COGNITIVE DIFFERENCES BETWEEN CONGENITALLY AND ADVENTITIOUSLY BLIND INDIVIDUALS

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It is apparent from the historical perspective regarding the theories of cognitive development and the cognitive functioning of individuals with visual impairments, that sight plays a major role in the development of certain cognitive processes. However, the affects of visual impairment on cognitive development remain to be at issue. Since sight seems to be highly integral in cognitive development beginning in the early stages of physical development, about the sixth month of life, and then begins to diminish in importance as verbal communication develops around eighteen months, then it should stand to reason that significant visual impairment or blindness occurring prior to this time would adversely impact an individual's cognitive development. Conversely, the occurrence of visual impairment or blindness after this critical period of development would have less of an impact. Cognitive theorists have proposed that visually impaired or blind persons may have developed different cognitive pathways to acquire, process, and accommodate sensory information. As a result, visually impaired or blind (VI/B) persons may "think differently" than sighted individuals. The present study was designed to address these issues as they relate to cognitive and neuropsychological development at various stages of growth and to examine possible differences in neuropsychological functioning dependent on the level of visual functioning a person retains; e.g. both the issues of age at onset and degree of impairment. It was also designed to study the

possible interaction effects of degree of impairment with the age of onset. Findings indicated that the only differences in cognitive functioning appear to be related to age of onset and not the level of visual impairment. The findings further suggested that congenitally blind individuals have indeed developed alternate methods of cognitively processing nonverbal, abstract, or complex information, especially information involving a high degree of spatial orientation. Implications of this study may influence the educational methods used to teach congenitally blind individuals in order to reinforce these alternate pathways and facilitate more effective means of negotiating in a sighted environment.

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CHAPTER I

INTRODUCTION

Over ten million people in the United States suffer from "significant impairment of vision which cannot be further improved by corrective lenses," (Leonard, 1999, 3) and of those, almost 610,000 are under the age of eighteen. Less than half of those between the ages of twenty-one and sixty-four, approximately forty-four per cent, are employed. It has been estimated that at least seven million more people worldwide become blind each year, with current estimates suggesting that these numbers may double in the next thirty years. This means that the cost to diagnose, treat, and rehabilitate persons with visual impairments in the United States is over $4 billion annually (Leonard, 1999). Given the magnitude of this disability, one basic question should then be, "How debilitating is this loss of sensory perception?"

In an effort to answer this question, one must determine differences between sighted individuals and those with visual impairment. Since all people need to think and perform within the same environment, then basic elements of cognition and mobility are primary tenets of survival. Much research has already been performed assessing mobility issues for the visually impaired, but very little is known about cognitive differences between the two groups. Additionally, since visual impairment and blindness may strike anybody at any age, differences between those individuals who are born with the impairment, the "congenitally blind," and those who lose their sight later in life, the "adventitiously blind," should also be examined. Since both the degree of the visual impairment and the age of onset are to be examined, then an understanding of human cognitive development and the individual's educational experience also needs to be taken into account.

Theories of Cognitive Development

Theories regarding human cognitive development stretch at least as far back as the medieval ages. Philosopher Rene Descartes proposed the notion of early development of cognitive processes as early as 1641 when he noted that novel judgements of a new observation were attributed to the "intellect" of the individual. However, he felt that this intellect was more the result of rational inferences about one's sensations, and that these sensations were first similarly experienced in the early years of development. Since one's initial sensory perception, the sensations and perceptions would have to become overlearned into what Helmholtz later identified as "inductive conclusion(s)" (Kirkeboen, 1998). These initial perceptions formed the basis for how an individual would perceive future experiences and sensations throughout their life. Since sight is one of the first sensations by which an individual encounters the world, then the absence of sight would, theoretically, put that individual at a serious disadvantage for survival and success later in life.

Another issue concerning cognitive development is the degree of continuity of progressive advancement from infancy to adulthood. Weinberg (1989) believed that evidence of this continuity existed in certain information-processing components of intelligence. He felt that the need to define certain problems, establish problem-solving approaches to those problems, and the monitoring of the effectiveness of those techniques persisted throughout the life span. Thompson and Fagan (1991) presented evidence that novelty preference during the first year of life not only predicted the future intelligence quotient (IQ) of the individual, but also further reflected the development of certain cognitive processes such as memory, discrimination, and attention. According to Siegler's rule-assessment approach to cognitive development and information processing (as cited in Flavell, 1985, 81), impairments or obstacles in the encoding of novel stimuli may impede the developmental process. He summarized that "children who do not adequately encode a relevant stimulus dimension may not profit from experiences designed to help them acquire more advanced rules that properly take that dimension into account. Improved encoding leads to improved ability to learn and thus could be considered a mechanism of cognitive development." One could assume, then, that the loss of vision would likely interfere with this encoding process. If the process were interfered with from the moment of birth, then those individuals who were congenitally blind should have thought processes and capabilities far different from those who lost their vision later in life. However, there currently exist a dearth of evidence to support this conclusion.

Regardless, Piaget further addressed this form of cognitive information processing in what he referred to as "assimilation." Piaget theorized that an infant will make deliberate, controlled efforts to procure and organize elements of the outside world. The child will explore the environment by physical methods such touching, smelling, tasting, and seeing, will then form those sensations into "psychic schemes," and then will repeat those actions in order to establish reliability of those experiences. This process of assimilation is how an individual begins to understand and interact with the environment. Repeated exposure to a novel stimulus then creates patterns of behavior by which the individual may address future novel stimuli. In the event that the individual has an experience that does not fit into a pre-existing “psychic scheme,” that individual may begin to alter those schemes to allow for additional modifications, a process referred to as “accommodation.” The dual process of assimilation and accommodation enables the individual to increasingly adapt to the world. Piaget proposed that this method of cognitive development begins immediately after birth and continues throughout the lifespan.

Furthermore, Piaget also reported that there appear to be significant critical periods throughout childhood development that help the child advance to the next major level of cognitive development. As a child masters the environment at one level, the process has begun to formulate assimilations at the next level. According to his theory, Piaget proposes that an infant first experiences the world through a sensori-motor process whereby basic elements of sensory properties are established. Next, the child advances to a stage of intuitive thought whereby the individual now has both the physical ability and mental capacity to acquire and accommodate information at an astounding rate. At about the age of 4 years, the child enters into a stage of concrete mental operations whereby the child operates within set, or concrete, rules of space, time, movement, measurement, and relationships. Once the child has mastered the rules, then those rules may be applied by various methods of trial-and-error reasoning and ultimately on to abstract thought and reasoning, whereby the standard rules of behavior and operations are tested and, sometimes, re-written (as cited in Isaacs, 1972). It is important to remember that this is a normal progression of cognitive development, and any deviation from normal development may impede an individual's cognitive growth. Therefore, any physical insult or psychological trauma may prevent an individual from fully experiencing the environment and progressing in their cognitive development. Since blindness is an obvious deviation from normal sensory input, then congenital blindness would likely impede an individual's ability to test the rules of ordinary behavior and therefore, develop cognitions that do not allow them to advance to more abstract levels. However, those individuals who lose their sight later in life and have experienced normal cognitive development, should still have the basic skills to operate successfully within their environment, albeit with some training and rehabilitation.

