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An Analysis of Vision-Based Subtests' Impact on Subtest Scores of the Wechsler Intelligence Scale for Children on Students with Cortical/Cerebral Visual Impairment

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AN ANALYSIS OF VISION-BASED SUBTESTS' IMPACT ON SUBTEST SCORES OF THE WECHSLER INTELLIGENCE SCALE FOR CHILDREN ON STUDENTS WITH CORTICAL/ CEREBRAL VISUAL IMPAIRMENT

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ABSTRACT

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It has been widely recognized that a visual impairment can limit an individual's ability to learn through visual observations. This decreased limited visual access which could impact how the skills to access and recognize the world around them develop. However, when the visual impairment was brain-based, such as in Cortical/Cerebral Visual Impairment (CVI), was that impact the same? For students with CVI, the top pediatric visual impairment in developed countries, the brain's processing and recognition of what the eyes took in was affected (Kran et al., 2019; Merabet et al., 2017; Ong et al., 2023). Cortical/Cerebral Visual Impairment could not be quantified through visual acuity or visual fields like an ocular visual impairment. For individuals diagnosed with CVI, the manifestations were a spectrum that transcended 16 visual behaviors. How these visual behaviors manifested for an individual with CVI affected their visual attention and visual recognition, resulting in struggles to access print materials or images across environments. However, when these students were educationally evaluated through standardized cognitive assessments, there was no way to filter out the impact of CVI on their cognitive abilities (Lund et al., 2014). Like many other cognitive assessments, the Wechsler Intelligence Scale for Children-Fifth Edition (WISC-V) relied on individuals' visual recognition of the presented visual stimuli (Wechsler, 2014a). The WISC-V used scaled subtests and index scores, with visual-based and timed subtests woven throughout.

The visual-based subtests were not uniform in their visual presentation. The visual information students were asked to engage with had varying visual demands and complexity levels. All of the timed subtests were visual-based subtests as well. If those visual-based subtests were removed and scored separately, would this present a different cognitive profile of the student? This study used comparative statistical analyses to understand the mean scale scores of the WISC-V evaluations of students diagnosed with CVI, peers with ocular conditions, and controls from the WISC-V normative sample. This study used four targeted research questions focused on visual access, visual media, complexity levels and timed demands to investigate the impact CVI may have on the scores of the visual-based and timed subtests as a whole and the varying levels of visual demands. It was found that, within the CVI group, visual- and picture-based subtests were statistically significant. Additionally, when comparing CVI participants to peers with ocular visual impairments, visual-based, picture-based, and timed and untimed subtests were statistically significant. These findings echoed recent CVI research findings, while bringing additional questions regarding the impact of timed subtests and symbol based subtests.

Keywords: Cortical/Cerebral Visual Impairment, CVI, Visual Impairment, Form Accessibility, WISC-V

DEDICATION

To my parents, William and Wendy Cantillon. None of this would be possible without their love, dedication to special education, support, and guidance. Thank you for teaching me to always take my time and check my work because I don't have to be the first one done.

To the heart of my work: my students, past, present, and future. May there come a day when you never have to change to fit the world's way.

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LIST OF ACRONYMS

APH:	American Printing House for the Blind
CVI:	Cortical/Cerebral Visual Impairment
ECC:	Expanded Core Curriculum
FAPE:	Free Appropriate Public Education
FVE:	Functional Vision Evaluation
IDEA:	Individuals with Disabilities Education Act
LRE:	Least Restrictive Environment
NEI:	National Eye Institute
NIH:	National Institutions of Health
NLP:	No Light Perception
ONH:	Optic Nerve Hypoplasia
OSEP:	U.S. Department of Education Office of Special Education and Rehabilitation Services' Office of Special Education Programs
OSERS:	U.S. Department of Education Office of Special Education and Rehabilitation Services
SES:	Socio-economic Statues
TVI:	Teacher of the Visually Impaired
WHO:	World Health Organization
WISC:	The Wechsler Intelligence Scale for Children
WISC-V:	The Wechsler Intelligence Scale for Children-Fifth Edition

CHAPTER I

INTRODUCTION

Due to an estimated diagnosis rate of less than 20% of all potentially affected individuals in the U.S., Cortical/Cerebral Visual Impairment (CVI) has been coined the hidden epidemic (McKinsey & Company, 2023; National Eye Institute [NEI], 2021). Cortical/Cerebral Visual Impairment (CVI) has no unique insurance code and has not been codified in the International Classification of Disease-10 (ICD-10) code. However, it has been estimated to effect at least 180,000 individuals in the U.S. (Kran et al., 2019; McKinsey & Company, 2023; National Eye Institute, 2021). The significance of this current reality has transcended multiple fields and disciplines and has been, fundamentally, a crisis of equitable educational access for students with CVI. The educational impact of CVI has not been limited to reduced visual access to materials but instead reduced access to the school experience as a whole. There has been no set of accommodations appropriate for all students with CVI to ensure their educational access. All students with CVI have been affected differently; there has been no standard outcome for CVI.

Cortical/Cerebral Visual Impairment is a brain-based visual impairment that disrupts how the brain processes the visual information the eyes take in and is not related to acuity or ocular health but stems from many related causes, epidemiology, and comorbidities (Merabet et al., 2017). Cortical/Cerebral Visual Impairment can affect an individual’s visual attention and visual recognition, which can translate to challenges in accessing almost all visual information (Atkinson, 2017; Das et al., 2007; Steendam, 2015). Brain-based visual impairments were first brought to light by Holmes's (1918) study of lesions to the visual cortex from World War I war injuries. Since then, CVI's presence on global and national blindness and visual impairment prevalence lists has ebbed and flowed based on year, location, and a nation's economic status (Benezra & Chirambo, 1977; Good et al., 2001; Jan et al., 1987). For example, the England and Wales 12-year blindness epidemiology study from 1948-1959 did not mention any CVI-related terms (Blindness in England and Wales, 1966). However, in the 1968 England and Wales epidemiology, visual dysfunctions and cerebral dysfunction impairments were mentioned (Henderson, 1968). Since the 1990s, the estimated prevalence of CVI has been seen consistently on blindness and visual impairment prevalence lists of nations with high economic status (Jan et al., 1987).

With the rise of CVI globally, the American Printing House for the Blind (APH) in 2008 brought together a group of CVI researchers to help provide consistency in the field related to the educational and vision services of students with CVI (Roman et al., 2008). This advisory group stressed that CVI has a spectrum of severity, but that severity level should not discount the individual with CVI as being classified as visually impaired. Nor should the severity of CVI or additional disabilities diminish the student's access to necessary services (Roman et al., 2008). Following this advisory, the APH changed its definition of blindness (American Printing House for the Blind [APH], n.d.; Kran et al., 2019; U.S. Department of Education Office of Special Education and Rehabilitative Services, 2017). The change brought about an expanded definition of functioning at the level of blindness category (APH, n.d.; Kran et al., 2019). Functioning at the level of blindness refers to a child's demised visual access compared to peers of the same age, resulting in visual functioning being that of an individual with legal blindness due to a brain-based injury, impairment, or dysfunction. However, legal definitions of blindness differ between nations, government institutions, and industries (APH, n.d.; Individuals with Disabilities Education Act [IDEA], 2004; National Federation for the Blind, 2022; Social Security Administration, 2022). Historically, in the U.S., the inclusion of functional legal blindness to represent the varying levels of visual access for individuals with CVI has been missing. The wide range of suspected causes and comorbidities of CVI has resulted in individual-specific manifestations of CVI impacting an individual's visual access. None of these differences should discredit individuals with CVI from access to vision services or exclusion from resources due to wavering legal definitions. The combination of American Printing House for the Blind's (APH) 2008 advisory group on educational services for students with CVI and their 2010 guidance on what a functionally legally blind category has underscored the long-standing need to provide educational accommodations and services to individuals whose visual access has been affected by brain-based visual impairments like CVI.

In recent years, research has focused on CVI's causes and related comorbidities. These studies have given insight into the estimated CVI population and prevalence. However, these have been just that, estimations. Like any area, getting an accurate prevalence rate has been nearly impossible. Many contributing factors have created challenges in estimating the CVI population: no ICD-10 code, no universal health care in the U.S., and no uniform diagnostic measures (Bennett et al., 2019; Teoh et al., 2021). McKinsey & Company (2023) estimated that at least 180,000 individuals in the U.S. have CVI. Again, that has only been an estimate. An east-coast school for students with blindness or visual impairments has estimated that, of its on-campus student population of 178, around 50% have a CVI diagnosis. (Perkins School for the Blind, n.d.-a). Cortical/Cerebral Visual Impairment has been reported as the top diagnosis for students enrolled at schools for students with blindness or visual impairments globally (Kong et al., 2012; Ong et al., 2023). But what about the prevalence of CVI in student populations outside of schools for blind students?

Students who are blind or visually impaired have no longer been limited to receiving educational services at schools for students with blindness or visual impairments (Act to Promote the Education of the Blind, 1879). According to the American Printing House for the Blind (APH, 2022), the majority of students who were blind or visually impaired attended public school and received vision services under the Individuals with Disabilities Education Act (IDEA, 2004). In the U.S., an estimated 85% of students with blindness or visual impairments have attended public schools, and 8% have attended schools for blind students, with 55,711 registered with APH (2022). Comparatively, there has been an estimated 5,000 Teachers of Students with Visual Impairments (TVIs) in the U.S., averaging a 1:11 TVI-to-student ratio from the student population registered with APH (Savaiano et al., 2022). Teachers of the Visually Impaired have provided the necessary educational services as determined through the special education evaluation process (IDEA, 2004; U.S. Department of Education, 2000). A TVI has had the responsibility and role to work with the student and educational team on vision-related skills, determine the appropriate accommodations, and access media for the student through specialized assessments to ensure the development of skills to learn, participate, and succeed in school and beyond (Olmstead, 2005). There have been multiple ways and models that TVI services may be provided. A TVI may work for one school, a whole district, or even a state (Olmstead, 2005). Other models have included agencies or schools for blind students that contract out services to districts that may not have a high enough prevalence of visual impairments among their student population to warrant hiring their own TVI (Olmstead, 2005). For example, an east-coast school for blind students advertised that it provided itinerant TVI vision services for students with visual impairments in public and specialized school systems. This itinerant TVI model highlighted that its services over 500 school-age students in 112 districts across New England, and the prevalence of CVI among the students serviced by this model was not fully understood (Perkins School for the Blind, n.d.-b).

The unknown prevalence of the student population with CVI can be attributed to multiple compounding factors such as various TVI service models, a low diagnosis rate, or no national registry (McKinsey & Company, 2023; Ong et al., 2023; Savaiano et al., 2022). By including a population analysis of participants in this study, a better understanding of the prevalence of CVI could be achieved. Through the target population, students with CVI, this study may uncover an estimate of the prevalence of students with CVI in public schools in the U.S. through demographic analysis. This may help agencies, schools, and medical professionals understand the need for educational services and resources for students with CVI.

A common goal of TVIs has been to help improve the lives and educational experiences of students diagnosed with or suspected to have CVI. Many changes could be made in the educational environment to help achieve this goal, starting with students' special education evaluations. Under the IDEA (2004), the evaluation process to identify the potential educational abilities of a student has been reliant on data-based assessments that were reliable and valid and tailored to the student's specific areas of educational need. This could be interpreted as the need for valid and standardized assessments that consider the access that a student with a visual impairment had to the test material (Lund et al., 2014). Unfortunately, as a collective disability group, visual impairment has been regarded as a low-incidence disability, and thus, CVI has represented a smaller subset of this relatively larger group. Only a small portion of special education evaluation and assessment materials have made accommodations for individuals with vision loss (APH, 2023). These accommodations have often been limited to two options: large print or Braille. However, even with those accommodations, the validity, reliability, or access of the standardized materials has not been examined outside of functional vision assessment (FVA) materials used to evaluate a student's use of functional vision (Lund et al., 2014; Williams et al., 2003).

The standardization, reliability, and validity of evaluation materials for the population of individuals with visual impairments has been a much broader issue that may require legislative guidance to ensure uniform changes. However, until then, methods to interpret the special education evaluation results of individuals with visual impairments, specific to their unique methods of access, should be researched. For students with CVI, accommodations to ensure an accessible education go beyond just an enlarged font size. The access needs have been much broader and individualized. Nevertheless, special education evaluation assessments have been used nationwide, presumably weekly or even daily, with little understanding of how accessible they were for individuals with CVI. It has been a disservice to students with CVI to subject them to inaccessible evaluations with results that did not represent their educational needs. Special education evaluation results should be presented in a manner that helps the team better understand how the student with CVI was accessing the world around them.

Too often, I have sat at evaluation meetings for students diagnosed or suspected to have CVI, where the special educational evaluation results from educational disciplines presented were too complex and could not be translated into the student's day-to-day life. The Wechsler Intelligence Scale for Children-Fifth Edition (WISC-V) has been a commonly used cognitive assessment designed to assess the students' skills related to the construct of intelligence or cognitive development (see Figure 1). Though, as standardized assessments, it must be given in the designed standardized manner. If and when the evaluator could not follow the standardization, the changes must be identified in the results. Thus, the results must be presented cautiously while conveying that the results may not be valid or reliable due to the changes. Unfortunately, too often, when the results were presented to a student with CVI's potential educational team, they were sometimes followed with phrases such as "We must take these with a grain of salt," "It does not give us the whole picture there," or "There are many more factors to consider." It could be disheartening to think a student participated in an extensive evaluation process, yet we were not fully able to take the results and ensure their access to educational materials in a way that matched their learning style. However, what if there was a way to look at the WISC-V results that could provide an understanding of a student diagnosed with CVI's abilities when the visual component was removed? This study aimed to be the first of its kind to analyze the visual demand levels of the WISC-V have on the subtest scores for students with CVI.

Figure 1

Wechsler Intelligence Scale for Children-Fifth Edition Indexes and Subtests

Note. The figure above is a self-created representation of the various combinations of indexes and subtests that comprise the WISC-V. There are four color-coded scales. Under the title of each index scale, the indexes are depicted by the same color as the title. Beneath those are the potential corresponding subtests. An administrator of the WISC-V only has to administer 10 of the subtests to get a Full Scale; the rest are optional. Adapted from Pearson (2018) and Wechsler (2014b).

Purpose of the Study

The purpose of this quantitative study was to use statistical analysis to compare the WISC-V scores of visual-based, picture-based, symbol-based and timed subtests along with the subtests' complexity levels between participants with CVI, OVI, and pre-existing data from a control group from the WISC-V Technical Manual (Wechsler, 2014c). The visual-based subtests were defined as WISC-V subtests comprised of and reliant on the visual recognition of testing materials. This study identified that 15 of the available 21 subtests of the WISC-V had visual demands and were deemed visual-based subtests (Block Design, Coding, Cancellation, Delayed Symbol Translation, Figure Weights, Immediate Symbol Translation, Matrix Reasoning, Naming Speed Literacy, Naming Speed Quantity, Picture Concepts, Picture Span, Recognition Symbol Translation, Symbol Search, Vocabulary, and Visual Puzzles; see Figure 2). The visual demands of the subtests were not uniform and required further categorization to help understand the visual demands on a student with CVI. The visual-based subtests were further divided into picture-based and symbol-based subtests (see Figure 3). These categories were then ranked by the level of complexity of the visual stimuli within the subtests (see Figure 4). For example, the Vocabulary subtest only relied on access to one image, which had reduced visual complexity. In contrast, Picture Span had a higher level of visual complexity due to its presentation of rows of images. The scores of timed subtests were also analyzed; of the potential 21 subtests, 8 were timed. All of the eight timed responses were visual-dependent (see Figure 5). The dependent variable, the WISC-V scores, had also been analyzed by being recorded by a certified or licensed psychologist trained in administering the WISC-V.

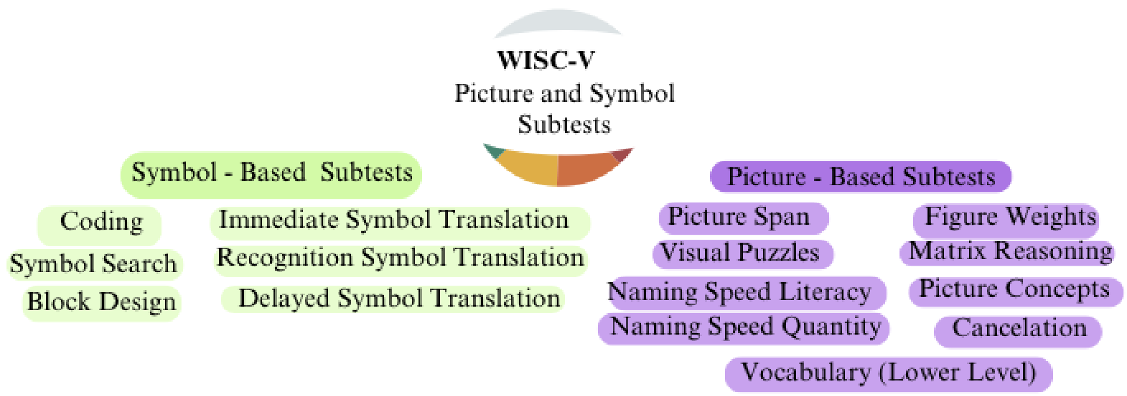
Figure 2

Wechsler Intelligence Scale for Children-Fifth Edition Indexes, Subtests with Visual Demands

Note. The visual above is the same self-created representation of the various combinations of subtests within the scales and indexes, now including blue color coding of the visual-based subtests. Adapted from Pearson (2018) and Wechsler (2014a, 2014b).

Figure 3

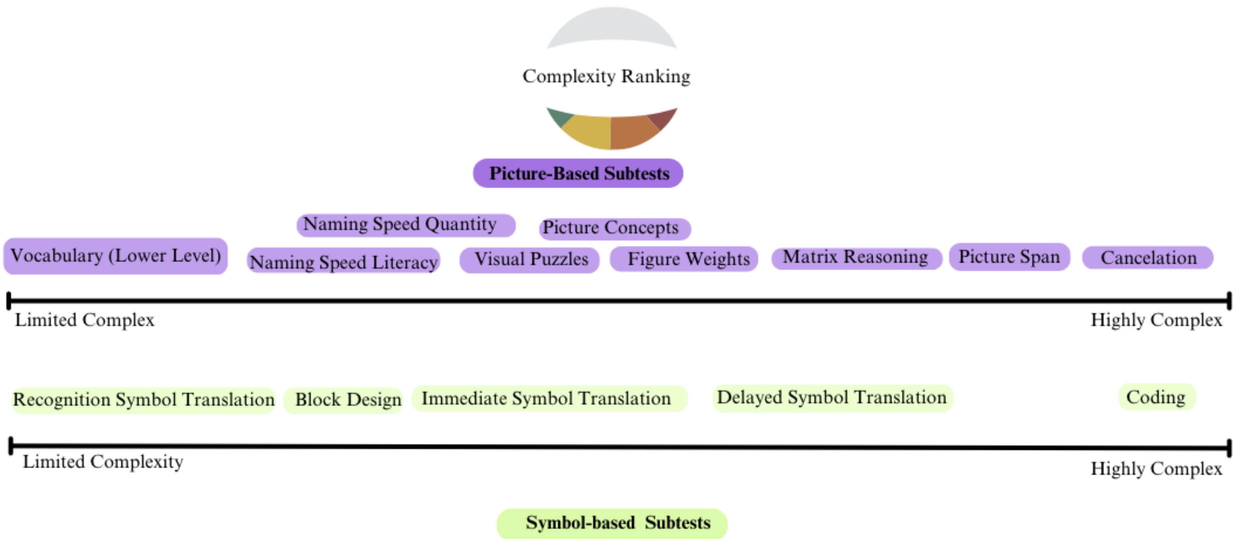
Picture- and Symbol-Based Subtests



Note. The figure shows all the available subtests of Wechsler Intelligence Scale for Children-Fifth Edition separated into two categories: low visual-based subtests in green on the left and visual-based subtests in purple on the right. Picture-based subtests were categorized following the Wechsler Intelligence Scale for Children-Fifth Edition identification of pictures and any subtest that used graphics resembling materials and items in the real world. Symbol-based subtests were identified as Wechsler Intelligence Scale for Children-Fifth Edition, categorized as symbols and visuals representing lines, letters, numbers, or basic shapes. Adapted from Pearson (2018) and Wechsler (2014a, 2014b).

Figure 4

Complexity Levels of Picture- and Symbol-Based Subtests



Note. The figure above shows the identified picture- and symbol-based subtests organized by the researcher's interpretation of their complexity levels. The average number of visual targets and colors on a page of the subtests of Wechsler Intelligence Scale for Children-Fifth Edition determines the complexity levels. Adapted from Pearson (2018) and Wechsler (2014a, 2014b).

Figure 5

Wechsler Intelligence Scale for Children-Fifth Edition and Timed Subtests

Note. The visual above is the same self-created representation of the various combinations of subtests within the scales and indexes, now including color coding of the timed subtests in brown. Adapted from Pearson (2018) and Wechsler (2014a, 2014b).

Figures 2, 3, 4, and 5 represent the subtests in the WISC-V and related visual and timed demands. Figure 2 looks at the full battery of subtests organized by corresponding index scales. It was noted that the complementary index scale was rarely used but was included in case study participants were given any of the subtests. In this representation, the vocabulary subtest was split into two as the younger age criteria did include three pictures to start the subtest. In contrast, the older range did not include those pictures. This study used self-created standards aligned with the WISC-V's identification of categories to determine if subtests had picture- or symbol visual demands. Six subtests were identified as symbol-based, and nine as picture-based (see Figure 3). This study also self-created the categories for the visual demand complexity levels of symbol- or picture-based subtests. Visual demand complexity was determined based on the number of visual stimuli presented for each task and the number of colors of the corresponding task (see Figure 4). Figure 5 follows the same presentation style seen in Figures 1 and 2. The WISC-V subtests were categorized into the corresponding index scale. The time-based subtests within each index scale was coded brown to depict the presence of timed subtests within each index.

Justification for the Study

Human eyes do not process what they see on their own. Information acquired through vision flows through more than 20 areas of the brain believed to be associated with visual processing, such as color, movement, size, or shape (Lueck & Dutton, 2015; Siu & Murphy, 2018). However, the delicate visual processing system can be disrupted by a brain bleed, oxygen deprivation, stroke, genetic conditions, and more, resulting in a brain-based visual impairment, such as CVI (Ong et al., 2023). The brain damage related to CVI, and visual processing dysfunction can be complex and poorly understood (Kran et al., 2019; Merabet et al., 2017). The impact manifestations related to CVI's visual processing have been categorized into visual behaviors (Baskin & Bennett, 2020; Dutton, 2015; Roman et al., 2008). Though defined separately, these visual behaviors have been intertwined in their influence on an individual with CVI's access to information. The understanding of CVI has been continually evolving; it has been consistently expressed that the manifestations of CVI and related visual behaviors were crucial to how individual learns and interact with their environment, including the visual materials of a cognitive assessment (Chokron & Dutton, 2023; Chokron et al., 2021; Roman et al., 2008).

For students with CVI, the manifestation of visual behaviors has decreased visual accessibility across all areas of their lives. Decreased visual accessibility has reduced incidental learning, affecting concept development and their ability to make inferences about the world and materials around them (Chokron & Dutton, 2023; Chokron et al., 2021; Lueck & Dutton, 2015). Even with the widely accepted understanding that CVI affected an individual's visual access, influence on the individual's development and access to the educational environment, CVI or any visual impairments have rarely been considered when standardizing educational evaluations (Williams et al., 2003). As a result of this lack of consideration, families/caretakers and educational teams have been left to piecemeal an interpretation of standardized special educational evaluation results. Standardized special educational evaluations have been the foundation for a child's special education evaluation (IDEA, 2004). Many student-appropriate standardized educational evaluations have been conducted to provide the educational team with the data needed to develop an appropriate individualized education program (IEP) for the student (IDEA, 2004). When a cognitive assessment has been proposed during the special education evaluation process, the certified school psychologist or licensed psychologist may have many assessment options, none of which have been standardized or validated for visual impairment or CVI (Groenveld & Jan, 1992; Pearson, 2018; Wechsler, 2014a)

One standardized assessment tool used during a special education evaluation to measure a child's intellectual abilities has been the WISC. First developed in 1949, the WISC is currently in its fifth edition (Wechsler, 1949, 2014a). The WISC-V is comprised of index scales that align with the different abilities that are most highly correlated with cognitive ability (e.g., Fluid Reasoning, Processing Speed, Verbal Comprehension, Visual Spatial, and Working Memory). Within these indices. There has been a variety of subtests that have been designed to measure different aspects of that broader ability. The Ancillary Index Scales have included Quantitative Reasoning Index, Auditory Working Memory Index, Nonverbal Index, General Utility Index, and Cognitive Proficiency Index. The Complementary Index Scale comprised the Naming Speed Index and Symbol Translation Index. However, the Complementary Scale subtests have infrequently been used during special education evaluations. The index scores have been comprised of scores from subtests; typically, each consisted of two subtests. The completion of 7 of the 10 core subtests has been used for a Full Scale IQ score. However, nine additional subtests could be substituted for a core subtest (Wechsler, 2014a, 2014b). There have been variations in what indexes and subtests a certified or licensed psychologist has chosen to administer for standardized scoring (Pearson, 2018). Many, 15 of the 21 available subtests, relied on a student's visual access and visual recognition of materials to participate in the assessment. In the Picture Span subtest, the student was presented with two or three rows of images and must select which visual stimuli went together (Wechsler, 2014a). For a student with CVI, their access to these visual-based subtests could differ from that of a sighted peer. For example, in the Picture Span subtest, the student with CVI may not recognize the image, there may be too many colors on the page, or the page's clutter may further effect the time and accuracy of the student's recognition of the visual stimuli. Evaluating a student's cognitive abilities using a test comprised of inaccessible methods could not accurately represent the student's ability.

This study did not seek to validate the use of the WISC-V for students with CVI. Instead, this study aimed to investigate if there was a relationship between CVI and scores of the visual-based and timed subtests of the WISC-V. By evaluating the visual-based subtests of the presented stimuli, pictures, or symbols and then further analyzing the complexity level of the subtests, the study sought to better understand potential correlations of stimuli and complexity levels on scores of students with CVI. If relationships existed, this may serve as a method to present a student with CVI's WISC-V results, delineating a student's abilities when visual access was not a factor.

Theoretical Framework

The ideology seen in constructivism was influential throughout this study. When considering equitable access to educational institutions for students who were blind, visually impaired, or diagnosed with CVI, the influence of experiences, engagement, and social opportunities could not be ignored. It was not enough for students who were blind, visually impaired, or who had CVI to be given the same special education evaluations as sighted peers with an accessibility clause. Individuals with CVI have had decreased opportunities to visually engage with their environment, directly affecting the student's ability to learn through observation (Chokron & Dutton, 2023; Chokron et al., 2021). Incidental learning or learning through observation of the visual world around them, has been one area in which all students with a visual impairment and CVI have had decreased opportunities (S. M. Kelly, 2019; S. W. Kelly, 2012;). Thus, students with CVI must be given increased opportunities to engage with materials directly and through lived experiences to help develop educational concepts. Efforts must be put forth to understand the educational benefits of special education evaluations. The study aimed to examine if there was a way to provide a more tailored look at a student with CVI's WISC-V results.

Study Overview

The study used a nonexperimental quantitative methodology, including the use of a statistical comparative design (Bell et al., 2020; Creswell & Creswell, 2018). This study occurred during University of Northern Colorado's Fall 2023, Winter 2024, and Spring 2024 semesters. Governing personnel and families of participants in this study were asked to provide the students' WISC-V scores, previously administered by a licensed or certified psychologist. The participants' evaluation report was analyzed through the comparison of three groups (participants diagnosed with CVI, with an ocular visual impairment, and the Control group WISC-V's normative data set; Wechsler, 2014c). The normative data set as a Control group were used for comparative statistical purposes. The Control group data set could not be changed or further analyzed, so there was a potential risk that these data included participants with CVI or an ocular visual impairment (OVI), which was not disclosed. The intent of the study was to analyze whether a statistical relationship existed between CVI and the individual's scores of vision-based subtest scores, as well as timed subtest scores on the WISC-V.

Identification of Variables

This study compared the statistical differences between three groups: the two independent participant groups, and a Control group of a data set. These two independent participant groups were: participants with CVI and participants with ocular visual impairments. These were compared against the Control group, the WISC-V normative data set (Wechsler, 2014c). The scores for these three groups were compared and analyzed by the vision-based and time-based subtests scores and the dependent variables of their respective WISC-V scores.

Research Questions and Hypotheses

Through statistical analysis, this study compared possible correlations of the WISC-V scores based on the subtest's visual demands for students diagnosed with CVI. When subtests within the scales and indexes were divided and analyzed by the visual demands of the subtest, was there a pattern amongst students with CVI? This study sought to investigate the potential statistical relationships between subtest scores of the WISC-V and individuals diagnosed with CVI. The WISC-V subtest scores were categorized by visual-based subtests, symbol-or picture-based media, media complexity levels, and timed requirements. By looking at the scores of vision-based and timed subtests in the WISC-V, this study sought to understand the role of the visual demands of the subtests had on the scores for individuals with visual impairments, including CVI. The statistical analysis of this study included the results of participants with ocular visual impairments and CVI, analyzed against the normative sample of the WISC-V (Wechsler, 2014c).

Research Questions

Q1 Do students diagnosed with CVI have lower cumulative vision-based subtest score than low-vision-based subtest score on the Wechsler Intelligence Scale for Children-Fifth Edition (WISC-V)?

Q2 Is there a significant difference between visual-based subtests that feature pictures vs symbols for students diagnosed with CVI's subtest scores on the Wechsler Intelligence Scale for Children-Fifth Edition (WISC-V)?

Q3 Does the complexity level within a specific visual media (picture or symbol) of a visual-based subtest have a correlation with a student diagnosed with CVI's subtest scores on the Wechsler Intelligence Scale for Children-Fifth Edition (WISC-V)?

Q4 Is there a significant difference between time-based subtests and untimed subtests for students diagnosed with CVI's subtest scores on the Wechsler Intelligence Scale for Children-Fifth Edition (WISC-V)?

Hypothesis

H1 The vision-based subtest scores significantly differ from low-vision-based subtests in the WISC-V for students with Cortical/Cerebral Visual Impairment.

H2 The symbol-based visual media subtest scores significantly differ from picture-based subtest scores in the WISC-V for students with Cortical/Cerebral Visual Impairment.

H3 The visual media subtest score significantly differs among the complexity levels of subtests in the WISC-V for students with Cortical/Cerebral Visual Impairment.

H4 The timed subtest scores significantly differ from un-timed subtests in the WISC-V for students with Cortical/Cerebral Visual Impairment.

Null Hypothesis

H01 There is no statistical significance in the visual-based and low-based subtest scores of the WISC-V for students with Cortical/Cerebral Visual Impairment.

H02 There is no statistical significance in the scores between picture- and symbol-based visual media sub-tests of the WISC-V for students with Cortical/Cerebral Visual Impairment.

H03 There is no statistical significance in the complexity levels among specific visual media subtest scores of the WISC-V for students with Cortical/Cerebral Visual Impairment.

H04 There is no statistical significance in the timed and untimed subtest scores of the WISC-V for students with Cortical/Cerebral Visual Impairment.

Definition of Terms

The following definitions were the operational definitions used within the study:

Age. Through the measurement of years and months, a child must have been between 6 and 16 and 11 months at the time of their WISC-V evaluation to be eligible for participation. If the child has not reached their 6th or has reached their 17th birthday, they were not included.

Caregivers. The term caregiver was in reference to an individual of legal adult age (> 18 years) who provided care to the child. This term was inclusive of all members of family units. It aimed to represent the multitude of individuals who may play a role in raising and caring for student participants outside of the educational environment.

Cortical/Cerebral Visual Impairment (CVI). The inclusion of both terms cortical and cerebral were included together in this study. Cortical/Cerebral Visual Impairment's history consisted of various terms that described the brain-based visual impairment not explained by ocular impairments. This study acknowledged and included related terms for CVI, including but not limited to cortical visual impairment, cerebral visual impairment, and cortical blindness. This study also followed the guidance of the National Institution of Health's (NIH) National Eye Institution (National Eye Institute, 2021) definition of the term CVI as "an umbrella term for subnormal visual function resulting from injury to vision processing centers, including higher-order association areas in the brain" (p. 63).

Cortical/Cerebral Visual Impairment (CVI) Evaluation. An evaluation that looked at how the related CVI visual behaviors affected the student's access to the environment and materials across multiple settings.

CVI Diagnosis. The term CVI diagnosis referred to the medical diagnosis an individual must have received prior to the study from a practicing licensed medical doctor, including but not limited to an eye care professional such as an ophthalmologist, pediatric ophthalmologist, neuro-ophthalmologist, or neurologist. The medical diagnosis could be defined and written in the diagnosis paperwork as cortical visual impairment, cerebral visual impairment, cortical/cerebral visual impairment, or cortical blindness, according to the definition of CVI above.

Expanded Core Curriculum (ECC) Screening. A screening that looked at how the students decreased visual access impacted their incidental learning opportunities across nine areas that a sighted peer would gain through observation and engagement in a visually accessible world.

Functional Vision Assessment (FVA). An analysis conducted by a teacher of the visually impaired to help a student's team better understand how students functionally used their vision compared to their clinical vision evaluation.

Functional Vision Evaluation (FVE). A functional vision evaluation is an educational evaluation conducted by a teacher of students with a visual impairment (TVI). This evaluation looked at how the student engaged with the educational environment due to potentially decreased visual access. This included how the child performed routine tasks in different places and with different materials throughout the day. An FVE could consist of a Function Vision Assessment (FVA), a Learning Media Assessment (LMA), and an Expanded Core Curriculum (ECC) Screening. A CVI evaluation should also be included for students diagnosed with or suspected to have CVI.

Learning Media Assessment (LMA). An assessment that gave the educational team an idea of how students used all their senses to engage with the environment and materials. It evaluated the use of their visual, auditory, and tactile sensory channels.

Low Visual-Based Subtest. The term low visual-based subtests referred to these subtests that were non-visual-based. However, low visual was used as a term to identify the test environment and the evaluation process was not free of visual stimuli. Even though a subtest may not be visual-based, the student may still be processing the administrator's facial expressions, the environment of the evaluation room, or other visual stimuli around them.

Ocular Visual Impairment. Participants of the ocular visual impairment group were to be diagnosed with an ocular visual impairment by a practicing and licensed medical professional. The term ocular visual impairment included but was not limited to reduced visual acuity, reduced visual fields, or a combination of co-occurring ocular impairments. Ocular visual impairment acuity was individuals with an acuity of 20/70 or worse with no brain-based visual impairment.

Picture-Based Subtest. Picture-based subtests were categorized following the WISC-V's identification of pictures and any subtest that used graphics resembling materials and items in the real world. There were eight subtests identified as picture-based.

Student. Using the WISC-V age criteria, a student was referencing an individual at the time of evaluation who were between 6 and 16 and 11 months years of age.

Subtest Complexity Level. The criteria to determine a subtest's level of complexity in this study was reliant on the amount of visual stimuli. The average number of visual targets and colors on a page of the WISC-V subtests determined this.

Specalized School. An educational setting that specializes in the education of students who are blind or visually impaired is identified as a Specalized school. How a student is admitted to the school, and the cost of attending varies between schools and states.

Symbol-Based Subtest. Symbol-based subtests were identified as WISC-V and categorized as symbols and visuals representing lines, letters, numbers, or basic shapes. There were six subtests identified as symbol-based.

Timed- Subtests. Of the potential 21 subtests of the WISC-V, 8 of them were identified as timed by the WISC-V. This meant that, when a subtest was administered, what the student completed in the predetermined amount of time were their results.

Visual Acuity. Normal visual acuity referred to an acuity of 20/20-20/40 in the United States.

Visual-Based Subtest. Visual-based subtest was a term that encompassed all subtests that required the student to visually access test materials to respond and engage with the subtest. Of the 21 WISC-V subtests, 14 have been identified in this study as visual-based subtests.

Visual Behaviors. Individuals with CVI may display or engage in behaviors due to decreased visual access. These were referred to as visual behaviors, the manifestations as a result of CVI and potentially impacted visual attention, and visual recognition of the world around them. The manifestations extended beyond visual attention and visual recognition; these were the foundation access points. The additional visual behaviors were presented in Chapter II which were the culmination of past research, including Foley (1987), Jan et al. (1987), Porro et al. (1998), Roman-Lantzy (2007, 2018), Lueck and Dutton (2015), and Baskin and Bennett (2020).

The Wechsler Intelligence Scale for Children-Fifth Edition (WISC-V). An individually administered cognitive ability assessment for children aged 6 to 16 and 11 months. Children's performance on a series of subtests and indexes were compared to those of same-aged peers (Wechsler, 2014a, 2014b).

WISC-V Evaluation Report. This study used the language of WISC-V evaluation report as an all-encompassing term. Students who were evaluated using the WISC-V may have had the evaluation done as part of a larger evaluation including but not limited to cognitive evaluation or psychological evaluation. The provided WISC-V evaluation report may be part of that larger evaluation. The crucial portion was the evaluation sub-test scores, index scores, when available the Full Scale IQ scores and evaluator notes.

Researcher's Assumptions

It was assumed, prior to the execution of this study, that students with CVI would have a statistically significant difference in scores on the visual-based subtests of the WISC-V than the low-vision-based subtests. It was assumed that there would be a statistically significant difference in the scores of picture-based or symbol-based visual subtests. It was also believed that the complexity levels of a given visual media subtest would be statistically significant. When the visual demands of a subtest were looked at, a different student profile was assumed to be presented. This comparison method may provide a student with CVI's educational team a means to understand how visual processing impacts their engagement with the educational environment and how it differs when visual processing is not the primary access method.

