AR	Scaled	Secondary
Naming Speed Literacy	NSL	Standard	Complementary
Naming Speed Quantity	NSQ	Standard	Complementary
Immediate Symbol Translation	IST	Standard	Complementary
Delayed Symbol Translation	DST	Standard	Complementary
Recognition Symbol Translation	RST	Standard	Complementary

APPENDIX F

PRIMARY INDEX SCALES CORRELATION TO CHC BROAD AND NARROW ABILITIES

Primary Index Scales correlation to CHC broad and narrow abilities

WISC-V Indexes and Subtests	**CHC Broad and Narrow Abilities**
Verbal Comprehension Index	Crystalized Intelligence (Gc)
Similarities	Lexical Knowledge (VL)
Vocabulary	Lexical Knowledge (VL)
Visual Spatial Index	Visual Processing (GV)
Block Design	Visualization (VZ)
Visual Puzzles	Visualization (VZ)
Fluid Reasoning Index	Fluid Intelligence (Gf)
Matrix Reasoning	Induction (I)
Figure Weights	General Sequencing Reasoning (RG)
Working Memory Index	Short-Term Memory (Gsm)
Digit Span	Working Memory Capacity (MW)
Picture Span	Memory Span (MS)
Processing Speed Index	Processing Speed (Gs)
Coding	Rate of Test Taking (R9)
Symbol Search	Perceptual Speed (P)

APPENDIX G

SUBTEST AND COMPOSITE SCORE APPROPRIATENESS RATING AND MODIFICATION CONSIDERATIONS FOR CHILDREN WHO ARE DEAR OR HARD OF HEARING, BY MODE OF COMMUNICATION

Subtest and Composite Score Appropriateness Rating and Modification Considerations for Children Who are Deaf or Hard of Hearing, by Mode of Communication (Day et al., 2015)

Subtest/Composite	**Oral**	**Total Communication**
Similarities	5	2M
Vocabulary	5	2M
Block Design	6T	6T
Visual Puzzles	6T	6T
Matrix Reasoning	6	6
Figure Weights	6T	6T
Digit Span	5M	3M
Picture Span	6	6
Coding	6T	6T
Symbol Search	6T	6T
Verbal Comprehension Index	5	2M
Visual Spatial Index	6T	6T
Fluid Reasoning Index	6T	6T
Working Memory Index	5M	3M
Processing Speed Index	6T	6T
Full Scale IQ	5M	2M
Nonverbal Index	6	6

Note 2 = Administration is possible but problematic and interpretation may be difficult
3 = Administration is possible but interpretation may be difficult
5 = Administration is possible with caveats due to pronunciation/auditory detection demands on the child
6 = Administration is possible with little to no modification
M = Modification by modality may alter the task demand or introduce construct irrelevant variance
T = Timed nature may affect performance and interpretation

* Only the test and modes of communication that were used for this study are presented.

APPENDIX H

LETTER FROM INSTITUTIONAL REVIEW BOARD (IRB) – DENTON

Institutional Review Board
Office of Research and Sponsored Programs
P.O. Box 425619, Denton, TX 76204-5619
940-898-3378
email: IRB@twu.edu
http://www.twu.edu/irb.html

DATE: April 6, 2017

TO: Ms. Leah Arrington
Teacher Education

FROM: Institutional Review Board (IRB) - Denton

Re: Exemption for An Investigation of the Cognitive Profile of Deaf and Hard of Hearing Students on the Wechsler Intelligence Scale for Children-Fifth Edition (Protocol #: 19519)

The above referenced study has been reviewed by the TWU IRB (operating under FWA00000178) and was determined to be exempt from further review.

If applicable, agency approval letters must be submitted to the IRB upon receipt PRIOR to any data collection at that agency. Because a signed consent form is not required for exempt studies, the filing of signatures of participants with the TWU IRB is not necessary.

Although your protocol has been exempted from further IRB review and your protocol file has been closed, any modifications to this study must be submitted for review to the IRB using the Modification Request Form. Additionally, the IRB must be notified immediately of any adverse events or unanticipated problems. All forms are located on the IRB website. If you have any questions, please contact the TWU IRB.

cc. Dr. Gina Anderson, Teacher Education
Dr. Jane Pemberton, Teacher Education
Graduate School

APPENDIX I

DATA COLLECTION SHEET

20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	ID#
																			Gender
																			Age
																			Grade
																			Type of Hearing Loss
																			Hearing Loss
																			Bilateral?
																			Type of amplification right
																			Type of amplification left
																			Mode of Communication
																			FSIQ
																			Nonverbal
																			Gc
																			Gv
																			Gf
																			Gsm
																			Gs
																			Similarities
																			Vocabulary
																			Block Design
																			Visual Puzzles
																			Matrix Reasoning
																			Figure Weights
																			Digit Span
																			Picture Span
																			Coding
																			Symbol Search