The processes by which an individual perceives the environment and reacts to elements and situations within that environment have resulted in numerous theories as to which are the most effective cognitive elements for successful adaptation. Generally, this field of study may be regarded as the heart of cognitive science and intellectual functioning.

One such principle was that of Sternberg's (1988) triarchic theory of intellectual functioning. Sternberg's theory attempted to describe the relationship of one's internal world, or perceptual framework, through various mental processes. His triarchic theory consisted of three distinct, although interrelated, elements: metacomponents, performance components, and knowledge-acquisition. Metacomponents were used to monitor and evaluate problem solving whereas the performance components were the processes by which the metacomponents were implemented. The knowledge-acquisition components were the processes used to learn to solve problems. Metacomponents served to activate the other two components, which then provided feedback to the metacomponents, thus creating a feedback loop for processing elements of the external world, internal experiences or perceptions, and the enmeshed relationship between the two. According to Sternberg's theory, the continual evolution of cognitive processes was highly dependent on vision, and any loss of vision during this evolution would result in underdeveloped cognitions.

Other theories of intellectual and cognitive development were not so dependent on visual input. Spearman (as cited in Sternberg, 1988) believed that intelligence could be identified by a single factor, which he labeled "g." This g factor was derived from a combination of individual differences in mental energy. These differences could then be measured by specific cognitive tasks, analyzed according to the individual's strengths and weaknesses, and then viewed as a general compensatory process that enabled the individual to comprehend and problem-solve a variety of verbal and nonverbal tasks. On the other hand, Thorndike (as cited in Bauman and Mullen, 1965) divided intelligence into only three types: abstract, concrete, and social. However, Gardner (as cited in Sternberg, 1988) proposed seven distinct intellectual or cognitive capabilities. His view of intelligence involved a convergence of multiple abilities such as linguistics, musical, logical-mathematical, spatial, kinesthetic, interpersonal, and intrapersonal experiences in determining how an individual would function. Finally, Thurstone (as cited in Sternberg, 1988) also proposed seven factors of intelligence which he referred to as "verbal comprehension, verbal fluency, inductive reasoning, spatial visualization, number, memory, and perceptual speed." Modern psychometrics primarily involves a combination of these theories, with Spearman's *g* and Thurstone's seven factors predominating the field of intelligence assessment.

So how, then, does vision effect cognitive development? Pibram (1999) addressed this issue when he tested the composition of conscious experience. He identified the synthesis of three-levels of "minding" which affected the brain's ability to organize conscious experience. Evidence of his studies with blind individuals indicated that (1) automatic processing of information involved interpreting frames of reference, and when those frames shift, a delay in processing occurs. The delay is then introduced to the executive processor (2), which then induces a conscious sensory response. Once the conscious sensory input is introduced, (3) the episodic system organizes it and the experience is fine-tuned by the executive system. The three levels are thus (1) reflexive and automatic, (2) phenomenal and referential, and finally (3) conscious and executive. Pibram concluded that the human brain organized information along a Cartesian reference frame and as a narrative consciousness primarily composed of episodic events.

Sternberg (1999) argued that cognitive mechanisms are sight-dependent. Descartes (Kirkeboen, 1998) and Pylyshyn (1999) acknowledge that although vision is influenced by one's cognitions, a coding of the physical properties of an image must mechanically move through the optic nerve and thusly represent a picture to the nervous system. However, Marr (1982) believed that this Cartesian coding or mechanical visual process might actually regard vision a symbolic process. Pylyshyn (1999) reported that visual perception may lead to changes in the representations of the world being observed by the individual.

Pylyshyn (1999) summarized the function of an “extra-visual effect” by the modulation of certain cortical cells located in the posterior parietal cortex. These cortical cells are activated jointly by signals originating in both the visual and motor systems which then trigger certain visual and specific anticipated behavior patterns. He reported that this dualistic process suggested that the dorsal system is tuned for what Milner and Goodale termed “vision for action” (cited in Pylyshyn, 1999). Evidence for this vision for action was found in Kosslyn’s (1994) report that a general activation of the visual system by voluntary cognitive activity was demonstrable by both positron emission tomography (PET) and functional magnetic resonance imaging (MRI). Additional evidence for the interrelatedness of vision and cognition may be found the case of visual agnosia, a condition whereby an individual who has received some sort of trauma to the visual system is able to correctly mechanically perceive objects, but is unable to name even those most familiar items (often in the case of close family members). However, the individual is often able to correctly remember the object upon subsequent presentations and can often demonstrate how to use certain familiar objects that can be perceived but cannot be named. This type of visual agnosia, anomia, is clearly demonstrable by PET, MRI, and neuropsychological testing that implicates a disconnection of sensory impulses and cognitive evaluations between Wernicke’s area in the temporal lobe and the visual cortex, located in the occipital lobe.

Given such findings, modern cognitive science has now come to accept that vision and cognition are intertwined, the question remains as to what role vision plays in the development of one's cognitions, and vice-versa. Although modern psychology has made the leap that certain cognitive processes determine an individual's level of intelligence, there still remain unanswered questions regarding vision, cognitive development, and cognitive processing.

Review of Cognition in the Visually Impaired

A review of objective psychometric data and neuropsychological functioning among individuals with visual impairment begins to shed more light on the relationship between sensory visual input and cognitive functioning. Marzi (1999) argued that blind individuals often behave to sensory input differently than sighted individuals when he discovered that residual visual functioning was often banned from consciousness when it was presented either to subcortical areas alone or was mediated by cortical areas that had not been exclusively associated with those functions. Morgan (1999) then described how a sample of blind individuals was able to form a three-dimensional cognitive map based on auditory information. These individuals used this cognitive map to assist them in moving about, or orienting, to the physical world. Morgan concluded that blind individuals would often compensate for their lack of vision with over-developed abilities in other sensory functions.

A further review of the literature provides additional evidence that cognitive processes influence sensory visual information and interpretation. This influence becomes more apparent as an individual ascends through advanced developmental stages.