Summary

This study intended to compare the possible statistical significance of the WISC-V scores based on a subtest's visual demands for students diagnosed with CVI. From the results of the intended statistical analysis, a discussion of the struggle to understand the effect visual access has had on a cognitive assessment score by families and educational teams of students with CVI could be had. The WISC-V has been a widely used and accepted evaluation tool that has helped educational teams provide a student-first, data-based educational program. To better understand the prevalence of CVI in public and specialized schools, this study included an analysis of the prevalence of CVI amongst participants as part of the demographic results section. The results of the study's population analysis not only provided critical region-specific prevalence data but also helped to understand the educational needs of students with CVI. The start of meeting a student's educational needs could stem from better understanding the results of their cognitive assessments as part of their special educational evaluations. In that case, this study could serve as a catalyst to accelerate the availability of the necessary resources to meet the students' CVI needs. By investigating the statistical relationship of the visual demands within the visual-based subtest scores of students with CVI on the WISC-V, the aim was to provide a supplemental view of the results. Depending on the statistical relationship findings between the scores, educational teams may be able to have a new discussion; what if we looked at the results with the visual demand level in mind?

CHAPTER II

REVIEW OF LITERATURE

A Constructivism Framework

To construct one's thoughts, beliefs, and understandings, an individual must experience and interact with the world (Crotty, 1998). However, what if those experiences and interactions were not visually accessible to an individual? Can they still make sense of the world around them to create meaning? This study argued yes. Following the constructivism philosophy, an individual with decreased visual access to the environment could not only create meaning through experiences and interactions, but these were the essential access methods when visual access was unavailable.

In the field of visual impairments, incidental learning has been defined as learning through visual observations, and often, students with a visual impairment, including CVI, had decreased incidental learning opportunities (Allman & Lewis, 2014). Reduced visual access and decreased incidental learning opportunities for a student with CVI resulted in decreased causal learning from the visual world around them (S. M. Kelly, 2019; S. W. Kelly, 2012). To accommodate for reduced incidental learning opportunities, targeted methodologies helped bring the world to students with CVI, such as the Cambourne model of immersion, demonstration, and engagement (Allman & Lewis, 2014; Cambourne, 1995; IRIS Center, 2022). The Cambourne model stressed that students with a visual impairment must be given opportunities equivalent to a sighted peer's incidental learning opportunities (Allman & Lewis, 2014; Cambourne, 1995). It was only when a student who was visually impaired was interested and engaged with learning materials could meaning be created (Allman & Lewis, 2014; Cambourne, 1995). The Cambourne model's use of immersion, demonstration, and engagement has been grounded in the constructivist theory that individuals created their own knowledge through experiences; they did not simply receive it (Cambourne, 1995; Crotty, 1998; Sweeney, 2012).

Cambourne (1995) was not the first model that related constructivism to the learning experiences of individuals who were blind or visually impaired. Vygotsky's revolution of the educational lenses stressed that individuals with disabilities were humans who deserved equal access (Gindis, 1995). Vygotsky's constructivist learning theories promoted access to socialization, appropriate materials, and methods to enhance access, all crucial for cognitive development (Sweeney, 2012; Vygotsky, 1983). Vygotsky argued that not all learners with vision loss needed braille, but they needed other sensory inputs to help elicit development (Gindis, 1995; Vygotsky, 1983). This sentiment was true for individuals with CVI, who may also require various access methods to learn and develop (Chokron et al., 2021).

Under the theory of constructivism, is it even equitable to use vision-based special education evaluations on students who had not had the same educational experience as sighted peers? A student with CVI, or any visual impairment, has had decreased incidental learning opportunities (Allman & Lewis, 2014). Unlike their sighted peers, they could not always watch, observe, and learn from an adult cook in the kitchen, peers running around on the playground, a bird flying in the sky, or rain moving in the wind. As a result of their decreased incidental learning opportunities, they must be provided thoughtful and strategic opportunities to learn that same information in an accessible way through immersion, engagement, and demonstrations (Allman & Lewis, 2014; Cambourne, 1995; Chokron et al., 2021; Crotty, 1998). There were multiple examples of influential situations where a student with CVI may have experienced inequitable education, a CVI diagnosis later, reduced funding for assistive technology, or no access to a TVI. If a student with CVI could not access the visual world around them to form their own knowledge, who were we to evaluate them with the same hindering methodology?

Introduction to Visual Impairments

Fourteen million children and 2.2 billion individuals of all ages globally were estimated to be blind or visually impaired (Rahi & Gilbert., 2016; Solebo et al., 2017; World Health Organization [WHO], 2023). The prevalence and epidemiology of blindness and visual impairments have varied significantly across the globe due to a nation's economic status and infrastructure (Gilbert & Foster, 2001; WHO, 2023). When looking at the global prevalence data, countries with lower economic status have had higher incidences of cataracts, corneal opacity, and retinopathy of prematurity (Rahi & Gilbert, 2016; Solebo et al., 2017; Yekta et al., 2022; World Health Organization, 2023). Nations that fell into middle and high economic statuses have had high rates of CVI, Optic Nerve Hypoplasia, and inherited retinal disorders (Ong et al., 2023; Solebo et al., 2017). However, many of these epidemiology prevalence data studies were estimations due to challenges accessing all potentially impacted individuals. These challenges could be due to healthcare systems, infrastructure, and variations in the definitions of blindness and visual impairments.

Historically, nations with government-based health care systems have had consistent prevalence data on individuals with blindness or visual impairments, as seen in publications from England, the Netherlands, and Nordic countries (Blindness in England and Wales, 1966; Henderson, 1968; Loewer-Sieger, 1975). Every decade or so, these countries have published prevalence data related to blind and visually impaired individuals gathered from their country's health care systems. These publications highlighted the prevalence changes in ocular conditions from the 1940s, 1950s, and 1960s to the present (Blindness in England and Wales, 1966; Good et al., 2001; Henderson, 1968; Jan et al., 1987; Loewer-Sieger, 1975). Seen consistently through these prevalence publications was an increase in trauma-based impairments in the 1930s and 1940s, a decrease in cataract-based impairments from the 1940s through the 1960s, and an increase in macular degeneration during the 1940s-1970s (Blindness in England and Wales, 1966; Henderson, 1968; Loewer-Sieger, 1975). These publications saw no constant trends regarding the prevalence of glaucoma or diabetic retinopathy (Blindness in England and Wales, 1966; Henderson, 1968).

When thinking of the epidemiology related to blindness and visual impairments in the U.S. over time, there was no consistent historical data. In the U.S., the prevalence of visual impairments has been studied by multiple agencies and industries but lacked consistency. Prevalence data has come from a multitude of sources over the years, including APH, Babies Count (Snyder et al., 2022), The U.S. Department of Education's Office of Special Education and Rehabilitation Services (U.S. Department of Education OSERS), The Centers for Disease Control and Prevention (CDC), Cornell University's Disability Status Report, and the U.S. Census (Erickson et al., 2023). The American Printing House for the Blind (APH, 2022) published annual reports on the student and children population levels gathered from their personal registry. By November of each year, TVIs were to submit to their state's APH representative how many students they serviced and identified which students were diagnosed as medically legally blind or functionally legally blind (APH, n.d., 2022). Babies Count is short for the Babies Count National Registry of Children with Blindness or Visual Impairment aged birth to 36 months (Babies Count, n.d.; Snyder et al., 2022). Babies Count was founded in 1995 to better understand the prevalence and demographic makeup of the blind or visually impaired population in the U.S., aged birth to 36 months, through data from public and private agencies (Snyder et al., 2022). The U.S. Department of Education Office of Special Education and Rehabilitative Services' Office of Special Education Programs (2023) 44th Annual Report to Congress identified four sources of data: ED*Facts* Data Warehouse, Institute of Education Sciences, The U.S. Department of Education Office of Special Education and Rehabilitative Services' Office of Special Education Programs (OSEP) public documents, and the U.S. Census Bureau. The CDC gathered its data for estimations on people to be blind or visually impaired through results of the U.S. vision and eye health surveillance systems that then used the Bayesian mate regression statistical modeling (CDC, 2022; Flaxman et al., 2021; Lundeen et al., 2022). Cornell University's Yang-Tan Institute on Employment and Disability ran Disability Statistics using information gathered from the U.S. Census Bureau's American Community Survey (ACS), which used random sampling of more than 3.5 million American households (Erickson et al., 2023).

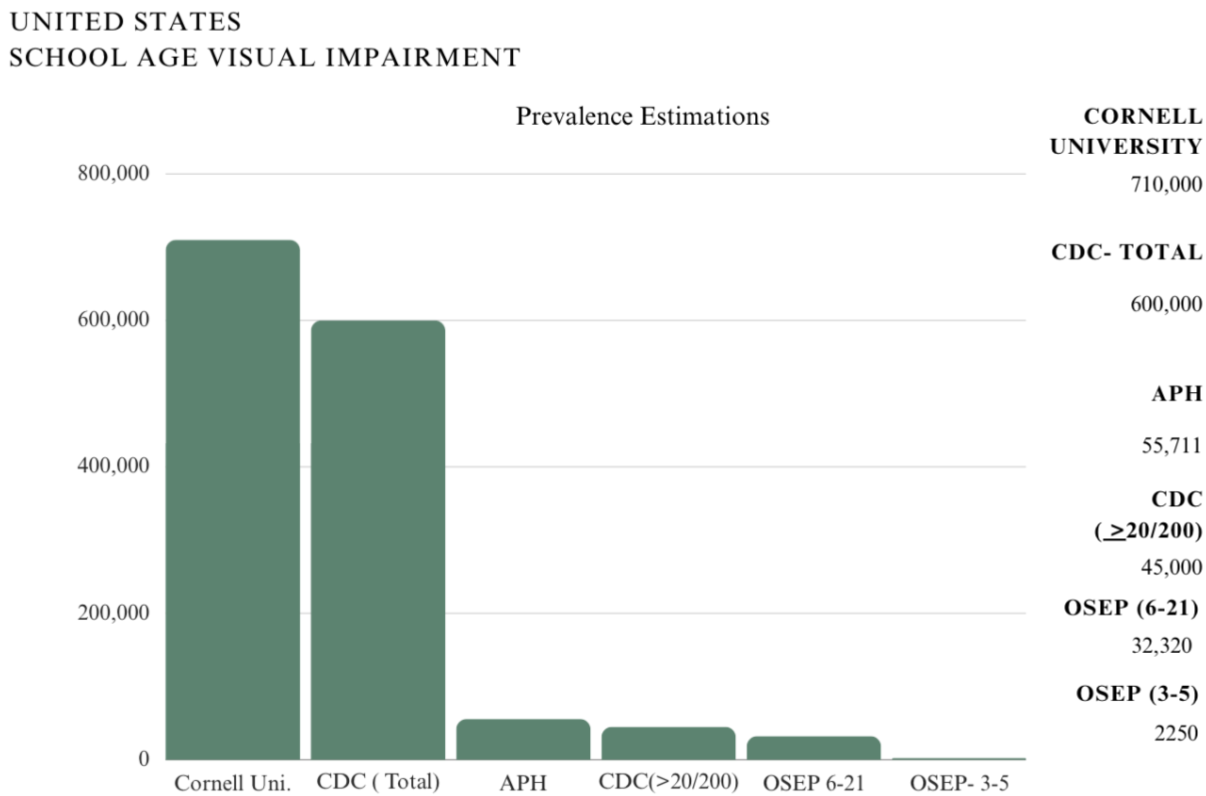
The most recent estimations have varied between reporting sources. The CDC estimated that, in the U.S., 600,000 or 6.8% of children aged birth to 17 years old had acuities 20/40 or worse, and of those, an estimated 45,000 or 3% had acuities 20/200 or worse (CDC, 2022; Flaxman et al., 2021; Lundeen et al., 2022). Cornell University estimated 710,000 students to have a visual impairment or blindness (Erickson et al., 2023). Yet only 55,711 students with visual impairments registered across all 50 states and territories of the United States were registered with APH in 2021-2022 (APH, 2022). In the U.S., 19 of the 50 states participated in 2022 Babies Count registry, of those 19 states, 755 children birth to 36 months were registered (Snyder et al., 2022). The U.S. Department of Education Office of Special Education and Rehabilitative Services' Office of Special Education Programs (2023), 44th Annual Report to

Congress identified in 2020, 750,313 children ages 3 through 5 and 6,464,088 students ages 6 through 21 were serviced under IDEA (2004). Of those, 0.3% of children 3-5 years old (~2250 children) and 0.5% of students 5-21 (~32,320 Students) under IDEA (2004) were identified as visually impaired.

The language and criteria used when running the models to gain prevalence data on the blind or visually impaired population were not always clear or consistent. There were drastic differences between the five reporting sources (see Figure 6). For example, the CDC and Cornell University's estimations differed by over 100,000 students with very different inclusion criteria. The CDC's criteria levels were visual acuities worse than 20/40 or worse than 20/200, whereas Cornell included severe difficulty seeing even with glasses as a visual disability (CDC, 2022; Erickson et al., 2023). These differed from the Individuals with Disabilities Education Act's (2004) and Social Security Administration's definitions of legal blindness. When we think of the prevalence of blindness and visual impairments, it could not be forgotten that students with CVI can have typical visual acuities and would not fall into either of these criteria (Kran et al., 2019; Merabet et al., 2017).

Figure 6

The United States School Age Visual Impairments



Note. This bar graph compared the prevalence estimates from the Centers for Disease Control and Prevention (2022), Erickson et al. (2023), U.S. Department of Education Office of Special Education and Rehabilitation Services' Office of Special Education Programs (2023), and APH (2022). These were used to showcase the differences between prevalence sources.

Even with these varying definitions and estimations, only 55,711 students were actively registered with APH. This was larger than the estimated 45,000 students with 20/200 or worse by the CDC. That may be because APH included medical and functional blindness definitions (APH, n.d., 2022). This meant that students with CVI, who had "typical" acuities, were not included as they did not have reliable visual access (Kran et al., 2019; Merabet et al., 2017). The

APH's registry was what dictated how much funding was allocated by the federal government to help support the education of students with a visual impairment through the Federal Quota Fund (Act to Promote the Education of the Blind, 1879; APH, n.d.). Each registered student was allotted around $460; the total number of students registered determined how much money was federally allocated. For example, in 2021, $26,114,184.03 Quota Funds were earmarked for the U.S. and territories. Specifically, 2,965 students were registered in Massachusetts, so the total money allocated for Massachusetts students was $1,389,825.27. Schools had to provide resources to ensure an accessible educational environment under the Individuals with Disabilities Education Act 2004 to ensure a Free Appropriate Public Education (FAPE), as reflected in 34 CFR § 300.101. The money allocated could only be used for APH products that provided immersive and engaging educational materials to help access decreased incidental learning opportunities. These varied prevalence estimations could result in inadequate allocation from the government for resources for students with blindness or visual impairments. This could result in inequitable educational experiences for students with blindness or visual impairments across the United States.

Educational Access for Individuals with Visual Impairments

All students' educational rights in the U.S. have been governed by the Individuals with Disabilities Education Act (IDEA, 2004). The IDEA (2004) was published by Congress into the Statutes that organized the laws of the Act by topic and given the United States Code, 20 U.S.C. Section 1400 et seq. From the laws of 20 U.S.C. Section 1400 et seq, the U.S. Department of Education developed regulations that further defined the laws of the Statues, under the Special Education Regulations in the Code of Federal Regulation referred to as 34 CFR Section 300. The goal of both 20 U.S.C. Section 1400 et seq. and 34 CFR Section 300 was to ensure the IDEA

(2004) was continently implemented and enforced. The regulations and laws of the were included in the citation IDEA (2004). The IDEA (2004) has guided states and districts on Free Appropriate Public Education (FAPE), the Least Restrictive Environment (LRE), and special education eligibility. The IDEA (2004) has provided guidance on what disabilities could be eligible for special education services to ensure students' access to the educational environment was supported. The Part B of the IDEA (2004) went a step further than some federal definitions of legally blind. Legally blind, defined by the Department of Social Security, was specific to an acuity of 20/200 or worse in the individual's best eye or a visual field reduced to 10 degrees or smaller (Social Security Administration, 2022). The broader definition of the IDEA (2004) was inclusive of the spectrum of visual impairments and the varying degrees of impact on access to the educational environment. Nevertheless, for students with blindness or visual impairments, their medical diagnosis did not dictate what educational modifications or accommodations they needed (Lawson et al., 2017; U.S. Department of Education Office of Special Education and Rehabilitation Services, 2017). A student with a medically diagnosed visual impairment must still undergo the special education evaluation process to determine special education services, including but not limited to necessary TVI services and implementation of accommodations to meet their accessibility needs (IDEA, 2004).

For a student with blindness or visual impairments, the evaluation process specifically related to the student's visual needs and services should be performed by a TVI. Teachers of the Visually Impaired are certified and trained professionals who specialized in educating individuals who were visually impaired to ensure access to FAPE (IDEA, 2004; Lawson et al., 2017; Spungin & Ferrell, 2007). Teachers of the Visually Impaired are not medical professionals, and they were not therapists. In their role, they did not provide medical treatments or optometric vision therapy, also referred to as vision therapy or behavioral vision therapy (Lawson et al., 2017). Vision therapy has a prescribed set of activities that could work on neurosensory or neuromuscular movements (Lawson et al., 2017). As TVIs are not medical professionals, they could not make diagnoses. A TVI uses standardized and student-specific evaluation tools to determine a visual impairment's impact on the student's educational access and learning. If the student was found eligible for special education services due to the effects of their visual impairment, the TVI developed specific accommodations or modifications to maximize the student's educational access (IDEA, 2004; Lawson et al., 2017). These accommodations, modifications and related services could and should go beyond the general education scope to include areas of the Expanded Core Curriculum (ECC; IDEA, 2004; Texas ECC Committee, 2014).

The nine areas of the Expanded Core Curriculum were developed to accommodate missed learning opportunities due to decreased incidental learning opportunities due to the visual impairment (Texas ECC Committee, 2014). The nine areas of the ECC are: (a) compensatory access, (b) sensory efficiency, (c) assistive technology, (d) orientation and mobility, (e) independent living skills, (f) social interaction, (g) recreation and leisure, (h) career education, and (i) self-determination (Allman & Lewis, 2014; Cantillon, 2021; Texas ECC Committee, 2014). The areas of the ECC and results of the FVE should be included in the development of the student's Individualized Education Program to ensure the students had access to FAPE in the LRE (Cantillon, 2021; IDEA, 2004). As a member of the student's educational team, an additional role of the TVI has been to train, inform, and consult with all team members on the educational impact of the visual impairment across the student's day. To be able to train, inform, and consult effectively, the TVI, when applicable, must be able to convey to the team the difference in the student's vision functioning and functional vision, especially for students with CVI (Bennett et al., 2019; Kran et al., 2019).

Functional Vision and Vision Functioning

The diagnosis process has not always been straightforward for individuals suspected of having CVI. There has been no federal regulation for how CVI was diagnosed or by whom. The NEI defined CVI as an umbrella term that included manifestations of abnormal visual functioning due to injury to the brain's vision processing centers (National Eye Institute, 2021). Often, licensed eye professionals diagnose CVI; these professionals could include, but not limited to; neurologists, ophthalmologists, neuro-ophthalmologists, or pediatric ophthalmologists. When evaluating an individual suspected to have CVI, the doctor focused on potential differences between vision functioning and functional vision (Bennett et al., 2019). This meant the individual may have typical ocular health, but they did not seem to be using their vision in a way that matched their ocular health (Bennett et al., 2019). However, individuals with CVI often have had coexisting ocular impairments.

Studies have found a wide range of estimated co-existing ocular conditions in individuals diagnosed with CVI. Of individuals diagnosed with CVI, an estimated 30-90% have had strabismus, between 11-92% were impacted by nystagmus as well as high correlations to reduced acuity, impacted visual fields, contrast impairments, and photophobia (Chokron & Dutton, 2023; Manley et al., 2023; Ong et al., 2023). Though there has been a wide range of potentially co-occurring ocular conditions with CVI, there were no definitive correlations between CVI and comorbidity ocular conditions, as an individual's vision function and functional vision were subjective (Bennett et al., 2019). The disconnect between vision functioning and functional vision could be challenging to identify and quantify. Due to these barriers, the number of individuals impacted by CVI has been assumed to be much higher (McKinsey & Company, 2023).

Cortical/Cerebral Visual Impairment

Cerebral Visual Impairment, Cortical Visual Impairment, Cortical/Cerebral Visual Impairment, and Cortical Blindness were all terms that have been used to describe the difference between an individual's vision functioning and functional vision (Bennett et al., 2019; Kran et al., 2019; Roman et al., 2008). Holmes first presented the effects of cortical blindness in 1918 from his findings of the visual impact of brain lesions due to related World War I injuries. Holmes conducted 16 case studies on soldiers who suffered war-related gunshot wounds to their heads between 1915 and 1918. In each case, when possible, Holmes extensively mapped the impacted areas, including the entry area, the shot trajectory in the brain, the affected brain areas, and both right and left visual fields. Of the 16 case studies, 14 had brain mapping. Nine of the 14 cases with brain mapping were shot in the back of the head towards the visual cortex area. Four were shot from the side, mainly around the ear region, and one from the front, through the frontal lobe. Holmes discussed the correlation between injury areas and visual field neglect, stating that the upper half of the retina was related to the dorsal stream, and the lower was related to the ventral stream. He also concluded that a moving target in an area where vision was neglected helped it be seen, whereas the object was not seen when stationary. He also concluded that light, color, and motion all appeared to help elicit visual responses in visual areas preserved as neglected. When an individual suffered cerebral lesions, Holmes (1918) found the individual's visual functioning had "various defects or disturbances of vision" (p. 354). Since then, the causes of atypical visual functioning have been an area of interest.

More than 100 years later, in 2021, the NEI of the National Institutes of Health (NIH) guided variations of terms used to describe what Holmes referred to as disturbances of vision due to a brain-related injury. Under this guidance, CVI has been an encompassing term that reflected the spectrum of visual behavior manifestations experienced by individuals diagnosed with CVI (National Eye Institute, 2021). This study used the term CVI, as intended by the NIE, and its subsequently related terms.

Lueck and Dutton (2015) proclaimed that CVI "describes deficiency in the functions of vision, due to damage or malfunction of visual pathways and visual center in the brain" (p. 13). In 2018, Roman-Lantzy stressed the need for distinction between cerebral and cortical visual impairment to meet an individual's medical and educational needs. Historically, the link to CVI was tethered only to lesions to the brain, an injury, stroke, or brain bleeds. However, this has no longer been the case (Lueck et al., 2019; Mohapatra et al., 2022; Ong et al., 2023).

The profile of students diagnosed or suspected to have CVI has changed for many reasons, including increased understanding of CVI, medical advances, and even industrial advances globally (Ong et al., 2023). In part due to the changing profile, the awareness of CVI, including both allocated medical and educational resources, all have played a role in the diagnosis rate of CVI (McKinsey & Company, 2023). This could be looked at in two folds: if medical professionals were not trained in up-to-date practices related to CVI's red flags and etiology, they may not know what to look for (Kran et al., 2019; Lueck et al., 2019; Merabet et al., 2017). On the other hand, with the increased understanding of the comorbidities related to CVI, students with a complex medical profile may be overlooked for CVI due to the severity of their other needs or the uncertainty of their functional vision (Chokron & Dutton, 2023; Merabet et al., 2017; Mohapatra et al., 2022). Both could be compounded by a family or a state's economic status. Access to current research-based practices has been an economic privilege that has played a role in a student's educational access across disabilities and geographical regions (Viswanath et al., 2023). As the understanding of CVI has advanced over the past 105 years, the foundation has remained the same: a brain-based visual impairment categorized by abnormal functional vision, not explained by an ocular condition (Bennett et al., 2019).

The Prevalence, Etiology, and Comorbidities of Cortical/ Cerebral Visual Impairment

Historical Prevalence of Cortical/Cerebral Visual Impairment

Holmes (1918) was among the first to investigate brain-based visual challenges unrelated to ocular visual impairments. However, cortical blindness, or any related CVI term, did not appear in prevalence data until the 1968 epidemiology of visual impairments of children in England and Wales (Henderson, 1968). This made sense as the onset of visual challenges was apparent during Holmes's investigation: a gunshot wound. The connection between brain-based visual impairments and blindness took more time to understand. In Henderson's (1968) prevalence study, CVI did not stand alone but was paired with the comorbidities of Cerebral Palsy and Epilepsy as cerebral dysfunction and visual deficiencies. Henderson (1968) described these dysfunctions and deficiencies as a child presenting as clumsy, distracted, and having difficulty preserving visuals like shapes.

Around the same time, a New York State evaluation of births registered as blind or visually impaired was conducted (Goldberg et al., 1967). This evaluation examined 553 birth registries and their related demographics and birth histories. It was found that prenatal factors and birth complications were highly associated with premature births. Of the 553 children registries in the study, 120 (17.9%) were identified to have had impaired cortical visual centers. This was one of the first mentions of cortical or brain-based impairments in the United States.

Another 10 years after Goldberg et al. (1967) and Henderson (1968) was a CVI-related term identified as a high-incidence visual impairment. Benezra and Chirambo (1977) evaluated the prevalence and related causes of blindness for children birth to 5 years old in Malawi. Of the 75 cases of blindness, 7 (9.3%) were deemed cortical blindness. Benezra and Chirambo explained that for these seven cases, the cause of blindness could not be determined as the ocular health of the individuals was normal. Throughout history, researchers started to make the connection that ocular health did not always correlate to perfect vision and that the individual's visual access could be affected by a brain-based cause.

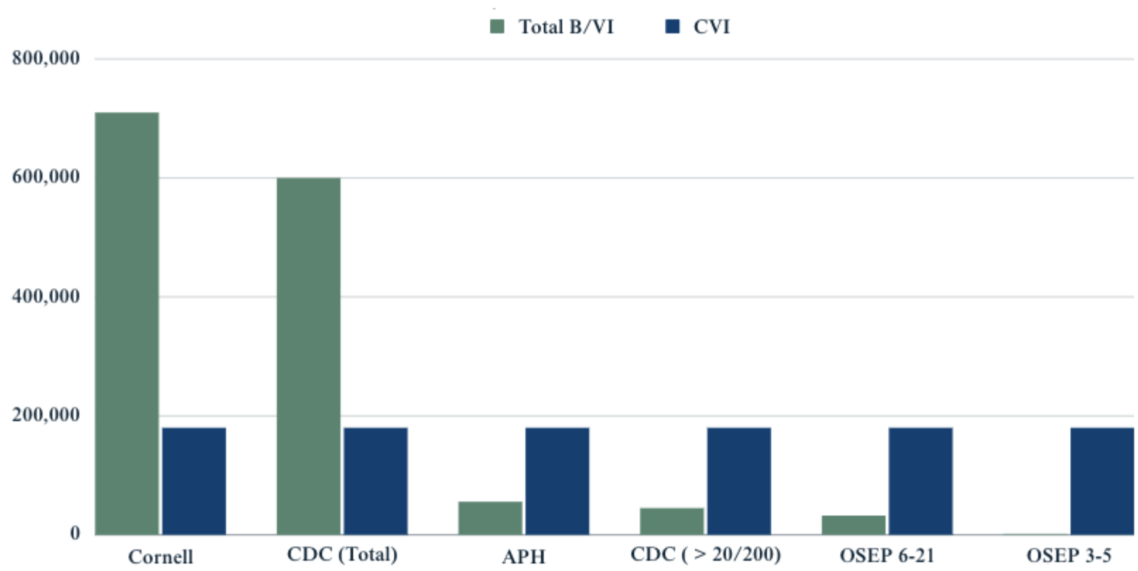
Recent Prevalence, Etiology, and Comorbidities of Cortical/Cerebral Visual Impairment (CVI)

Identifying the population of individuals with CVI has been the first step to understanding the educational impact of CVI. Since the early 1990s, CVI has been maintained as the top visual impairment in developed countries (Chong & Dai, 2014; Chong et al., 2019; Good et al., 2001; Kong et al., 2012; Rahi & Cable, 2003; Wilton et al., 2021). McKinsey & Company (2023) analyzed medical information related to CVI in the U.S.; the prevalence has been estimated to be at least 180,000 of the population. Additional estimations were made that only 20% of individuals with CVI have been diagnosed and that there were four students potentially with CVI for every one student formally diagnosed. To conduct this analysis, McKinsey & Company used Komodo Health Insurance Claims data and a combination of ICD-10 diagnosis codes under which CVI could be categorized. They paired that data with a machine learning model to analyze and predict how many individuals with CVI had been diagnosed and how many potentially could have CVI based on correlated red flags in medical history (McKinsey & Company, 2023).

McKinsey & Company (2023) identified that their machine learning model was more likely to miss someone who had CVI than to misdiagnose them with CVI with a strong specificity (99%) and low sensitivity (71%). This estimate showed new light on the magnitude of CVI. When the estimated prevalence of CVI was put next to the total prevalence amounts presented by Cornell, the CDC, U.S. Department of Education OSEP, and APH, it was greater than two of the reporting sources (APH, 2022; CDC, 2022; Erickson et al., 2023; U.S. Department of Education Office of Special Education and Rehabilitation Services' Office of Special Education Programs, 2023). This meant the estimated population of individuals with CVI was five times greater than the total amount of registered students with APH and six times more than all students serviced by U.S. Department of Education OSEP (see Figure 7; APH, 2022; McKinsey & Company, 2023; U.S. Department of Education Office of Special Education and Rehabilitation Services' Office of Special Education Programs, 2023).

Figure 7

The United States School Age Visual Impairments Compared to Cortical/Cerebral Visual Impairment Estimates

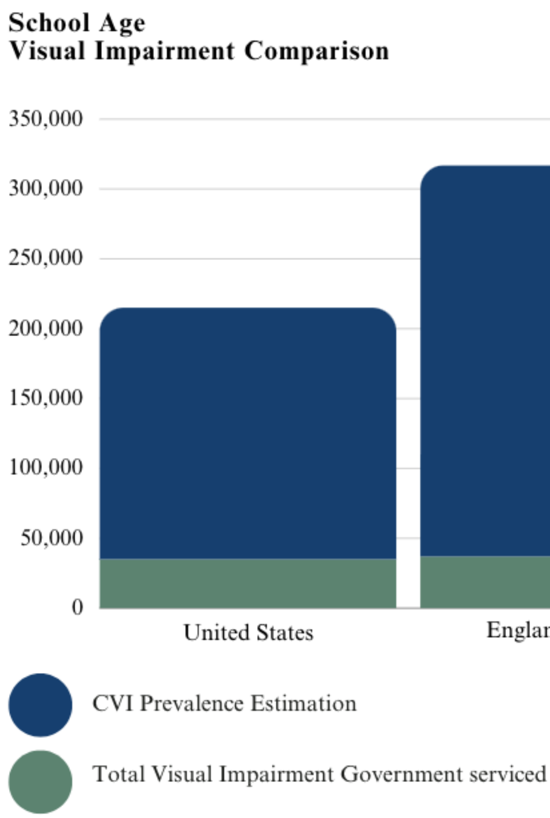


Note. The self-created figure above shows six estimations of the number of school-aged students who are blind or visually impaired in the U.S., compared to the estimated prevalence of Cortical/Cerebral Visual Impairment. Gathered from the estimations from APH (2022), CDC (2022), Erickson et al. (2023), McKinsey & Company (2023), and U.S. Department of Education Office of Special Education and Rehabilitation Services' Office of Special Education Programs (2023).

In comparison, the 2021 study in the United Kingdom (UK) estimated that 1 in 30 children may be impacted by CVI-related visual challenges (Teoh et al., 2021). Compared to the estimated school-age population of the UK, 9,359,533 came to an estimated 280,000 students (British Educational Suppliers Association, n.d.). This compared to the estimated 37,000 students in the UK who were serviced and registered with the Royal Society for Blind Children (RSBC, n.d.). A similar outcome has been seen with the CVI prevalence estimation in the U.S.; the estimated CVI prevalence has been almost eight times the total registered student population with blindness or visual impairments. Another area of interest has been the comparative estimations of U.S. and UK student populations. There has been an estimated 10.3 million school-age students in the UK and 75.5 million in the U.S. (British Educational Suppliers Association, n.d.; U.S. Census Bureau, 2023). Respectively, of the total estimated school-age populations, there was an estimate that a CVI-related visual impairment impacted 3% of students in the UK, yet in the U.S., 0.24% were estimated to be impacted (see Figure 8; British Educational Suppliers Association, n.d.; McKinsey & Company, 2023; Teoh et al., 2021; U.S. Census Bureau, 2023). Without consistent international recognition by the International Classification of Disease (ICD10), the prevalence of CVI may continue to remain a challenging diagnosis to estimate.

Figure 8

The United States and United Kingdom School Age Visual Impairments and Cortical/Cerebral Visual Impairment



Note. The self-created figure above compares the estimations of registered school-aged students who are blind or visually impaired with government agencies in the U.S. and the UK, compared to the estimated prevalence of Cortical/Cerebral Visual Impairment. Adapted from the estimations from the British Educational Suppliers Association (n.d.), McKinsey & Company (2023), Teoh et al. (2021), and U.S. Department of Education Office of Special Education and Rehabilitation Services' Office of Special Education Programs (2023).

It has not been enough to only know the prevalence of CVI. To effectively address the condition's impact, one must look at the related epidemiology to ensure increased awareness, related training across fields, and access to necessary resources. When a medical professional evaluates for CVI and assesses an individual's ocular health, the individual's medical history plays a crucial role in identifying CVI-related red flags (Bennett et al., 2019; Kran et al., 2019; McConnell et al., 2021). Red flags have been considered events or diagnoses in an individual's medical history that have had a historically high correlation to CVI (Kran et al., 2019). Ong et al. (2023) identified hypoxia and hypoglycemia as the top causes of CVI. Ong et al. (2023) explained that the cause of CVI could also be multifaceted and have varying impacts depending on the onset timing, location, and severity. Related causes of CVI have not been isolated to hypoxia or hypoglycemia events. Correlations have been linked to CVI and infectious etiologies, environmental or drug toxins, and genetic disorders (Bosch et al., 2014; Khetpal & Donahue, 2007; McKinsey & Company, 2023; Ong et al., 2023; Pehere et al., 2018). The research around the etiology or suspected causes of CVI has evolved with the world's medical advances. The advances in understanding the etiology of individuals with CVI have helped to ensure that professionals across fields and disciplines know what to look for when reviewing an individual's medical history.

With the heightened awareness of the etiology related to CVI, there has been an increased understanding of the connection between CVI and comorbidities. The correlation between CVI and neurological disorders such as Cerebral Palsy (CP) and Epilepsy has now been much better understood (Chokron & Dutton, 2023). It has been estimated that 65-70% of individuals with CP were diagnosed with CVI, and 64% of individuals with Epilepsy were also diagnosed with CVI (McKinsey & Company, 2023; West et al., 2021). There was a 38% prevalence rate between individuals with Down syndrome and CVI (Wilton et al., 2021). McKinsey & Company (2023) estimated that 20% of individuals with CVI have also had genetic anomalies. More specifically, CVI’s link to genetic conditions has been seen in individuals with the CDKL5 deficiency disorder, with an estimated 76% of individuals having CVI (Demarest et al., 2019).

The prevalence rates of CVI, etiology, and comorbidities have changed across regions, countries, and ages (McKinsey & Company, 2023; Teoh et al., 2021). Nevertheless, the variations in prevalence, etiology, and comorbidities for individuals with CVI have stressed the need for early diagnosis to ensure access to student-specific appropriate educational accommodations (Chang & Borchert, 2020). Unfortunately, this has not always been the case. When an individual had a complex medical profile, it could be challenging to identify if they had CVI as it may be overshadowed by additional disabilities (Chokron et al., 2021; Lueck et al., 2019; Merabet et al., 2017; Steendam, 2015). This could delay the diagnosis process, which leads to delayed access to appropriate educational materials as determined through the special educational evaluation process (Kran et al., 2019; Tsirka et al., 2020). Not having a complete understanding of a student’s visual access or visual processing could affect an educational team’s understanding of the student’s abilities across all disciplines. A student with an undiagnosed visual impairment may not have access to a TVI (IDEA, 2004). Thus, the students' visual needs could not be evaluated or conveyed to the team to ensure the students’ access. If a team did not know a student had CVI and was given complex worksheets they could not visually access and, thus, did not complete the work, the student may be deemed noncompliant (CVI Scotland, n.d.). When, in reality, they were not noncompliant, they were just not being educated in a way that was accessible to them. No two profiles or manifestations of CVI have been the same. A student with CVI must have access to a comprehensive educational team, especially to address the impact of additional disabilities, to ensure their educational access needs are met throughout all learning environments (Chokron & Dutton, 2023; Chokron et al., 2021; Merabet et al., 2017).

Cortical/Cerebral Visual Impairment's Impact on Visual Processing as Visual Behaviors

Cortical/Cerebral Visual Impairment's impact on an individual's access to the world around them has not been uniform; their functional vision could change in different environments, with different materials, day-to-day or even hour-to-hour (Chokron et al., 2021; Fazzi et al., 2015). In Figure 9, the artist Zhu Xi Caruso (2023b), an individual with CVI, depicted their interpretation of a tree and person. This was one individual's expression of their interpretation of the world. However, this representation was not uniform across the following two additional figures of their work. This represented how an individual with CVI's own visual access and recognition fluctuated based on many external and internal factors.