Nevskaya, Leushina, & Bondarko (1998) assessed visual functions and mental representations of the environment in 800 infants aged 2-18 months and discovered that infants with even slight visual impairments performed significantly worse than sighted infants on tests of visual concepts and the development of visual thinking. They proposed that even mild visual impairments in early infancy would likely result in delaying future intellectual development. Elbers and van Loon-Vervoorn (1999) reported that from about the age of 4, children begin to learn the meaning of words not just through visual experience, but also through a "decontextualized" manner whereby the child defines meaning through conceptual, verbally-based relationships of the words. For example, when a young, sighted child learns the meanings of words, that child is able to visualize surrounding elements of the target word, such as a jungle surrounding a lion. The child is able to then relate that a lion is an animal that lives in the jungle. However, blind children are not able to discern the ancillary information, and must go through a process of verbal relationships, such as "what is lion – an animal like a cat, sometimes with a long hair around its head – that lives in the jungle – an area with big trees and plants in really hot, humid areas." As the children grow older, the sighted child may have a better grasp of the use of contextual information, but a less developed ability to semantically associate those elements together; whereas a blind child has a much better developed ability to "link" information. This is what Easton, Greene, & Svinis (1997) referred to as structural priming, which is the ability to semantically link information in the process of concept formation and may result in the blind child's ability to think divergently, or in a non-traditional and creative manner. Wyver and Markham (1999) defined divergent thinking as “the ability to find multiple solutions to a single problem” and considered this ability to be an important component in creativity and cognitive flexibility. Other researchers have identified that this creativity and flexibility impact an individual’s academic performance (Hartley and Greggs, as cited in Wyver and Markham, 1999), disinhibition (Martindale and Daily, as cited in Wyver and Markham, 1999), adaptation to organizational change (Basadur and Hausdorf, as cited Wyver and Markham, 1999), and a preference for novel stimuli (Martindate et al., as cited in Wyver and Markham, 1999). Additionally, divergent thinking also correlated positively with social play and intelligence (Wyver and Markham, 1999). All of these areas are generally determined to be major factors in sociability and occupational success.

More concretely, using the more traditional theories of intelligence offered by both Spearman and Thurston (as cited in Sternberg, 1988), MacCluskie, Tunick, Dial, & Paul (1998) reported that visual impairment often resulted in a significant scattering of ability with discrete abilities emerging in more concrete patterns. The inability of blind individuals to abstractly conceptualize was indicative of Ahlberg and Csocsan’s (1999) report that blind children tended to solve numerical operations sequentially. This assessment was supported by Paivio’s conclusion (as cited in Vander Kolk, 1977) that the scattering of test scores for blind individuals may be the result of deprivation and reliance on auditory and tactual clues in order to compensate for their lack of vision. Vander Kolk (1977) then added, “It cannot be concluded that blindness in itself is intellectually handicapping but rather, when damage to the central nervous system includes loss of vision, impairment in intellectual functioning may also occur.” The conclusion could therefore be drawn that visually impaired or blind individuals free from neurological trauma should have neuropsychological test results similar to sighted individuals with regard to the traditionally accepted cognitive intellectual processes of verbal comprehension, verbal fluency, inductive reasoning or concept formation, numerical reasoning, memory, perceptual speed, and spatial visualization.

Groenveld and Jan (1992) conducted what is perhaps considered one of the cornerstone studies of intelligence and visual impairment. Their research utilized the Wechsler verbal intelligence scales to assess children with varying degrees of visual impairment. They reported that totally blind children appeared to have considerable skill in acquiring verbal concepts without reference to direct experience and tended to perform better on tasks that required auditory memory skills and that their concepts, although they used the same key words, were not anchored in the same experience of reality. Additionally, totally blind children tended to have more concrete problem-solving strategies than those children who possessed even minimal sightedness. Overall, "these severely impaired children tended to have more difficulty with verbal tasks that involved practical experience and verbal reasoning (comprehension)" (Groenveld and Jan, 1992, 69). Wyver, Markham, & Hlavacek (1999) concluded from their research that although blind children may have understood visual words, they often had difficulty applying the knowledge in everyday situations. The researchers took the blind child's lack of experience one step further when they reported, "children with visual impairments may be given less explicit instructions in dealing with (social comprehension) situations…because there may be fewer expectations that they will be in these situations." This argument presented the notion that the intellectual capacity of visually impaired children may be more the result of experiences rather than true cognitive capacity. According to their argument, this dearth of experience should then manifest itself in other measures of intellectual cognitive functioning.

Efforts to evaluate other measures of cognitive functioning among the blind and visually impaired have historically met with inadequate results. One of the first attempts was the modification of the Stanford Binet intelligence test, which, in 1930, became sufficiently modified and normed for use with visually impaired and blind subjects. The Hayes version of the Binet test was normed on a population of 2192 blind subjects and was found to have a mean IQ score of 98 with a standard deviation of 20 (Stolle, 2001). In 1942, Hayes then reported the development of alternative scales of measurement with the blind, and found that the alternative measures were woefully inadequate at both the high and low end ranges of normalization. He felt that the Wechsler–Bellvue test of intelligence gave a more accurate rating in the upper-age levels as well as having established an adequate basis for comparison of blind persons to the sighted population, especially through the non-sight dependent verbal subtests, primarily the Vocabulary subtest (Hayes, 1942). Hopkins and McGuire (1966) compared the Hayes-Binet Intelligence Test and the verbal scale of the Wechsler Intelligence Scale for Children® (WISC) (Wechsler Intelligence Scale for Children is a registered trademark of The Psychological Corporation, San Antonio, TX) and determined that derived IQ scores were significantly different at the ninety-nine percent confidence interval, with the Hayes-Binet quotient approximately eight-and-one-half points higher than that derived by the WISC. They found that the primary differences appeared in the WISC Comprehension subtest, with the congenitally totally blind subjects being the most inferior. Additionally, they found greater intra-individual differences among the blind subjects when compared to the sighted cohort. Denton (1954) found similar results between the Hayes-Binet and WISC verbal intelligence quotient (VIQ), with a correlation between the scores of .81. In 1967, Hopkins and McGuire reported that test-retest reliabilities between the two measures revealed that the Hayes-Binet had greater retest reliability to the WISC verbal scales than it did to itself after a four-year retest interval.

Another modification of the Stanford-Binet was reported by Davis of the Perkins Institute for the Blind, and was known as the Perkins-Binet Test of Intelligence (Davis, 1980). The Perkins-Binet was intended to replace the now outdated Hayes-Binet and was developed to include a series of non-verbal tasks for both visually impaired and blind adults and children. Stolle (2001) reported that the Perkins-Binet was eventually withdrawn from the market for having significant flaws, one of which was that the test was never normed on a sighted population to allow for comparison.