The etiology and comorbidities have affected how the individual with CVI was impacted (Bosch et al., 2014; Kran et al., 2019). Cortical/Cerebral Visual Impairment's impact on visual processing was hard to translate in a way for individuals without CVI to understand. There was no quantitative representation of their struggles, like visual acuity or visual fields. What could be explained was evaluated through research, observations, and first-hand accounts. Through these methods, an attempt was made to understand how an individual with CVI viewed the world. These research methods have been used to connect an individual's challenges with visual processing to related visual behaviors (Baskin & Bennett, 2020). Such related areas of impact may be but were not limited to visual attention, visual recognition, motion processing, gaze control, visual clutter, form accessibility, visual processing time, and sensory integration (Chang & Borchert, 2020; Chokron et al., 2021; Das et al., 2007; Dutton, 2015; Jan et al., 1987; Manley et al., 2023; Porro et al., 1998).

Figure 9

Visualization of Cortical/Cerebral Visual Impairment 1

Note. The figure above is an image taken and modified by Cortical/Cerebral Visual Impairment artist Zhu Xi Caruso (2023b) depicting how she accesses the world. Here is an adapted image of a tree and a person.

Roman-Lantzy (2007, 2018) identified 10 characteristics of CVI correlating to her CVI Range to help evaluate the impact of CVI on a child's visual access. Since then, understanding of areas potentially impacted by CVI has been expanded, and Perkins School for the Blind has developed a research-based list of 16 related visual behaviors (Baskin & Bennett, 2020; Jan et al., 1987; Porro et al., 1998). Throughout this study, the impact of CVI was referenced as visual behaviors and followed the terminology presented by Perkins School for the Blind (Baskin & Bennett, 2020). The 10 characteristics and 16 visual behaviors overlapped in their areas of impact and shared the same goal: to understand how an individual with CVI accesses the world (Table 1).

Table 1

Comparison of Terminology Between the Cortical Visual Impairment Range's 10 Characteristics and the Perkins Cortical/Cerebral Visual Impairment Protocol Visual Behaviors

Cortical Visual Impairment Range	Characteristics
Color Preference	The Attraction to color, even one particular color
Visual Latency	Delayed response in looking at objects
Need for movement	Movement is needed to initiate and/or sustain attention. Movement may be needed to see the object.
Visual Field Preferences	The areas that targets can or cannot be seen within the peripheral fields.
Difficulty with visual complexity	Includes difficulties with complexity levels of a surface, array, sensory environment, and human faces.
Need for light	The attraction to lighting sources. Also, the need for light to visually attend.
Difficulty with visual novelty	More visual attention to familiar targets decreased visual curiosity.
Difficulty with visually guided reach	Being able to look and reach for a target at the same time.
Difficulty with distance viewing	The inability to look at and locate targets at a distance.
Atypical visual reflexes	The lack of blink in response to an item coming towards the face.
The Perkins Cortical/Cerebral Visual Impairment Protocol	**Visual Behaviors**
Impact of Color	The impact of color as it relates to awareness, attention, and/or visual recognition. Impact of color is monitored in relation to the impact of crowding (too many colors) and color-coding skills.
Response Interval	The length of time it takes a student to become visually aware of a target, establish visual attention, process, and recognize that target.

Table 1 (continued)

Perkin's Protocol	Visual Behaviors
Impact of Motion	The impact of movement in establishing and maintaining visual attention and in supporting visual recognition. Over-attention to movement (inability to disengage) is evaluated in addition to challenges with motion perception.
Visual Field Abilities	The availability of the visual fields (peripheral and central) as it relates to awareness, established and/or maintained attention, and recognition.
Impact of clutter/crowding/spacing	The ability to attend to, recognize, and/or navigate materials or learning environments with varying levels of arrays/clutter/crowding.
Impact of light	The awareness and attention to light sources (target lighting, back lighting, environmental lighting). This area also evaluates the impact of backlighting on visual attention.
Visual recognition	The visual recognition skills with considerations for form, distance, familiarity, environment, context clues, and auditory/tactile cues.
Visual guidance of the upper limbs	The visual motor skills in relation to hand-eye coordination.
Visual curiosity	The incidental access in new and unfamiliar environments, visual curiosity in all fields and visual curiosity at distance is determined.
Movement of the Eyes	The abilities to control eye movements and to shift gaze between items.
Appearance of Eyes	The appearance of the eyes for alignment, and for any atypical features.
Sensory integration	The impact that simultaneous tactile and/or auditory input has on visual efficiency.
Visual Guidance of the Lower Limbs	The visual motor skills in relation to foot-eye coordination.
Visual attention	The visual attention skills and sustained visual attention skills needed to locate and recognize materials.
Form accessibility	The optimal and accessible media form based on their visual abilities (i.e., attention, recognition). Assessment includes evaluation of the visual accessibility of multicolored materials vs. solid-colored materials, attention to and recognition of two dimensional and three-dimensional materials.

Table 1 (continued)

Perkin's Protocol	Visual Behaviors
Access to people	The visual behavior surrounding attention to faces, facial recognition, and interpretation of facial expressions and body language. Additionally related to the impact of crowding.

Note. This table compares the terms used to describe the impact of Cortical/Cerebral Visual Impairment found in the Cortical Visual Impairment Range and Perkins's Visual Behaviors as adapted from Roman-Lantzy (2007, 2018) and Baskin and Bennett (2020).

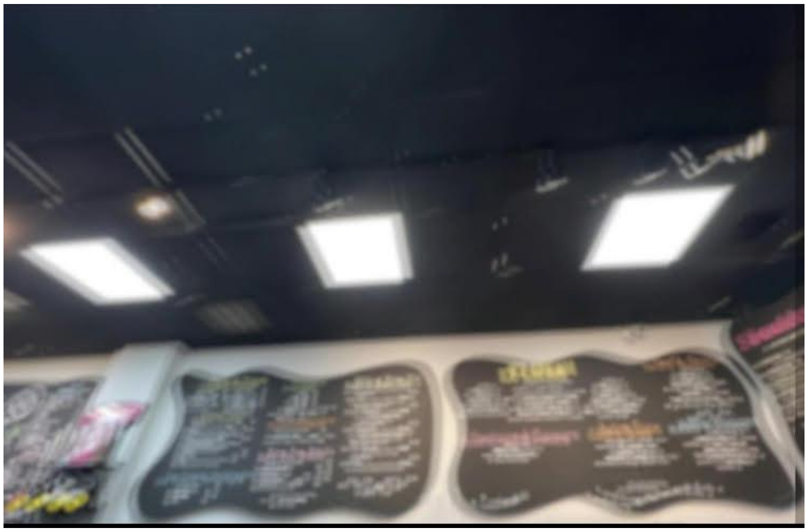
It was important to note that the visual behaviors related to CVI did not act alone (Lueck & Dutton, 2015). Rarely has anyone been in a position where only one piece of visual information, such as color or motion, needed to be processed. When accessing the visual world, the brain must process a multitude of information simultaneously, color, size, and shape, to aid recognition, which takes time (Bennett et al., 2019; Bramão et al., 2011; Cohen-Maitre & Haerich, 2005; Morelli et al., 2022). The visual behaviors have been interconnected in their ability to aid the individual in making sense of the world around them (Das et al., 2007; Good et al., 1994; Jan et al., 1987). As some of the visual behaviors are discussed below, it should be noted that an individual was also tasked with processing more than the discussed visual behaviors. For example, the Symbol Search subtest of the WISC-V was not limited to the individual processing a symbol (form accessibility) but having to maintain fixation (visual attention), understand what they were looking at (visual recognition), process a large area or print (impact of clutter), the lack of color (impact of color), the lighting (impact of lighting), while processing additional sensory inputs of the environment (Bramão et al., 2011; Dutton, 2015; Manley et al., 2023).

Visual Attention

Visual attention could be thought of as one of the foundational visual processing skills. Without visual attention, an individual would not been alerted to what was around them and could not maintain the focus needed to process the visual information (Vancleef et al., 2020). Figure 10 is another depiction of the artist Zhu Xi Caruso's (2023a, 2023b) visual access to their environment. Compared to Figure 9, the representation and style of this image is slightly different). This may be purposeful or unintentional, as the artist's visual access and functioning changed daily. In this picture, two aspects may draw the viewers' visual attention: the lights above and the color coding on the board. The challenges for an individual with CVI to look at and sustain visual attention have long been a focus of researchers (Das et al., 2007). Atkinson (2017) explained how complex the act of visually attending was as it fell into multiple facets: selective attention, sustained attention, and executive control of attention. Prieler et al. (2018) explained how selective attention was developed through an individual's ability to process multiple sensory inputs while ignoring unnecessary visual inputs. This may manifest in difficulties processing complex information, tripping or appearing clumsy when navigating various environments, or difficulty maintaining visual fixation (Dutton, 2015). It was found in a sample study of children with CVI that colorful and moving objects increased the children's maintained visual attention, with motion having more of an impact than color (Cohen-Maitre & Haerich, 2005). Visual attention has been a foundational prerequisite for visual access. Without visual attention, an individual with CVI may be unable to look at or access the materials of the WISC-V.

Figure 10

Visualization of Cortical/Cerebral Visual Impairment 2



Note. The figure above is an image taken and modified by Cortical/Cerebral Visual Impairment artist Zhu Xi Caruso (2023a) to depict a representation of how she accesses the world. An adapted image of an ice shop's menu is hanging above the checkout counter.

Visual Recognition

Visual attention could be called visual recognition's prerequisite skill. For any individual to visually access their surroundings, they must be able to visually attend and recognize what they were looking at (Steendam, 2015). Figure 11 is a still from a film created by two artists representing how individuals with CVI's may visually access the world. This style was much different than the previous two figures, further exemplifying how visual access for individuals with CVI was very individual. When we think of visual recognition, it directly correlated to familiarity with the visual target. This image's door, trash can, and brick wall stood out as they were common features in everyday life. However, these features might be unfamiliar to an individual who had not experienced them.

Figure 11

Visualization of Cortical/Cerebral Visual Impairment 3

Note. The figure above is a screen grab from *Synchronicity* [Film] by Fox and Wallace, 2021. This film depicts representations of how individuals with Cortical/Cerebral Visual Impairment may view the world.

Individuals with CVI may have difficulties recognizing objects, images, people, facial expressions, and the time it takes to recognize these visual stimuli due to damage to their ventral and dorsal streams or potentially temporal lobes (Dutton, 2015). The challenges an individual with CVI experiences related to visual recognition or visual memory have not been isolated to recognizing one type of object or image but rather to processing multiple unfamiliar visual stimuli (Chokron et al., 2021). Notably, looking did not always mean recognizing; for individuals with CVI, distinguishing when a child with CVI visually recognized what they were looking at or for could be challenging (Steendam, 2015). Color, familiarity, spacing, lighting, level of clutter, and field of presentation could all affect an individual with CVI's success in finding and recognizing a visual target (Bennett et al., 2019; Manley et al., 2022; Manley et al., 2023; Zhang et al., 2022). Zhang et al. (2022) found a direct correlation between the spacing, field of view, and the success rate of an individual with CVI finding a visual target. This was also seen in Manley et al. (2022) when individuals with CVI were asked to locate a visual target in a virtual reality scene. The scene's visual clutter negatively impacted their success. So, even if an individual with CVI was looking at the subtests of the WISC-V, it did not mean they had located the visual target or recognized what it is.

Form Accessibility

The form an item was presented in could play an essential role in how an individual with CVI interprets it. Form accessibility, a visual behavior identified by Perkins School for the Blind (Baskin & Bennett, 2020) in this study referred to what modality materials were presented and how accessible they were to the individual. In Figure 12, Zhu Xi Caruso (2023c) provides an interpretation of how she accesses a Wilson reading system card. This was a flat index card with a two-dimensional image of an apple and an uppercase A next to a lowercase A at the top. When we would think of visual attention, the size and color of the apple may draw the eye first, though it was hard to distinguish if it was an apple, a tomato, or a red ball. The upper- and lower-case letter "A" may also be challenging to recognize if the viewer was unfamiliar with the Wilson program or was not anticipating seeing a literacy card. The form this was presented in, the viewer's familiarity with the object, and what drew their visual attention impacted the interpretation and visual access as seen in Figure 12. For individuals with CVI, interpreting a 2D image could be more challenging than a 3D item. The same would go for the various types of 2D images: real images, realistic, abstract, color, or black-and-white images (Manley et al., 2023). Individuals with CVI's interpretations of the various material forms may be impacted by coloring, style, their recognition, ventral processing stream, or visual object agnosia.

Figure 12

Visualization of Cortical/Cerebral Visual Impairment 4

Note. The figure above is an image taken and modified by Cortical/Cerebral Visual Impairment artist Zhu Xi Caruso (2023c) to depict how she accesses the world. The image is an adapted representation of the Wilson letter A card.

An individual's ability to relate an image of an object to a real object has been known as perceptual constancy (Norman & Thaler, 2021). Making the connections between images and objects has been a foundational skill to visually recognize the world around oneself (Norman & Thaler, 2021). However, this skill, perceptual constancy, has been identified as one of the most significant recognition challenges for individuals with CVI (Chokron et al., 2021). Due to the significance of this challenge, Lueck and Dutton (2015) stressed the caution that should be taken when using symbols and icons with individuals with CVI. Manley et al. (2023) evaluated the impact form accessibility had on individuals with CVI recognition. Using 60 images of 5 image styles (real images, realistic color images, realistic black and white images, abstract color images, and abstract black-white images). The participants were asked to identify the presented images verbally. At the same time, their eye gaze was tracked using a Tobi eye gaze. It was found that, compared to controls, CVI participants had the lowest success rate identifying abstract black and white images, followed by abstract-colored images. Realistic images had an almost 100% identification accuracy. Manley et al. (2023) findings aligned with Bramão et al. (2011), that color positively impacted an individual's identification of an image. If an individual with CVI's access to form accessibility was affected, how may their access to the images and visual information of the WISC-V be impacted?

Significant Cortical/Cerebral Visual Impairment Studies

Historically, there have been few quantitative experimental studies with a target population of individuals with CVI. Nevertheless, a handful of researchers have targeted this gap to gain a better understanding of the educational implications of CVI. Many studies have utilized virtual reality, or eye gaze technology, to help capture the visual processing methods of individuals with ocular and brain-based visual impairments (Bennett at al., 2021; Manley et al., 2022; Manley et al., 2023). Virtual reality and eye gaze technology have allowed researchers to evaluate in controlled settings representing classrooms, hallways, or community environments. This methodology has bridged the research and educational implementation gaps across fields.

Visual Access Trends for Individuals with Cortical/ Cerebral Visual Impairment

A commonality found among the recent CVI-specific quantitative studies was the impact of visual clutter on search area, response interval, and accuracy. Bennett et al. (2021) used eye gaze technology to capture participants' reaction time, search area, and gaze error (CVI and controls) when accessing a virtual reality scene of a toybox. Participants were asked to locate the visual target they selected from a choice of three (duck, truck, ball) presented in various scenes depicting a toybox. The participants' reactions and engagement were measured through eye tracking, eliminating the need for verbal receptive or expressive communication. Using a toybox helped simulate a potential daily activity that participants were familiar with searching for a desired toy. It was found that the 10 participants with CVI had decreased visual search patterns compared to the controls. This meant that, as the CVI participants were looking for a visual toy in the toybox, they looked across a more extensive search area. It took them longer to find the visual target; when they did find it, they had more difficulty keeping their gaze on the target. Similar results were seen in Zhang et al. (2022), who compared search patterns through eye gaze tracking when CVI participants accessed a virtual reality scene against controls. It was found that CVI participants had increased visual search areas, reaction time, and gaze errors compared to controls. Zhang et al. (2022) found that the spacing on the screen impacted the CVI participants' success and the time to locate the visual target.

When a virtual reality-based simulation included motion, the results were also similar. Manley et al. (2022) used eye gaze tracking to investigate the access of the toybox and hallway simulation in a virtual reality scene. In this task, participants were asked to locate a target principal of their choice in a school hallway where distractors and the principal would walk toward the participant. In the hallway, the crowd level and where the principal appeared changed. This study showcased that CVI participants had a lower success rate and an increased search area than controls. However, the CVI participants' reaction times were statistically significant across the three levels of crowds. It took CVI participants significantly longer to locate the target principle with a larger crowd on the screen than with a smaller crowd. The combination of toybox and hallway results showcase increased visual clutter, and complexity negatively impacted individuals with CVI visual access.

Manley et al. (2023) used eye gaze technology and participant's verbal identification to evaluate both CVI and control's access to a variety of five 2D image styles (real images, realistic color images, realistic black and white images, abstract color images, and abstract black-white images). This study evaluated if the type of 2D image presented impacted the individual with CVI's ability to identify. Abstract black-and-white images were the most difficult, and realistic images were easier for individuals with CVI to identify. The individuals with CVI had increased search patterns, reaction time, and number of fixations compared to the control group. This highlighted that individuals with CVI typically searched a wider area with increased fixations, increasing their reaction time.

Cortical/Cerebral Visual Impairment's Impact on Reading

The WISC-V has not only relied on individuals' access to images but their access to printed materials and symbols as well. A study on visual functioning and neuropsychological profiles by Morelli et al. (2022), which included 51 individuals with CVI, included the evaluation of an individual's reading abilities. The results of the study found that the contrast of a reading task was statistically significant to the participant's access. Lighting and colored overlays were found to have a positive correlation but were not statistically significant. An individual's ocular motor abilities were found to have no statistical significance on reading abilities. Morelli et al. (2022) identified that CVI had the potential to negatively impact an individual's learning, including reading and mathematical skills.

Huurneman et al. (2012) reviewed 30 studies to evaluate the impact of crowding on an individual's reading rate and comprehension among three groups: controls (children and adults), children with an ocular impairment, and children with cerebral visual impairment. The impact of crowding on the groups was found to be indeterminable. However, the contributing factors to reading abilities were gaze stability, contrast, and background color.

A 4-year longitudinal study on the reading, cognitive, and visual development of four children with CVI (4, 6, 13, and 16 years of age) was conducted between 1996 and 2002 (Ek et al., 2003). All the children were readers during the study, but none enjoyed reading. Three of the four children were print readers. All of the children who were print readers struggled with long words and used context clues to aid their understanding of the long words. At the end of the study, the three print readers had low reading and comprehension scores but made few reading errors. This meant that the three print readers read at a slow pace but were accurate with their identification of the words. However, their processing and understanding of what they read could have been higher.

Cortical/Cerebral Visual Impairment's Impact on Learning

As a child develops, a visual impairment's impact on that development could become increasingly evident. The effect CVI has had on a student's learning could be all-encompassing. CVI could affect a student's motor, social, emotional skills, and sensory and cognitive development (Chokron & Dutton, 2023; Sumalini et al., 2023; Vancleef et al., 2020). This was because, from a young age, the child could not visually access what was around them and learn through incidental observations. Visual access has been a foundation for understanding, from facial expressions to motor engagement, imitations, and access to literacy (Chokron & Dutton, 2023). If a student's visual recognition and visual attention were impacted, all subsequent skill development areas were assumed to be affected (Chokron et al., 2021). Due to these visual access and visual processing challenges, a student with CVI's brain compensated for this through neuroplasticity (Merabet et al., 2017). Through neuroplasticity, compensatory skill development elicited different methodologies of accessing a skill and processing that information (Martin et al., 2016).

The developed compensatory skills have often played to the individual's strengths, such as identification through auditory or tactile senses (Dutton, 2015). Students who struggled with visual field loss or eye movement may compensate through head tilting or developing specific eye movements to position materials in their stronger field (Lueck & Dutton, 2015). A student with CVI's compensatory skills were often self-developed to help themselves access the world as they knew it. Students with CVI often have not experienced vision in any other way and, thus, did not recognize that the world was not as accessible as it could be (Chokron et al., 2021).

When a student with CVI was educationally evaluated to identify their areas of strength, areas of need, and developmental levels, those evaluations needed to consider the complexity of a student with CVI access methods or their developed compensatory skills. When evaluating a student with CVI's cognitive abilities, their visual access skills should not be the marker of their cognitive abilities.

Individuals with Disabilities Education Act Evaluation Process for Students with a Visual Impairment

When a student was diagnosed with CVI and entered the educational system, even with a medical diagnosis, they must be educationally evaluated to determine eligibility for special education services (IDEA, 2004). For individuals with medically diagnosed sensory impairments, such as visual impairment, hearing loss, or concurrent visual and hearing losses, the medical diagnosis was honored as part of the IDEA (2004), the 34 CFR § 300.304 evaluation process and necessary accommodations must be considered during the special education evaluation process. Assessments have been required to evaluate how the sensory loss impacted the student's educational access and how the sensory impairment impacted other areas of access and development (Lund et al., 2014). For a student with CVI, this would be conducted by a TVI, including a Functional Vision Evaluation comprised of a functional vision assessment (FVA), learning media assessment (LMA), CVI evaluation, and expanded core curriculum screening (Baskin & Bennett, 2020; Cantillon, 2021; Olmstead, 2005).

This eligibility process has been governed under IDEA (2004); an individual must first be found eligible for special education through the evaluation process following identified procedures. During the special education evaluation, the individual would be entitled to and must be evaluated using a variety of data-based assessments that gave the best overview of the individual's abilities, not just one tool (IDEA, 2004). These assessments were to be matched to the individual's areas to be assessed to determine the individual's special education eligibility (IDEA, 2004).

For individuals diagnosed with CVI or any visual impairment, the assessments used during the evaluation process were to reflect the individual's aptitude level, not the reflection of their impaired visual access (IDEA, 2004). With that, the tools used must also provide applicable information to help determine the individual's educational needs (IDEA, 2004). Individuals diagnosed with CVI have had decreased access to incidental learning, impacting their cognitive, social, and behavioral development (Chokron & Dutton, 2023; Chokron et al., 2020). As a result of the potential developmental impact, during the special education evaluation process, individuals with CVI should receive appropriate cognitive evaluations related to their medically diagnosed visual impairment, CVI (IDEA, 2004).

What could then be done about equitable access to special education evaluation methods for students with CVI? Equality would mean each student received the same evaluations as part of their special education evaluation regardless of their access methods. Whereas equity would consider the access methods and sensory impairments of the students and ensure the tools were not measuring their inability to visually access (IDEA, 2004). It would be understood that special education evaluations evaluated how a student could access the educational environment, removed from medical diagnosis, except for sensory impairments (IDEA, 2004). However, inconsistent interpretation of the implementation of IDEA's (2004) 34 CFR § 300.304 appeared to be a disservice to students with visual impairments, resulting in inequitable special education evaluations. If an individual with CVI was given a cognitive assessment whose primary method of access was visual, was the assessment evaluating the student's abilities or ability to visual access?

Potential Cognitive Scale Accommodations

The accessibility of cognitive scales for children with CVI has had no new concern. In the first-of-its-kind study from the Kennedy Krieger Institute, a pilot study was being conducted on the accommodations needed for students with CVI to access the Bayley Scales of Infant and Toddler Development Cognitive Scale (Albert et al., 2023). This study highlighted the complex needs of individuals with CVI and the impact CVI had on their access to visual information as well as their development. The study looked at two domains of accommodations: environmental and stimulus presentation. It was stressed that three areas of accommodations were needed to accommodate the environment when evaluating students using this scale. First were the students' motor needs, including physical support. Second was the environmental sensory complexity, including the examiner's presentation, auditory stimuli, room complexity, and lighting; and third was the child's visual fatigue. The study identified four areas of accommodation needed to support the visual stimuli presentation. These areas were: (a) familiarity with materials, (b) the field of view materials, (c) providing auditory and lighting support to orient visual attention to stimuli, and (d) processing support, allowing time to attend visually. Though this was a pilot study in a population not included in the WISC-V, it highlighted the wide breadth of accommodations a student with CVI potentially needs to access a cognitive scale (Albert et al., 2023). It should be noted that the study did not suggest changing the materials or structure of the Bayley Scales but rather providing additional supports to ensure the student was given every chance to access and be evaluated in a way that did not evaluate their visual impairment but rather their cognitive abilities (IDEA, 2004).

The Wechsler Intelligence Scale for Children-
Fifth Edition

In its fifth edition, the WISC-V identified itself as a comprehensive intellectual ability assessment for children (Wechsler, 2014a). The WISC-V was developed for children ages 6-16, with average scores falling between 90-110 and a percentile rank between 25 and 75 being considered average for a Full Scale IQ Score (Pearson, 2018). The WISC-V was comprised of three index scales: (a) Primary, (b) Ancillary, and (c) Complementary index scales. These could be used to evaluate a student’s cognitive abilities. The Primary Index Scale has been the most often completed battery of subtests and was composed of five domains, with two subtests in each domain totaling up to ten subtest (Pearson, 2018). Evaluators may also choose to use the Ancillary Index Scale which has contained 5 domains with up to 12 subtest selections (Pearson, 2018), The other option has been the Complementary Index Scale, which included two domains with five potential subtest selections (Pearson, 2018; Wechsler, 2014a). It should be noted that the complementary index scale was only used in the WISC-V if a need was identified by the evaluating licensed/certified psychologist and specified in the report. Nevertheless, this inclusion of complementary Index and its corresponding subtests were included in the study, discussion points and graphics if a potential participant has had any of the components included in their WISC-V. There were 21 subtests of the WISC-V. A Full Scale IQ score (FSIQ) was achieved by completing seven core subtest scores (Block Design, Similarities, Matrix Reasoning, Digit Span, Coding, Vocabulary, and Figure Weights). There were an additional nine subtests that could be substituted for a core subtest (Visual Puzzles, Picture Span, Symbol Search, Information, Picture Concepts, Letter-Number Sequencing, Cancellation, Comprehension, and Arithmetic; Pearson, 2018; Wechsler, 2014a).

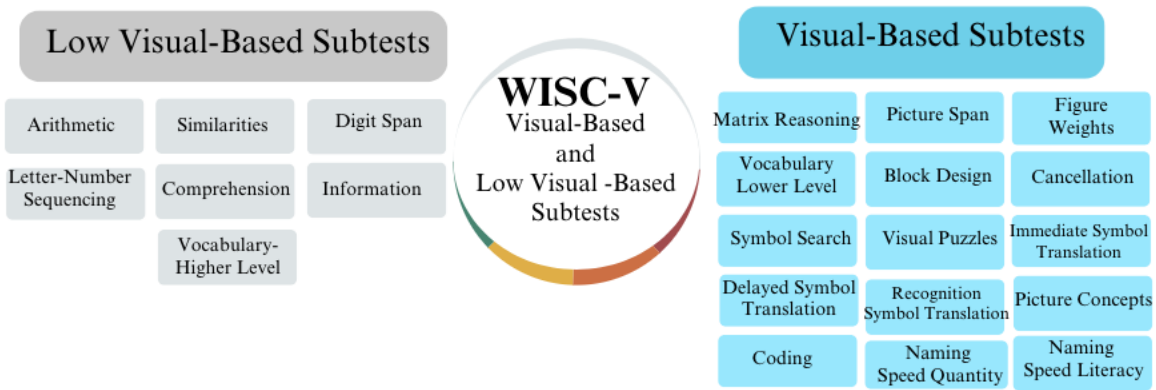
Access Demands of the Wechsler Intelligence Scale or Children-Fifth Edition

When looking at the visual demands of a subtest, it was not simply whether the subtest was contingent on the student's visual access, but what level of access and visual processing were needed? Thinking back to the varying manifestations of CVI, each student's access to visual information was different. Not only were the manifestations of CVI essential to consider, but also the individual's past experiences, access to learning opportunities, and incidental learning opportunities played a role in how they may access any component of the WISC-V. The visual subtests of the WISC-V were not uniform in their visual presentations or visual demands. Subtests were picture-based based or symbol-based. Some had color or were in black and white, all with varying levels of visual complexity. For example, the subtest Block Design includes processing shapes, lines, and colors, whereas the Picture Span subtest required the recognition of various pictures in different image styles (Pearson, 2018; Wechsler, 2014a, 2014b). Thinking of how an individual with CVI may be impacted by form accessibility, some individuals may only be able to access real images, while others may recognize and process abstract black-and-white images (Manley et al., 2023). It would be important to remember that recent studies have shown higher levels of visual complexity had a negative impact on individuals with CVI's response time, accuracy, and visual search patterns (Baskin & Bennett, 2020; Manley et al., 2022; Manley et al., 2023; Zhang et al., 2022). Subtests and indexes could incorporate a variety of access modes to evaluate the targeted skill. However, it was stated that some subtests could be substituted for core subtests when an individual could not access the core subtests (Pearson, 2018; Wechsler, 2014a, 2014b). When evaluating a student with CVI, it was key to follow IDEA (2004) regulation 34 CFR § 300.304I(3), that the assessment tools measured what was intended and not the student's area of impairment.

When an individual was evaluated using the WISC-V, they were asked to access novel materials using a variety of access modalities (Wechsler, 2014a). The two primary modes of access were auditory and visual. Of the 21 subtests, 15 had been identified by this study as having a visual component (see Figure 13). Some subtests were only auditory, some were only visual, and some combined both. For example, the Auditory Working Memory Index included Digit Span and Letter Number Sequencing subtests, both of which were auditory task (Pearson, 2018; Wechsler, 2014a, 2014b). The visual processing demands across each subtest varied depending on the evaluated skill. Some subtests were visually dominant, as seen in the Visual Spatial Index, comprised of the subtests, Block Design, and Visual Puzzles. Additionally, when thinking of the implications of an individual with CVI processing visual information, the time it took to process that visual information must also be considered. Of the 21 subtests of the WISC-V, 8 were timed. Those eight subtests were all visual-based subtests accept for the arithmetic subtest (see Figure 14).

Figure 13

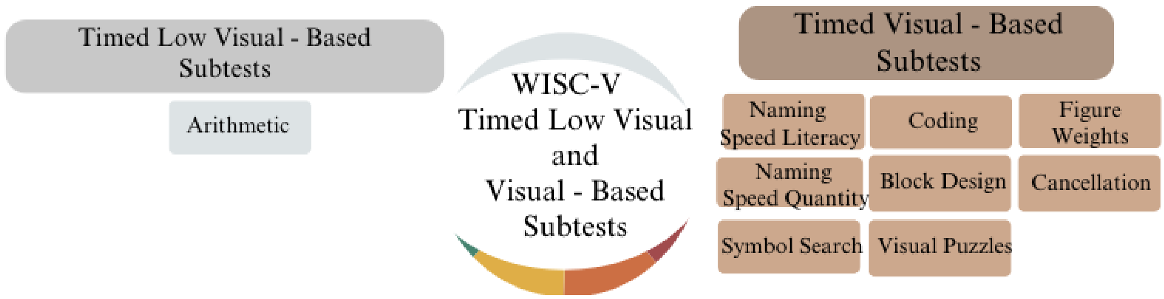
Wechsler Intelligence Scale for Children-Fifth Edition Subtests by Visual Demands



Note. The figure shows all the available subtests of Wechsler Intelligence Scale for Children-Fifth separated into two categories: low visual-based subtests in gray on the left and visual-based subtests in blue on the right. The researcher categorized the visual-based subtest as any subtest requiring visual access or visual recognition of materials. Low visual-based subtests were any subtests that did not require visual access. Adapted from Pearson (2018) and Wechsler (2014a, 2014b).

Figure 14

Visual-based Timed Subtests



Note. The figure shows all the available subtests of Wechsler Intelligence Scale for Children-Fifth Edition separated into two categories: timed low visual-based subtests on the left and timed visual-based subtests in brown on the right. There are no timed low visual-based subtests. All of the timed subtests are visual-based. Low visual-based subtests were any subtests that did not require visual access. Adapted from Pearson (2018) and Wechsler (2014a, 2014b).

Validity and Standardization

The Wechsler Intelligence Scale for Children has been a method of assessing children's cognitive abilities since 1949. Each iteration and updated edition of the WISC was evaluated amongst various student profiles (Pearson, 2018; Wechsler, 1949, 2014a). Currently in its fifth edition, the WISC-V has frequently been assessed by outside researchers for its accessibility and standardization for specific student populations (Coceski et al., 2022; De Jong, 2023; Kuehnel et al., 2019; MacAllister et al., 2019; Williams et al., 2003). For the fifth edition, 14 special groups were evaluated using the WISC-V to examine reliability and validity. These included intellectually gifted, intellectually disabled, specific learning disabilities, traumatic brain injury, English learners, autism spectrum disorder, and hearing impairment (Pearson, 2018).

Unfortunately, one population and student profile consistently absent from these evaluations was the visualIy impaired population.

The WISC-IV's reliability testing had a sample size of 2,200 participants ages 6-16 with a Full Scale IQ internal consistency of 0.97 and a Full Scale IQ test-retest standard deviation of 0.46 (Williams et al., 2003). The WISC-V's reliability testing used a sample size of 2,200 participants ages 6-16 with a split-half coefficient for the Full Scale IQ at 0.92 (Wechsler, 2014a, 2014c).

The WISC-IV and WISC-V conducted special group evaluations on children with Traumatic Brain Injury (TBI). Though there was no identifiable information presented if any of the participants with a TBI had co-occurring ocular visual impairments or CVI, one could make the stretch that an individual with TBI's visual process had the potential to be impacted. This could provide insight into how individuals with CVI may present or access WISC-V. The WISC-IV and WISC-V testing found that the Visual-Spatial, Fluid Reasoning and Working Memory scores were lower than the controls at a statistically significant level (Pearson, 2018; Wechsler, 2014a, 2014c; Williams et al., 2003). There has been no validity or independent study on the validity of the WISC-V for visually impaired children with an ocular condition or a brain-based visual impairment.

Additional Populations' Access to the Wechsler Intelligence Scale for Children-Fifth Edition

Though there has been no targeted independent study on the access or reliability of the WISC-V for the visually impaired population, populations with a high comorbidity rate of CVI have been included in recent studies regarding access to the WISC-V. MacAllister et al. (2019) examined how individuals with Epilepsy accessed and scored on the WISC-V. It has been estimated that 64% of individuals with Epilepsy were also diagnosed with CVI (West et al., 2021). Coceski et al. (2022) examined how individuals with Cerebral Palsy's IQ presented using the WISC-V. Of the total population of individuals with cerebral palsy, 64-60% were estimated to also have CVI (Chokron & Dutton, 2023; West et al., 2021). The verbal scales of the WISC-IV Chinese edition were evaluated for visually impaired students by Chen et al. (2021). These did not specifically target the CVI population or examined the differences between the visual and low visual-based subtests. However, these three populations have a history of shared comorbidities with CVI and may better inform the foundational understanding of this study's intent.

MacAllister et al. (2019) first evaluated the WISC-V on individuals with Epilepsy with 80 participants; it was found that the participants scored significantly lower on all subtests than controls, individuals without Epilepsy. The most significant differences between controls were in the Working Memory Index and Processing Speed Index. The specific subtests of these indexes were Digit Span, Symbol Search, Coding, and Picture Span. The only subtest equal to the controls' scores was Figure Weights. MacAllister et al. (2019) concluded that the WISC-V was sensitive to the profiles of individuals with Epilepsy but did not provide insight into the known areas of deficits like memory and processing speeds.

The WISC-V was evaluated for individuals with mild and moderate CP to assess three methods of minimizing fine motor demands (Coceski et al., 2022). The study then compared the scores of the three motor-demand levels with traditional methods to compare overall Full Scale IQ scoring. It was found that, when motor demands were removed, the participants' Full Scale IQ score increased by three to six points. A similarity was found between the two evaluation methods, one using the adapted motor techniques and two using six nonmotor subtests; both resulted in similar Full Scale IQ scores that better evaluated the participants' abilities. They found that using either adaptive techniques or removing the motor demands altogether gave a better and more accurate picture of the participants' cognitive abilities. Similar to the goal of this study, Coceski et al. (2022) stressed that, when evaluating a student's cognitive abilities, the limitations of the disabilities should not hinder the understanding of their cognitive abilities, like motor or visual limitations.

Though the WISC-IV was not included in the study, Chen et al. (2021) was the first evaluation of a WISC edition specific to the visually impaired population since 1998 (MacCluskie et al., 1998; Vander Kolk, 1977, 1982; Wechsler, 2003). In addition, Chen et al. (2021) evaluated the use of the Chinese version of the WISC-IV which, in 2021, was the most current version used in China. The 100 participants had varying levels of functional vision, including braille readers. There was statistical significance in the participants' verbal scores compared to the norms. Vocabulary and Information were the two subtests with the most significant standard deviation from the norms. Chen et al. (2021) brought up the point that some vocabulary, like "transparent," may not have been relatable for students with a visual impairment. The Chinese version of the WISC-IV was valid and reliable compared to the overall norms for individuals with visual impairments.

Summary

Cortical/Cerebral Visual Impairment has been a spectrum that impacts each individual differently. There has been no quantitative representation of the impact. Nor has there been a visual representation of how individuals with CVI viewed the world. It has been known that individuals with CVI struggle to access and process the world around them visually. Not all individuals with CVI have chosen to use vision as their primary method of access to the world. The visual access challenges have varied from individual to individual; nevertheless, their visual access abilities depended on their visual attention and recognition. Not all individuals with CVI could locate visual stimuli visually and then visually recognize what they were looking at to engage with the world around them. The world has been visually dominant. If individuals could not visually access the environment, they would have decreased incidental learning opportunities, which may impact their development.

To understand the educational impacts of CVI, individuals should have a battery of data-based assessments to identify the implications across domains. Suppose a student with CVI was to participate in a cognitive assessment as part of a special education evaluation. In that case, these assessment results should be analyzed to allow all team members to gain better insight into the child's development and cognitive abilities without the impact of their visual impairment. It would be unjust to make any individual sit through testing or an evaluation that could not be utilized to its fullest extent. This study did not seek to validate the use of standardized WISC-V for students with CVI but to use it as a tool to better understand if the information gathered from the WISC-V could be used in a way better to understand the challenges or impact for individuals with CVI.