Other tests specifically designed for use in assessing blind and visually impaired individuals included the Stanford-Ohwaki-Kohs Block Design Test for the Blind (Suinn, Dauterman, & Shapiro, 1965), an adapted version of the Raven's Colored Progressive Matrices (Anderson, 1964), the Haptic Intelligence Scale for Adult Blind (Shurrager & Shurrager, 1964), and the Intelligence Test for Visually Impaired Children (Dekker, Drenth, Zaal, & Koole, 1990). Each of these tests attempted to provide a measure of nonverbal intellectual abilities in the blind and visually impaired. The Stanford-Ohwaki-

Kohs Block Design (SOKBD) test was a modification of the Block Design subtest of the Wechsler scales in which texture patterns were used in place of the familiar color patterns used in the Wechsler version. Advantages of the Stanford-Ohwaki-Kohs test were that it was easy to administer, could be used for both adults and children, and could be quickly administered. Disadvantages of this test were in its lack of discrimination at the lower IQ scales and that it had poor psychometric data (Brand, Pieterse, & Frost, 1986). Although it had good reliability, the validity of SOKBD to the Wechsler verbal was extremely poor (Dauterman, et al, 1967) (Brand, et al, 1986).

Anderson (1964) introduced a tactual form of the Raven's Colored Progressive Matrices as a measure of nonverbal intelligence that was known as the Tactual Raven's Progressive Matrices (TRPM). Although Dauterman et al. (1967) reported that the TRPM had an excellent reliability of .93-.95, Anderson reported its validity with the Wechsler Adult Intelligence Scale® (WAIS) (Wechsler Adult Intelligence Scale, WAIS, WAIS-R and WAIS-III are registered trademarks of The Psychological Corporation, San Antonio, TX) verbal at .49, a dismal performance at best.

So far, the use of nonverbal measures of intelligence among the visually impaired had been disappointing. Other attempts at assessing performance capabilities among this population took a different approach and used the concept of "haptics" to measure intelligence. Haptics is a process of tactual sensory input and processing. Bailes and Lambert (1986) evaluated the cognitive aspects of haptic form recognition and found that sighted subjects encoded objects by using strategies that involved strong verbal components while blind subjects tended to rely more on imagery-coding strategies. The use of tactual information as a measure of nonverbal cognitive abilities was the foundation for the development of the Haptic Intelligence Scale for Adult Blind (HISAB), which was introduced by Shurrager & Shurrager (1964). The HISAB was primarily adapted from various Wechsler performance scales and normed on totally blind subjects, aged 16-64. It had a test-retest reliability of .91 with a .65 validity correlation to the WAIS verbal; an improvement, but still somewhat lacking in its overall usage. However, using the VIQ as a reference point to validate a non-verbal IQ test may not be the best standard. For example, the WAIS-R is reported to have a correlation of .74 between the VIQ and the performance (non-verbal) intelligence quotient (PIQ) (n = 1,880). Therefore, the variability studies of non-verbal tests for the blind could not express to achieve higher correlations than approximately .74 (Wechsler, 1981).

A more recent attempt to integrate haptic performance with verbal intelligence in the visually impaired and blind population was the Intelligence Test for Visually Impaired Children (ITVIC) (Dekker, et al., 1990). The ITVIC was based on Thurston's factor theory of intelligence and included both haptic and verbal subtests. Dekker et al. reported a .76-.92 reliability rating for the test, but it has so far only been validated in Holland. An additional drawback for the ITVIC is that it was designed for children and currently does not offer any norms for assessing VI/B adults.

Other attempts to create new or modify existing nonverbal tests of intelligence have also proven to be rather ineffective. Price et al. (1987) reported several of the more successful tests of nonverbal intelligence for use with VI or blind individuals were the memory component of the Tactual Performance Test of the Halstead-Reitan

Neuropsychological Test Battery (HRB), the Klove-Matthews Sandpaper Test to assess tactile sensitivity, and Benton's Test of Motor Impersistence. In their review of nonverbal measures, Bigler and Tucker (1981) determined that the Tactual Performance Test was "probably the most useful nonvisual neuropsychological measure to differentiate blind organic and nonorganic" participants. However, utilizing just one or two particular tests, made it virtually impossible to develop a composite score for nonverbal intelligence.

Since the primary focus of assessing cognitive abilities among the VI/B population based solely on nonverbal measures has not yielded wholly satisfactory results, the focus on the impaired individual's verbally-based cognitive abilities may provide a better picture. It has already been noted that there existed some concern regarding the visually impaired individual's paucity of experience as a debilitating factor in the development of their cognitive abilities (Smits and Mommers, 1976) (Tillman, 1967). In an attempt to accommodate these concerns, Miller (1977) identified elements of the "verbal intelligence" factor in his research among visually impaired individuals with varying degrees of blindness. He noted that all six verbal subtests of the WAIS contributed significantly to the verbal intelligence factor. The Information, Comprehension, Vocabulary, and Similarities subtests were generally regarded as primarily verbal comprehension in nature, whereas the Arithmetic and Digit Span subtests were more sensitive to the assessment of memory, attention, and concentration abilities. Miller then proposed that much of this dispersion on tasks of verbal intelligence by blind persons could be attributed to differences in verbal memory of the individual. Regardless, of all the subtests, Information contained the highest impact, or factoral loading, on the verbal intelligence factor. However, one significant limitation of the Wechsler verbal subtests for use in assessing blind individuals is that the test administrator must deviate from the standardization of the instrument, thereby jeopardizing the validity of the results. Although once a major concern, this deviation has since been found to be negligible.

Price et al. (1987) reported, “The verbal subtests are all appropriate to the visually impaired and yield a verbal IQ that correlates .95 with full scale IQ.” MacCluskie (1990) not only replicated the validity of the WAIS-R for visually impaired persons, but reported similar results for an adaptation of the WISC-R along the same lines. Miller (1977, 147) cited studies indicating that factors which may be used to assess one’s “ability to assimilate experiences and meanings and to adapt conceptually, retain specific information, and hold onto and sequence symbols” may be “usable for extremely low vision or totally blind children.” These factors were labeled “verbal comprehension,” “acquired knowledge,” and “sequencing ability.” A forth factor, “spatial ability,” was determined to be unsuitable for low vision or blind individuals. Unfortunately, the same adaptations of standardized procedures for performance tasks of nonverbal abilities cannot be so easily accommodated.

Since ad-hoc measures of both verbal and nonverbal assessment of cognitive abilities in the VI/B population have not provided a complete understanding by themselves, the next logical approach would be to utilize measures that provide a composite examination of all areas of intelligence and cognitive functioning. Neuropsychological test batteries provide such a composite and comprehensive measure.

The most common and frequently researched test batteries of neuropsychological functioning, the Halstead-Reitan Battery and the Luria-Nebraska Neuropsychological Battery, require significant modifications and omission of certain subtests when examining blind persons. Although some researchers have offered that, even with such modifications, the remaining items "can be interpreted by an analysis of the ability involved in the task as well as the manner in which the item is approached by the individual being tested" (Price et al., 1987, 30). However, such deviations from standardized procedures will, by design, likely invalidate the entire test battery. Therefore, even the most common tests of neuropsychological functioning are woefully inadequate when assessing blind individuals.

One of the most concerted efforts to develop a highly valid, reliable neuropsychological test specific to blind and visually impaired individuals resulted in the development of the Cognitive Test for the Blind (CTB) (Dial, et al, 1989). The CTB was "designed as a standardized and quantitative method of assessing cognitive, intellectual, and information-processing skills" by "focusing on active problem solving, learning, and memory in addition to acquired knowledge and experience" (Dial, et al., 1989, C-1). The CTB was based on Luria's neuropsychological model and designed to evaluate verbal, spatial, and cognitive functions and is a key component of the Comprehensive Vocational Evaluation System. It has excellent reliability for both verbal and performance domains, .96 and .93, respectively, with a total overall reliability of .95. The total correlation to the WAIS-R full scale IQ is .82, with a .90 correlation to the WAIS-R VIQ for non-disabled subjects. For congenitally and adventitiously blind subjects, the CTB Verbal score had a

.75 correlation with WAIS-R VIQ scores (Dial et al., 1990). Elliot, Dial, Gray, and Chan (1991) reported that the CTB was preferable over the WAIS-R for assessing visually impaired or blind individuals based on their findings that, although the WAIS-R tended to be more sensitive in determining premorbid cognitive functioning in the case of adventitiously blind individuals, the CTB was more accurate in determining residual cognitive abilities in both verbal and performance areas as opposed to just verbal abilities assessed by the WAIS-R. Although the findings were significant for adventitiously blind subjects, the follow-up question then becomes an issue for assessing differences between the congenitally and adventitiously blind.

The issue regarding the age of onset of visual impairment and the degree of severity of the impairment also poses some interesting questions. One such question is whether there exist any differences in cognitive abilities or the processing of those abilities depending on the age of onset of impairment. It has already been addressed herein that there is perhaps a difference in the cognitive processing between congenitally blind and adventitiously blind individuals. Based on developmental theory, it should be reasonable to assume that these two groups would indeed process information differently, based not only on their educational opportunities, but on their developmental experiences as well. Wyver et al. (1999) addressed this very question and discovered that visually impaired children were disadvantaged and performed significantly lower than their sighted peers on the WISC-R Comprehension and Similarities subtests and those tasks which included a high degree of visual content. MacCluskie et al. (1998) examined age differences between legally and totally blind adults who were grouped according to their age of onset of visual impairment. These researchers found that there was no significant difference between congenitally blind and adventitiously blind individuals in terms of their verbal abstraction abilities, non-verbal reasoning, but that performance on these indicators was influenced by the individual's educational experience.

Regarding degree of impairment, Groenveld & Jan (1992) examined children based on three levels of visual acuity; visually impaired, legally blind, and totally blind. They determined that there are indeed differences between sighted, low vision, and totally blind individuals. For low-vision, or visually impaired, children, their visual perception abilities seemed to follow a hierarchical trend insofar as there was no discernible difference between sighted and VI children in their ability to reproduce geometric block patterns (WISC-R Block Design), but that differences did begin to appear in those tasks which required reconstructing familiar patterns from memory; e.g. they had more difficulty identifying missing elements in a simple line drawing, that errors on the Picture Arrangement subtest were due more to misperceptions as opposed to faulty logic, and that they had the most difficulty on tasks requiring symbol-associative skills. In the case of the latter, sighted children tended to complete these tasks by scanning between stimulus cues and the incomplete corresponding pattern. In contrast, younger VI children tended to rely more on verbal memory, but worked quickly, and older VI children worked much more slowly, thereby decreasing their scores due to slow perceptual-motor processing. Although blind children performed within average limits on most tasks of verbal comprehension, their performance on tasks of social judgment were significantly lower than their sighted counterparts. Stolle (2001) attributed this drop in performance due to reduced experience in community activities and a significant reduction in incidental learning. In their study of VI and blind children, Smits and Mommers (1976) reported similar results with the differences in social judgment, but reported that both the VI and blind children performed significantly better than their sighted counterparts on tasks of immediate verbal recall (Digit Span). Interestingly enough, they also reported that there was much less subtest scatter among VI/B subjects than among the sighted subjects. To summarize, Groenveld and Jan (1992) reported that children with total blindness had difficulty on the Comprehension subtest, performed more efficiently on tasks of verbal memory, and were more concrete in their thinking. In general, it is apparent that a loss of vision does indeed affect certain abilities depending on levels of impairment.

Tests of cognitive functioning involving degrees of visual impairment have shown that (1) individuals with high levels of visual impairment tend to be disadvantaged by items that possess high or complex levels of visual content or imagery and (2) there appear to be significant group differences between individuals with severe visual impairment and those with lesser degrees of impairment on tests involving minimal visual content and more concrete or logical thinking (Wyver, et al., 1999). Given the paucity of previous research in the area of cognitive functioning among the blind and visually impaired, there exists a strong need to further investigate cognitive functioning for this population with regard to the degree of visual impairment while accounting for age of onset and educational experiences. With the advent of valid assessment tools designed specifically for this population, it is now possible to more fully investigate these issues. Practical implications for this research would be in the development of more effective rehabilitation programs for the adventitiously blind, curriculum design and delivery for the congenitally and early-blind, and vocational training for all visually impaired persons.

Research Questions

It is apparent from the historical perspective regarding the theories of cognitive development and the cognitive functioning of individuals with visual impairments, that sight plays a major role in the development of certain cognitive processes. However, the effects of the degree and timing of blindness have yet to be determined. Since sight seems to be highly integral in cognitive development beginning at about the sixth month of life and then diminishes at about the time verbal communication develops, around 18-36 months of age, then it should stand to reason that significant visual impairment or blindness occurring prior to this time would adversely affect an individual's cognitive development, and visual impairment or blindness occurring after the third year of life would have less of an impact, with increasingly diminished effects the later in life that the loss of sight occurs. Additionally, the degree of visual impairment may have a major impact on the developmental process as well. Individuals with some residual vision may still be able to ascertain essential physical properties or elements of the surrounding environment. It is still unclear, however, how much visual input is needed to meet the demands of normal cognitive development. Finally, since cognitive development is an extremely complex interaction of various abilities and sensations, it is also unclear which developmental processes may be affected by both the timing and degree of visual impairment.