CHAPTER III

RESEARCH METHODOLOGY

Research Design

This study used a quantitative nonexperimental design. The intent of this nonexperimental comparative design, as defined by Creswell & Creswell (2018), was to analyze the relationship between two or more variables through statistical analysis. Each past and current edition of the WISC has been vetted among numerous populations of students but never the visually impaired or specifically, those with CVI. Using a quantitative comparative design, the composite and subtest scores of the WISC-V of CVI students, ocular visually impaired (OVI) peers, and WISC-V normative sample control were divided by the visual demands of a subtest, cumulative visual-based subtests, the visual media of the visual-based subtest, the complexity of the visual media, and whether there was a timing requirement for tests (Wechsler, 2014c). Comparing the visual demands of these subtests was used to identify whether visual access played a role in overall scoring. Individuals with CVI have decreased visual access and processing visual information tends to take them longer. To understand if the processing time of visual information played a role, the scores of the timed subtests were analyzed.

This study sample included students with CVI and OVI who were in educational environments outside of schools for the blind. This information is included in the demographics portion of this chapter, as is information related to the year the WISC-V was given, age at time of evaluation, and visual diagnosis.

Research Questions and Hypotheses

Research Questions

Q1 Do students diagnosed with CVI have lower cumulative vision-based subtest score than low-vision-based subtest score on the Wechsler Intelligence Scale for Children-Fifth Edition (WISC-V)?

Q2 Is there a significant difference between visual-based subtests that feature pictures vs symbols for students diagnosed with CVI's subtest scores on the Wechsler Intelligence Scale for Children-Fifth Edition (WISC-V)?

Q3 Does the complexity level within a specific visual media (picture or symbol) of a visual-based subtest have a correlation with a student diagnosed with CVI's subtest scores on the Wechsler Intelligence Scale for Children-Fifth Edition (WISC-V)?

Q4 Is there a significant difference between time-based subtests and untimed subtests for students diagnosed with CVI's subtest scores on the Wechsler Intelligence Scale for Children-Fifth Edition (WISC-V)?

Hypothesis

H1 The vision-based subtest scores significantly differ from low-vision-based subtests in the WISC-V for students with Cortical/Cerebral Visual Impairment.

H2 The symbol-based visual media subtest scores significantly differ from picture-based subtest scores in the WISC-V for students with Cortical/Cerebral Visual Impairment.

H3 The visual media subtest score significantly differs among the complexity levels of subtests in the WISC-V for students with Cortical/Cerebral Visual Impairment.

H4 The timed subtest scores significantly differ from un-timed subtests in the WISC-V for students with Cortical/Cerebral Visual Impairment.

Null Hypothesis

H01 There is no statistical significance in the visual-based and low-based subtest scores of the WISC-V for students with Cortical/Cerebral Visual Impairment.

H02 There is no statistical significance in the scores between picture- and symbol-based visual media sub-tests of the WISC-V for students with Cortical/Cerebral Visual Impairment.

H03 There is no statistical significance in the complexity levels among specific visual media subtest scores of the WISC-V for students with Cortical/Cerebral Visual Impairment.

H04 There is no statistical significance in the timed and untimed subtest scores of the WISC-V for students with Cortical/Cerebral Visual Impairment.

Research Sample and Setting

Target Population

The target population of this study included children medically diagnosed with CVI. The inclusion criteria for the study were individuals aged 6:00 and 16:11, in alignment with the WISC-V standardization norm sample. Additionally, participants needed to have a medical diagnosis of CVI, be native English speakers, and have verbal speaking abilities. Other inclusion criteria included having completed a WISC-V cognitive assessment by a certified school psychologist or licensed psychologist in the last 5 years. As there were variations across the country in the title of these evaluation reports, the categorical title was all inclusive, as long as the WISC-V was used. For example, one report may have been titled as a cognitive evaluation, or another may have had the title of psychologist report, but both included standard scores from a recent WISC-V evaluation. If the evaluation report included the WISC-V evaluation and scoring, the original protocol was unnecessary.

CVI and OVI participants may have had co-occurring visual impairments and met the criteria of legal blindness. The exclusion criteria for the ocular participant group included individuals diagnosed with Cerebral Palsy, Epilepsy, or Down syndrome due to the high prevalence of CVI in these populations. Additional exclusion criteria for all participants were if they were not residents of the United States. As the control participant group came from the data sample from the WISC-V Technical Manual (Wechsler, 2014a), inclusionary nor exclusionary criteria could uphold.

Sample Size

The statistical power analysis, G*Power (Version 3.1.9.6), was used with the A priori feature to find the target sample size estimate of 210 participants (Faul et al., 2009; Faul et al., 2007). The data analysis was intended to use G*Power's grouping labeled *t*-test with means: Difference between two independent means (two groups). The input parameters were set to Effect size d: 0.5, Alpha 0.05, and Power 0.95. This determined that the total sample size estimate should aim to be 210 participants. This study recruited 80 participants between the CVI and OVI groups. These were compared against the WISC-V normative data set of 242 (Wechsler, 2014c). Multiple actions were taken to help account for the stark difference in ratio between the three groups. The first method was to reduce the total sample of CVI and OVI to create a more equal ratio than $n = 13$ and $n = 67$. The participants who did not engage in more than 1 Visual subtest were removed from the data set. This created two data sets with both CVI and OVI had sample sizes of Total data set $n = 80$ and Partial data set $n = 22$. An additional method, when comparing the CVI to Control or OVI to Control, was to use Welch's *t*-test. This method is used when unequal variances are assumed (Bell et al., 2020). Despite the small sample size, it was representative of the target population based on the careful inclusion/exclusion criteria and since CVI is considered a low-incidence disability (McKinsey & Company, 2023).

Sampling

With no sampling frame or national data registry for individuals with CVI, this study utilized resources currently serving the target population. One resource for sampling opportunities was specialized schools at focus on educating blind or visually impaired students as identified by Council of Schools & Services for the Blind (Harris, 2017). For example, one east coast school for blind students, Perkins School for the Blind, advertised that an average of

50% of its on-campus student population had a diagnosis of CVI (Perkins School for the Blind, n.d.-a). Perkins also promoted its Educational Partnerships and Community Programs that served over 500 students in more than 125 school districts in New England (Perkins School for the Blind, n.d.-b). A second sampling method was through social media. One example of a CVI targeted social media avenue used was CVINow's Parent group, which, as of September 2023, had over 2,100 members (Perkins School for the Blind, 2023).

Sampling Procedure

After the Institutional Review Board (IRB) approved the study (see Appendix A), the potential participants were recruited using non-probability sampling, convenience sampling by the investigator, and snowball sampling. Recruitment was conducted through a combination of recruitment letters and word-of-mouth recruitment. The researcher contacted schools for blind students, school districts, licensed practicing school psychologists, and individuals identified as eligible by the inclusion and exclusion criteria. Snowball sampling was used to accommodate for no sampling frame and a small target population. Snowball sampling may occur through community resources available to caregivers that were not accessible sources for researchers, such as parent support groups or parent resource groups. Participants' records were redacted, deidentified, and given a numerical code. The parental consent form can be found in Appendix B.

Participant Sampling Results

This section presents the steps throughout the data collection process that led to the data analysis. In this case, and in many cases of special education research, a randomized sample was not possible. There have been an estimated 180,000 students with CVI in the U.S., with only 26,000 diagnosed (McKinsey & Company, 2023). As stated, there was no central database, registration organization, or universal ICA code for students with CVI, resulting in no standardized sampling frame or chance of randomized sampling. Nevertheless, through broad recruitment strategies, the researcher was able to create a diversified sample of youth identified with CVI.

Under the exempt research criteria, Institutional Review Board (IRB) approval was received on November 1, 2023; this kicked off the first round of recruitment (Appendix A). The first step was engagement with east coast schools that specialize in the education of students who are blind or visually impaired. During this first step of engagement, a recruitment method used was distributing social media pamphlets on CVINOW Instagram and the CVINOW Parent Facebook group. Both of these helped to identify additional CVI specific social media accounts across various platforms. Additionally, snowball sampling methods were used to spread awareness of the study through distribution of the study's pamphlet. From these methods, an east coast specialized school connected myself with their psychology department to help identify and redact WISC-V evaluations conducted in the last 5 years.

In tandem with these efforts, additional efforts were made to spread awareness of the study to resources across the country. Also, social media, such as Facebook, was used to distribute information about the study. Facebook group administrators were contacted, and if they approved, posts were made about the study and providing the study's recruitment materials. These groups included caregiver groups of children with visual impairments, TVI professional groups, and psychologist groups. These posts occurred twice, once in December and once in January.

As this study joined the TVI and psychology field, efforts were made to recruit and engage with licensed psychologists or certified school psychologists. Recruitment from this field stemmed from direct communication with psychologists, including e-mail communications. These psychologists identified Facebook groups and national associations where they could share study information to help the researcher recruit a larger sample. As these efforts fell under snowball sampling, it was unknown how many e-mails or social media posts were made through these efforts.

Distribution of recruitment materials occurred through TVI groups as well. The primary e-mail distribution occurred through the chapters of The Association for Education and Rehabilitation of the Blind and Visually Impaired (AER), which was an international membership program for professionals in the field of blindness and visual impairment. Many teachers of the visually impaired TVI were members of this association as it brought together resources in the community to this small, tight-knit field. AER has chapters internationally and across the U.S. based on geographic regions. In the United States, there were 35 chapters. Each chapter was contacted via e-mail to inquire about the distribution of study recruitment materials. Of the 35 chapters contacted, 4 e-mails bounced back. From the 31 e-mails presumed to have gone through, 6 chapters responded by December 31, 2023, and 4 chapters distributed information through their e-mail list and on their social media pages.

In addition, specialized schools, including those for visually impaired students across the United States, were contacted by e-mail inquiring about recruiting redacted WISC-V evaluation reports. Of the identified 35 schools specializing in educating students with visual impairments in the U.S. gathered from the Council of Schools & Services for the Blind list (Harris, 2017), 26 were contacted. Nine schools listed on Council of Schools and Services for the Blind were not approached as they had either (a) had already been contacted, (b) were no longer operating or (c) their contact was the same as the AER chapter contact. Of the 26 schools contacted, 10 responded to the inquiry and took the steps to participate in the study by December 2023 (Table 2). However, these participants resulted in no participants.

Table 2

Recruitment Response Rates

Recruitment Site	Response Percentage	Response Ratio
The Association for Education and Rehabilitation for the Blind and Visually Impaired (AER) Chapters	35.5	11 / 31
Specialized Schools	53.8	14 / 26
Public School Districts	21.3	10 / 47

Note. The percentage and ratios above indicate the cumulative response rate to an inquiring email sent between November 2023 and January 2024. These rates include responses even after a follow-up to a previously unanswered email. These also include both accepting and being unable to help.

In early January 2024, additional communication efforts were made to 25 AER chapters and 10 specialized schools, including schools for the blind that did not respond to earlier communications. From these second rounds of communications, an additional five AER chapters and four specialized schools replied (Table 2). This coincided with the second round of social media posts on the previously named platforms.

A final recruitment effort was made in late January 2024 to large public school districts across the United States. This effort was inspired by the realization that many large school districts did not contract for TVI services but had their own personnel who filled this role. To identify the largest school districts in the country, the U.S. Department of Education's National

Education Centers for Education Statistic's 2019 *The Condition of Education* report (McFarland et al., 2019) was referenced, as well as the U.S. Census Bureau's (2023) 2020-2022 city and town population totals. These combined resources were used to help gain representation from as many states and geographical areas as possible. The special education units or help services of school districts were contacted via e-mail to inquire about possible study participation. Of these districts, 10 responded (Table 2). To ensure the privacy of participants, schools, and school districts who responded and how they responded were not disclosed. However, of the ten public school districts that were contacted and responded in January, zero participants were provided. From the cumulative recruitment efforts, 19 participants were provided from five different districts from earlier efforts. Three participants were provided from social media posts. Specalized schools provided 59 participants.

Participant Sample

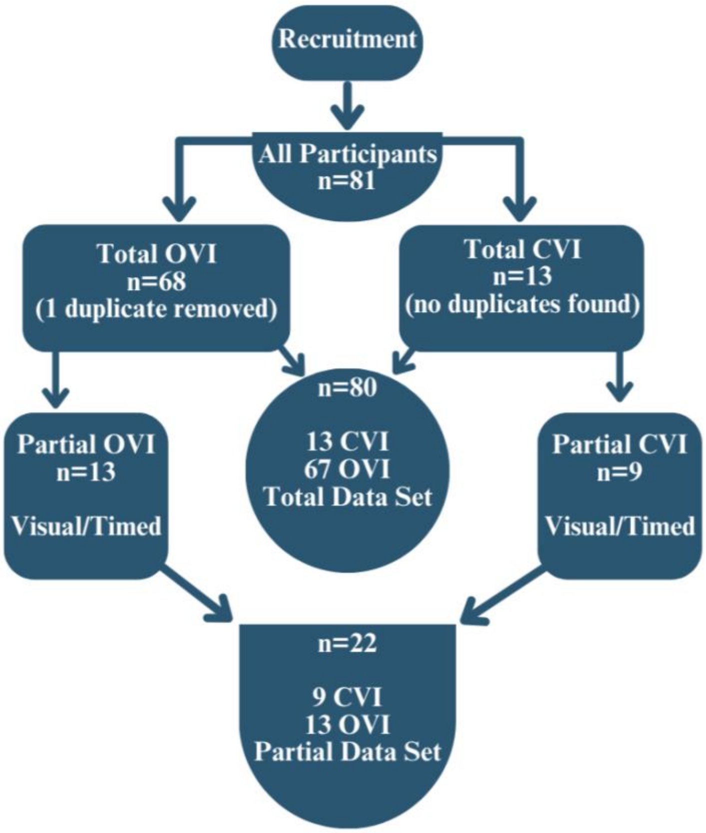
To understand the data sample from the WISC-V evaluation reports, it is important to recognize where the data comes from and what it comprises. From the combined recruitment efforts from November 2023 through January 2024, 81 WISC-V evaluations were received and 80 were included in this study, one was removed due to duplication provided by two separate sources (see Figure 15). Of the 80 participants, 13 (16.25%) had a diagnosis of CVI, and 67 participants (83.75%) had additional ocular or other visual impairments with no CVI.

Data Sets

To help combat this imbalance in group size and have a comparative analysis accurate to both the target population and sample, the participants who did not participate in subtests containing visual or timed components were excluded from a secondary data set, referred to as a Partial data set. Due to this new exclusion criteria, the large discrepancy between CVI and OVI groups was significantly decreased. When the evaluations without visual or timed subtests were removed, there were nine CVI participants (40.91%) and thirteen OVI participants (59.09%). The sample size of the Partial data set was n = 22, and the Total data set remained, n = 80 (see Figure 15).

Figure 15

Participant Decision Flow Chart



Instruments and Data Collection

Research Instruments

This study used WISC-V evaluation reports completed in the past five years as a research tool. The WISC-V is a standardized assessment tool used to evaluate a child's cognitive abilities

(Pearson, 2018; Wechsler, 2014a). As previously stated, the WISC-V is comprised of three broad index scales (a) Primary Index Scales, (b) Ancillary Index Scales, and (c) Complementary Index Scales. These three index scales can be further divided into potentially 11 indexes; (a) Verbal Comprehension Index, (b) Visual-Spatial Index, (c) Fluid Reasoning Index, (d) Working Memory Index, (e) Processing Speed Index, (f) Quantitative Reasoning Index, (g) Auditory Working Memory Index, (h) Nonverbal Index, (i) General Ability Index, (j) Cognitive Proficiency Index, (k) Naming Speed Index, and (l) Symbol Translation (Pearson, 2018; Wechsler, 2014a). Each index is comprised of certain that are aligned with cognitive process being measured, though some index subtests could be substituted for alternative subtests. Practitioners can administer seven standard subtests to obtain a Full Scale IQ score or 10 subtests to obtain the IQ score plus four index scores (Verbal Comprehension, Perceptual Reasoning, Working Memory, and Processing Speed). These are the two most common administration approaches if a child does not have a disability or language difference that requires an alternative approach to administration.

For this study, a participant's WISC-V scores was used to compare the impact of visual demands of visual-based subtests on the overall score for students with CVI. To be eligible, a certified school psychologist or licensed psychologist must have completed the WISC-V evaluation within the last five years. However, a Full Scale IQ was not an inclusion criterion. Participants with partial WISC-V scores were included with the number of subtests completed recorded for analysis, as not all participants were evaluated with the same subtest battery. The materials used consisted of the scaled score of each administered subtest that was provided by the practitioner.

Data Collection and Procedures

The data collection process might occur in two ways; the researcher received redacted, deidentified WISC-V's evaluations or a caregiver-initiated participation. Following the sampling procedures, the researcher worked with the identified sampling sources to obtain redacted and deidentified completed WISC-V reports, including the participants' scores on each WISC-V subtest. Obtaining redacted and deidentified WISC-V evaluation reports was the most secure method of ensuring potential participants' confidentiality. When redaction was not possible, or participation in the study was initiated by the participants' caregiver, the researcher helped caregivers of the participants understand the contents of the consent form (see Appendix B). The explanation identified the study's purpose, risks, personal data protection, and rights to end participation. Identification of the personal data protection policies included a description of how identifiers were removed to ensure confidentiality. After reviewing the study's procedures, the caregivers of the participants were asked if they consented to provide the WISC-V evaluation report. If they consented, they were asked to provide a wet or electronic signature of consent, and the participants' evaluation results were included in the study. The caregivers had the option to redact and deidentify prior to providing the evaluation reports. The caregivers were also given the option of providing the evaluations electronically or as a physical copy. The total time for the participation from the caregiver was estimated at 1 hour, depending on the difficulty of obtaining records. After being presented with information of the study, no parent refused to participate. In total, 78 redacted evaluations were received, with three requiring the researcher's redaction.

After WISC-V evaluation results were obtained and any needed redaction and deidentification procedures were completed, the results were input into an Excel file. The data were organized by subtests, subtest scores, index scores, and total scores. The data collected from the evaluation report included the following demographic and participant information: age, diagnoses, year of evaluation, state, educational site, and any unexpected events in the evaluation process. The data collected were housed in a password-protected Excel file on a password-protected laptop, only accessed by the researcher.

The results of the evaluations were collected using the participants' WISC-V's scaled score. The scaled scores were inputted under the corresponding subtest and indices. These subtests were grouped and coded based on their corresponding correlation to the related research question. The coding was done following the color-coding groupings as seen in previous figures 2, 3, 4 and 5, and in Table 3. The first coding separated visual-based subtests (16) and low visual-based subtests (7). The second coding took the visual subtests and separated them by their use of visual materials that were primarily picture-based (10) or symbol-based (6). The third coding separated the timed (8) and untimed subtests (15). Not all participants were evaluated with each subtest. However, these coding methods were used to ensure if a participant did complete or attempted a subtest, it was categorized correctly (Table 3).

Table 3

Subtest Coding of the Wechsler Intelligence Scale for Children-Fifth Edition

Visual-Based	Picture- or Symbol-Based	Timed
Verbal Comprehension	Verbal Comprehension	Verbal Comprehension
Similarities	Similarities	Similarities
Vocabulary	Vocabulary	Vocabulary
Information	Information	Information
Comprehension	Comprehension	Comprehension
Visual Spatial	Visual Spatial	Visual Spatial
Block Design	Block Design	Block Design
Visual Puzzles	Visual Puzzles	Visual Puzzles
Fluid Reasoning	Fluid Reasoning	Fluid Reasoning
Matrix Reasoning	Matrix Reasoning	Matrix Reasoning
Figure Weights	Figure Weights	Figure Weights
Picture Concepts	Picture Concepts	Picture Concepts
Arithmetic	Arithmetic	Arithmetic

Table 3 (continued)

Visual-Based	Picture- or Symbol-Based	Timed
Working Memory	Working Memory	Working Memory
Digit Span	Digit Span	Digit Span
Picture Span	Picture Span	Picture Span
Letter-Number Sequence	Letter-Number Sequence	Letter-Number Sequence
Processing Speed	Processing Speed	Processing Speed
Coding	Coding	Coding
Symbol Search	Symbol Search	Symbol Search
Cancellation	Cancellation	Cancellation
General ability	General ability	General ability
Cognitive Proficiency	Cognitive Proficiency	Cognitive Proficiency
Complementary Index Scores	Complementary Index Scores	Complementary Index Scores
Naming Speed	Naming Speed	Naming Speed
Naming Speed literacy	Naming Speed literacy	Naming Speed literacy
Naming Speed quantity	Naming Speed quantity	Naming Speed quantity

Table 3 (continued)

Visual-Based	Picture- or Symbol-Based	Timed
Symbol Translation	Symbol Translation	Symbol Translation
Immediate symbol translation	Immediate symbol translation	Immediate symbol translation
Delayed symbol translation	Delayed symbol translation	Delayed symbol translation
Recognition symbol translation	Recognition symbol translation	Recognition symbol translation
Storage and Retrieval	Storage and Retrieval	Storage and Retrieval
Naming Speed Index	Naming Speed Index	Naming Speed Index
Symbol Translation Index	Symbol Translation Index	Symbol Translation Index

Note. The above table is color coded to represent the coding used to create variables is SPSS when analyzing the data related to the four research questions. The presented subtests are listed under their associated Index using the Full Scale IQ score model. The first table is coded with 16 subtests blue to indicate they are visual-based subtests. The second column has those same 16 subtests coded either purple or green. Purple indicates the subtest uses picture-based media. Green indicated the subtests used symbol-based media. The third column has eight subtests coded orange, indicating they were timed subtests.

Q1 Do students diagnosed with CVI have lower cumulative vision-based subtest score than low-vision-based subtest score on the Wechsler Intelligence Scale for Children-Fifth Edition (WISC-V)?

The three newly created variables that were developed to target Research Question 1 were total subtests, which comprised all subtest scores for all data points in the Partial data set. That variable was then copied and split into two, creating the subtest CVI and subtest OVI. These two variables had all subtests data points specific to the related target group, CVI or OVI. In the low visual-based subtest category, seven of the WISC-V subtests were included, as these were the 7 subtests the sample participated in that were of low visual-based demands (Similarities, Vocabulary, Information, Comprehension, Arithmetic, Digit span, and Letter Number Sequence). The developed visual-based subtest variable created in SPSS comprised the nine visual-based subtests the sample completed (Matrix Reasoning, Picture Concepts, Picture Span, Clock Design, Coding, Symbol Search, Visual Puzzles, Figure Weights, and Cancellation). These two created variables were coded as total low visual-based and total visual-based. All collected data from the CVI and OVI groups related to the specific category were included in those data sets. Each created variable was then recreated for the specific group and coded as low visual-based CVI, low visual-based OVI, visual-based CVI, and visual-based OVI.

Participant Privacy

The researcher collected and retained copies of the provided materials (see Appendices A and B). During this time, all personally identifiable information was removed. Participants' evaluation results were given a numerical identifier. Identifying labels within the materials, such as name, date of birth, residency address, or evaluation location, were redacted and deidentified. Due to the analysis nature of the study, it was assumed this design would not present as a threat to participants (see Appendix A).

Internal and External Validity

Internal Validity

In this study, many factors helped to contribute to an increase in internal validity. One such factor was the blinding effect. As a retroactive analysis, the individual who administered the WISC-V was unaware of the potential use of the evaluation report for future analysis of the student's access. Thus, it was assumed that they did not deviate from standardizing the test to accommodate the student's visual needs unless identified in the report. Another factor was random selection. Though the participants were selected through non-probability sampling, convenience sampling, and snowball sampling, the same could not be said for the licensed or certified psychologist. The psychologist who performed the evaluation was random to the study. The psychologists' awareness and understanding of CVI were unknown, and the psychologists would not be aware that their work may have been selected for the study. The final factor was the standardization of the WISC-V. Though the evaluators who administered the actual tests were different, the hope was that each followed the standardized practices of the WISC-V, or if they modified to accommodate the child's vision, that information was noted in the report. This extended to the test materials themselves. The subtests within the WISC-V did not change; each participant engaged in the same subtests used the same materials unless the administer chose not to administer certain tests if they believed the subtests were inaccessible to the student (Pearson, 2018; Wechsler, 2014a).

External Validity

When looking at the threats to external validity, there was the threat of interaction of selection and treatment as well as the interaction of setting and treatment (Creswell & Creswell, 2018). As a retroactive study, the characteristics and control of the WISC-V evaluation room could not be managed (Pearson, 2018; Wechsler, 2014a). A review of the evaluation results for identifying threats to the evaluation setting was done to accommodate this. If any were found that were deemed a risk to the evaluation results, they were not counted. No such evaluations were found to have noted extenuating circumstances related to the evaluation environment. In addition to setting, selection was a potential external validity risk factor. With a low-incidence disability, such as CVI, the selection of participants may be small, with a risk of not representing the community. To accommodate this external threat, the researcher developed a demographic statistical analysis to identify the make-up of the sample to better compare to the target population. To accommodate for this, recruitment covered a wide range in an attempt to identify and reach as many students with CVI as possible.

Data Analysis

The mean scaled score results came from the standardized WISC-V, which has undergone multiple reliability and validity testing with the populations mentioned above. The participants' evaluation results were transcribed from the evaluation report and scoring card and inputted into a secure Excel (Version 16.74) computer file. The secure Excel file was a coded Excel spreadsheet documenting the participants' scores for the completed s index and subtest scaled scores. The subtests were categorized as visual or low visual-based, the type of visual media presented (picture or symbol), the visual media's complexity level, and timed or untimed (Pearson, 2018; Wechsler, 2014a). This Excel file was uploaded to a password protected Google Sheets to run descriptive analysis on the Total and Partial data sets using pivot tables. The Excel file was then also uploaded to IBM SPSS Statistics (Version 28) to run the inference analysis for the comparative and inferential statistical design. The statistical analysis used multiple analyses to gain the most holistic interpretation of the subtest scores and potential relationships.

The first method of data analysis, described in more detail in Chapter IV, was a demographic analysis, through Google Sheets pivot tables. This was to provide an overview of the population sample included in the current study. After which, a comparative analysis using independent, and paired sample *t*-tests was used to look for mean, median, mode and standard deviation across subtest scores of participants with CVI and OVI. The following statistical analyses were used to compare the differences between the three participant groups. Independent and paired sample *t*-tests were used to compare the mean scores for CVI and OVI groups, against the Control group data from the WISC-V manual (Wechsler, 2014a, 2014c). The above-mentioned criteria categorized the results including their index and total WISC-V scores. Additionally, paired samples and independent samples *t*-tests comparisons though coupled groups were used to evaluate the differences between couplings (Bell et al., 2020).

Descriptive Statistics

To evaluate if the target population was represented within the study, a demographic analysis was included to understand better the population of students with visual impairments (both CVI and OVI) in public and specialized schools. The demographic analysis presented a comprehensive participation profile including but not limited to ocular diagnosis, year of WISC-V completion, and age at time of evaluation. The descriptive analysis results are presented in Chapter IV through a narrative summary and comparative table.

Inferential Statistics

The comparative design of the study analysis compared the WISC-V evaluation results of the CVI, OVI, and a Control group, between groups, within groups and comparatively between the three. This was done using hand calculated analysis, independent *t*-tests, and paired samples tests in SPSS. Before starting the study, G*power (Version 3.1.9.6) was used to run an a priori power analysis; the input parameters were set to Effect size 0.5, Alpha 0.05, and Power 0.95 (Faul et al., 2009, Faul et al., 2007). Although a minimum sample size of 210 was indicated, 80 participants between the CVI and OVI groups were recruited. The study achieved a CVI sample of $n = 13$ and an OVI sample of $n = 67$. These were compared against the WISC-V normative data set from the technical manual which was used as a control comparison with a total of 242 participants (Wechsler, 2014c). During the data analysis period, Google Sheets, Excel, GraphPad and SPSS were utilized to determine the statistical significance of the null and alternative hypotheses posed in Research Questions 1, 2, 3, and 4. The results are presented in a table format. A p-value of 0.05 was used in this study.

Summary

This study represents one of the first attempts to understand how children with CVI perform on the WISC-V subtests that are more or less visually loaded. By using a nonexperimental study design, the goal was to limit any risk, threat, or time commitment for participants and their families. Individuals with CVI have tended to be grouped under the larger blindness umbrella, and in some cases individuals with CVI also experience co-occurring ocular visual impairments. Therefore, it was important to understand how students with CVI only and OVI perform on the WISC-V r when compared to the standardization sample. As CVI is being identified more frequently, the spectrum of blindness should be represented in research related to the special education evaluation process.

CHAPTER IV

RESULTS

Individuals with CVI access the visual world around them differently from those who do not have this condition (Dutton, 2015; Jan et al., 1987; Kran et al., 2019). Sometimes children with CVI are recommended for a special education evaluation and will receive a cognitive evaluation, such as the WISC-V. Unfortunately, most ability tests, including the WISC-V, use visual stimuli and timed performance throughout the items, creating questions about how well this type of assessment might accurately measure ability for youth with CVI. The purpose of this quantitative study was to use statistical analysis to compare the WISC-V scores of visual-based, picture-based, symbol-based and timed subtests along with the subtests' complexity levels between participants with CVI, OVI, and pre-existing data from a control group from the WISC-V Technical Manual (Wechsler, 2014c). These statistical analyses compared the categorized subtest variables: visual-based, low visual-based, picture- and symbol-based, and timed and untimed. By looking at the three groups' scores across the developed categories, the hope was to uncover any potential statistical trends in the data.

Analysis Profile

The cumulation of the data of the participants' WISC-V scores presented many ways to look at the data. Though quantitative analysis was meant to be straightforward, the subjective nature of the selection of statistical analysis should be considered. Researchers bring their experiences, expertise, comforts, and conscious and unconscious biases. These biases could play a role in the selection of the statistical analysis. This study utilized various statistical analysis approaches to help mediate and reduce the potential limitations to provide a well-rounded view. The statistical analyses used a combination of Google Sheets, Excel, GraphPad, and SPSS. These included the execution of descriptive analysis, comparative methods including means, Welch's *t*-test, independent-samples *t*-test, paired-samples *t*-tests, and group correlations. The descriptive analysis was primarily used to help understand the demographics of the participant groups, including both the Total and Partial data sets.

The comparative analysis occurred in multiple steps to first provide the foundational understanding of the data collected through preliminary analysis, using hand calculations, GraphPad, and *t*-tests in SPSS. The preliminary results of the Total data sets are mentioned in narrative format and tables until the research question section. The analysis of the research questions used only the Partial data set to ensure a representative sample and account for unequal variances. All *t*-tests assumed unequal variances. Next came the use of the new variables created in SPSS that targeted the specific research questions (Table 4). The variables were evaluated through independent-samples *t*-tests and paired-samples *t*-tests (Creswell & Creswell, 2018).

Table 4

Research Question Statistical Procedures and Variables

Research Question		Analysis Method	Independent Variable	Dependent Variable
Q1	Do students diagnosed with CVI have lower cumulative vision-based subtest score than low-vision-based subtest score on the Wechsler Intelligence Scale for Children-Fifth Edition (WISC-V)?	Welch's *t*-test, Independent-Samples *t*-test, Paired-Samples *t*-test	Visual Diagnosis	Visual-Based Subtest Scores Low Visual-Based Subtest Scores
Q2	Is there a significant difference between visual-based subtests that feature pictures vs symbols for students diagnosed with Cortical/Cerebral Visual Impairment's subtest scores on the Wechsler Intelligence Scale for Children-Fifth Edition (WISC-V)?	Welch's *t*-test, Independent-Samples *t*-test, Paired-Samples *t*-test	Visual Diagnosis	Picture-Based Subtest Scores Symbol-Based Subtests Scores
Q3	Does the complexity level within a specific visual media (picture or symbol) of a visual-based subtest have a correlation with a student diagnosed with CVI's subtest scores on the Wechsler Intelligence Scale for Children-Fifth Edition (WISC-V)?	Complexity ranking, Independent-Samples *t*-test, Paired-Samples *t*-test	Visual Diagnosis	Picture-Based Subtest Scores Symbol-Based Subtest Scores
Q4	Is there a significant difference between time-based subtests and untimed subtests for students diagnosed with Cortical/Cerebral Visual Impairment's subtest scores on the Wechsler Intelligence Scale for Children-Fifth Edition (WISC-V)?	Welch's *t*-test, Independent-Samples *t*-test, Paired-Samples *t*-test	Visual Diagnosis	Timed Subtest Scores Untimed Subtest Scores

Descriptive Analysis

Total Data Set Participants

From the Total data set, 67 (83.8%) of the 80 evaluations were from OVI participants. Of the 67 OVI evaluations, 61 included a medical or vision related identifier related to the individual's visual impairment. Of those 61, 21 (34.4%) described the student as being blind. The most frequently vision-related term identified in 12 (19.7%) reports for OVI individuals was no light perception (NLP; see Table 5). The second most frequently used term in 10 (16.9%) reported for OVI participants was Optic Nerve Hypoplasia (ONH). Optic Nerve Hypoplasia could result in an individual having no light perception. However, no evaluation report overlapped using both terms (NLP or ONH) in one report (see Table 5).

Of the CVI participants in the Total data set, four (30.7%) identified additional visual impairment (see Table 6). Of those four, multiple visual impairments were listed per report, all visual impairment related diagnosis are listed in Table 4. Of the Total CVI participants with WISC-V reports, 5 of the 13 had additional disabilities identified within the medical background section (see Table 7). There were multiple additional disabilities listed in three of the five reports. As there was no diagnostic standard for CVI present in the United States, understanding the additional diagnosed disabilities of participants with CVI could help to understand the population sample of this study for future study replication (Kran et al., 2019; McKinsey & Company, 2023).

Table 5

Ocular/Other Visual Impairments of Total Data Set

Visual Diagnosis	Count
No Light Perception (NLP)	12
Optic Nerve Hypoplasia (ONH)	10
Visual impairment	6
Albinism	5
Leber’s	4
Glaucoma	3
Brain Tumor	3
Optic Nerve Atrophy	2
Ocular Motor Apraxia	2
Bardet-Biedl Syndrome	2
Septo-Optic Dysplasia	1
Retinopathy of Prematurity	1
Retinoblastoma	1
Retinal Detachment	1
Peter’s Anomaly	1
Ocular Lens Condition	1
Limited Vision	1
Goldenhar syndrome	1
Congenital Nystagmus	1
Congenital Bilateral Microphthalmia	1
Charge syndrome	1
Anterior Subcapsular Polar Infantile	1
Total	61

Table 6

Additional Cortical/Cerebral Visual Impairments' Visual Impairments

Visual Diagnoses	Count
Septic Optic Hypoplasia	1
Optic Nerve Hypertrophy	1
Nystagmus	1
Myopia	1
Blepharitis	1
Astigmatism	1
Amblyopia	1
Total	7

Table 7

Additional Cortical/Cerebral Visual Impairments' Disabilities

Additional Diagnoses	Count
Attention-Deficit /Hyperactivity Disorder (ADHD)	3
Cerebral Palsy	2
Traumatic Brain Injury	1
Stroke	1
Seizures	1
Mood Dysregulation Disorder	1
Fetal Alcohol Syndrome	1
Dyslexia	1
Autism Spectrum Disorder	1
Anxiety	1
Total	13

Total Data Set Demographics

The year of test completion and age at the time of evaluation were asked to be kept visible on the WISC-V evaluation reports to ensure they fell within the study's inclusion parameters. In Table 8, the seven states that were represented in the collected 80 WISC-V evaluation reports can be seen (CO, GA, MA, NH, NJ, NY, and SD). The data sample represented public education systems and specialized schools which included those that focused on the education of students with visual impairments. Of the 80 reports, 78 indicated the educational setting of the participant (see Table 9). Most evaluations (74, 92.5%) were conducted in the educational settings by certified school psychologists or licensed psychologists. The remaining six (7.5%) were conducted by outside an outside agency, usually by a licensed psychologist. The six outside evaluations were indicated in the WISC-V report or communicated to the researcher by the providing party. One participant was home-schooled at the time of the evaluation period. To help ensure participant privacy, the participant's visual impairments, the state of the evaluation, and the educational setting were not compared together. As visual impairments represent a low-incidence disability, providing the comparative data together would risk the participant or educational institution's identity. However, to understand the data, it was important to recognize the majority came from Massachusetts, and a handful came from other states (see Table 8). The educational settings of the OVI and CVI participants, public, or specialized schools, is an additional demographic to recognize (see Table 9).

Table 8

Participant Demographic Analysis from the Total Data Set

Visual Diagnosis	State	*n*	%	*Mdn* Age at Evaluation
Cortical/Cerebral Visual Impairment	MA	12	15.0	11.7
	NJ	1	1.3	8.4
Cortical/Cerebral Visual Impairment Total		13	16.3	11.0
Ocular Visual Impairment	MA	32	40.0	11.8
	NY	21	26.3	12.5
	GA	9	11.3	12.5
	SD	3	3.8	
	NH	1	1.3	9.1
	CO	1	1.3	12.0
Ocular Visual Impairment Total		67	83.8	12.0
Grand Total		80	100.0	12.0

Table 9

Analysis by Educational Setting from the Total Data Set

Visual Diagnosis	Number Attending	*Mdn* Age at evaluation
Public Schools		
Ocular Visual Impairment	12	9.1
Cortical/Cerebral Visual Impairment	7	9.5
Public Schools Total	19	9.1
Specialized Schools		
Ocular Visual Impairments	54	12.5
Cortical/Cerebral Visual Impairment	5	13.1
Specialized Schools Total	59	12.5

Partial Data Set

To address the assumed unequal variances and to ensure that groups were comparable to one another in terms of the number of subtests completed, the Total data set (n = 80), was reduced to a Partial data set (n = 22). As might be expected given the level of vision loss in some participants, not all 80 individuals of the Total data set completed all of the WISC-V subtests. However, in order to conduct the proposed analysis, it was necessary that the sample had completed visual and timed subtests. The Partial data set added the inclusion criteria that a participant's scored subtests must include two visual and timed subtests to randomize the selection of included evaluations and make the comparisons equal. This aligned well with the total participants that had completed the Full Scale IQ, or General Ability Index, 17 of the total 80.