The current study is designed to address both issues of timing and degree of impairment. The study is based on the following ideas: 1) that congenital blindness may have a greater impact on cognition than adventitious blindness and 2) that degree of blindness will effect cognitive development. Given the paucity of research in the area of visual impairment and cognitive development, this study has been designed to allow for an exploratory examination of possible effects on development while accounting for the degree of impairment and the age of onset.

Implications of this study will be primarily along four dimensions: technical, developmental, functional, and theoretical. Technical implications of this study will be to further validate the standard instruments of assessment for both sighted and VI/B individuals. Developmental implications are along current assumptions that vision is integral at all stages of cognitive development. The size and scope of this study should provide ample evidence to more fully evaluate these assumptions. Functional implications will be primarily for individuals in the fields of education, psychology, physical rehabilitation, and vocational preparation to more accurately address the cognitive needs of persons with visual impairment or blindness at any stage of life.

CHAPTER 2

METHODS

This chapter provides a methodological overview as well as a description of the instruments utilized, selection of subjects, and statistical analyses employed.

Subjects

Data were drawn from a combination of archival review of persons with visual impairment or blindness and additional normative testing of sighted individuals. The archival information was obtained from a database of over 2000 client-consumers of the Texas Commission for the Blind (TCB). The TCB consumers were males and females over the age of eighteen who had a diagnosed visual impairment or blindness. Additional normative testing utilized a pool of volunteers who were employees of the TCB and had received continuing education credit as required by the TCB as remuneration, as well as, student volunteers from the University of North Texas in Denton, Texas. All data were provided as a raw data file from which all identifying information such as Social Security number, name, address, etc. had been removed. Each person had received an extensive battery of neuropsychological tests, administered in a standardized manner by technicians trained specifically for that purpose. This battery of tests included portions of the Comprehensive Vocational Evaluation System (CVES), specifically the verbal subtests of the Wechsler Adult Intelligence Scale®-R (WAIS-R) (Wechsler Adult Intelligence Scale, WAIS, WAIS-R, and WAIS-III are registered trademarks of The Psychological Corporation, San Antonio, TX) (Wechsler, 1981) and the complete CTB.

Subject selection criteria included the following: On the basis of history and medical records, no person had a medically diagnosed neurological illness, brain damage, traumatic brain injury, autoimmune disorder, substance abuse, attention deficit disorder, or learning disability. Participants consisted of 285 males and 239 females who ranged from 18 to 77 years of age (M = 32.6). The VI/B subjects were from the TCB client-consumer database (n = 476); 147 were visually impaired (VI), 296 were legally blind (LB), and 33 were totally blind (TB). Of the VI/B subjects, 229 were congenitally blind (CB = birth through 23 months), 31 were early blind (EB = 2 through 5 years of age), 39 were school age blind (SB = 6 through 18 years of age), and 113 were adults at the onset of blindness (AB = over 18 years of age). The volunteers were free from significant visual impairment and constituted the sighted group (SG = 44). Levels of visual functioning were separated in accordance with standards set forth by the American Foundation for the Blind (1989), using the following criteria:

> Visual impairment may be defined as blindness in one or both eyes or the inability to read regular newspaper print, or report of any other trouble seeing even when wearing glasses or contacts. Estimates of vision impairment in the United States indicate that 15-26% of the adult population has some degree of vision impairment.
>
> Blindness is a general term for individuals with some significant degree of visual impairment. Approximately 2% of Americans over the age of 45 report being blind in both eyes. The degree of blindness is usually broken down into three categories: totally blind, legally blind, and visually impaired or “low

vision." Blindness may be either congenital or adventitious. Blindness may be the result of dysfunction within the eye itself, in the optic pathways, or in the brain. Dysfunction in the latter is known as "cortical blindness."

Adventitious blindness is a visual impairment developed sometime after birth. It may be the result of injury, illness, or emotional trauma (although none of the participants in the present study had an etiology of emotional trauma for their blindness).

Congenital blindness is a visual impairment that has existed since birth and may be the result of in-vitro injury, developmental delay, or illness.

Legally blind is a term used to describe a visual impairment that involves a corrected visual acuity of 20/200 or less.

Totally blind is a term used to describe a visual impairment in which an individual has no measurable vision or perceives only light and dark.

Visually impaired is a term used to describe a visual impairment that involves a corrected visual acuity from 20/70 to 20/200.

Instruments

Two instruments were utilized as a means of obtaining dependent measures. They were the WAIS-R (Wechsler, 1981) and the Cognitive Test for the Blind (CTB; Dial, Mezger, Gray, Chan, & Massey, 1991). The WAIS-R provides a full-scale intelligence quotient that is derived from the subtest scores in both a verbal domain and a performance domain of functioning. The WAIS- R consists of six verbal subtests and five performance subtests. The Verbal Intelligence Quotient (VIQ) is composed of six subtests; they are Information, Similarities, Arithmetic, Digit Span, Vocabulary, and Comprehension. The Performance Intelligence Quotient (PIQ) is composed of the following five subtests: Picture Completion, Picture Arrangement, Block Design, Object Assembly, and Coding. Since the focus of this particular study is on the cognitive differences dependent on visual status, only the VIQ was subject to analysis. Sattler (1982) presented an enumeration of the following subtests comprising the VIQ that were subject to analysis:

Information:	general fund of knowledge and long range memory
Comprehension:	social judgment, social conventionality, meaningful and emotional relevant use of facts
Arithmetic:	reasoning ability, numerical accuracy in mental arithmetic, concentration, attention, and memory
Similarities:	verbal concept formation and logical thinking
Vocabulary:	learning ability, richness of ideas, memory, concept formation, and language development
Digit Span:	attention and short-term memory

The Cognitive Test for the Blind (CTB) is one component of a battery, the Comprehensive Evaluation System for the Visually Impaired (Dial, et al., 1991). It is a measure of cognitive, intellectual, and information processing skills for individuals with visual impairments. The primary focus of the CTB is on active problem solving, learning, and memory. It consists of a verbal and a non-visual performance scale from which a total score is derived. The CTB yields a Total standard score reliability of .95, a Verbal factor standard score reliability of .96, and a performance factor standard score reliability of .93 (Dial, et al., 1991). The CTB Total score is derived from the following ten subtests: Auditory Analysis, Immediate Digit Recall, Vocabulary, Language Comprehension and Memory, Letter-Number Learning, Haptic Category Learning, Haptic Category Memory, Memory Recognition, Pattern Recall, and Spatial Analysis. In addition to a total score, the CTB also yields a priori factor scores for Conceptual, Learning, Verbal Memory, Non-Verbal Memory, Language, and Spatial abilities. These factors assess the following abilities:

Conceptual: abstract learning and problem solving; derived by scores on Category Learning and Spatial Analysis

Learning: verbal and spatial learning skills; derived by scores on Letter-Number Learning and Category Learning

Verbal Memory: immediate and short-term memory of verbal information; derived from scores on Digit Recall and Language Comprehension and Memory

Non-verbal Memory: immediate and short-term tactile-spatial memory functions; derived from scores on Category Memory, Memory Recognition, and Pattern Recall

Language: primary verbal receptive and expressive language functions; derived from scores on Auditory Analysis, Language Comprehension and Memory, and Vocabulary

Spatial: spatial organization and analysis; derived from Pattern

Recall and Spatial Analysis

The five subtests comprising the Verbal Factor are Auditory Analysis and Sound Repetition, Immediate Digit Recall, Letter-Number Learning, Language Comprehension and Memory, and Vocabulary. The five subtests that comprise the Performance Factor are Memory Recognition, Pattern Recall, Spatial Analysis, Category Learning, and Category Memory. A description of the CTB subtests follows (Dial et al., 1991):

Auditory Analysis and Repetition:

attention, auditory detection, acoustic analysis and basic expressive abilities

Immediate Digit Recall:

attention, concentration, recognition of basic numbers, and immediate memory recall. Analogous to the WAIS-R Digit Span subtest

Language Comprehension and Memory:

receptive language, memory for verbal detail, and basic expressive language

Letter-Number Learning:

attention, concentration, verbal memory, and rote verbal learning

Vocabulary:

word knowledge, long term memory, and expressive language

Haptic Category Learning:

non-verbal/spatial concept learning, abstract spatial reasoning and learning

Haptic Category Memory:

non-verbal test of incidental memory

Haptic Memory Recognition:

immediate tactile memory

Pattern Recall:

complex immediate and short term spatial memory, organizing and response planning

Spatial Analysis:

complex spatial analysis and orientation

Procedures

In the current study, there were two primary research questions. Does congenital blindness have a greater impact on cognition than adventitious blindness? Second, does the degree of blindness effect cognitive development? Standard norming procedures were utilized to minimize the effects of both gender and ethnicity. Furthermore, standard norming procedures were used to correct for differences in age, as is standard practice for the WAIS-R and, more recently, the CTB.

The effects of education on verbal cognitive performance have been well-documented. Since Reitan and Wolfson (1996) further identified that higher-educated individuals performed better on WAIS subtests than lower-educated individuals and Malec, Ivnik, Smith, and Tangalos (1992) identified that certain verbal subtests of remote memory, such as the Vocabulary and Information subtests of the WAIS-R, are more sensitive to educational attainment, the effects of education on cognitive performance were thusly accounted for through the use of an analysis of covariance (ANCOVA). This multivariate procedure provides regression analysis and analysis of variance for dependent variables by one or more covariates. The ANCOVA technique is used to test the main and interaction effects of categorical variables on a continuous dependent variable, controlling for the effects of selected other continuous variables covaried with the dependent variable. Use of the ANCOVA technique was to control for factors which cannot be randomized but which can be measured on an interval scale. Once the confounding effects of education had been rendered statistically nonessential, the factors of age at onset of blindness and the level of visual functioning were then isolated through the use of a single analysis of covariance in each subsequent step of the current study. It was then possible to examine the true effects of level of visual impairment and age at onset of blindness.

In the present study, ANCOVA was used to compare the cognitive abilities of persons with blindness and sighted individuals. All analyses were performed using the SPSS Version 10.0.5 (SPSS, 1999) software program. The first analysis was to determine if differences exist within the levels of visual functioning. Four levels of visual functioning were examined: Sighted (visual acuity > 20/70); Visually Impaired (visual acuity from 20/70 to 20/200); Legal Blindness (visual acuity of 20/200 or less); and Total

Blindness (no vision or can discern only light and dark). Classification of level of visual impairment had been made at the time of assessment based on review of records and communication with the referral source. The second analysis examined the influence that age at the onset of blindness had on verbal cognitive abilities. Age of Onset was examined using four operationally defined levels: Congenital Blindness (birth through 23 months), Early Blindness (2 through 5 years of age), School Age Blindness (6 through 18 years), and Adult Blindness (over 18 years of age). Dependent variables for all analyses were based on the WAIS-R VIQ and the CTB factor scores.

Based on an analysis of demographic data and in accordance with findings of previous studies (Reitan & Wolfson, 1998 and MacCluskie, 1990), education was used as a multiple covariate with both the analysis of level of visual functioning and age at onset. Once the effects of education had been determined, then the effects of education only were determined for the level of visual functioning and then the age at onset of blindness. Now that the effects of education had been isolated across all levels, then the effects of visual functioning on the age at onset were determined, and vice versa. On those variables in each analyses that demonstrated significant main effects, post hoc analyses were performed using Tukey's Honestly Significant Difference (HSD) test to make all pairwise comparisons between groups. Tukey's HSD is considered one of the more powerful post hoc tests when analyzing a large number of pairs of means (SPSS, 1999).

The following table outlines the steps for analysis in the present study.

Table 1

Methods of Analysis of Cognitive Differences

Step 1: Age Corrections

- WAIS-R subtest Scores
- CTB subtest Scores

Step 2: Ethnicity Corrections

- WAIS-R & CTB subtest scores

Step 3: Gender Corrections

- WAIS-R & CTB subtest scores

Step 4: Analysis of Covariance

- WAIS-R Verbal IQ & CTB subtest scores
  - Visual Status covaried by both Education and Age at Onset
  - Age at Onset covaried by both Education and Visual Status
  - Visual Status covaried by Education
  - Visual Status covaried by Age at Onset
  - Age at Onset covaried by Education
  - Age at Onset covaried by Visual Status

Step 5: Post-hoc analysis of main effects for each ANCOVA

Step 6: Repeat Steps 4 and 5 for factor scores, if necessary.