The visual impairments identified in the reports of the Partial data set's OVI group differed from those in the Total data set (see Table 10). There was no longer NLP, or Optic Nerve Hypoplasia, identified as the OVI group's listed visual impairments. Rather, the most common vision impairments were listed as Visual Impairment and Albinism. There was no change in the additional disabilities listed for CVI participants, and those remained the same as those listed in Table 7.

Table 10

Ocular/Other Visual Impairments of Partial Data Set

Visual Diagnosis	*n*
Visual impairment	3
Albinism	3
Retinal detachment	1
Ocular Motor Apraxia	1
Goldenhar syndrome	1
Charge syndrome	1
Bardet-Biedl Syndrome	1
Total	11

The majority of the participants in the Partial data set (95%) were from the east coast region (see Table 11). The average age at evaluation was lowered from 12.0 years in the Total data set to 10.8 years in the Partial data set. The ratio between educational locations also changed between data sets. In the Total data set, the primary educational location was specialized schools (75.6%). In the Partial data set, of the 20 that had educational location identified, 75% attended public school (see Table 12). A comparative analysis between the participants' state, visual diagnosis, education location, age at evaluation, and year of evaluation was not presented in an effort to ensure participant confidentiality.

Table 11

Participant Demographics of Partial Data Set

Visual Diagnosis	State	*n*	%	*Mdn* Age at Evaluation
Cortical/Cerebral Visual Impairment	MA	8	36.4	10.3
	NJ	1	4.6	8.4
Cortical/Cerebral Visual Impairment Total		9	40.9	9.5
Ocular Visual Impairment	MA	11	50.0	11.4
	NH	1	4.6	9.1
	CO	1	4.6	12.0
Ocular Visual Impairment Total		13	59.1	11.4
Total		22	100.0	10.8

Table 12

Analysis by Educational Setting Comparison of Partial Data Set

Visual Diagnosis	Number Attending	*Mdn* Age at evaluation
Public Schools		
Ocular Visual Impairment	9	8.9
Cortical/Cerebral Visual Impairment	6	10.3
Public Schools Total	15	9.3
Specialized Schools		
Ocular Visual Impairment	4	12.9
Cortical Visual Impairment	1	13.4
Specialized Schools Total	5	13.0

Preliminary Analysis

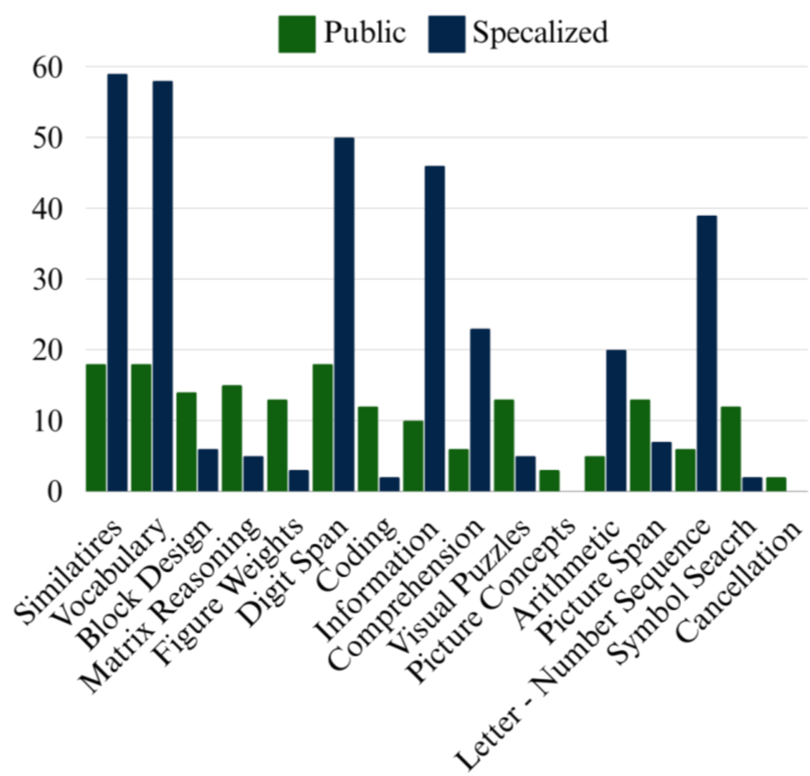
When a student was evaluated using the WISC-V, the certified school psychologist or licensed psychologist had 21 subtests at their disposal to help gain an understanding of the student's cognitive ability. The typical approach was the use of a combination of the 7 to 10 core subtests that could be used to calculate the participant's Full Scale IQ score (Wechsler, 2014a). When a student participated in a WISC-V evaluation and each subtest was scored, they received an initial raw score that was then scaled and given a percentile (Wechsler, 2014a, 2014b). This study used the participants' scaled scores as the comparison. Due to these professional options and the students' abilities, not all evaluation reports received in this study comprised the same subtests, indexes, General Ability Index, or Full Scale IQ. Practitioners used both the referral question and clinical judgment in deciding on which subtests to administer to any one student. For example, if the question was related to a child's ability, the 7 subtests of the FSIQ might be administered, or more commonly, 10 subtests that created 4 index scores, and 7 of which were used for the FSIQ. If a clinician found there was wide variation in the scores or believed that certain subtests might not accurately reflect a child's abilities, they may opt for different indices as an estimate of a child's ability. For example, using a General Ability Index (GAI) for a child with ADHD or using a nonverbal index for a child with hearing loss or who speaks a language other than English. Understanding the cumulative results of all evaluation samples, educational locations, and diagnosis were important.

Group Statistics of Specialized and Public Schools

This comparative analysis used a combination of Excel, Google Sheets' Pivot Tables, and SPSS to represent the culminative data of educational setting. Due to the low incidence of the disability category and to ensure participant confidentiality, results were not presented by a joint comparison of state and educational location. The count of the total data set's subtests, by educational location, can be seen in Figure 16. When comparing the index usage of the Total data set (n = 80), both specialized and public schools calculated a Verbal Comprehension Index score the most and a General Ability Index (GAI) the least. A considerable discrepancy between the groups was the Auditory Working Memory Index; specialized schools provided these scores 36 times compared to the public school group's 4 times (Appendix C). The scores of the indexes did vary between educational location groups. The specialized schools highest average index was in the Working Memory Index (n = 4, M = 106.76) with the lowest average score in Auditory Working Memory (n = 13, M = 88.08). Comparatively, the public school group's highest average score was the Verbal Comprehension Index (n = 17, M = 91.35) and the lowest in the Auditory Working Memory Index (n = 4, M = 70.0; Appendix D). Both the specialized (59) and public school (18) groups used the Similarities subtest frequently. The Similarities subtest was the most frequently used subtests in the specialized school groups. Similarities were tied with Vocabulary and Digit Span, all given 18 times (Appendix E). The specialized school group's highest average subtest was the Symbol Search (*n* = 2, *M* = 12.00) with the lowest average score in Comprehension (*n* = 23, *M* = 5.65). However, the public school group's highest average score was Cancellation (*n* = 2, *M* = 8.50) and the lowest average in Coding (*n* = 12, *M* = 4.08; Appendix F).

Figure 16

Total Data Set Educational Setting Subtest Count

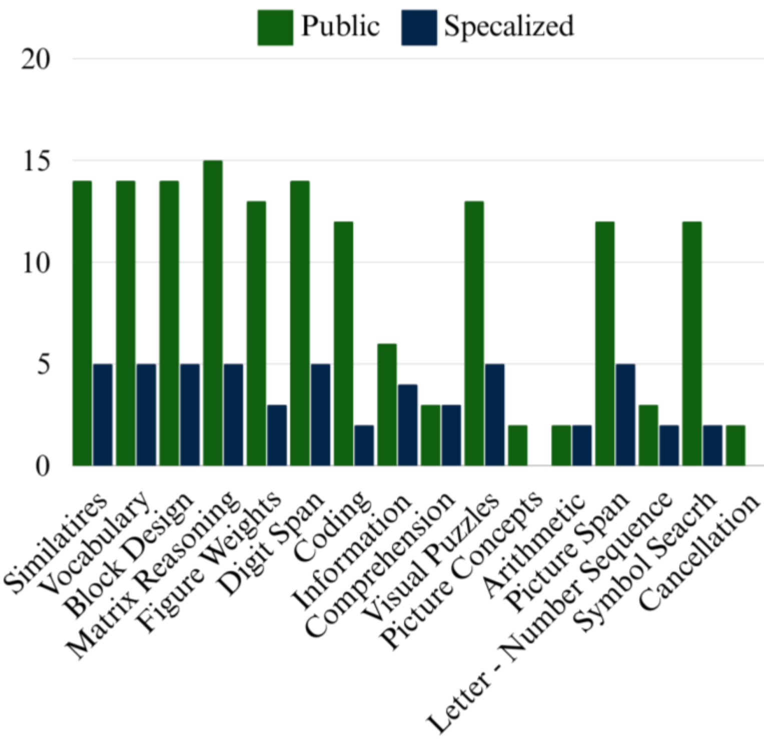


This comparison was then run with the Partial data set (*n* = 22) to compare the count and average score for both indexes and subtests across educational settings. The count of each subtest, by educational location, can be seen in Figure 17. The specialized (13) and public school

(5) groups maintained the Verbal Comprehension Index as the most scored index. The least scored index of both the specialized (*n* = 1) and public school (*n* = 1) groups was Auditory Working Memory Index (Appendix G). This represented a substantial change between the frequency of use with the Total data set. The highest average index score of the specialized schools was in the Working Memory Index (*n* = 4, *M* = 106.75) and Verbal Comprehension Index (*n* = 13, *M* = 89.39) for the public school group (Appendix H). The highest mean scaled scores were the same highest indexes of the Total data set. The specialized school group's lowest average score maintained as Verbal Comprehension Index (*n* = 5, *M* = 99.00). The public school group's lowest average index also maintained as the Auditory Working Memory Index (*n* = 1, *M* = 46.00; Appendix H). When looking at the subtests frequency count, there was a tie seen in both the specialized and public school groups: (a) Similarities, (b) Vocabulary, (c) Block Design, (d) Matrix Reasoning, (e) Digit Span and the specialized school group also used (f) Visual Puzzles and (g) Picture Span just as often (Appendix I). The specialized school group's highest average subtest maintained as the symbol search (*n* = 2, *M* = 12.00) with the lowest average score in Coding (*n* = 12, *M* = 7.00). Similarly, the public school group's highest average score was also maintained as a Cancellation (*n* = 2, *M* = 8.50), but the lowest average was in Letter-Number Sequencing coding (*n* = 3, *M* = 2.67; Appendix J).

Figure 17

Partial Data Set Educational Setting Subtest Count



Subtest and Index Count for Cortical/Cerebral Visual Impairment and Ocular Visual Impairment

As seen in the educational setting comparison, there were 6 indexes, 17 subtests, as well as the Full Scale IQ and General Ability Index calculations used across both the Total and Partial data sets for the CVI and OVI groups. Across the Total and Partial data sets, both CVI and OVI groups, practitioners used the Similarities and Vocabulary subtests most often (see Table 13). The Similarities was the only subtest given to 100% of participants in the Total data set. Whereas, in the Partial data set, 5 subtests were given to all 22 participants across OVI and CVI groups: (a) Similarities, (b) Vocabulary, (c) Matrix Reasoning, (d) Block Design, and (e) Digit Span. In the Total and Partial data sets, both CVI and OVI groups had the three least used subtests as: (a) Picture Concepts, (b) Cancellation, and (c) Naming Speed Literacy. No index was scored with all participants in neither the Total nor Partial data set (see Table 13). However, the Verbal Comprehension Index was used with all OVI participants of Partial data set and 95% of all participants. Similarly, it was used with 95% of participants in the Total data set.

Group Statistics

The preliminary analysis which used comparative methods and *t*-tests of all data sets included a look at the group statistics looking at; mean, standard deviation, sample size, difference, *df*, *t*-value, *p*-value (.05), standard error, and 95% CI level. Significance was at the level of $\alpha = 0.05$, with 95% CIs. The WISC-V normative data set from the WISC-V Technical Manual was used as a comparison for the CVI and OVI groups (Wechsler, 2014a, 2014c). The Control normative data set had a sample size of 242, aged between 6 and 16. The normative data set included mean, standard deviation, and sample size limiting any statistical analysis to hand-based calculations. Due to the wide scope in sample size, times, and locations of collections, the study maintained that variances were not assumed equal. In the group statistics, the Welch's *t*-test was used to accommodate for the difference in unequal variances and sample sizes. Subtests were labeled with either or neither Visual or Visual/Timed. These indicated if that subtest was a visual subtest and untimed and a visual timed subtest. All timed subtests were also visual subtests. The results specific to the scores of visual and timed subtests are discussed more in the research question sections below. These labels provided an early look at potential trends in the subtests through the lens of visual and time demands. To help maintain consistency through the multiple methods of presentation and representation of the data, CVI data were in the left column, with related groups to the right.

Table 13

Count of Administered Indexes and Subtests from Total and Partial Data Sets

	Total Data Set				Partial Data Set		
Indexes/Subtests	Cortical/Cerebral Visual Impairment	Ocular Visual Impairment		Indexes/Subtests	Cortical/Cerebral Visual Impairment	Ocular Visual Impairment	
	n	*n*	Total		*n*	*n*	Total
Indexes							
Verbal Comprehension	12	64	76	Verbal Comprehension	8	13	21
Fluid Reasoning	7	10	17	Fluid Reasoning	7	10	17
Working Memory	6	13	19	Working Memory	6	12	18
Visual Spatial	6	11	17	Visual Spatial	6	11	17
Processing Speed	5	9	14	Processing Speed	5	9	14
Auditory Working Memory	4	36	40	Auditory Working Memory	1	1	2
General Ability	3	2	5	General Ability	3	2	5
Full Scale	6	8	14	Full Scale	6	8	14
Subtests							
^Similarities	13	67	80	^Similarities	9	13	22
^Vocabulary	13	66	79	^Vocabulary	9	13	22

Table 13 (continued)

	Total Data Set				Partial Data Set		
Indexes/Subtests	Cortical/Cerebral Visual Impairment	Ocular Visual Impairment		Indexes/Subtest	Cortical/Cerebral Visual Impairment	Ocular Visual Impairment	
	n	*n*	Total		*n*	*n*	Total
^Digit Span	12	59	71	^Matrix Reasoning	9	13	22
^Block Design	10	13	23	^Block Design	9	13	22
Information	9	47	56	^Digit Span	9	13	22
^Matrix Reasoning	9	14	23	^Figure Weights	8	10	18
^Figure Weights	8	10	18	^Visual Puzzles	7	12	19
Comprehension	7	22	29	^Coding	7	9	16
Picture Span	7	14	21	Picture Span	6	12	18
Visual Puzzles	7	12	19	Symbol Search	6	9	15
^Coding	7	9	16	Information	5	5	10
Letter-Number Sequence	6	40	46	Letter-Number Sequence	3	3	6
Symbol Search	6	9	15	Comprehension	3	3	6
Arithmetic	5	20	25	Arithmetic	2	2	4

Table 13 (continued)

	Total Data Set				Partial Data Set		
Indexes/Subtests	Cortical/Cerebral Visual Impairment	Ocular Visual Impairment		Indexes/Subtests	Cortical/Cerebral Visual Impairment	Ocular Visual Impairment	
	n	*n*	Total		*n*	*n*	Total
Picture Concepts	1	2	3	Picture Concept	1	1	2
Naming Speed literacy	1	1	2	Cancellation	1	1	2
Cancellation	1	1	2	Naming Speed Literacy	1	0	1

Note. The Total data set had an $n = 80$ and the Partial data set had an n of 22. Subtests with a [^] in front of its name is indicative of that subtest being one of the core seven subtests of the Full Scale IQ score.

Group Statistics of the Total Data Set

Using the Total data set, (n = 80), the mean scaled scores for each subtest were listed from the CVI groups from greatest to least, with one exception, the Coding subtest was listed first (see Table 14). The Coding subtest was the only subtest that the CVI group (M = 5.29, SD = 2.75) had a higher mean than OVI group (M = 4.78, SD = 2.77). The Coding subtest was both visual and time-based. The CVI group's lowest mean scaled score subtest was letter-number sequencing (M = 2.83, SD = 1.72) which was neither a visual nor timed subtest. Of the CVI group's top five subtests means, three of them were visual and time-based subtests. Yet, the CVI group's lowest five means also had three that were visual-based and one that is timed (see Table 14). Therefore, it did not appear to be a clear pattern of students with CVI from the Total data set, scoring lower on visual, timed tasks

The OVI group's highest mean scaled score was Visual Puzzles (M = 10.17, SD = 3.98) which was also both visual and timed. Coding was the OVI group's lowest mean scaled score (M = 4.78, SD = 2.77). The Control group's highest mean scaled score subtest was Cancellation (M = 11.1, SD = 2.0), a visual and time-based subtest. The lowest mean subtest scaled score was Picture Span (M = 10.1, SD = 2.8), a visual-based subtest (see Table 14). As the Control data set is not from raw data, the decimal point can only be reported one decimal out.

The CVI, OVI, and Control groups' mean, standard deviation, and sample size for indexes had similar patterns as the educational location findings. The CVI group's most frequently scored index also had its highest mean scaled score, the Verbal Comprehension Index (M = 85.17, SD = 16.63, n = 12). However, this was not the same for the OVI group. The OVI group's most frequently scored index was the Verbal Comprehension Index (M = 91.44, SD = 16.56, n = 64) which was the third highest mean score. The highest mean index score for the

OVI Total data set was the Visual Spatial Index (*M* = 99.46, *SD* = 17.15, *n* = 11). Comparatively, the Control group's highest mean index was the Fluid Reasoning Index (*M* = 104.3, *SD* = 13.6, *n* = 239). However, the Control group's most frequently scored index was the Visual Spatial Index (*M* = 102.8, *SD* = 13.2, *n* =241; see Table 14).

As the Control group's data only included mean, standard deviation, and sample size, SPSS or other statistical programs were not able to calculate significance. These were calculated with GraphPad's Welch's *t*-test. The Welch's *t*-test accounted for the difference in sample size and for assumed unequal variances. The means, standard deviations, and sample sizes in Table 14 were used to calculate the statistical significance at $\alpha = 0.05$ level and with 95% CIs. This method has limitations identified in Chapter V. However, as a novel study, these methods were beneficial for identifying potential trends. Table 15 compares the subtests, indexes including the Full Scale IQ, and General Ability of the CVI group and Control. Two subtests (Cancellation and Picture Concepts) could not be compared due to an *n* of 1. There was no statistically significant difference found between the groups on the General Ability Index, $t(2) = 3.68$, $p = 0.067$, 95% CI [-19.53, 1.53]. At $\alpha = 0.05$, with 95% CIs, all other subtests and indexes were found to be statistically different.

Table 14

Total Data Set Group Statistics

Indexes/Subtests	Cortical/Cerebral Visual Impairment			Ocular Visual Impairment			Control		
	M	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*	*n*
Indexes									
Full Scale	71.67	20.13	6	85.75	18.01	8	104.4	11.8	233
General Ability	95.00	4.00	3	98.50	36.06	2	104.0	12.4	235
Verbal Comprehension	85.17	16.63	12	91.44	16.56	64	102.7	13.0	238
Working Memory	75.33	11.93	6	92.69	20.36	13	101.7	12.5	239
Processing Speed	73.00	17.39	5	76.78	17.02	9	103.7	15.0	240
Fluid Reasoning	72.57	14.01	7	91.90	18.12	10	104.3	13.6	239
Visual Spatial	67.00	16.79	6	99.46	17.15	11	102.8	13.2	241
Auditory Working Memory	54.25	13.87	4	89.83	23.18	36	102.5	12.7	240
Subtests									
^Coding (Visual/Timed)	5.29	2.75	7	4.78	2.77	9	10.7	3.0	241
Cancellation (Visual/Timed)	8.00	-	1	9.00	-	1	11.1	3.0	242
^Similarities	7.46	4.01	13	8.30	2.89	67	10.6	2.6	239
^Vocabulary	6.31	2.90	13	8.47	3.49	66	10.5	2.7	241

Table 14 (continued)

Indexes/Subtests	Cortical/Cerebral Visual Impairment			Ocular Visual Impairment			Control		
	M	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*	*n*
^Matrix Reasoning (Visual)	3.78	2.73	9	7.36	3.70	14	11.0	2.9	240
^Figure Weights (Visual/Timed)	5.38	3.11	8	9.50	3.87	10	10.5	2.7	241
Information	4.89	2.09	9	7.32	3.50	47	10.3	2.4	242
Comprehension	4.71	2.75	7	6.36	3.51	22	10.4	2.8	242
Symbol Search (Visual/Timed)	4.67	3.45	6	7.11	3.72	9	10.6	2.9	241
^Block Design (Visual/Timed)	4.60	3.24	10	8.00	4.14	13	10.6	2.7	241
^Digit Span	4.50	3.53	12	7.58	3.81	59	10.5	2.5	241
Picture Span (Visual)	4.29	3.15	7	9.64	4.75	14	10.1	2.8	240
Picture Concepts (Visual)	4.00	-	1	10.00	2.83	2	10.6	2.9	241
Visual Puzzles (Visual/Timed)	3.71	2.81	7	10.17	3.98	12	10.4	2.8	242
Arithmetic (Timed)	3.00	1.41	5	6.55	3.67	20	10.4	2.5	241
Letter-Number Sequence	2.83	1.72	6	7.85	4.27	40	10.4	2.8	241

Note. Subtests with a [^] in front of its name is indicative of that subtest being one of the core seven subtests of the Full Scale IQ score.

Table 15

Total Data Set's Welch's t-Test of the Cortical/Cerebral Visual Impairment and Control Group

Indexes/Subtests	Cortical/Cerebral Visual Impairment		Control						
	M	*SD*	*M*	*SD*	*df*	*t*	*p*	*SE*	95% CI
Indexes									
Full Scale	71.67	20.13	104.4	11.8	5	3.97	.0107*	8.25	[-53.95, -11.51]
General Ability	95.00	4.00	104.0	12.4	2	3.68	.067	2.45	[-19.53, 1.53]
Verbal Comprehension	85.17	16.63	102.7	13.0	11	3.60	.0042*	4.87	[-28.26, -6.80]
Working Memory	75.33	11.93	101.7	12.5	5	5.75	.0022*	4.94	[-41.06, -15.68]
Processing Speed	73.00	17.39	103.7	15.0	4	3.92	.0173*	7.84	[-52.46 -8.94]
Fluid Reasoning	72.57	14.01	104.3	13.6	6	5.91	.0010*	5.37	[-44.87, -18.60]
Visual Spatial	67.00	16.79	102.8	13.2	5	5.18	.0035*	6.91	[-53.56, -18.05]
Auditory Working Memory	54.25	13.87	102.5	12.7	3	6.91	.0062*	6.98	[-70.47, -26.03]
Subtests									
^Coding (Visual/Timed)	5.29	2.75	10.7	3.0	6	5.12	.0022*	1.06	[-8.00, -2.82]
Cancellation (Visual/Timed)	8.00	-	11.1	3.0	-	-	-	-	-
^Similarities	7.46	4.01	10.6	2.6	12	2.79	.0163*	1.13	[-5.59, -0.69]

Table 15 (continued)

Indexes/Subtests	Cortical/Cerebral Visual Impairment		Control						
	M	*SD*	*M*	*SD*	*df*	*t*	*p*	*SE*	95% CI
^Vocabulary	6.31	2.90	10.5	2.7	13	5.09	.0002*	0.82	[-5.967 -2.41]
^Figure Weights (Visual/Timed)	5.38	3.11	10.5	2.7	7	4.60	.0025*	1.11	[-7.75, -2.49]
Information	4.89	2.09	10.3	2.4	8	7.58	.0001*	.71	[-7.06, -3.77]
Comprehension	4.71	2.75	10.4	2.8	6	5.39	.0017*	1.06	[-8.27, -3.11]
Symbol Search (Visual/Timed)	4.67	3.45	10.6	2.9	5	4.17	.0087*	1.42	[-9.58, -2.28]
^Block Design (Visual/Timed)	4.60	3.24	10.6	2.7	9	5.77	.0003*	1.04	[-8.35, -3.64]
^Digit Span	4.50	3.53	10.5	2.5	11	5.82	.0001*	1.03	[-8.27, -3.73]
Picture Span (Visual)	4.29	3.15	10.1	2.8	6	4.83	.0029*	1.20	[-8.76, -2.86]
Picture Concepts	4.00	-	10.6	2.9	-	-	-	-	-
^Matrix Reasoning (Visual/Timed)	3.78	2.73	11.0	2.9	8	7.77	.0001*	0.93	[-9.36, -5.08]
Visual Puzzles (Visual/Timed)	3.71	2.81	10.4	2.8	6	6.00	.001*	1.12	[-9.42, -3.69]

Table 15 (continued)

Indexes/Subtests	Cortical/Cerebral Visual Impairment		Control						
	M	*SD*	*M*	*SD*	*df*	*t*	*p*	*SE*	95% CI
Arithmetic (Timed)	3.00	1.41	10.4	2.5	4	11.37	.0003*	0.65	[-9.21, -5.59]
Letter-Number Sequence	2.83	1.72	10.4	2.8	5	10.44	.0001*	0.73	[-9.43, -5.71]

Note. Subtests with a [^] in front of its name is indicative of that subtest being one of the core seven subtests of the Full Scale IQ score.

* $p < .05$.

Table 16 uses the mean, standard deviation, and sample size of the OVI group (also seen in Table 14) to compare the subtests, indexes, Full Scale IQ, and General Ability Index to the Control group. As in Table 15, this table used hand calculations and GraphPad to add in the statistical analysis of the groups. The levels of significance maintained at $\alpha = 0.05$, with 95% CI. One subtest could not be compared due to an *n* of 1, Cancellations. At $\alpha = 0.05$, with 95% CI, 12 subtests, three indexes, and the Full Scale IQ were found to be of statistical significance. Of the four subtests that were not at a statistically significant level, all four were visual-based, and two of the four were timed subtests.

Table 16

Total Data Set's Welch's t-Test of the Ocular Visual Impairment and Control Group

Indexes/Subtests	Ocular Visual Impairment		Control						
	M	*SD*	*M*	*SD*	*df*	*t*	*p*	*SE*	95% CI
Indexes									
Full Scale	85.75	18.01	104.4	11.8	7	2.91	.0227*	6.41	[-33.82, -3.48]
General ability	98.50	36.06	104.0	12.4	1	0.22	.8648	25.51	[-329.65, 318.65]
Verbal Comprehension	91.44	16.56	102.7	13.0	84	5.04	.0001*	2.24	[-15.70, -6.82]
Processing Speed	76.78	17.02	103.7	15.0	8	4.68	.0016*	5.76	[-40.19, -13.65]
Auditory Working Memory	89.83	23.18	102.5	12.7	38	3.21	.0027*	3.95	[-20.67, -4.68]
Fluid Reasoning	91.90	18.12	104.3	13.6	9	2.14	.0611	5.80	[-25.51, 0.71]
Visual Spatial	99.46	17.15	102.8	13.2	10	0.64	.538	5.24	[-15.02, 8.34]
Working Memory	92.69	20.36	101.7	12.5	12	1.58	.1402	5.70	[-21.44, 3.42]
Subtests									
^Coding (Visual/Timed)	4.78	2.77	10.7	3.0	8	6.28	.0002*	0.94	[-8.10, -3.75]
^Similarities	8.30	2.89	10.6	2.6	97	6.14	.0001*	0.39	[-3.18, -1.62]
^Vocabulary	8.47	3.49	10.5	2.7	87	4.38	.0001*	0.46	[-2.95, -1.11]
Information	7.32	3.50	10.3	2.4	54	5.59	.0001*	0.53	[-4.05, -1.91]

Table 16 (continued)

Indexes/Subtests	Ocular Visual Impairment		Control						
	M	*SD*	*M*	*SD*	*df*	*t*	*p*	*SE*	95% CI
Comprehension	6.36	3.51	10.4	2.8	23	5.25	.0001*	0.77	[-5.63, -2.45]
Symbol Search (Visual/Timed)	7.11	3.72	10.6	2.9	8	2.78	.0238*	1.25	[-6.38, -0.60]
^Block Design (Visual/Timed)	8.00	4.14	10.6	2.7	12	2.24	.0449*	1.16	[-5.13, -0.07]
^Digit Span	7.58	3.81	10.5	2.5	70	5.60	.0001*	0.52	[-3.96, -1.88]
^Matrix Reasoning (Visual/Timed)	7.36	3.70	11.0	2.9	13	3.62	.0031*	1.01	[-5.81, -1.47]
Arithmetic (Timed)	6.55	3.67	10.4	2.5	20	4.60	.0002*	0.84	[-5.60, -2.11]
Letter-Number Sequence	7.85	4.27	10.4	2.8	44	3.65	.0007*	0.70	[-3.96, -1.14]
Picture Span (Visual)	9.64	4.75	10.1	2.8	13	0.36	.7256	1.28	[-3.23, 2.31]
Picture Concepts (Visual)	10.00	2.83	10.6	2.9	1	0.30	.815	2.01	[-26.14, 24.94]
Visual Puzzles (Visual/Timed)	10.17	3.98	10.4	2.8	11	0.20	.847	1.16	[-2.79, 2.33]
^Figure Weights (Visual/Timed)	9.50	3.87	10.5	2.7	9	0.81	.439	1.23	[-3.80, 1.80]
Cancellation (Visual/Timed)	9.00		11.1	3.0					

Note. Subtests with a [^] in front of its name is indicative of that subtest being one of the core seven subtests of the Full Scale IQ score.

* $p < .05$.

Group Statistics of the Partial Data Set

The Partial data set had an *n* of 22. The use of a Partial data set aided the consistency of comparison between the CVI and OVI groups. This method was also used to ensure that participants' data included visual and timed subtests, allowing for the CVI and OVI groups to be equally compatible. As with the Total data set, the evaluating certified or licensed psychologist had the professional discretion of which subtests to use with which students. Contributing factors like the participants' visual diagnosis, the certified or licensed psychologist's familiarity with visual impairments, or the practices of the educational setting were unmeasured potentially influential factors. It should be noted that statistically, more students were diagnosed with OVI conditions than CVI. The diagnosed ratio of OVI to CVI in the general population was not a one-to-one correlation.

The group statistics of the Partial CVI and OVI groups with the Control group highlighted the mean average scaled score, standard deviation, and sample size for each completed subtests and indexes of the WISC-V. The Picture Concepts and Cancellation subtests are included in Table 17; however, each had sample of one for the CVI and OVI groups, resulting in an inability to compare. Table 17 is organized from the CVI groups highest mean average subtest score, and highest index mean score. Though the Coding subtest was listed first as it again was the only subtest with a higher mean then the OVI group; CVI ($M = 5.29$, $SD = 2.75$, $n = 7$), OVI ($M = 4.78$, $SD = 2.77$, $n = 9$). The Coding subtest difference was noted only as one of interest as the difference between the groups was not of statistical significance, $t(13) = 0.36$, $p = .721$, 95% CI [-2.50, 3.52] (Table 20).

From Table 17, the group statistics for the three groups (Partial CVI, Partial OVI, and Control) were different from the Total data set group statistics in Table 14. The CVI group of the

Partial data set's five highest mean subtests (excluding Coding) only had one that was visual-based (Figure Weights) which was also timed. Of the five lowest mean scored subtests, three were visual-based and two of those were also timed. The CVI group's highest mean scored subtest was Similarities (*M* = 8.44, *SD* = 4.33) and the lowest was letter-number sequencing (*M* = 2.67, *SD* = 2.08). Neither of these were visual nor time-based subtests. The OVI group had the highest mean in the Information subtest (*M* = 10.20, *SD* = 2.29) and lowest in Coding (*M* = 4.78, *SD* = 2.77). The information subtest was neither a visual nor timed subtest, yet Coding was both visual and time-based. The Control groups remained the same as in Table 14.

The Welch's *t*-test calculations were used to compare the scores of subtests and indexes between CVI and Control, as well as OVI and Control (see Tables 18 and 19). These were again calculated by hand and with GraphPad to accommodate for the drastic difference in sample sizes and variations in sample sizes of the subtests and indexes. An independent-samples *t*-test under the assumption of unequal variances was used to compare the subtests and indexes between the CVI and OVI Partial data set groups (see Table 20).

Unlike Table 15, the CVI to Control Welch's *t*-test for the Total data set, Table 18 did not have a sweep of statistical significance across subtests and indexes. In Table 18, two subtests had inadequate sample size for the CVI group and were unable to be calculated. Under significance levels of $\alpha = 0.05$, with 95% CI, three subtests were found to be not of statistical significance, Comprehension, $t(2) = 2.29$, $p = 0.149$, 95% CI [-11.71 – 3.57]; Similarities, $t(8) = 1.49$, $p = 0.176$, 95% CI [-5.51, 1.19]; and Arithmetic $t(1) = 6.34$, $p = 0.0996$, 95% CI [-19.23, 6.43]. Neither Comprehension, Similarities, were visual or time-based subtests. However, Arithmetic is a timed subtest. The remaining 12 subtests and 5 indexes were found to be statistically different between the CVI and Control groups at the level of $\alpha = 0.05$, with 95% CI (see Table 18).

Table 17

Partial Data Set Group Statistical Comparison

Indexes/Subtests	Cortical/Cerebral Visual Impairment			Ocular Visual Impairment			Control		
	M	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*	*n*
Indexes									
Verbal Comprehension	90.63	16.70	8	96.39	20.42	13	102.7	13.0	238
Working Memory	75.33	11.93	6	92.08	21.14	12	101.7	12.5	239
Processing Speed	73.00	17.39	5	76.78	17.02	9	103.7	15.0	240
Fluid Reasoning	72.57	14.01	7	91.90	18.12	10	104.3	13.6	239
Visual Spatial	67.00	16.79	6	99.46	17.15	11	102.8	13.2	241
Auditory Working Memory	46.00		1	103.00		1	102.5	12.7	240
Subtests									
^Coding (Visual/Timed)	5.29	2.75	7	4.78	2.77	9	10.7	3.0	241
^Similarities	8.44	4.33	9	9.39	3.99	13	10.6	2.6	239
^Vocabulary	6.89	3.10	9	9.39	3.69	13	10.5	2.7	241
Comprehension	6.33	3.06	3	7.33	1.53	3	10.4	2.8	242
Information	5.80	1.30	5	10.20	2.29	5	10.3	2.4	242
^Figure Weights (Visual/Timed)	5.38	3.11	8	9.50	3.87	10	10.5	2.7	241

Table 17 (continued)

Indexes/Subtests	Cortical/Cerebral Visual Impairment			Ocular Visual Impairment			Control		
	M	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*	*n*
^Digit Span	5.11	3.66	9	8.46	3.48	13	10.5	2.5	241
^Block Design (Visual/Timed)	4.89	3.297	9	8.00	4.14	13	10.6	2.7	241
Picture Span (Visual)	4.83	3.06	6	8.75	4.52	12	10.1	2.8	240
Symbol Search (Visual/Timed)	4.67	3.45	6	7.11	3.723	9	10.6	2.9	241
Arithmetic (Timed)	4.00	1.41	2	9.50	3.54	2	10.4	2.5	241
^Matrix Reasoning (Visual)	3.78	2.73	9	7.31	3.838	13	11.0	2.9	240
Visual Puzzles (Visual/Timed)	3.71	2.81	7	10.17	3.98	12	10.4	2.8	242
Letter-Number Sequence	2.67	2.08	3	6.33	4.041	3	10.4	2.8	241
Cancellation (Visual/Timed)	8.00		1	9.00		1	11.1	3.0	242
Picture Concepts (Visual/Timed)	4.00		1	12.00		1	10.6	2.9	241

Note. Subtests with a [^] in front of its name is indicative of that subtest being one of the core seven subtests of the Full Scale IQ score.

Table 18

Partial Data Set's Welch's t-Test of the Cortical/Cerebral Visual Impairment and Control Group

Indexes/Subtests	Cortical/Cerebral Visual Impairment		Control						
	M	*SD*	*M*	*SD*	*df*	*t*	*p*	*SE*	95% CI
Indexes									
Verbal Comprehension	85.17	16.63	102.7	13.0	11	3.60	.0042*	4.87	[-28.26, -6.80]
Working Memory	75.33	11.93	101.7	12.5	5	5.75	.0022*	4.94	[-41.06, -15.68]
Processing Speed	73.00	17.39	103.7	15.0	4	3.92	.0173*	7.84	[-52.46, -8.94]
Fluid Reasoning	72.57	14.01	104.3	13.6	6	5.91	.0010*	5.37	[-44.87, -18.60]
Visual Spatial	67.00	16.79	102.8	13.2	5	5.18	.0035*	6.91	[-53.56, -18.05]
Subtests									
^Coding (Visual/Timed)	5.29	2.75	10.7	3.0	6	5.12	.0022*	1.06	[-8.00, -2.82]
^Vocabulary	6.89	3.10	10.5	2.7	8	3.45	.0088*	1.05	[-6.03, -1.19]
^Digit Span	5.11	3.66	10.5	2.5	8	4.38	.0023*	1.23	[-8.23, -2.55]
Information	5.80	1.30	10.3	2.4	4	7.48	.0017*	0.60	[-6.17, -2.83]
^Figure Weights (Visual/Timed)	5.38	3.11	10.5	2.7	7	4.60	.0025*	1.11	[-7.75, -2.49]
^Block Design (Visual/Timed)	4.89	3.297	10.6	2.7	8	5.13	.0009*	1.11	[-8.28, -3.14]
Picture Span (Visual)	4.83	3.06	10.1	2.8	5	4.18	.0087*	1.26	[-8.52, -2.03]

Table 18 (continued)

Indexes/Subtests	Cortical/Cerebral Visual Impairment		Control						
	M	*SD*	*M*	*SD*	*df*	*t*	*p*	*SE*	95% CI
Symbol Search (Visual/Timed)	4.67	3.45	10.6	2.9	5	4.17	.0087*	1.42	[-9.58, -2.28]
^Matrix Reasoning (Visual)	3.78	2.728	11.0	2.9	8	7.78	.0001*	0.93	[-9.36, -5.08]
Visual puzzles (Visual/Timed)	3.71	2.81	10.4	2.8	6	6.21	.0008*	1.08	[-9.33, -4.05]
Letter-Number Sequence	2.67	2.08	10.4	2.8	2	6.37	.0238*	1.21	[-12.96, -2.51]
Arithmetic (Timed)	4.00	1.41	10.4	2.5	1	6.34	.0996	1.01	[-19.23, 6.43]
Comprehension	6.33	3.06	10.4	2.8	2	2.29	.149	1.78	[-11.71, 3.57]
^Similarities	8.44	4.33	10.6	2.6	8	1.49	.176	1.45	[-5.51, 1.19]
Picture Concepts (Visual)	4.00		10.6	2.9					
Cancellation	8.00		11.1	3.0					

Note. Subtests with a [^] in front of its name is indicative of that subtest being one of the core seven subtests of the Full Scale IQ score.

* $p < .05$.

There was a drastic change in results between the Total data set OVI to Control comparison (see Table 16) and the Partial data set's OVI to Control comparison in Table 19. There were seven fewer subtests and one less index that were of statistical significance. Two subtests (Cancellation and Picture Concepts) and one index (Auditory Working Memory Index) could not be compared due to inadequate sample size. The four statistically significant subtests at the level of $\alpha = 0.05$, with 95% CI were: (a) Block Design, $t(12) = 2.24$, $p = .0449$, 95% CI [-5.13, -0.07]; (b) Symbol Search, $t(248) = 3.51$, $p = .0005$, 95% CI [-5.45, -1.53]; (c) Coding, $t(8) = 6.28$, $p = .0002$, 95% CI [-8.10, -3.74]; and (d) Matrix Reasoning, $t(12) = 3.41$, $p = .005$, 95% CI [-6.05, -1.34]. All the statistically significant subtests were visual-based, and three of the four were also timed subtests. The one index of statistical significance was the Processing Speed Index, $t(8) = 4.68$, $p = .0016$, 95% CI [-40.19, -13.58]. The Full Scale IQ was also statistically significant, $t(7) = 2.91$, $p = .0227$, 95% CI [-33.82, -3.48].

The Partial data set's CVI and OVI groups were compared using SPSS's independent *t*-tests with equal variances not assumed in Table 20. Though the sample size had additional inclusionary criteria added and reduced to be inclusive of a more compatible sample representative of the target total population, there were not equal samples across subtests. To account for this missing, or unequal data, an independent-samples *t*-test with the assumption of unequal variances was used. Consistent with previously reported statistical data, the level of α = 0.05 with 95% CI was used.

Table 19

Partial Data Set's Welch's t-Test of the Ocular Visual Impairment and Control Group

Indexes/Subtests	Ocular Visual Impairment		Control						
	M	*SD*	*M*	*SD*	*df*	*t*	*p*	*SE*	95% CI
Indexes									
Full Scale	85.75	18.01	104.4	11.8	7	2.91	.0227*	6.41	[-33.82, -3.48]
General Ability	98.50	36.06	104.0	12.4	1	0.22	.865	25.51	[-329.65, 318.65]
Processing Speed	76.78	17.02	103.7	15.0	8	4.68	.0016*	5.76	[-40.19, -13.58]
Verbal Comprehension	96.38	20.42	102.7	13.0	12	1.10	.291	5.73	[-18.80, 6.16]
Working Memory	92.69	20.36	101.7	12.5	11	1.56	.146	6.16	[-23.17, 3.93]
Fluid Reasoning	91.90	18.12	104.3	13.6	9	2.14	.0611	5.80	[-25.51, 0.71]
Visual Spatial	99.46	17.15	102.8	13.2	10	0.64	.538	5.24	[-15.02, 8.34]
Auditory Working Memory	103.0		102.5	12.7					
Subtests									
^Block Design (Visual/Timed)	8.00	4.14	10.6	2.7	12	2.24	.0449*	1.16	[-5.13, -0.07]
^Symbol Search (Visual/Timed)	7.11	3.72	10.6	2.9	248	3.51	.0005*	1.00	[-5.45, -1.53]
^Coding (Visual/Timed)	4.78	2.77	10.7	3.0	8	6.28	.0002*	0.94	[-8.10, -3.74]
^Matrix Reasoning (Visual)	7.31	3.84	11.0	2.9	12	3.41	.005*	1.08	[-6.05, -1.34]

Table 19 (continued)

Indexes/Subtests	Ocular Visual Impairment		Control						
	M	*SD*	*M*	*SD*	*df*	*t*	*p*	*SE*	95% CI
^Digit Span	8.46	3.48	10.5	2.5	12	2.09	.0591	0.98	[-4.17, 0.09]
Comprehension	7.33	1.53	10.4	2.8	2	3.401	.077	0.90	[-6.95, 0.81]
Information	10.20	2.29	10.3	2.4	4	0.10	.928	1.04	[-2.98, 2.78]
^Figure Weights (Visual/Timed)	9.50	3.87	10.5	2.7	9	0.81	.439	1.24	[-3.80, 1.80]
Vocabulary	9.39	3.69	10.5	2.7	12	1.07	.306	1.04	[-3.37, 1.15]
Picture Span (Visual)	8.75	4.52	10.1	2.8	11	1.03	.327	1.32	[-4.25, 1.55]
^Similarities	9.39	3.99	10.6	2.6	12	1.08	.301	1.12	[-3.65, 1.21]
Arithmetic (Timed)	9.50	3.54	10.4	2.5	1	0.36	.781	2.51	[-32.77, 30.97]
Visual puzzles (Visual/Timed)	10.17	3.98	10.4	2.8	11	0.20	.847	1.16	[-2.79, 2.33]
Letter-Number Sequence	6.33	4.04	10.4	2.8	2	1.74	.224	2.34	[-14.14, 6.00]
Picture Concepts (Visual)	12.00		10.6	2.9					
Cancellation (Visual/Timed)	9.00		11.1	3.0					

Note. Subtests with a [^] in front of its name is indicative of that subtest being one of the core seven subtests of the Full Scale IQ score.

* $p < .05$.

Two subtests could not be calculated due to limited sample size (Cancellation and Picture Concepts). Between the CVI and OVI Partial data set groups, 6 (43%) of the 14 measured subtests were found to be of statistical significance (see Table 20). The six subtests were: Visual Puzzles, $t(16.2) = -4.13$, $p = < .001$, 95% CI [-9.76, -3.14]; Information, $t(6.3) = -3.75$, $p = .009$, 95% CI [-7.24, -1.56]; Figure Weights, $t(15.9) = -2.51$, $p = .023$, 95% CI [-7.61, -0.64]; Matrix Reasoning, $t(19.9) = -2.52$, $p = 0.20$, 95% CI [-6.45, -0.61]; Digit Span, $t(16.7) = -2.16$, $p = .046$, 95% CI [-6.63, -0.07]; and Picture Span, $t(14.2) = -2.17$, $p = 0.48$, 95% CI [-7.78, -0.05]. Four of the five of the statistically significant subtests were visual, and two of the five were timed (see Table 20).

Reducing the sample size from $n = 80$ in the Total data set to $n =22$ of the Partial data set resulted in fewer statistically significant scores. This was expected as with the lower sample size, there was less power. From the Total subtest comparisons of CVI to Control, only one score (General Ability) was not statistically significant, yet in the Partial data set, two additional subtests (Comprehension and Similarities) were not statistically significant. Across the Partial data set comparisons, one subtest (Matrix Reasoning) was of statistical significance between all group comparisons, a visual and timed subtest. Overall, the preliminary analysis including the groups' statistics comparisons of three groups within the Total and Partial data set presented a foundational understanding of how the three groups' subtests (Index, Full Scale IQ, and General Ability) scores compare.

Table 20

Partial Data Set Independent-Samples t-Test between Cortical/Cerebral Visual Impairment and Ocular Visual Impairment Groups

Subtests	*t*	*df*	*p*	95% CI	*SE*
Visual Puzzles (Visual/Timed)	-4.13	16.16	< . 001*	[-9.76, -3.14]	1.56
Information	-3.75	6.36	.009*	[-7.24, -1.56]	1.17
^Figure Weights (Visual/Timed)	-2.51	15.99	.023*	[-7.61, -0.64]	1.65
^Matrix Reasoning (Visual)	-2.52	19.96	.020*	[-6.45, -0.61]	1.40
^Digit Span	-2.16	16.78	.046*	[-6.63, -0.07]	1.55
Picture Span (Visual)	-2.17	14.17	.048*	[-7.78, -0.05]	1.81
^Similarities	-0.52	16.26	.611	[-4.78, 2.90]	1.81
^Vocabulary	-1.72	19.12	.102	[-5.54, 0.55]	1.45
Comprehension	-0.51	2.94	.648	[-7.35, 5.35]	1.97
Arithmetic (Timed)	-2.04	1.31	.240	[-25.39, 14.96]	2.69
Letter-Number Sequence	-1.40	2.99	.257	[-12.03, 4.70]	2.62
^Block Design (Visual/Timed)	-1.96	19.51	.065	[-6.43, 0.21]	1.59
^Coding (Visual/Timed)	0.36	13.10	.721	[-2.50, 3.52]	1.39

Table 20 (continued)

Subtests	*t*	*df*	*p*	95% CI	*SE*
Symbol Search (Visual/Timed)	-1.30	11.47	.218	[-6.55, 1.66]	1.88
Cancellation (Visual/Timed)					
Picture Concepts (Visual)					

Note. Equal variances not assumed for all independent-samples *t*-tests. Subtests with a [^] in front of its name is indicative of that subtest being one of the core seven subtests of the Full Scale IQ score.

* $p < .05$.

Research Question Data Analysis Methodology

Only the Partial data set was used to evaluate this study's four research questions to help balance sample set that was representative of the target populations. The research questions used specifically created variables from the combined subtests that targeted each research question. These variables did not include indexes, the General Ability or Full Scale IQ as those were scores derived from the combination of subtests. This study excluded the Number Speed Literacy subtest as it had a different scoring method than that of the other scale scored subtests, which would skew the analysis results. Additionally, the Vocabulary subtest was included in the low visual-based subtests. Younger participants who were given the WISC-V Vocabulary subtest were shown visual cards. However, no participant fell into that age group (6-7 years old) making it unlikely that the visual cards were used. The analysis used for each research question assumed unequal variances. Each research question maintained the level of statistical significance at $\alpha =$ 0.05 with 95% CI.

Research Question 1

Q1 Do students diagnosed with CVI have lower cumulative vision-based subtest score than low-vision-based subtest score on the Wechsler Intelligence Scale for Children-Fifth Edition (WISC-V)?

The sample groups in the study encompassed a wide spectrum of visual impairments. Before evaluating the results of Research Question 1, it was important to remember the bases for the terms visual-based and low visual-based subtests. The term low visual-based subtest was used to represent the collective student visual diagnosis (with an assumed typical visual status for the control group) across the three participant groups (CVI, OVI, and Control). The visual-based subtests were determined based on the requirement of the evaluated student to visual access presented media to complete the subtest.

The Partial data set's comparative group statistics used the Welch's t-test and independent-samples t-tests to show the statistical differences of visual-based, and low visual-based subtests with the pairings (CVI and Control; CVI and OVI). The CVI and Control comparison showed that eight (100%) of the eight visual-based subtests were statistically significant, and four of the seven (57%) low visual-based subtests were statistically significant. The three low visual-based subtests that were not of statistical significance were Arithmetic, Similarities, and Comprehension (see Table 21).

Using SPSS, statistical significance of the difference in scores between the CVI and OVI groups from Table 17 were evaluated and organized by visual and low-visual subtests (see Table 22). Four (57%) of the seven visual-based subtests were of a level of statistical significance. The four visual-based subtests were: Visual Puzzles, $t(16.1) = -4.13$, $p = < .001$, 95% CI [-9.76, -3.14]; Figure Weights, $t(15.9) = -2.51$, $p = .023$, 95% CI [-7.61, -0.64]; Matrix Reasoning, $t(19.9) = -2.52$, $p = 0.20$, 95% CI [-6.45, -.61]; and Picture Span, $t(14.2) = -2.17$, $p = 0.48$, 95% CI [-7.78, -0.05]. Two (29%) of the seven of the low visual-based subtests were found to be statistically significant: Information, $t(6.3) = -3.75$, $p = .009$, 95% CI [-7.24, -1.56] and Digit Span, $t(16.8) = -2.16$, $p = .046$, 95% CI [-6.63, -0.07] (see Table 23).

Table 21

Visual and Low Visual-Based Subtests Welch's t-Test of the Cortical/Cerebral Visual Impairment and Control Group

Subtests	Cortical/Cerebral Visual Impairment			Control							
	M	*SD*	*n*	*M*	*SD*	*n*	*df*	*t*	*p*	*SE*	95% CI
Visual-Based											
^Coding	5.29	2.75	7	10.7	3.0	241	6	5.12	.0022*	1.06	[-7.80, -2.82]
^Figure Weights	5.38	3.11	8	10.5	2.7	241	7	4.60	.0025*	1.11	[-7.75, -2.49]
^Block Design	4.89	3.297	9	10.6	2.7	241	8	5.13	.0009*	1.11	[-8.28, -3.14]
Picture Span	4.83	3.06	6	10.1	2.8	240	5	4.18	.0087*	1.26	[-8.52, -2.03]
Symbol Search	4.67	3.45	6	10.6	2.9	241	5	4.17	.0087*	1.42	[-9.58, -2.28
^Matrix Reasoning	3.78	2.73	9	11.0	2.9	240	8	7.78	.0001*	0.93	[-9.36, -5.08]
Visual puzzles	3.71	2.81	7	10.4	2.8	242	6	6.21	.0008*	1.08	[-9.33, -4.05]
Cancellation	8.00	-	1	11.1	3.0	242	-	-	-	-	-
Picture Concepts	4.00	-	1	10.6	2.9	240	-	-	-	-	-
Low Visual-Based											
^Vocabulary	6.89	3.10	9	10.5	2.7	241	8	3.45	.0088*	1.05	[-6.03, -1.19]
Information	5.80	1.30	5	10.3	2.4	242	4	7.48	.0017*	0.60	[-6.17, -2.83]
^Digit Span	5.11	3.66	9	10.5	2.5	241	8	4.38	.0023*	1.23	[-8.23, -2.55]

Table 21 (continued)

Subtests	Cortical/Cerebral Visual Impairment			Control							
	M	*SD*	*n*	*M*	*SD*	*n*	*df*	*t*	*p*	*SE*	95% CI
Letter-Number Sequence	2.67	2.08	3	10.4	2.8	241	2	6.37	.0238*	1.21	[-12.96, -2.51]
Arithmetic	4.00	1.41	2	10.4	2.5	241	1	6.34	.0996	1.01	[-19.23, 6.43]
^Similarities	8.44	4.33	9	10.6	2.6	239	8	1.49	.176	1.45	[-5.51, 1.19]
Comprehension	6.33	3.06	3	10.4	2.8	242	2	2.29	.149	1.78	[-11.71, 3.57]

Note. Subtests with a [^] in front of its name is indicative of that subtest being one of the core seven subtests of the Full Scale IQ score.

* $p < .05$.

Table 22

Visual and Low Visual-Based Subtests Independent-Samples t-Test of Cortical/Cerebral Visual Impairment and Ocular Visual Impairments Groups

Subtests	*t*	*df*	*p*	95% CI	*SE*
Visual-Based					
Visual Puzzles	-4.13	16.16	< .001*	[-9.76, -3.14]	1.56
^Figure Weights	-2.51	15.99	.023*	[-7.61, -0.64]	1.65
^Matrix Reasoning	-2.52	19.96	.020*	[-6.45, -0.61]	1.40
Picture Span	-2.17	14.17	.048*	[-7.78, -0.05]	1.81
^Block Design	-1.96	19.51	.065	[-6.43, 0.21]	1.59
^Coding	0.36	13.10	.721	[-2.45, 3.51]	1.39
Symbol Search	-1.30	11.47	.218	[-6.55, 1.66]	1.88
Picture Concepts					
Cancellation					
Low Visual-Based					
Information	-3.75	6.36	.009*	[-7.24, -1.56]	1.17
^Digit Span	-2.16	16.78	.046*	[-6.63, -0.07]	1.55

Table 22 (continued)

Subtests	*t*	*df*	*p*	95% CI	*SE*
^Similarities	-0.52	16.26	.611	[-4.78, 2.90]	1.81
^Vocabulary	-1.72	19.12	.102	[-5.54, 0.55]	1.45
Comprehension	-0.51	2.94	.648	[-7.35, 5.35]	1.97
Arithmetic	-2.04	1.31	.240	[-25.39, 14.39]	2.69
Letter-Number Sequence	-1.40	2.99	.257	[-12.03, 4.70]	2.62

Note. Subtests with a [^] in front of its name is indicative of that subtest being one of the core seven subtests of the Full Scale IQ score.

* $p < .05$.

To further evaluate Research Question 1, if students diagnosed with CVI had a lower cumulative vision-based subtest score on the WISC-V, the categorized groups visual-based and low visual-based were used to create nine variables in SPSS. Six of the nine created variables for Research Question 1 were (total subtest, total subtests CVI, total subtests OVI, total visual-based, visual-based CVI, and visual-based OVI). The additional three subtests were specific to the low visual-based subtests (total low visual-based, low visual-based CVI, and low visual-based OVI). There were nine visual-based subtests (Matrix Reasoning, Picture Concepts, Picture Span, Visual Puzzles, Figure Weights, Cancellation, Block Design, Coding, and Symbol Search). There were seven low visual-based subtests (Information, Digit Span, Similarities, Vocabulary, Comprehension, Arithmetic, and Letter-Number Sequencing). These created variables were evaluated using independent-samples *t*-tests and paired-sample *t*-tests. The paired-sample *t*-tests helped to understand the connection within the group, (CVI to CVI). Independent-samples *t*-tests looked at the data from between the groups, CVI to OVI.

Using the created variables, a paired-samples *t*-test was used to look at the different pairings' statistical differences within the groups (see Table 23). These were used to look at the collective total of all groups and subtests, the Partial subtest separated by groups (CVI, OVI) and the different visual demands (low and visual-based subtests). Six pairings were analyzed related to the visual demand of subtests. Two of those pairings had statistical difference (total subtests–visual-based), and (total subtests–visual-based CVI). The (total subtests–visual-based) looked at the collective totals of both groups (CVI and OVI), $t(21) = 2.22$, $p = .038$, 95% CI [0.04, 1.27]. The second pairing (total subtests–visual-based CVI) compared the collective total to just the CVI visual-based subtest, $t(8) = 2.60$, $p = .032$, 95% CI [0.10, 1.66]. It was concluded that these two separate pairings had significant difference at level of α = 0.05 at 95% CI [0.04, 1.27] and [0.10, 1.66] (see Table 23).

The independent-samples *t*-test was used considering normal assumptions and a sample size of $n = 22$ in Table 24. This test looked at the data between the CVI and OVI groups related to the low visual-based and visual-based subtests. The total subtest comparison was included to look at comparatively the statistical significance between CVI and OVI groups across all subtests. For the total subtest comparisons, the *p*-value was 0.05, less than $\alpha = 0.05$ with 95% CI levels at [-5.14, -0.63]. It was concluded that there was significant statistical difference between the CVI and OVI's total subtest scores.

Group 1 was defined as Low Visual-based Subtest and Group 2 was defined as Visual-based subtest. The Null (H01) and alternative hypotheses (H1) for Research Question 1 were:

$$\begin{cases} H01: \mu_1 = \mu_2 \\ H1: \mu_1 \neq \mu_2 \end{cases}$$

H01 There is no statistical significance in the visual-based and low visual-based subtest scores of the WISC-V for students with Cortical/Cerebral Visual Impairment.

H1 The vision-based subtest scores significantly differ from low visual-based subtests in the WISC-V for students with Cortical/Cerebral Visual Impairment.

Table 23

Visual and Low Visual-Based Paired-Samples t-Test of Cortical/Cerebral Visual Impairment and Ocular Visual Impairments Groups

Categorized Variable Pairings	*M*	*SD*	*SEM*	95% CI	*t*	*df*	*p*
Total Subtests–Visual-based	*0.66*	*1.39*	0.30	[0.04, 1.27]	*2.22*	*21*	*.038**
Total Subtest–Visual-Based Cortical/Cerebral Visual Impairment	0.88	1.02	0.34	[0.10, 1.66]	2.60	8	.032*
Total Subtest–Low Visual- Based Cortical/Cerebral Visual Impairment	-1.27	1.97	0.66	[-2.79, 0.24]	-1.94	8	.088
Low Visual Cortical/Cerebral Visual Impairment–Visual Cortical/Cerebral Visual Impairment	2.16	2.89	0.96	[-0.06, 4.37]	2.24	8	.055

Note. * $p < .05$.

Table 24

Low Visual-Based and Visual-Based Subtests Independent-Samples t-Test

Categorized Subtest Variables	*t*	*df*	*p*	Difference	*SE*	95% CI
Total Subtest Scores	-2.67	19.67	.015*	-2.89	1.08	[-5.14, -0.63]
Low Visual-Based	-1.37	17.48	.186	-1.95	1.42	[-4.93, 1.03]
Visual-Based	-2.52	20.00	.020*	-3.26	1.30	[-5.97, -0.56]

Note. Equal variances not assumed for any of the independent-samples *t*–tests.

* $p < .05$.

The test of Equality of Variance was not used as the *t*-test was run under the assumption of nonequal variances. With a *p*-value of 0.186, *t*-value of -1.37 and 95% CI of [-4.93, 1.03], it is concluded low visual-based subtests do not have statistical significance at the level of $\alpha = 0.05$. Additionally, with a *p*-value of 0.02, *t*-value of -2.52 and 95% CI of [-5.97, -0.56], it is concluded visual-based subtests have statistical significance at the level of $\alpha = 0.05$ (see Table 24). This study rejected the Research Question 1 null hypothesis and found statistical significance difference of visual-based subtests at $\alpha = 0.05$, *p*-value: 0.02 and 95% CI [-5.97, -0.56].

Research Question 2

Q2 Is there a significant difference between visual-based subtests that feature pictures vs symbols for students diagnosed with CVI's subtest scores on the Wechsler Intelligence Scale for Children-Fifth Edition (WISC-V)?

The same groupings seen in Research Question Q1, were used for the comparative group statistics which included: CVI to Control, and CVI to OVI were represented and categorized by picture- and symbol-based subtests. There were six subtests identified as picture-based with four used in calculations due to limited sample size. Three subtests were identified as symbol-based. All three were included in all analyses. In Table 25, there was seven out of seven (100%) significant statistical differences across all calculated comparisons between the CVI and Control groups at the $\alpha = 0.05$, 95% CI level.

Table 25

Picture- and Symbol-Based Subtests Welch's t-Test of Cortical/Cerebral Visual Impairments and Control Groups

Subtests	Cortical/Cerebral Visual Impairment			Control								
	M	*SD*	*n*	*M*	*SD*	*n*	Difference	*df*	*t*	*p*	*SE*	95% CI
Picture-Based												
^Figure Weights	5.38	3.11	8	10.5	2.7	241	-5.12	7	4.60	.0025*	1.11	[-7.75, -2.49]
Picture Span	4.83	3.06	6	10.1	2.8	240	-5.27	5	4.18	.0087*	1.26	[-8.52, -2.03]
^Matrix Reasoning	3.78	2.73	9	11.0	2.9	240	-7.22	8	7.78	.0001*	0.93	[-9.36, -5.08]
Visual puzzles	3.71	2.81	7	10.4	2.8	242	-6.69	6	6.21	.0008*	1.08	[-9.33, -4.05]
Cancellation	8.00		1	11.1	3.0	242						
Picture Concepts	4.00		1	10.6	2.9	240						
Symbol-Based												
^Block Design	4.89	3.30	9	10.6	2.7	241	-5.71	8	5.13	.0009*	1.11	[-8.28, -3.14]
^Coding	5.29	2.75	7	10.7	3.0	241	-5.41	6	5.12	.0022*	1.06	[-8.00, -2.82]
Symbol Search	4.67	3.45	6	10.6	2.9	241	-5.93	5	4.17	.0087*	1.42	[-9.58, -2.28]

Note. Subtests with a [^] in front of its name is indicative of that subtest being one of the core seven subtests of the Full Scale IQ score.

* $p < .05$.

Using the SPSS *t*-test calculations between the CVI and OVI groups, four of the seven subtests were found to have significant statistical differences (see Table 26). All four of the statistically significant comparisons were picture-based subtests. The four subtests were: (a) Visual Puzzles, t (16.2) = -4.13, p = < .001, 95% CI [-9.76, -3.14]; (b) Figure Weights, t(15.9) = -2.51, p = .023, 95% CI [-7.61, -.64]; (c) Matrix Reasoning, t(19.9) = -2.52, p = 0.20, 95% CI [-6.45, -0.61]; and (d) Picture Span, t(14.2) = -2.17, p = 0.48, 95% CI [-7.78, -0.05]). No symbol-based subtest analysis was found to have a significant statistical difference.

Table 26

Picture- and Symbol-Based Subtests Independent-Samples t-Test of Cortical/Cerebral Visual Impairment and Ocular Visual Impairments Groups

Subtests	*t*	*df*	*p*	95% CI	*SE*
Picture-Based					
Picture Span	-2.17	14.17	.048*	[-7.78, -0.05]	1.81
Visual Puzzles	-4.13	16.16	< . 001*	[-9.76, -3.14]	1.56
^Figure Weights	-2.51	15.99	.023*	[-7.61, -0.64]	1.65
^Matrix Reasoning	-2.52	19.96	.020*	[-6.45, -0.61]	1.40
Picture Concepts					
Cancellation					
Symbol-Based					
^Block Design	-1.96	19.51	.065	[-6.43, 0.21]	1.59
^Coding	0.36	13.10	.721	[-2.50, 3.51]	1.39
Symbol Search	-1.30	11.47	.218	[-6.55, 1.66]	1.88

Note. Subtests with a [^] in front of its name is indicative of that subtest being one of the core seven subtests of the Full Scale IQ score.

* $p < .05$.

Six new variables were created using SPSS to target Research Question 2 and the potential for differences between picture- and symbol-based subtest scores for students with CVI. Six of the created variables for Research Question 1 were carried over to be used in the Research Question 2 analysis (total subtest, subtests CVI, subtests OVI, total visual-based, visual-based CVI, and visual-based OVI). The previously identified nine visual-based subtests remained consistent in the Research Question 2 analysis. Those nine subtests were broken into two categories (picture-based and symbol-based). The picture-based variable included six subtests (Matrix Reasoning, Picture Concepts, Picture Span, Visual Puzzles, Figure Weights, and Cancellation). Though Vocabulary was previously identified as a picture-based subtest, it was not included as the participants' engagement with the visual-based components of that was not able to be determined. The symbol-based variable included three subtests (Block Design, Coding, and Symbol Search). Each created variable was then split into two, one specific to CVI participant data, and the other specific to OVI specific data. This resulted in six new variables (total picture, picture CVI, picture OVI, total symbol, symbol CVI and symbol OVI).

From the created variables in SPSS, paired-samples *t*-tests were run between picture- and symbol-based subtest variables, resulting in 10 new pairings (see Table 27). Of those 10 pairings, 6 were of significant statistical difference at the $\alpha = 0.05$ level, with 95% CI. Only one statistically significant pairing was specific to the CVI group (total subtest–picture-based CVI), $t(8) = 2.73$, $p = 0.026$, 95% CI [0.18, 2.14]. This pairing looked at the collective total subtests to just the CVI picture-based subtests. Of note, there were four statistically significant pairings specific to the OVI group:

1. Picture-based OVI–symbol-based OVI, $t(12) = 2.84$, p = .015, 95% CI [0.37, 2.82]

2. Visual-based OVI–picture-based OVI, $t(12) = -3.28$, $p = .007$, 95% CI [-1.05, -0.21]

3. Total subtests–symbol-based OVI, $t(12) = 2.68$, $p = .02$, 95% CI [0.28, 2.66]

4. Visual-based OVI–symbol-based OVI, $t(12) = 2.53$, $p = .27$, 95% CI [0.13, 1.20].

No pairing was of significant statistical difference that was specific to the CVI group and symbol-based subtests (see Table 27).

Under normal assumptions and a sample size of $n = 22$, an independent-samples *t*-test was used in Table 28. Using the sample data of the CVI and OVI groups, an analysis was conducted to look at the potential statistically significant differences related to the picture- and symbol-based subtests of the WISC-V. Group 1 was defined as picture-based and Group 2 was defined symbol-based. The null (H02) and alternative (H2) hypotheses for Research Question 2 were:

$$\begin{cases} H02: \mu_1 = \mu_2 \\ H2: \mu_1 \neq \mu_2 \end{cases}$$

H02 There is no statistical significance in the scores between picture- and symbol-based visual media sub-tests of the WISC-V for students with Cortical/Cerebral Visual Impairment.

H2 The symbol-based visual media subtest scores significantly differ from picture-based subtest scores in the WISC-V for students with Cortical/Cerebral Visual Impairment.

Table 27

Picture- and Symbol-Based Paired-Sample t-Test of Cortical/Cerebral Visual Impairment and Ocular Visual Impairments Groups

Categorized Variable Parings	*M*	*SD*	*SEM*	95% CI	*t*	*df*	*p*
Total Subtests–Symbol-based	1.13	1.77	0.38	[0.35, 1.92]	3.00	21	.007*
Visual-based Ocular Visual Impairment–Picture-based Ocular Visual Impairment	-0.63	0.69	0.19	[-1.05, -0.21]	-3.28	12	.007*
Picture-Based Ocular Visual Impairment–Symbol-Based Ocular Visual Impairment	1.60	2.02	0.56	[0.37, 2.82]	2.84	12	.015*
Total Subtests–Symbol-based Ocular Visual Impairment	1.47	1.98	0.55	[0.28, 2.66]	2.68	12	.020*
Total Subtests–Picture-based Cortical/Cerebral Visual Impairment	1.16	1.27	0.42	[0.18, 2.14]	2.73	8	.026*
Visual-based Ocular Visual Impairment–Symbol-based OVI	0.97	1.38	0.38	[0.13, 1.20]	2.53	12	.027*
Total Subtests–Picture-based	0.40	1.80	0.38	[-0.40, 1.20]	1.04	21	.308
Total Subtests–Symbol-based Cortical/Cerebral Visual Impairment	0.64	1.39	0.46	[-0.42, 1.71]	1.39	8	.202
Visual-based Cortical/Cerebral Visual Impairment–Picture-based Cortical/Cerebral Visual Impairment	0.28	0.81	0.27	[-0.34, 0.90]	1.04	8	.328

Table 29 (continued)

Categorized Variable Parings	*M*	*SD*	*SEM*	95% CI	*t*	*df*	*p*
Visual-based Cortical/Cerebral Visual Impairment–Symbol-based Cortical/Cerebral Visual Impairment	-0.24	0.96	0.32	[-0.98, 0.50]	-0.74	8	.478
Picture-based Cortical/Cerebral Visual Impairment–Symbol-based Cortical/Cerebral Visual Impairment	-0.52	1.76	0.59	[-1.87, 0.83]	-0.89	8	.402

Note. * $p < .05$.

Table 28

Picture- and Symbol-Based Independent-Samples t-Test

	t	*df*	*p*	*SE*	95% CI
Categorized Subtest Variables					
Picture-Based Subtests	-3.11	19.92	.006*	1.34	[-6.98, -1.37]
Symbol-Based Subtests	-1.49	19.73	.152	1.38	[-4.95, 0.83]

Note. Equal variances not assumed for either of the Independent-samples *t*-tests.

* $p < .05$.

The test of Equality of Variance was not used as the *t*-test was run under the assumption of nonequal variances. With a *p*-value of 0.006, *t*-value of -3.11, and 95% CI of [-6.98, -1.37], it was concluded there were statistical significance differences between the picture-based subtests of the CVI and OVI groups at the level of $\alpha = 0.05$, with 95% CIs. However, with a *p*-value of 0.152, *t*-value of -1.49 and 95% CI of [-4.95, 0.83], there was not a statistically significant difference between CVI and OVI symbol-based subtests at the level of $\alpha = 0.05$ (see Table 28). This study rejected the Research Question 2 null hypothesis and found statistical significance of picture-based subtests at 95% CI, and $p = 0.5$. However, this study failed to reject part of Research Question 2 null hypothesis that there was no statistical significance in the scores between symbol-based visual media subtests of the WISC-V for students with Cortical/Cerebral Visual Impairment at 95% CI, and $p = 0.5$.

Research Question 3

Q3 Does the complexity level within a specific visual media (picture or symbol) of a visual-based subtest have a correlation with a student diagnosed with CVI's subtest scores on the Wechsler Intelligence Scale for Children-Fifth Edition (WISC-V)?

To evaluate the impact complexity levels had on students with CVI's subtest scores, the primary modes of analysis were ranked mean comparison and paired-samples *t*-tests. These analysis methods were used to evaluate each picture- and symbol-based subtest against the collective subtest totals, and total visual-based scores. The ranked comparative means used the developed complexity rating of subtests identified in Chapters II and III. In Table 29, the picture- and symbol-based subtests are on the left and on the right the subtests are ranked in ordered from the highest complexity levels to the least (1) Cancellation, (2) Picture Span (3) Matrix Reasoning, (4) Figure Weights, (5) Picture Concepts, and (6) Visual Puzzles. The three symbol-based subtests ranked by complexity: (a) Symbol Search, (b) Coding, and (c) Block Design.

The ranked picture complexity analysis (see Table 3) showed CVI's highest mean score (*M* = 8.00) the cancellation subtest, which is ranked the most complex. However, the Cancellation subtest had a n of one. The second highest mean for the CVI group was the Figure Weights subtest (*M* = 5.38, *SD* = 3.11) which is ranked fourth of six. The lowest mean score of the CVI group, (*M* = 4.00) was the Picture Concept subtest, which was ranked fifth out of 6, however, that also had a small sample size. Of the OVI group, the highest mean was Picture concepts (*M* = 12.00). This was also a subtest with an *n* of one. The second highest subtest for the OVI group was Visual Puzzles (*M* = 10.17, *SD* = 3.98), which was ranked the least complex of the six. The Control group had the highest mean in the highest ranked complex subtest, Cancellation (*M* = 11.1, *SD* = 3.0). It's lowest mean subtest for the Control group was the second highest ranked complexity subtest, Picture Span (*M* = 10.1, *SD* = 2.8).

The ranked symbol complexity analysis (see Table 29) found the highest mean subtest for the CVI group was Coding (*M* = 5.29, *SD* = 2.75) which was the second of the three. The OVI group's highest mean subtest was Block Design (*M* = 8.00, *SD* = 4.14) which was the least complex of the symbol-based subtests. The Control group's highest subtest was Coding, (*M* = 10.7, *SD* = 3.0) which was the second of three.

Table 29

Picture- and Symbol-Based Subtest Complexity Ranking

Complexity Ranking of Subtest	Cortical/Cerebral Visual Impairment		Ocular Visual Impairment		Control	
	M	*SD*	*M*	*SD*	*M*	*SD*
Picture-Based						
1. Cancellation	8.00		9.00		11.1	3.0
2. Picture Span	4.83	3.06	8.75	4.52	10.1	2.8
3. ^Matrix reasoning	3.78	2.73	7.31	3.84	11.0	2.9
4. ^Figure Weights	5.38	3.11	9.50	3.87	10.5	2.7
5. Picture concepts	4.00		12.00		10.6	2.9
6. Visual puzzles	3.71	2.81	10.17	3.98	10.4	2.8
Symbol-Based						
1. Symbol Search	4.67	3.45	7.11	3.72	10.6	2.9
2. ^Coding	5.29	2.75	4.78	2.77	10.7	3.0
3. ^Block Design	4.89	3.30	8.00	4.14	10.6	2.7

Note. Subtests with a [^] in front of its name is indicative of that subtest being one of the core seven subtests of the Full Scale IQ score.

The paired-samples *t*-test was used to analyze the influence picture- or symbol-based subtests had on the larger groups (total subtests, visual-based subtest, and picture- or symbol-based subtests). The goal of these paired-samples *t*-tests was to see if there were statistically significant differences among certain ranked subtests. Table 30 looked at the picture-based subtests for the CVI and OVI groups. Both found statistically significant differences of the Matrix Reasoning subtest at the $\alpha = 0.05$ level, with 95% CIs. The Matrix Reasoning subtest was ranked third of six, so right in the middle. Nevertheless, the CVI group found statistically significant differences between the paired-samples *t*-tests of (total subtest CVI–Matrix Reasoning), $t(8) = 4.09$, $p = .004$, 95% CI [0.76, 2.74].

Table 30

Picture-Based Paired-Samples t-Test of the Cortical/Cerebral Visual Impairment and Ocular Visual Impairment Groups

Categorized Variable Pairings	*M*	*SD*	*SEM*	95% CI	*t*	*df*	*p*
Total Subtests Cortical/Cerebral Visual Impairment–Matrix Reasoning	1.75	1.29	0.43	[0.76, 2.74]	4.09	8	.004*
Picture-based Ocular Visual Impairment–Matrix Reasoning	1.24	1.62	0.45	[0.26, 2.22]	2.75	12	.018*
Total Subtests Ocular Visual Impairment–Matrix Reasoning	1.11	1.77	0.49	[0.04, 2.18]	2.26	12	.043*
Visual-Based Cortical/Cerebral Visual Impairment–Matrix Reasoning	0.87	1.14	0.38	[0.00, 1.75]	2.30	8	.050
Total Subtests Cortical/Cerebral Visual Impairment–Visual Puzzles	1.62	2.70	1.02	[-0.88, 4.11]	1.58	6	.164
Total Subtests Cortical/Cerebral Visual Impairment–Figure Weights	0.31	1.37	0.49	[-0.84, 1.45]	0.63	7	.548
Total Subtests–Picture Concepts	-2.92	4.12	2.92	[-39.98, 34.14]	-1.000	1	.500
Total Subtests–Picture Span	0.15	3.11	0.73	[-1.39, 1.70]	0.21	17	.836
Visual-Based Cortical/Cerebral Visual Impairment–Figure Weights	-0.06	1.88	0.67	[-2.16, 0.99]	-0.87	7	.412
Visual-Based Cortical/Cerebral Visual Impairment–Visual Puzzles	0.66	2.08	0.79	[-1.26, 2.58]	0.84	6	.435

Table 30 (continued)

Categorized Variable Pairings	*M*	*SD*	*SEM*	95% CI	*t*	*df*	*p*
Visual-Based Cortical/Cerebral Visual Impairment–Picture Span	-0.04	1.64	0.67	[-1.75, 1.68]	-0.06	5	.956
Picture-Based Cortical/Cerebral Visual Impairment–Figure Weights	-0.07	1.86	0.66	[-2.27, 0.09]	-1.08	7	.318
Picture-Based Cortical/Cerebral Visual Impairment–Visual Puzzles	0.69	1.72	0.65	[-0.90, 2.28]	1.06	6	.329
Picture-Based Cortical/Cerebral Visual Impairment–Matrix Reasoning	0.59	1.03	0.34	[-0.20, 1.38]	1.73	8	.123
Picture-Based Cortical/Cerebral Visual Impairment–Picture Span	-0.08	1.52	0.62	[-1.68, 1.51]	-0.13	5	.899

Note. * $p < .05$.

When looking at the paired-samples *t*-test for the symbol-based subtests, no statistically significant parings were found specific to the CVI group. However, there were OVI groupings of note, only one subtest was consistently significant across one group (see Table 31). The Coding subtest was found to have had statistically significant differences within three pairings of the OVI group. These were found between the pairings (total subtest OVI–Coding), $t(8) = 3.63$, $p = .007$, 95% CI [1.16, 5.17], (Visual-based OVI–Coding), $t(8) = 4.30$, $p = 0.003$, 95% CI [1.49, 4.93], and (Symbol-based OVI–Coding), $t(8) = 3.60$, $p = 0.007$, 95% CI [0.69, 3.16]). The Coding subtest was ranked second out of three symbol-based subtests .

The ranking of subtest complexity was a subjective measure that could have been interpreted differently by different parties. This study's ranking did not show a correlation between complexity level of picture- or symbol-based subtests and the participants' scores. This study failed to reject the Research Question 3 null hypothesis that there was no statistical significance in the complexity levels among specific visual media subtest scores of the WISC-V for students with Cortical/Cerebral Visual Impairment at 95% CI, and $p = 0.5$.

Table 31

Symbol-Based Paired-Samples t-Test of Cortical/Cerebral Visual Impairment and Ocular Visual Impairment Groups

Categorized Variable Pairings	*M*	*SD*	*SEM*	95% CI	*t*	*df*	*p*
Total Subtests–Coding	2.09	2.56	0.64	[0.72, 3.45]	3.26	15	.005*
Total Subtests Ocular Visual Impairment–Coding	3.17	2.61	0.87	[1.16, 5.17]	3.63	8	.007*
Visual-Based Ocular Visual Impairment–Coding	3.21	2.24	0.75	[1.49, 4.93]	4.30	8	.003*
Symbol-Based Ocular Visual Impairment–Coding	1.93	1.61	0.54	[0.69, 3.16]	3.60	8	.007*
Total Subtests Cortical/Cerebral Visual Impairment–Block Design	0.64	1.74	0.58	[-0.70, 1.98]	1.11	8	.301
Total Subtests Cortical/Cerebral Visual Impairment–Coding	0.70	1.82	0.69	[-0.99, 2.39]	1.01	6	.350
Total Subtests Cortical/Cerebral Visual Impairment–Symbol Search	0.96	2.52	1.03	[-1.69, 3.61]	0.93	5	.395
Visual-Based Cortical/Cerebral Visual Impairment–Block Design	-0.24	1.40	0.47	[-1.32, 0.84]	-0.51	8	.624
Visual-Based Cortical/Cerebral Visual Impairment–Coding	-0.21	2.02	0.77	[-2.08, 1.67]	-0.27	6	.796
Visual-Based Cortical/Cerebral Visual Impairment–Symbol Search	-0.03	1.63	0.67	[-1.74, 1.68]	-0.05	5	.962
Symbol-Based Cortical/Cerebral Visual Impairment–Block Design	0.00	1.44	0.48	[-1.11, 1.11]	0.00	8	1.000

Table 31 (continued)

Categorized Variable Pairings	*M*	*SD*	SEM	95% CI	*t*	*df*	*p*
Symbol-Based Cortical/Cerebral Visual Impairment–Coding	0.00	1.45	0.55	[-1.34, 1.34]	0.00	6	1.000
Symbol-Based Cortical/Cerebral Visual Impairment–Symbol Search	0.00	1.32	0.54	[-1.38, 1.382	0.00	5	1.000

Note. * $p < .05$

Research Question 4

Q4 Is there a significant difference between time-based subtests and untimed subtests for students diagnosed with CVI's subtest scores on the Wechsler Intelligence Scale for Children-Fifth Edition (WISC-V)?

The Welch's *t*-tests and SPSS calculated *t*-test with assumed unequal variances were categorized by timed and untimed subtests between the three groups comparisons. In Table 32, the CVI to Control group comparisons, five (63%) of the eight untimed subtests were found to have significant statistical differences. The two untimed subtests that were not of significant statistical difference were: Similarities, and Cancellation. All other subtests of the comparisons were found to have significant statistical difference at the level of $\alpha = 0.05$. The comparison of the CVI and OVI groups in Table 33, found two (40%; Visual Puzzles and Figure Weights) of the five calculated timed subtests to be of significant statistical difference. Four (44%; Matrix Reasoning, Picture Span, Information, and Digit Span) of the nine untimed subtests were found to have had significant statistical differences.

Table 32

Time and Untimed Subtests Welch's t-Test of Cortical/Cerebral Visual Impairments and Control Groups

Subtests	Cortical/Cerebral Visual Impairment			Control							
	M	*SD*	*n*	*M*	*SD*	*n*	*df*	*t*	*p*	*SE*	95% CI
Timed											
^Coding	5.29	2.75	7	10.7	3.0	241	6	5.12	.0022*	1.06	[-7.80, -2.82]
^Figure Weights	5.38	3.11	8	10.5	2.7	241	7	4.60	.0025*	1.11	[-7.75, -2.49]
^Block Design	4.89	3.30	9	10.6	2.7	241	8	5.13	.0009*	1.11	[-8.28, -3.14]
Symbol Search	4.67	3.45	6	10.6	2.9	241	5	4.17	.0087*	1.42	[-9.58, -2.28]
Visual puzzles	3.71	2.81	7	10.4	2.8	242	6	6.21	.0008*	1.08	[-9.32, -4.05]
Arithmetic	4.00	1.41	2	10.4	2.5	241	1	6.34	.0996	1.01	[-19.23, 6.43]
Cancellation	8.00		1	11.1	3.0	242					
Untimed											
^Vocabulary	6.89	3.10	9	10.5	2.7	241	8	3.45	.0088*	1.05	[-6.03, -1.19]
Information	5.80	1.30	5	10.3	2.4	242	4	7.48	.0017*	0.60	[-6.17, -2.83]
^Digit Span	5.11	3.66	9	10.5	2.5	241	8	4.38	.0023*	1.23	[-8.23, -2.55]
Picture Span	4.83	3.06	6	10.1	2.8	240	5	4.18	.0087*	1.26	[-8.52, -2.03]
^Matrix Reasoning	3.78	2.73	9	11.0	2.9	240	8	7.78	.0001*	0.93	[-9.36, -5.08]

Table 32 (continued)

Subtests	Cortical/Cerebral Visual Impairment			Control							
	M	*SD*	*n*	*M*	*SD*	*n*	*df*	*t*	*p*	*SE*	95% CI
Letter-Number Sequence	2.67	2.08	3	10.4	2.8	241	2	6.37	.0238*	1.21	[-12.96, -2.51]
^Similarities	8.44	4.33	9	10.6	2.6	239	8	1.49	0176	1.45	[-5.51, 1.19]
Comprehension	6.33	3.06	3	10.4	2.8	242	2	2.29	.149	1.78	[-11.71, 3.57]
Picture Concepts	4.00		1	10.6	2.9	240					

Note. Subtests with a [^] in front of its name is indicative of that subtest being one of the core seven subtests of the Full Scale IQ score.

* $p < .05$

Table 33

Time and Untimed Subtests Independent-Samples t-Test of Cortical/Cerebral Visual Impairment and Ocular Visual Impairment Groups

Subtests	*t*	*df*	*p*	95% CI	*SE*
Timed					
Visual Puzzles	-4.13	16.16	< .001*	[-9.76, -3.14]	1.56
^Figure Weights	-2.51	15.99	.023*	[-7.61, -0.06]	1.65
^Block Design	-1.96	19.51	.065	[-6.43, 0.21]	1.59
^Coding	0.36	13.10	.721	[-2.50, 3.51]	1.39
Symbol Search	-1.30	11.47	.218	[-6.55, 1.66]	1.88
Arithmetic	-2.04	1.31	.240	[-25.39, 14.39]	2.69
Cancellation					
Untimed					
*Matrix Reasoning	-2.52	19.96	.020*	[-6.45, -0.61]	1.40
Picture Span	-2.17	14.17	.048*	[-7.78, -0.05]	1.81
Information	-3.75	6.36	.009*	[-7.24, -1.56]	1.17
^Digit Span	-2.16	16.78	.046*	[-6.63, -.007]	1.55

Table 33 (continued

Subtests	*t*	*df*	*p*	95% CI	*SE*
^Similarities	-0.52	16.26	.611	[-4.78, 290]	1.81
^Vocabulary	-1.72	19.12	.102	[-5.54, 0.55]	1.45
Comprehension	-0.51	2.94	.648	[-7.35, 5.35]	1.97
Letter-Number Sequence	-1.40	2.99	.257	[-12.03, 4.70]	2.62
Picture Concepts					

Note. Subtests with a [^] in front of its name is indicative of that subtest being one of the core seven subtests of the Full Scale IQ score.

* $p < .05$.

When analyzing the data related to the timed and untimed subtest data, the research analysis was able to use three of the previously created variables in SPSS (total subtest, subtest CVI and subtest OVI). There were six new variables created for this analysis (total timed, timed CVI, timed OVI; total untimed, untimed CVI, and untimed OVI). These variables were used in both paired-samples *t*-tests and independent-samples *t*-tests. The paired-samples *t*- tests looked within each group (for example, CVI to CVI; see Table 34). The target of Research Question 4 was the CVI group's potential to have a statistically significant difference between the untimed and timed subtests. The paired-samples *t*-test analysis used 15 pairings to evaluate the potential influence the timed constraints of a WISC-V subtest have on CVI and OVI group participants' scores (see Table 34). Of the 15 pairings, none (0%) were statistically different at the level of α = 0.05.

Table 34

Time and Untimed Paired-Samples t-Test of Cortical/Cerebral Visual Impairment and Ocular Visual Impairment Groups

Categorized Variable Pairings	*M*	*SD*	*SEM*	95%CI	*t*	*df*	*p*
Total Subtests–Untimed Cortical/Cerebral Visual	-0.51	0.85	0.28	[-1.16, 0.14]	-1.78	8	.110
Total Subtests–Timed Cortical/Cerebral Visual	0.60	1.12	0.37	[-0.26, 1.46]	1.60	8	.148
Timed Cortical/Cerebral Visual Impairment–Untimed Cortical/Cerebral Visual Impairment	-1.19	1.77	0.59	[-2.55, 0.17]	-2.02	8	.078
Untimed–Timed	0.86	2.22	0.47	[-0.12, 1.85]	1.82	12	.083
Visual-Based Cortical/Cerebral Visual–Untimed Cortical/Cerebral Visual	-1.39	1.83	0.61	[-2.79, 0.02]	-2.28	8	.052
Visual-Based Cortical/Cerebral Visual–Timed Cortical/Cerebral Visual	-0.28	0.57	0.19	[-0.72, 0.15]	-1.50	8	.173
Low Visual-Based Cortical/Cerebral Visual–Untimed Cortical/Cerebral Visual	0.77	1.23	0.41	[-0.18, 1.71]	1.87	8	.098
Low Visual-Based Cortical/Cerebral Visual–Timed Cortical/Cerebral Visual	1.87	2.92	0.97	[-0.38, 4.12]	1.92	8	.091

Note. * $p < .05$.

The same criteria of Research Question 1 and Research Question 2 was used for the Research Question 4 independent-samples *t*-test, under normal assumptions, with equal variances not assumed and a sample size of *n* = 22 (see Table 35). The categorized timed and untimed variables were compared against the independent variable, visual diagnosis, categorized by CVI and OVI to look at the potential statistically significant differences. Group 1 was defined as untimed, and Group 2 was defined as timed. The null (H04) and alternative (H4) hypotheses for Research Question 4 were:

$$\begin{cases} H04\colon \mu_1 = \mu_2 \\ H4\colon \mu_1 \neq \mu_2 \end{cases}$$

H04 There is no statistical significance in the timed and untimed subtest scores of the WISC-V for students with Cortical/Cerebral Visual Impairment.

H4 The timed subtest scores significantly differ from untimed subtests in the WISC-V for students with Cortical/Cerebral Visual Impairment.

Table 35

Time and Untimed Independent-Samples t-Test of Cortical/Cerebral Visual Impairment and Ocular Visual Impairment Groups

Categorized Subtest Variables	*t*	*df*	*p*	*SE*	95% CI
Untimed Subtests	-2.13	19.35	.046*	1.16	[-4.90, -0.05]
Timed Subtests	-2.43	20.00	.025*	1.25	[-5.64, -0.43]

Note. Equal variances not assumed.

* $p < .05$.

The test of Equality of Variance was not used as the *t*-test was run under the assumption of nonequal variances. With a *p*-value of 0.046, *t*-value of -2.13, and 95% CI [-4.90, -0.05], it was concluded there were statistically significant differences between the untimed subtests of the CVI and OVI groups at the level of $\alpha = 0.05$. The time-based subtest analysis resulted in a *p*-value of .025, *t*-value of -2.43, and 95% CI [-5.64, -0.43]. There was a statistically significant difference between CVI and OVI time-based subtests at the level of $\alpha = 0.05$. There were statistically significant differences between the scores of the CVI and OVI groups for both timed and untimed subtests (see Table 35). However, as shown in Table 34, there were no statistically significant differences amongst the CVI group and their scores on timed and untimed subtests. Thus, this study failed to reject the Research Question 4 null hypothesis that there was no statistical significance in the timed and untimed subtest scores of the WISC-V for students with Cortical/Cerebral Visual Impairment.

Conclusion

When analyzing the results of the WISC-V subtests between the three comparison groups (CVI, OVI, and Control from the normative data), it is be important to remember the differences between these groups (Wechsler, 2014a, 2014c). That being said statistical analysis methods were used to account for variations in collected and obtained data, which resulted in multiple areas found to have statistically significant differences. The Welch's *t*-test preliminary analysis, used the Partial data set's CVI and Control groups, 12 (85%) of the calculated 14 subtests were found to be statistically significant at the level of $\alpha = 0.05$. The CVI and OVI Partial data set found 5 (36%) of the 14 subtests to be of statistically significant difference at the level of $\alpha = 0.05$.

Research Question 1 rejected the Research Question 1 null hypothesis and found a statistically significant difference for visual-based subtests of the WISC-V at $\alpha = 0.05$, p-value: 0.02 and 95% CIs [-5.97, -0.56]. Research Question 2 found partially statistically significant differences, as there were the Research Question 2 had unanticipated two parts. Research Question 2 rejected the null hypothesis and found statistically significant differences of Picture-based subtest scores of the WISC-V of students with CVI at 95% CI, and $p = 0.5$. However, it failed to reject the null hypothesis that there was no statistical significance in the scores between symbol-based visual media subtests of the WISC-V for students with Cortical/Cerebral Visual Impairment at 95% CI, and $p = 0.5$. Research Question 3 failed to reject the null hypothesis as there was limited indication that the complexity levels of the picture-based or symbol-based subtests impacted subtest scores. For Research Question 4, the CVI and OVI groups timed and untimed subtests scores were both had statistically significant differences, timed subtests, $t(20.0) = -2.24$, $p = .037$, 95% CI [-5.64, -0.20] and untimed subtests, $t(19.3) = -2.15$, $p = .044$, 95% CI [-4.95, -0.07]. However, within the CVI group there was no statistically significant differences amongst their scores on timed and untimed subtests. Thus, this study failed to reject the Research Question 4 null hypothesis that there was no statistical significance in the timed and untimed subtest scores of the WISC-V for students with Cortical/Cerebral Visual Impairment.

CHAPTER V

DISCUSSION AND CONCLUSIONS

This study aimed to understand the WISC-V scores of individuals with CVI while comparing those scores to individuals with OVI, and a control group derived from the norming sample of the WISC-V. Through these statistical comparisons, the goal was to gain an understanding of potential trends related to the visual and time demands of the WISC-V on children who have been identified with CVI or OVI. Through a variety of recruitment methods, the researcher was able to collect 80 usable, redacted evaluation reports. Although the Total collected data set sample was $n = 80$, for some analyses, the sample was reduced to 22, to help balance the ratio between CVI and OVI participant data based on the number of subtests that had been completed for each case. As all information was de-identified, the evaluation results needed to have included visual and time subtests in the second Partial data set, $n = 22$. The varying degree of difference between the CVI and OVI participant levels was unexpected. It was a driving force in the reduction of the sample size to help accommodate for missing data of the target subtests, visual and timed subtests. Statistical analyses were used with the Partial data set including Welch's *t*-test, independent-samples *t*-tests and paired-samples *t*-tests. It was hypothesized that this study would reject the nulls of all four research questions. Two of the four research questions failed to reject the null hypothesis (Research Questions 3 and 4), and two (Research Questions 1 and 2) rejected the null hypothesis.

Research Questions

Q1 Do students diagnosed with CVI have lower cumulative vision-based subtest score than low-vision-based subtest score on the Wechsler Intelligence Scale for Children-Fifth Edition (WISC-V)?

Q2 Is there a significant difference between visual-based subtests that feature pictures vs symbols for students diagnosed with CVI's subtest scores on the Wechsler Intelligence Scale for Children-Fifth Edition (WISC-V)?

Q3 Does the complexity level within a specific visual media (picture or symbol) of a visual-based subtest have a correlation with a student diagnosed with CVI's subtest scores on the Wechsler Intelligence Scale for Children-Fifth Edition (WISC-V)?

Q4 Is there a significant difference between time-based subtests and untimed subtests for students diagnosed with CVI's subtest scores on the Wechsler Intelligence Scale for Children-Fifth Edition (WISC-V)?

Summary of Findings

Research Question 1

Q1 Do students diagnosed with CVI have lower cumulative vision-based subtest score than low-vision-based subtest score on the Wechsler Intelligence Scale for Children-Fifth Edition (WISC-V)?

H1 The vision-based subtest scores significantly differ from low-vision-based subtests in the WISC-V for students with Cortical/Cerebral Visual Impairment.

To understand if students diagnosed with CVI would have lower cumulative vision-based subtest scores on the WISC-V, coded subtests were compared individually and with newly grouped variables. When the subtests were compared individually between the three groups (CVI and Control, (OVI and Control, and CVI and OVI), the CVI and Control group comparison resulted in 100% of the calculated subtests having significant statistical differences, the comparison of the OVI and Control groups resulted in 57% of the subtests, indicating statistically significant differences. Due to the source and availability of the Control group's data, only the CVI and OVI groups were compared using the created limited and visual-based subtest variables.

There were statistically significant differences between CVI and OVI Visual-based subtests, $p = .02$ 95% CI [-5.97, -0.56], meaning students with CVI performed worse than their OVI peers. When compared to the collective total of subtest scores, the CVI visual-based subtests' scores were also statistically significant. Even though a subtest was not visually demanding, the student may have used their vision to engage in the evaluation environment around them. When CVI students' performance on visual-based subtests was looked at next to all completed subtests, they performed worse than OVI peers. All other comparisons were not determined to be of statistical significance. This highlighted that they performed worse when the CVI group was compared to the OVI and Control group's total and visual-based subtests. However, their performance was not as different when the CVI group was compared to the OVI group's low visual-based subtests.

Research Question 2

Q2 Is there a significant difference between visual-based subtests that feature pictures vs symbols for students diagnosed with CVI's subtest scores on the Wechsler Intelligence Scale for Children-Fifth Edition (WISC-V)?

H2 The symbol-based visual media subtest scores significantly differ from picture-based subtest scores in the WISC-V for students with Cortical/Cerebral Visual Impairment.

When a student was given the WISC-V, the visual-based subtests could contain picture or symbol-based visual materials. The criteria for picture or symbol-based was guided by the WISC-V's labeling of subtests and explained in Chapter I. Six of the nine visual-based subtests were categorized as pictures and three as symbols. Compared to the Control group, the CVI group had 100% statistically significant differences for both picture- and symbol-based subtests.

The OVI group scores compared to the Control group were not significantly different for any picture-based subtests and were 100% for the three symbol-based subtests. When comparing the CVI and OVI groups, their scores for picture-based subtests differed, with no significance when comparing the symbol-based scores. The CVI group scores of the picture-based subtests compared to the total subtests did have a difference in performance, yet this was not seen when CVI symbol-based subtests were compared to the whole group. For the CVI group, their scores on a picture-based subtest have a greater difference than their scores on symbol-based subtests.

Research Question 3

Q3 Does the complexity level within a specific visual media (picture or symbol) of a visual-based subtest have a correlation with a student diagnosed with CVI's subtest scores on the Wechsler Intelligence Scale for Children-Fifth Edition (WISC-V)?

H3 The visual media subtest score significantly differs among the complexity levels of subtests in the WISC-V for students with Cortical/Cerebral Visual Impairment.

To answer Research Question 3, the variables created for the Research Question 2 comparison between picture- and symbol-based subtests were used to understand the group's scores in relation to the complexity levels of the subtests, as seen in Tables 30 and 31. For both CVI and OVI groups, matrix reasoning, a picture-based subtest, differed in scores related to the total and visual-based subtests. Matrix reasoning was ranked third most complex out of the six picture-based subtests. The coding subtest for the OVI group was the only subtest with a significant difference for symbol-based subtests. No CVI subtest score revealed the complexity level related to the students' scores.

Research Question 4

Q4 Is there a significant difference between time-based subtests and untimed subtests for students diagnosed with CVI's subtest scores on the Wechsler Intelligence Scale for Children-Fifth Edition (WISC-V)?

H4 The timed subtest scores significantly differ from un-timed subtests in the WISC-V for students with Cortical/Cerebral Visual Impairment.

The final research question (Research Question 4) used the created timed and untimed variables and hand calculations to investigate the potential influence of timed and untimed subtests in the WISC-V. It was noted that all the timed subtests were also visual-based. No timed test fell under the low visual-based category. Of the timed subtests completed by the CVI and OVI groups, three were picture-based and three were symbol-based. The hand calculations using Welch's *t*-tests between the CVI and Control groups indicated that 100% of the timed subtests were statistically different and 80% of the untimed subtests also had statistical differences. For the OVI and Control group comparison, 40% of the timed and 11% of the untimed subtests had statistical significance. When looking at the created variable comparison, no comparison showed statistical differences among any of the pairing or statistical analysis measures. It could not be said at this time whether a subtest was timed or untimed if it would impact results for students with CVI.

Implications of Research

The impact of a specific WISC-V subtest on a student with CVI's score could be seen through the multiple grouping comparisons: (a) visual-based, (b) low visual-based, (c) picture-based, (d) symbol-based, (e) timed, and (f) untimed. Visual-based subtests were more challenging for students with CVI, resulting in lower or more significantly different scores. This extended to picture-based subtest scores, which were also more significant in the visual-media categories. Symbol-based subtest scores were not as different or impactful on overall scores. The complexity levels of the picture-based subtests did not appear to play a role in the students' scores. The difference in scores of timed and untimed subtests within the CVI group was not significant. However, there was a difference between the timed and untimed subtests of the CVI and OVI groups. This meant that, regardless of whether a subtest was timed or untimed, an individual with CVI would score differently than an individual with an OVI. However, when comparing the same timed and untimed subtests within the CVI group, there was less of a difference in scores. This may suggest that the visual component is more impactful for individuals with CVI than timing.

Much of the current literature has supported the finding that students and individuals with CVI struggled to access pictures and scenes, especially those with high complexity levels (Bennett et al., 2021; Manley et al., 2023; Merabet et al., 2017). This study found no correlation between the complexity level of the subtest in the scores of the participants. The format of the WISC-V stimuli may not have included the level of complexity described in the above research. Much of the complexity-related studies included stimuli with figure-ground or backgrounds. Though the WISC-V has complex subtests, all were on a plain background with stimuli on top. There was no complex background or additional processing needed outside of the visual stimuli related to the task. However, additional research on the structure, placements, and novel access should be completed to examine how participants access these complex subtests in real-time.

Past research also supported that individuals with CVI were impacted by the novelty of what they were seeing (Bennett et al., 2021; Kran et al., 2019; Merabet et al., 2017). The novelty of the WISC-V and its subtests for participants was not evaluated and could be an unknown contributing factor. As the average age was between 8-12 years old, and first tested at the age of 6 years old, participants may have had 2-3 exposures to the test stimuli. Past research also supported that extended time, or the time it took for individuals with CVI, was longer than for those without (Bennett et al., 2021; Chang & Borchert, 2020; Lueck & Dutton, 2015; McDowell & Budd, 2018). This study found no correlation between the CVI group and the scores of timed and untimed subtests. The results brought forth many additional questions, which included whether the familiarity of the test and the structure of the test was an impacting factor for participants. The WISC-V's Administration and Scoring Manual and Supplemental Manual identified the shortest test-retest interval was not yet determined (Wechsler, 2014b). Additionally, the WISC-V's Administration and Scoring Manual and Supplemental Manual also stressed that different subtests and the participants' age impact the length of time needed between WISC-V administrations to reduce the risk of previous performance on the scores (Wechsler, 2014b). Across all WISC-V subtests, the risk of previous evaluations impacting the results was minimized after 2 years (Wechsler, 2014b). These results prompted and strengthened the need for future research into the educational access methods of students with CVI to better understand the impact of symbol-based materials, the influence of novelty, and the influence of time-based tasks on a large sample size.

Theoretical Implications

When examining the implications of the findings of this study, it was natural to first look back at its theoretical foundation. This study was grounded in Cambourne's Model and Vygotsky's learning theories, both of which fell under the constructivism framework (Cambourne, 1995; Crotty, 1998; Sweeney, 2012; Vygotsky, 1983). These theories purported that an individual was in charge of their knowledge. An individual's lived experiences and methods of access to the world around them influence the information they take in. This study examined one method of evaluating an individual's cognitive profile, the WISC-V (Wechsler, 2014a). An individual's cognitive profile may represent their learning profile and the individual's access methods. The WISC-V was a means to evaluate if there were trends for the cognitive profiles of CVI and OVI participants, as well as visual and time-based scores, compared to the Control group (Wechsler, 2014c). This study's findings suggested connections between the CVI, OVI, and the Control groups' scores of the visual-based subtests.

Additionally, there was a statistical difference in the scores of picture-based subtests. In this study, each group's visual access to the visual information differed due to the presence or lack of presence of visual diagnosis. Theoretically, if they accessed visual information differently, that impacted how they took in information and created their own knowledge. This study's findings supported the constructivist works of Cambourne's Model and Vygotsky's that decreased visual access plays a role in the targeted learning methodologies for individuals with CVI and visual impairments (Allman & Lewis, 2014; Cambourne, 1995; Crotty, 1998; Sweeney, 2012; Vygotsky, 1983).

Research Implications

The results of this research have the potential to both influence and support additional research. The Wechsler battery of evaluations is commonly used in educational settings and research (Manley et al., 2023). Portions of the WISC-IV and Wechsler Intelligence Scale for Adults-Fourth Edition (WAIS) were used by Manley et al. (2023) to obtain their participants' verbal IQs using subtests under the verbal comprehension scale, finding CVI participants had a mean and standard deviation of 89.53 ± 27.24, while controls had a mean and standard deviation of 111.02 ± 17.46 *SD*, $t(82.19) = -4.621$, $p < 0.001$, $d = 22.981$. This study found similar results, with CVI Partial data set participants had a mean of 85.17 and a standard deviation of 16.63, and the Control group had a mean of 102.7 and a standard deviation of 13 that resulted in statistical significance difference of the Verbal Comprehension Index, $t(11) = 3.60$, $p = .0042$, 95% CI [-28.26, -6.80]. Additionally, Manley et al. (2023) found that CVI participants had a difference in their access to picture-based images compared to the Control group. Similar results were found here, extending beyond the Control groups to a statistical difference between CVI and OVI group's access to visual-based subtests (p = .02, 95% CI [-5.97, 0.56]) and picture-based subtests (p = .006, 95% CI [-6.98, -1.37]).

It has been estimated that 64% of individuals with Epilepsy were also diagnosed with CVI (West et al., 2021). Therefore, consideration of the work of MacAllister et al. (2019) may be relevant to these findings. In their study, researchers evaluated the WISC-V scores of participants with Epilepsy compared to controls, finding statistical significance across all but one of the subtests, Figure Weights. As additional diagnoses were not consistently collected in this data set, it was unknown how many participants also had a diagnosis of Epilepsy. However, when CVI participants' subtests were compared to controls, this study's findings did match those of MacAllister et al. (2019), which had statistical differences across subtests, including the subtest of Figure Weights.

Chokron et al. (2021) stated that all subsequent skill development areas were assumed to be affected if an individual's visual recognition and visual attention skills were affected. Cortical/Cerebral Visual Impairment has impacted visual recognition and attention (Chokron et al., 2021; Lueck & Dutton, 2015). As such, this study found visual-based subtests as a collective whole, and specifically picture-based subtests, were statistically significant between CVI and OVI groups and between CVI and Control groups. This study, paired with the early findings of Manley et al. (2023), supported the idea that visual access to pictures affected the educational access of individuals with CVI.

This study not only answered questions but created a dialogue of new questions between the fields of teachers of the visually impaired and certified school psychologists or licensed psychologists who work with children with CVI. As a quantitative study, practitioner narratives or interviews were not included. However, many were eager and open to discussing their practices and methods. A qualitative study related to practitioner decision-making as related to cognitive assessment methodologies used with children who have CVI would help enhance our understanding of the varying approaches that were represented in this study. Hopefully, this study will influence further collaborative, cross-domain research to help provide the most holistic understanding of students with CVI and visual impairments. A cross-domain research study on the methodologies of certified or licensed psychologists when administering the WISC-V, or additional standardized cognitive evaluations, to individuals with CVI or OVI would shed further light on this novel research topic.

Implications for Research

Understanding a student's cognitive profile and educational access methods was critical to developing an accessible educational experience. This study did not seek to validate or influence the use of the WISC-V with students with CVI or OVI in any way. The purpose of this quantitative study was to use statistical analysis to compare the WISC-V scores of visual-based, picture-based, symbol-based and timed subtests along with the subtests' complexity levels between participants with CVI, OVI, and pre-existing data from a control group from the WISC-V Technical Manual (Wechsler, 2014c). However, this study should provide a new viewpoint of the potential results and how those may be applied in the educational space. A student's educational team was not siloed to teachers or teachers of the visually impaired but a collaborative team across fields. When looking at the application of this study, an additional benefit was to spread awareness of CVI and emphasize that students with CVI were a prominent part of educational communities and required specific adaptations, accommodations, and methodologies to help ensure their educational access.

Recommendations for Educational Sites

The understanding of CVI by both the medical and educational community has been ever-changing and ever-growing. Insulating research knowledge in one domain could restrict the growth and accessible educational experiences for all students. McKinsey & Company (2023) highlighted CVI-related resources' geographical and socioeconomic impact. Not every individual on every educational team would be a master of all disabilities. Team collaboration would be recommended for ensuring individual-specific developed educational plans and continual implementation of the strategies. This study showed that the subtests used between private and public institutions varied. As qualitative information or interviews with the certified or licensed psychologist were not conducted, and their familiarity with CVI has yet to be discovered. However, it is likely that those practitioners who work within specialized settings have greater familiarity and knowledge about assessment practices for children with CVI and OVI than practitioners in a general educational setting or a private practice. That being said, collaboration with the teacher of the visually impaired may ensure the certified or licensed psychologist is aware of the individual impact of CVI and does not provide subtests that are beyond the student's reach or underestimated the student and does not provide a subtest due to fear of the student's access. It would also be recommended that teachers of the visually impaired conduct their evaluation before the psychologist or collaborate with the psychologist during evaluations to ensure open communication and sharing of knowledge related to evaluating accessibility needs such as the impact of clutter, sensory needs, appropriate lighting, visual field access, material positioning or font size.

It would be recommended for specialists working with individuals with visual impairments not to lower expectations due to limited visual access. Assumptions of a student's abilities prior to evaluation could result in missed learning opportunities and relegating them to simply maintenance of skills instead of ensuring meaningful development of skills (Endrew F. v. Douglas County School District RE-1, 2017).

Recommendations for Teachers of the Visually Impaired

The WISC-V is a complex cognitive assessment that utilizes visual and auditory access methods to understand the individual's cognitive profile and access methods. These complex visual tasks resulted in statistically significant scores between participants with CVI compared to OVI data and OVI to Control groups. This study utilized both CVI and OVI groups as the OVI population had not been evaluated prior, and the assumptions of CVI individuals' access methods could not be assumed but must be statistically analyzed. As teachers of the visually impaired, it would be recommended to understand the access methods and the overall evaluation tools used on students with blindness or visual impairment. The WISC-V was one of these. It was not the place of a teacher of the visually impaired to dictate the subtests or methodologies used by a certified or trained licensed psychologist. However, being unaware of the subtests' visual and time-based demands would be a disservice concerning the needed ability to help translate the results of the test to the educational environment. Awareness that specific subtests had different visual access methods (picture verse symbol) and individuals with CVI had lower scores on the picture-based subtests than OVI or Control groups was critical for effective educational collaboration.

A continued recommendation for teachers of the visually impaired would be to be aware of the characteristics and visual behaviors of CVI and those influences. Part of the evaluation practices of a teacher of the visually impaired would be team interviews to understand how other team members were seeing the student use their vision functionally across different domains.

The continued use of these collaborative methods would be recommended and stressed to be used with both students diagnosed or suspected to have CVI. Sharing the viewpoints between specialists could help ensure the cohesive implementation of strategies and accessible evaluation methodologies. Ensuring open dialogue between evaluators, the tools they were using, and the varying visual and time demands could help ensure a collaborative practice.

Limitations

The researcher has made conscious efforts to reduce the significance of external and internal factors on a study's result. These efforts have required systematic planning throughout the planning process, while also requiring a thorough rechecking of methodologies and data in the collection and analysis stages. Being cognizant of the limitations of a study would help a researcher make necessary decisions throughout the study's lifetime. However, limitations are a part of the research process. Being aware of how both internal and external factors would allow for a researcher to continue to grow and refine their practice would be crucial to ensuring their work could be implemented to the greater target population. The limiting factors to this study included CVI diagnosis rate; CVI awareness; recruitment time period; sample size; limited access to control raw data; exclusion of participants medical backgrounds; variations professional selection of WISC-V subtests; certified or licensed psychologist's familiarity with visual impairments; the participants familiarity with the WISC-V; and COVID-19's influence on evaluation practices.

Design and Internal Validity

Creswell and Creswell (2018) defined internal validity as the experimental procedures, treatments, or experiences extending to the selection methods and statistical conclusion validity. This study recorded participants' state, education location, age at evaluation, year of evaluation, and visual diagnosis. Though conscious recruitment efforts were made, the study represented only 7 of the 50 states. The majority (65 of the total 80 participants) came from the east coast of the U.S. Part of this effort also sought to include samples from public schools and specialized schools, including schools for the blind. The majority of the total participants (59 out of the total 80) came from specialized schools. This was different than what was reported by the American Printing House for the Blind's 2022 Annual Report, that the population of students with blindness or visual impairments in the U.S., 8% attend a school for the blind, and 85% attend public school (APH, 2022). However, when the data set was split into a Partial set, the majority came from public schools, with 14 out of 22. The Partial data set was also heavily skewed, with 20 out of the 22 coming from the east coast. This study also did not record participants' gender, race, or family socioeconomic status. As these factors were not recorded, the certainty of the sample representing these areas of the target population was inconclusive.

The total sample of the CVI group (*n* = 13) and the partial sample for the CVI group (*n* = 9) was believed to be a limited example of the total CVI population that was evaluated using WISC-V in the last 5 years. Additionally, the small sample size of the CVI group was a limitation to the statistical analysis and its relation to the whole CVI population. Efforts were made in the analysis process to combat these. However, this did not substitute the benefit a larger sample size would have. It was worth noting the difference in the estimated sizes between the OVI and CVI populations (Erickson et al., 2023; McKinsey & Company, 2023; U.S. Department of Education Office of Special Education and Rehabilitation Services' Office of Special Education Programs, 2023). Erickson et al. (2023) estimated the collective U.S. school-age population with blindness or visual impairments was around 700,000. McKinsey & Company (2023) estimated the U.S. population with CVI may be 180,000, with only around 26,000 diagnosed. Yet the APH (2022) only reported around 6,000 registered students with blindness or visual impairment, including CVI, in the United States. The variations in population estimations and registered individuals also highlighted the challenge in recruitment. This study suggested a replication study could be done in the hopes of reaching a larger sample size.

To understand how the CVI and OVI groups compared to the greater population, the WISC-V normative data set from the WISC-V technical manual was used. For subtest-related data, the sample included subtest means, sample size, and standard deviation but no raw data. Due to this, in-depth analysis could not be conducted. Additionally, SPSS was not used with the control data and all calculations were done with GraphPad. These factors limited the analysis that occurred.

The exclusion of the participants' medical history beyond their visual diagnosis limited the study's findings and could have unintentionally included a participant with undiagnosed CVI. The exclusion of personal participant information was intended to bolster the potential sample size of this study; participants' medical history was not required and could be redacted from WISC-V evaluations. That being said the additional disabilities of both the CVI and OVI groups were provided sparingly. From the provided heading titles of the study's WISC-V reports, what was included under a student's medical history was not uniform across evaluation report styles. The medical history of additional disabilities of the Control group from the WISC-V technical manual was also unknown (Wechsler, 2014b). As these were unknown, there was the risk that individuals in the Control group may have had a visual impairment of some degree that was unknown to the study. Cortical/Cerebral Visual Impairment has been the top pediatric visual impairment in developed countries and has been increasingly connected to other medical conditions and comorbidities (Bosch et al., 2014; McKinsey & Company, 2023; Ong et al., 2023). It has been estimated 65-70% of individuals with CP, 64% of individuals with Epilepsy and an estimated 38% of individuals with Down Syndrome have CVI (McKinsey & Company, 2023; West et al., 2021; Wilton et al., 2021). Gathering information of additional disabilities may lead to understanding the risk of influence other disabilities may have had on the results. For example, the symbol-based subtest was found to have no statistical significance between CVI and OVI, CVI and Control, and OVI and Control. However, suppose individuals in either the CVI or OVI groups were diagnosed with a reading disability such as dyslexia. In that case, this may have swayed the results, and those individuals could be removed to help ensure a valid analysis. Additional disabilities such as hearing loss, motor impairments, attention deficits, or emotional regulation challenges may have other contributing factors. All of these could have influenced the results. It would be recommended that comprehensive additional disability data be gathered in future studies. With no comprehensive understanding of each participant's medical background, the confounding influence on WISC-V results was not evaluated.

Through the recruitment process, as only the visual diagnosis was part of the required inclusion information, there was a skew in collected participant WISC-V evaluation reports. Though extensive recruitment efforts were made, the influence of those is discussed more in the external validity section; the recruitment results were not equal. Of the Total data set (n = 80), 67 individuals were categorized into the OVI group and 13 into the CVI group. This significant skew, though problematic for statistical analysis, seemed representative of the diagnosed visual impairment community. Cortical/Cerebral Visual Impairment has been known to be underdiagnosed (McKinsey & Company, 2023). There were 55,711 students K-12, registered with the American Printing House in 2022, with 26,000 diagnosed with CVI reported by

McKinsey & Company in 2023. However, McKinsey & Company (2023) estimated that the prevalence of CVI was as high as 180,000 students in the United States.

The Partial data set was created to combat the skewed ratio of OVI and CVI participants in the Total data set. The Partial data set was used to balance the ratio between CVI and OVI participants, including 9 CVI participants and 13 OVI participants. The inclusion criteria for the Partial data set were the completion of both visual and timed. As the participants' data were already coded and de-identified, the selection of the 22 evaluations was not correlated to who or where the results were completed but rather the numbers and subtests completed.

The execution of the WISC-V by a certified school psychologist or licensed psychologist could also be a factor related to internal validity. The level of familiarity with visual impairments by the evaluating party was unknown. Practitioners had the professional discretion of which subtest they administered. The WISC-V contains several subtest variations; this study accepted any variation provided in the evaluation report. Due to that, the total number of participants for each subtest scores varied. This could have affected the accuracy of the representation of this sample to the target sample. The certified or licensed psychologist's familiarity with CVI and OVI students may have influenced the selected subtests.

Additionally, a small percentage of evaluations for the CVI and OVI groups (26%) occurred during 2020 and 2021, which may have been subjected to protocols related to the COVID-19 pandemic. These small percentages of evaluations and the significance of restrictions on working with students may also be inconsistent across schools or states. These methodologies and overall educational changes due to the pandemic may have affected the students' scores.

This study used a 5-year inclusion timeline to account for the COVID-19 pandemic and variations in evaluation periods. As data collection extended into 2024, one evaluation report from 2018 and one from 2024 were included. This timeline effort was also to be cognizant of the risk of duplicate evaluations due to a student being evaluated twice in 5 years. One student provided two separate years' evaluations; the most recent one was used. There was one duplication of the evaluation reports provided by two separate parties; one duplicate was removed. Aside from that event, no additional evaluations were removed, and there were no requests for the removal of previously provided materials.

Though only one participant had an additional evaluation from a prior year, a participant’s familiarity with the WISC-V could not be assumed. The average age of the CVI participants in the Total data set was 11.0. The average age for OVI participants from the Total data set was 12.0. The average ages for the CVI and OVI groups were slightly lower for the Partial data set at 9.5 for CVI and 10.8 for OVI. The WISC-V was standardized for individuals aged 6-16.9. Of the Total data set participants (n = 80), there was age representation across all age groups, with the youngest aged 6.5 and the oldest 16.5, and an average age at the most recent evaluation of 11.6. There is uncertainty of whether the study’s participants were familiar with the WISC-V added a criterion that would benefit future studies' inclusion criteria. It would be recommended that future studies inquire if the participants had been evaluated with the WISC-V previously.

To reduce the significance of limitations, this study benefited from the collaboration and willingness of others to teach and inform on the practices related to the WISC-V, its administration, and how some variations may occur to accommodate a student’s visual access needs. There were variations of reporting styles of the WISC-V. This extended to what was or was not included in background or medical background sections. The understanding of extenuating circumstances during the evaluation period when the certified or licensed psychologist administered the WISC-V relied on additional information about the evaluation procedures in their evaluation report. Many psychologists noted that the student had a visual impairment, but no accommodations were noted outside of one use of a CCTV magnifier.

This study's statistical analysis methods also benefited from the collaboration with individuals well-versed in statistical analysis, specifically related to visual impairment and educational analysis. These collaborative efforts occurred in tandem with the guidance of the WISC-V's administration manual and technical manual (Wechsler, 2014b, 2014c). The WISC-V conducted its own validity and reliability evaluations and supplementary evaluations related to 12 areas of disability. These methods were utilized and inspired to help ensure consistency, demonstrating correlations between groups related to WISC-V evaluations and scores.

Awareness of the limitations of this study are critical and of its exploratory nature. Additionally, collaboration with others would be needed when recruiting, collecting data, analyzing data, and reporting on the results. It would not be a weakness to identify one's limitations but rather a weakness not to accept help in those areas.

External Validity and Generalization

The risk to a study's validity could extend beyond the sample to its generalization to the target population (Bracht & Glass, 1968; Gall et al., 1996). Creswell and Creswell (2018) stressed that, when examining the external validity of a study, one must look at treatment, selection, and setting. To understand how this study could relate to the population outside the study, we must first examine how the study's sample was recruited and selected. Each state in the U.S. was contacted or shared recruitment information through either AER Chapters, targeted emails to the specialized schools that educate students with visual impairments or targeted emails to each state's largest public school districts. Efforts were made to reach participants of all geographical areas and socioeconomic status; however, these efforts did not result in a holistic sample.

The participant sampling took place through digital recruitment in three phases from November 2023 through January 2024. The social media recruitment that was first utilized may have reduced recruitment time and limited the reach of potential participants. Social media platforms were used throughout the recruitment phase, and many CVI social media pages for professionals and families boasted thousands of members. However, these methods only added three participants, two for CVI and one for OVI. The late recruitment on additional CVI Facebook sites in January 2024 may have also reduced the number of potential participants through these efforts.

Additional recruitment efforts that targeted teachers of the visually impaired through AER chapters' newsletters, email lists, or social media also yielded no participants. Considerable time was spent on these efforts that may have been better suited utilizing school psychology newsletters, groups, or social media platforms. However, as a TVI, the researcher was not allowed to post for recruitment on social media platforms for school psychologists. The majority of WISC-V evaluations were provided or facilitated by a school psychologist. Collaboration with these populations from November may have increased the sample size, resulting in a more comprehensive representation of the target population.

If early recruitment through public school systems had been used earlier, the results might have better represented the target population. In November 2023, local Massachusetts and greater New England towns/cities affiliated with east coast specialized schools shared recruitment materials. However, public schools beyond were not initially contacted directly, assuming that recruitment through TVIs may be better suited. Reflectively, this was not the case.

Reaching out to public school districts directly in January 2024 resulted in greater communication of the study, with higher response rates than recruitment with TVIs. However, the January 2024 public school efforts did not result in participant evaluation reports. If this method had been used sooner, this might have had a different result.

Another assumption that may have limited the sample size was that the recruitment of participants through families/caregivers was conducted exclusively through digital means. This effort was made to ensure the accessibility of recruitment materials for those with blindness or visual impairments through alternative text (alt text), image descriptions, and narrative statements. However, this was naive considering students' varying socioeconomic status across the United States. Additional recruitment through sharing paper-based recruitments to families/caregivers of students identified as having a visual impairment and being evaluated with the WISC-V could have been done through collaborative efforts with schools.

The final limiting factors influencing the samples correlation to the target population were the length of the recruitment period and compensation. The recruitment period started in November 2023 and continued through the first week of February 2024. Many schools had two to three weeks off during this period due to the Thanksgiving and winter holiday breaks. These periods of breaks may have resulted in inconsistency with checking e-mails, accessing appropriate staff, or designating staff related to research and records. This recruitment time may have also affected parental use of social media and their own response time if contacted by a school, teacher of the visually impaired, or certified or licensed psychologist who conducted the evaluation. Additionally, there was no compensation for participants’ inclusion of their WISC-V evaluation results. Using compensation or compensatory methods, especially for families and caregivers of students with a visual impairment, may have affected the sample size and helped reach a larger geographical area.

As a low-incidence disability, the understanding and diagnostic criteria for CVI across the U.S. varied from state to state and geographical area within each state, impacting the overall underdiagnosis of students with CVI (Kran et al., 2019; McKinsey & Company, 2023). The limited and varied understanding and diagnoses of CVI across the U.S. was a limiting factor to both the recruitment, and prevalence of students with CVI evaluated with the WISC-V. A family/caregiver's access to medical staff who were trained and understood CVI, and its manifestations could play a role if and when a student was diagnosed with CVI. In addition to geographical access to trained medical, socioeconomic status played a role in diagnosis (Kran et al., 2019; McKinsey & Company, 2023). Similarly, suppose there were medical professionals who were familiar with CVI in an area it may not be financially accessible for that family/caregiver to take the student to that medical professional. Due to these factors, it could not be certain that there were no students with CVI who were not diagnosed in the contacted communities.

The areas of external validity were not siloed to the influence of this study but rather an echo of the calls to action across the field of visual impairments (National Eye Institution, 2021). It has long been known and now widely voiced that CVI has been an underdiagnosed and widely prevalent visual impairment in the United States. Awareness, training, and diagnosis rates of CVI were believed to be strong influencing factors in the external validity of this study. The continued research in the area of CVI would help bring forth the need for changes to help ensure that research samples were representative of the target population of individuals with CVI.

Recommendations for Future Research

For future research related to individuals with CVI, the inclusion of a comprehensive background would be highly recommended. As discussed, the manifestation of CVI could derive from many sources (Chokron & Dutton, 2023; Dutton, 2015; Khetpal & Donahue, 2007). Due to those variations, individuals with CVI may have varying results in research studies. For example, a child with Trisomy 13 is likely to have a lower cognitive score that may be separate from the effect of the CVI. Whereas a child with Autism, might have strengths in certain areas that are again, unrelated to their CVI. Having access to medical history, ethnicity, gender, age, and other demographic information such as SES may help future researchers identify trends related to CVI and within the CVI community. geographical location, and medical profession who provided the CVI diagnosis. Though these areas may seem irrelevant to the content of research studies, as our understanding of CVI has been continually developing and relatively new, it would be necessary to account for all variability. Access to socioeconomic status, geographical living location, and geographical location of diagnosis would help researchers and professionals, among other fields, identify trends and access to CVI-related care nationwide.

This study looked at one of many standardized cognitive evaluations. Each evaluation tool has its own similarities and differences between one another. To have a comprehensive understanding of the accessibility of cognitive evaluation tools, a large-scale comparative study building on this would be recommended. The use of completed evaluation scores could be used to compare within each tool and between the other tools. It was not just or right to only have one recommended or evaluated tool for a population (IDEA, 2014). This research recommendation would allow related specialists to understand how individuals with CVI access the different tools and how that access compares between the tools.

Cognitive evaluations, such as the WISC-V, were not only used with the age group of 6 to 16. Continued research on standardized assessments across all age groups for students with CVI would be recommended. If research was to continue to utilize the Wechsler battery, there would be two additional cognitive evaluations that would expand the ages 2:6 to 90:11. In that case, it would be recommended to evaluate both the Wechsler Preschool and Primary Scale of Intelligence-Fourth Edition (WPPSI-IV) which was standardized for ages 2:6-7:7, and the Wechsler Adult Intelligence Scale Fourth Edition (WAIS–IV), standardized for individuals aged 16:0 through 90:11. The impact of visual impairments has not been isolated to the academic world. It also was not isolated to elementary, middle, and high school. Cortical/Cerebral Visual Impairment effects individuals across their lifetime. By conducting research using the WPPSI, researchers may be able to identify trends in access methods for students with visual impairment at a younger age, helping to ensure individualized educational plans that match their learning styles throughout their lives. Similarly, when a student ages out of the educational system, CVI will not disappear. By researching the tools used in adult ages, the hope would again be to find trends to help with access methods leading towards independence.

As the primarily challenging subtests were picture-based, research into the challenges associated with 2D image processing and access for students with CVI would be recommended. Manley et al. (2023) found this was also true, that 2D images were, as a whole, more challenging for CVI participants to identify than the Control groups. Further investigation into the raw scores of the picture-based subtests and the related features among those subtests may be beneficial in understanding trends between the three subtests and methods to generalize those findings into everyday or other evaluation areas.

Future research would be recommended for cognitive or psychological evaluations and should extend to all popular standardized evaluation methods across fields. This should include academic achievement evaluations and even behavioral evaluations. When these tools were used to help create an IEP, the student's methods of access and the impact of that access method on educational tools must be considered. Standardized evaluation tools have sometimes accounted for visual impairments, but none have yet been explicitly standardized for the learning profiles of students diagnosed with CVI. Research in the accessibility and access trends of these standardized evaluation tools would be needed to ensure that the recommendations, methodologies, and strategies that stem from these evaluations provide students with CVI with an appropriate and accessible educational experience.

A major factor that would be recommended to be researched was the anxiety levels and mental health of students with CVI. It would first be suggested that this be evaluated in correlation with standardized assessments. A multitude of past research has looked into test anxiety, but there has not yet been an evaluation related to students with CVI (Chokron et al., 2021; Fréchette-Simard et al., 2022; Owenz & Cruz, 2023). Understanding potential correlations between scores and anxiety levels would be beneficial for TVIs, educational and medical teams to help understand the influence of CVI on visual and sensory access.

This research method would not only be suggested for standardized test-related anxiety levels but also to research if there was an influence in visual access related to anxiety levels and an overarching influence on mental health. Riazi et al. (2023) found that there was a statistically significant difference in the anxiety and avoidance levels of sighted individuals and those with blindness or visual impairments. It was also found that there were greater levels of anxiety and avoidance in individuals who were sighted or had moderate visual impairments than those who were totally blind. It has been reported in studies and from first-person reports that living with CVI was not static (McDowell & Budd, 2018). Each hour, day, and event could result in a different visual access experience.

Practical, real-world research has also been recommended for students with CVI. Too often, the research-to-practice gaps were discussed, and using research methodology that helped bring directly actionable items to the field was critical. It may be beneficial to conduct this evaluation using eye gaze technology to look at students with CVI's access to the materials while the evaluation occurs. This research methodology would also help families understand their evaluation results at a deeper level. By gaining information into how the student was accessing the evaluation in real-time, the analysis would blend into understanding if there were field cuts, missed areas, or time restraints related to visual search methodologies. Seamless research methods that help give practical information as specific as possible to families, caregivers, and educational teams should be a continued goal of the future.

One method to also help research the access methods and variations in access would be to conduct real-time experiments of visual access using eye tracking technology. Conducting in-class research on students with CVI would help ensure a holistic understanding of students and an understanding of environmental factors that may play a role in their access to the educational environment. The WISC-V has been a cognitive evaluation that helps educational teams understand a student's profile and access methods and the fitting accommodations, strategies, and methodologies that may help ensure access to the educational environment. Though this study looked at students with CVI's access to the evaluation, research should extend to how that student accessed the classroom.

An additional method of evaluating students with CVI's access to educational spaces would be to conduct an experimental research study that looks at varying levels of classroom complexity, visual, auditory, and other sensory inputs. These research efforts could be paired with participants self-reporting their access to identify if they experienced changes in access methods, how their visual access felt, changes in their auditory access, and stress or anxiety levels. Previous research related to the accessibility of the educational environment for students with CVI also used interview and survey methods with teachers and students with CVI to identify and understand environmental influences on access and learning (McDowell & Budd, 2018).

Research into the accommodations placed in an IEP following evaluation results and how those accommodations affect the student may shed light on the full circle of evaluation, IEP writing, and implementation of those recommended strategies. This research could again tie into the accommodations identified by the WISC-V or other standardized assessments, the use, practicality, and student-reported benefits or use of the accommodations. In addition to an accommodation-based study, a longitudinal study should be conducted to look at the accommodations within the IEPs of students with CVI, changes over time, and any reported changes in their functional vision evaluations and related medical evaluations. The benefit of this study would be to identify how accommodations change over time in relation to a given student's evaluation results and any trends in the student's visual access levels and identified accommodations.

It is believed that quantitative studies should be followed by qualitative research. During this study, many questions arose about the methods used when a certified or licensed psychologist evaluated a student with CVI using the WISC-V. For example, some lingering questions are regarding the certified or licensed psychologist's familiarity with CVI or why specific subtests were used. A qualitative study that blends survey methodology and interviews would be a useful design to understand the evaluation methodologies of certified and licensed psychologist when evaluating students with CVI. During the data collection process of this study, a school psychologist asked if I would like to watch how the WISC-V was administered. The observation of how the WISC-V is administered would be a wonderful addition, or an entirely separate qualitative study. Another element that could be added, the inclusion on the students who were being evaluated would allow the audience to connect the experiences of the evaluator and the evaluated. An additional qualitive study that branches from this study, would be, the experiences of students with CVI during the entire special education evaluation process. Having insight into the experiences of taking the evaluations, as well as the effects of schedule changes would provide the field great understanding of cumulative emotional toll of the special education evaluation.

By conducting the quantitative aspect first, the relationships and connections with the psychologist would be built, helping to pave the way for collaborative quantitative studies. Conducting quantitative research first could help identify what additional questions would need to be answered from a qualitative lens.

Conclusion

The world’s understanding of Cortical/Cerebral Visual Impairment and its effect on afflicted individuals has been growing and changing. New research and findings have helped to understand better the number of individuals potentially impacted by CVI. In the U.S., only around 26,000 individuals have been diagnosed with CVI, and an estimated 180,000 individuals have had CVI (McKinsey & Company, 2023). As the medical understanding of CVI has grown and evolved, it has been key that the educational field also works to uplevel educational standards and practices that match the needs of students with CVI.

As a brain-based visual impairment, CVI is not an impairment to the eye or ocular structures (Jan et al., 1987; National Eye Institute, 2021); instead, it includes a difference in how the brain processes the visual information that it takes in (Merabet et al., 2017). The effect of processing visual information would be different for each individual, as many contributing and unknown factors could be at play like the affected area of the brain, genetic conditions, lived experiences, and even the age of diagnoses (Bosch et al., 2014; Chokron & Dutton, 2023; Dutton, 2015; Martin et al., 2016). The potential significance of CVI has been correlated to various visual processing characteristics. Dr. Roman-Lantzy (2007) identified the 10 characteristics of CVI (Table 1). Perkins School for the Blind has communicated its development of the CVI Protocol, which identified 16 visual behaviors related to CVI (Table 1; Baskin & Bennett, 2020). The understanding of CVI's effect on a student's educational access was a collaborative effort by a student's team to ensure their education matches their access needs (Cantillon, 2021; Chokron et al., 2021; Fazzi et al., 2015; Kran et al., 2019)

The WISC-V is a commonly used standardized cognitive evaluation administered to students aged 6:00-16:11 by a trained examiner (Wechsler, 2014a, 2014b). The WISC-V has been validated and has been a reliable source of cognitive functioning for many student populations. In its supplemental technical manual, research using the WISC-V evaluated 11 different student populations to ensure its rigor and standards also matched these students' needs. However, neither the CVI nor the visually impaired community were a target of these supplemental studies. Other research using the WISC-V has been conducted on student populations with high correlations to CVI, such as Cerebral Palsy, and Epilepsy (Coceski et al., 2022; MacAllister et al., 2019). Additional studies also looked at the access of the evaluation tool, fourth edition, with blind or visually impaired students using another version, like the Chinese edition (Chen et al., 2021). However, no study used the WISC-V-English edition, with CVI and blind or visually impaired as targeted independent sample groups.

The WISC-V is comprised of 21 subtests, 11 indexes, and 4 scales (Wechsler, 2014a). The most often used combination of subtests and indexes came from the Full Scale IQ score, which had a core of 7 subtests or up to 16 that could be used as part of the 7 to make up the index score (Wechsler, 2014a). The scaled subtest scores of the WISC-V were derived from the students' raw scores. The subtests’ scaled scores were then added to make up the index score, which then, if appropriate, would give a total standard score.

This study used a nonexperimental design that gathered the scaled subtest and index scores of the WISC-V evaluation reports to better understand the potential trends in participants' CVI scores. These evaluation reports occurred in the last 5 years, with one report from 2018 and one from 2024. This study targeted four research questions that looked at the scaled scores of subtests within each group parameter visual or low visual-based (Research Question 1), picture- or symbol-based (Research Question 2), picture- or symbol-based complexity levels (Research Question 3), and timed or untimed (Research Question 4). The Partial and Total data sets were compared to the WISC-V normative data set (n = 242) of the WISC-V Technical Manual. As these data set did not include raw data, data were calculated by hand and with GraphPad. These comparisons were limited to subtests, calculating the t-value, p-value, standard error, and confidence intervals at 95%.

The primary analysis of the research questions used the data from the Partial Data Group (n = 22). To evaluate if there was a difference between these subtest groupings, variables were created in SPSS to look at the subtests of those groups and compare them again with the other groups of subtests and between and within the CVI and OVI groups. Research Questions 1 and part of Research Question 2 rejected the null and found statistical significance of visual-based subtests of the CVI group and picture-based subtests of the CVI group at Effect size 0.5, α 0.05, and Power 0.95. Research Question 3 and Research Question 4 failed to reject the null hypothesis that picture- or symbol-based complexity levels or timed subtests had a statistical significance for CVI Participants. This meant that visual-based subtests of the WISC-V, especially a picture-based subtest of the WISC-V, scored lower for students with CVI than OVI peers and the Control group. Similarly, symbol-based subtests, the complexity of subtests, and whether a subtest was timed could not be said for certain if it affected the score.

First-person accounts and research studies have long reported that images were more challenging for students with CVI to interpret (Chokron et al., 2021; Lueck & Dutton, 2015; Manley et al., 2023). A concept under the Perkins CVI protocol identified a visual behavior of CVI as form accessibility (Baskin & Bennett, 2020). Form accessibility was the ability to make connections of what something was through various visual presentations; 3D, 2D images, black and white, or abstract. This was also seen in Manley et al. (2023) through the evaluation of 2D images that inspired and collaborated with Matt Tietjen and his 2D image assessment. Further investigation into the compounding factors that result in individuals with CVI's challenges to processing pictures and 2D images needs to be done. This study further supported that 2D images and picture-based images were a challenge for individuals with CVI, and as a result, the scores of the subtests that included accessing pictures resulted in lower scaled scores. This has only been a beginning step, in the assurance of accessible and equitable practices for students with CVI across fields and disciplines. It was the researcher's hope that one day, there may come a time when individuals with blindness or visual impairment, including those with CVI, never have to change to fit the world's way.

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APPENDIX A

INSTITUTIONAL REVIEW BOARD APPROVAL

UNIVERSITY OF
NORTHERN COLORADO

Institutional Review Board

Date:	11/01/2023
Principal Investigator:	Emily Cantillon
Committee Action:	**IRB EXEMPT DETERMINATION – New Protocol**
Action Date:	11/01/2023
Protocol Number:	2310054158
Protocol Title:	An Analysis of Vision-Based Subtests Impact on Subtest Scores of the Wechsler Intelligence Scale for Children on Students with Cortical/Cerebral Visual Impairment
Expiration Date:	

The University of Northern Colorado Institutional Review Board has reviewed your protocol and determined your project to be exempt under 45 CFR 46.104(d)(702) for research involving

Category 2 (2018): EDUCATIONAL TESTS, SURVEYS, INTERVIEWS, OR OBSERVATIONS OF PUBLIC BEHAVIOR. Research that only includes interactions involving educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior (including visual or auditory recording) if at least one of the following criteria is met: (i) The information obtained is recorded by the investigator in such a manner that the identity of the human subjects cannot readily be ascertained, directly or through identifiers linked to the subjects; (ii) Any disclosure of the human subjects' responses outside the research would not reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, educational advancement, or reputation; or (iii) The information obtained is recorded by the investigator in such a manner that the identity of the human subjects can readily be ascertained, directly or through identifiers linked to the subjects, and an IRB conducts a limited IRB review to make the determination required by 45 CFR 46.111(a)(7).

You may begin conducting your research as outlined in your protocol. Your study does not require further review from the IRB, unless changes need to be made to your approved protocol.

As the Principal Investigator (PI), you are still responsible for contacting the UNC IRB office if and when:

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Institutional Review Board

- You wish to deviate from the described protocol and would like to formally submit a modification request. Prior IRB approval must be obtained before any changes can be implemented (except to eliminate an immediate hazard to research participants).
- You make changes to the research personnel working on this study (add or drop research staff on this protocol).
- At the end of the study or before you leave The University of Northern Colorado and are no longer a student or employee, to request your protocol be closed. *You cannot continue to reference UNC on any documents (including the informed consent form) or conduct the study under the auspices of UNC if you are no longer a student/employee of this university.
- You have received or have been made aware of any complaints, problems, or adverse events that are related or possibly related to participation in the research.

If you have any questions, please contact the Interim IRB Administrator, Chris Saxton, at 970-702-5427 or via e-mail at chris.saxton@unco.edu. Additional information concerning the requirements for the protection of human subjects may be found at the Office of Human Research Protection website - http://hhs.gov/ohrp/ and https://www.unco.edu/research/research-integrity-and-compliance/institutional-review-board/.

Sincerely,
Michael Aldridge
Interim IRB Administrator

University of Northern Colorado: FWA00000784

APPENDIX B

CONSENT FORM

UNIVERSITY OF
NORTHERN COLORADO

Informed Consent Form for Participation in Research

Title of Research Study: An Analysis of Vision-Based Subtests' Impact on Subtest Scores of the Wechsler Intelligence Scale for Children on Students with Cortical/Cerebral Visual Impairment

Researcher: Emily Cantillon, School of Special Education
Phone Number: (978) 835-6515 Email: cant6810@bears.unco.edu

Research Advisor: Dr. Silvia Correa-Torres
Phone Number: (970) 351-1660 Email: silvia.correa-torres@unco.edu

Procedures: We would like to ask you to include your child's WISC-V evaluation report in the research study. This study looks at the subtest scores of completed WISC-V evaluation reports from the last five years. Your participation would be providing your child's report electronically. The inclusion of your Child's WISC-V evaluation report in this study will not be shared with outside persons or institutions. *Though the researcher works to uphold the highest standard of confidentially and security, it cannot control data leaks of brands such as Gmail, Microsoft Teams, and other electronic sharing tools.*

From there, if your child's WISC-V report is included in the study, all personal identifying information will be removed from the report. This means your name, your child's name, and the psychologist's name will be removed. Any pronouns used (He/her/she/him) will also be removed. The school or assessment location will also be removed. Finally, any identifying medical professions, Doctors' names, or medical facilities will be removed. This will result in a redacted and deidentified evaluation. From there, the following information will be gathered from the evaluation report:

- Age at the time of evaluation (not their birth date)
- Education location (the state and public or private school)
- Medical diagnoses
- Subtest, index, and full-scale scores

All of the collected information will be recorded anonymously and transferred to a nonidentified Excel. The scores will be compared to see if there is a relationship between the visual demands of the subtests and the scores groups of children/students receive. After the researcher's analysis, you can meet with the researcher to discuss your child's results from a visual complexity lens. This discussion will compare the visual demands of each subtest and your child's scores.

Questions: If you have any questions about this research project, please feel free to contact Emily Cantillon at (978) 835-6515 or cant6810@bears.unco.edu or her advisor, Dr. Silvia Correa-Torres at (970)351-1660 or silvia.correa-torres@unco.edu. If you have any concerns about your selection or treatment as a research participant, please contact Laura Martin, UNCO's Director of Research Compliance, at laura.martin@unco.edu.

Voluntary Participation: Please understand that your participation is voluntary. You may decide not to want your child's report included in this study, and if you begin participation, you may still choose to stop and withdraw the report at any time. Your decision will be respected and will not result in loss of benefits to which you are otherwise entitled.

Please take all the time you need to read through this document and decide whether you would like to participate in this research study.

If you agree to participate in this research study, please sign below. You will be given a copy of this form for your records.

______________________________ ____________
Participant Signature Date

______________________________ ____________
Investigator Signature Date

APPENDIX C

TOTAL DATA SET INDEX COUNT BY EDUCATIONAL LOCATION

Table 36

Total Data Set Index Count by Educational Location

	School Setting			
Indexes	Public	Specialized School	Home	Total
Verbal Comprehension	17	56	2	75
Auditory Working Memory	4	36	0	40
Working Memory	13	4	2	19
Visual Spatial	12	4	1	17
Fluid Reasoning	12	3	1	16
Processing Speed	11	2	1	14
General Ability	2	1	1	4
Full Scale	10	2	1	13

APPENDIX D

TOTAL DATA SET INDEX MEAN BY EDUCATIONAL LOCATION

Table 37

Total Data Set Index Mean by Educational Location

Indexes	School Setting			Total
	Public	Specialized School	Home	
	M	*M*	*M*	*M*
Verbal Comprehension	91.35	89.29	110.50	90.32
Visual Spatial	85.17	102.50	64.00	88.00
Working Memory	81.69	106.75	84.00	87.21
Auditory Working Memory	70.00	88.08	-	86.28
Fluid Reasoning	79.92	101.33	85.00	84.25
Processing Speed	70.46	97.50	86.00	75.43
General ability	84.00	124.00	99.00	97.75
Full Scale	76.80	80.00	102.00	79.23

APPENDIX E

TOTAL DATA SET SUBTEST COUNT BY EDUCATIONAL LOCATION

Table 38

Total Data Set Subtest Count by Educational Location

	School Setting		
Subtests	Specialized School	Public	Total
	n	*n*	*n*
^Similarities	59	18	77
^Vocabulary	58	18	76
^Digit Span	50	18	68
Information	46	10	56
Letter-Number Sequence	39	6	45
Comprehension	23	6	29
Arithmetic	20	5	25
^Block Design	6	14	20
^Matrix Reasoning	5	15	20
Picture Span	7	13	20
Visual puzzles	5	13	18
^Figure Weights	3	13	16
^Coding	2	12	14
Symbol Search	2	12	14
Picture Concepts	0	3	3
Cancellation	0	2	2

Note. Subtests with a [^] in front of its name is indicative of that subtests being one of the core seven subtests of the Full Scale IQ score.

APPENDIX F

TOTAL DATA SET SUBTEST AVERAGE BY EDUCATIONAL LOCATION

Table 39

Total Data Set Subtest Average by Educational Location

Subtests	School Setting: Specialized School	School Setting: Public	Total
	M	*M*	*M*
Cancellation		8.50	8.50
Visual puzzles	9.60	7.62	8.17
Picture Span	9.86	7.08	8.05
^Similarities	7.98	8.17	8.03
^Vocabulary	7.98	8.06	8.00
Picture Concepts		8.00	8.00
^Figure Weights	11.00	6.85	7.63
Letter-Number Sequence	7.64	4.83	7.27
^Digit Span	7.48	5.56	6.97
Information	6.94	6.90	6.93
^Block Design	7.33	6.29	6.60
^Matrix Reasoning	9.20	5.20	6.20
Symbol Search	12.00	5.17	6.14
Comprehension	5.65	7.17	5.97
Arithmetic	6.15	4.60	5.84
^Coding	7.00	4.08	4.50

Note. Subtests with a [^] in front of its name is indicative of that subtest being one of the core seven subtests of the Full Scale IQ score.

APPENDIX G

PARTIAL DATA SET INDEX COUNT BY EDUCATIONAL LOCATION

Table 40

Partial Data Set Index Count by Educational Location

	School Setting			
Indexes	Public	Specialized School	Home	Total Count
Verbal Comprehension	13	5	1	19
Working Memory	12	4	1	17
Visual Spatial	12	4	0	16
Fluid Reasoning	12	3	0	15
Processing Speed	11	2	0	13
Full Scale	10	2	0	12
General Ability	2	1	0	3
Auditory Working Memory	1	1	0	2

APPENDIX H

PARTIAL SET INDEX AVERAGE BY EDUCATIONAL LOCATION

Table 41

Partial Set Index Average by Educational Location

	School Setting			
Indexes	Public	Specialized School	Home	Total Average
General ability	84.00	124.00		97.33
Verbal Comprehension	89.39	99.00	100.00	92.47
Visual Spatial	85.17	102.50		89.50
Working Memory	80.17	106.75	74.00	86.06
Fluid Reasoning	79.92	101.33		84.20
Auditory Working Memory	46.00	103.00		74.50
Full Scale	76.80	80.00		77.33

APPENDIX I

PARTIAL DATA SET SUBTEST COUNT BY EDUCATIONAL LOCATION

Table 42

Partial Data Set Subtest Count by Educational Location

	School Setting		
Subtests	Specialized School	Public	Total
^Similarities	5	14	19
^Vocabulary	5	14	19
^Block Design	5	14	19
^Matrix Reasoning	5	14	19
^Digit Span	5	14	19
Visual puzzles	5	13	18
Picture Span	5	12	17
^Figure Weights	3	13	16
^Coding	2	12	14
Symbol Search	2	12	14
Information	4	6	10
Comprehension	3	3	6
Letter-Number Sequence	2	3	5
Arithmetic	2	2	4
Cancellation	0	2	2
Picture Concepts	0	2	2

Note. Subtests with a [^] in front of its name is indicative of that subtest being one of the core seven subtests of the Full Scale IQ score.

APPENDIX J

PARTIAL DATA SET SUBTEST AVERAGE BY EDUCATIONAL LOCATION

Table 43

Partial Data Set Subtest Average by Educational Location

	School Setting		
Subtests	Specialized School	Public	Total Average
^Similarities	10.40	7.93	8.59
Cancellation		8.50	8.50
Visual puzzles	9.60	7.62	8.17
Information	10.25	6.50	8.00
Picture Concepts		8.00	8.00
^Vocabulary	9.20	7.50	7.95
Picture Span	10.40	6.50	7.65
^Figure Weights	11.00	6.85	7.63
^Block Design	8.40	6.29	6.84
Comprehension	7.33	6.33	6.83
^Digit Span	10.20	5.57	6.79
Arithmetic	9.50	4.00	6.75
Symbol Search	12.00	5.17	6.14
^Matrix Reasoning	9.20	5.00	6.11
Letter-Number Sequence	7.50	2.67	4.60
^Coding	7.00	4.08	4.50

Note. Subtests with a [^] in front of its name is indicative of that subtests being one of the core seven subtests of the Full Scale IQ score.