CHAPTER 3

RESULTS

Demographic Analyses

T-tests were used to evaluate age and education differences between the Visually Impaired/Blind group (VI/B), Sighted group (St). Chi-square analyses were used to analyze differences in gender, ethnicity, and age of onset of visual impairment. Demographic information is presented in Tables 2, 3 and 4. Table 2 reveals that significant differences among the visually impaired and sighted groups were observed for both age, t (525) = 6.53, $p<.001$, and level of education, t (402) = 12.8, $p < .001$.

Table 2

Demographic Characteristics for Blind and Sighted Groups

Variable	Blind Mean/SD	Sighted Mean/SD	t
Age (525)	31.5/12.5	43.6/11.3	6.53***
Education (402)	12.1/1.98	15.9/1.8	12.8***

***p<.001

Table 3 shows that significant differences were also observed for gender χ^2 (1, N = 524) = 4.04, $p<.05$, ethnicity χ^2 (2, N = 525) = 114.25, $p<.001$, and age of onset of visual impairment χ^2 (4, N = 456) = 307.47, $p < .001$.

Table 3

Chi-Square Analyses for Blind and Sighted Groups Demographic Characteristics

Variable	Chi-Square
Gender	(1, N=524) = 4.04*
Ethnicity	(2, N=525) = 114.25***
Age of Onset	(4, N=456) = 307.47***

*$p<.05$ ***$p<.001$

Demographic Influences

Previous research has repeatedly indicated that educational experience is a primary determinant on the development of various cognitive skills. Chronological age is, by nature, also a primary factor, as is ethnicity. In order to control for these factors, age, gender, and ethnicity differences were controlled for by standard norming procedures for each subtest of the CTB and WAIS-R as well as for each factor of the CTB and the verbal intelligence quotient (VIQ) of the WAIS-R. The demographic effects of both age and education for the various groups are noted in Table 4. An analysis of covariance (ANCOVA) was used to control for differences in education in both the level of visual functioning analyses as well as the age at onset of visual impairment analyses. Post hoc analyses of significant variables were performed using Tukey's Honestly Significant Difference (HSD). Statistical analyses were performed using SPSS for Windows, Version 10.0.5.

Table 4

Means, Std. Deviations, and ANOVAs for both Age at Onset and level of Visual Functioning Groups

	Age		Education	
	n	Mean/SD	n	Mean/SD
Age at Onset				
Total	412	31.72/12.84	349	12.10/1.99
CB	229	26.58/10.53	184	12.26/1.49
EB	31	34.71/13.85	13	11.85/1.57
SB	39	28.82/10.58	39	11.23/2.60
AB	113	42.33/10.80	113	12.18/2.40
F	(3, 412)	54.49***	(3, 349)	3.07*
Visual Functioning				
Total	525	32.62/12.88	402	12.57/2.32
St	49	43.63/11.31	49	15.92/1.81
VI	147	28.69/10.51	42	12.31/1.58
Blind	329	32.74/13.12	311	12.07/2.03
F	(2, 525)	27.27***	(2, 402)	81.56***

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

Analysis of Visual Functioning

This analysis used visual status as the independent variable, with three levels of visual functioning: Sighted (St), Visually Impaired (VI), and Blind (Bld), which was a combination of both legally blind and totally blind individuals. Multiple Analysis of Covariance (MANCOVA) was used to evaluate education and age of onset of blindness differences between the groups.

The analysis of visual status covaried by both education and age at onset of visual impairment, presented in Table 5, indicates significant differences in the intercepted main effects for most of the subtests of the WIAS-R and all subtests of the CTB. The only subtests that were not significantly influenced by both these factors were the Comprehension, Information, and Arithmetic subtests of the WAIS-R, and all three of these approached a level of significance at the 95% confidence interval. Of those subtests that are similar in design on both the WAIS-R (Digit Span and Vocabulary) and CTB (Immediate Digit Recall and Vocabulary) the results were very similar and generally consistent, as would be expected given their respective reliabilities. The Tukey's Honestly Significant Difference (HSD) post hoc analyses indicate that each subtest of the WAIS-R that had a significant main effect also had significant interaction effects. In each case, the sighted group outperformed both the visually impaired and the blind group on the Comprehension and Arithmetic subtests. The St group also outperformed the Bld group on the Information subtest, but not at the same level of significance as the other two subtests. Table 6 lists the post hoc results for interaction effects of education and age at onset on the level of visual functioning.

Table 5 MANCOVA for Visual Status covaried by Education & Age at Onset

Variable	Sighted (n=44)	VI (n=41) Means/SD	Blind (n=295)	F	Sig.
WAIS-R					
Comprehension	10.67 3.23	10.27 2.64	9.75 2.90	3.60	0.06
Information	11.24 2.15	9.93 3.32	9.91 2.88	3.10	0.08
Digit Span	10.15 2.62	10.22 2.73	9.85 2.92	27.41	.000**
Arithmetic	11.16 2.45	10.08 3.44	9.83 2.81	3.29	0.07
Similarities	11.88 3.21	10.35 2.75	9.71 2.76	7.12	.008**
Vocabulary	11.91 3.11	9.56 2.79	9.69 2.74	4.21	.04*
CTB					
Auditory Analysis	10.36 2.21	10.89 2.44	9.99 3.01	53.12	.000***
Immediate Digit Recall	10.38 2.46	10.17 2.76	9.89 2.84	44.65	.000***
Language Comp.& Memory	11.63 2.74	10.11 2.60	10.13 2.89	22.41	.000***
Letter-Number Learning	8.90 2.31	9.82 2.20	9.98 2.94	63.80	.000***
Vocabulary	11.64 2.95	9.91 2.84	9.96 2.89	4.03	.05*
Category Learning	10.05 2.94	9.82 3.26	10.01 2.79	63.18	.000***
Category Memory	8.70 3.25	9.62 2.79	10.04 2.89	60.33	.000***
Memory Recognition	10.09 3.05	9.96 2.54	9.57 2.93	80.80	.000***
Pattern Recall	9.86 3.08	9.99 2.72	10.08 2.73	75.13	.000***
Spatial Analysis	9.88 3.02	10.10 2.53	9.97 3.00	99.01	.000***

*p<.05 **p<.01 ***p<.001

Table 6

Significant Post hoc Analyses for MANCOVA of Visual Status covaried by Education & Age at Onset

Subtest	Sighted	VI	Blind	Tukey's HSD	
		Means			
WAIS-R Comprehension	10.67	10.27	9.75	St > VI	.006**
				St > Bld	.006**
WAIS-R Information	11.24	9.93	9.91	St > Bld	.02*
WAIS-R Arithmetic	11.16	10.08	9.83	St > VI	.03*
				St > Bld	.01**

*p<.05 **p<.01 ***p<.001

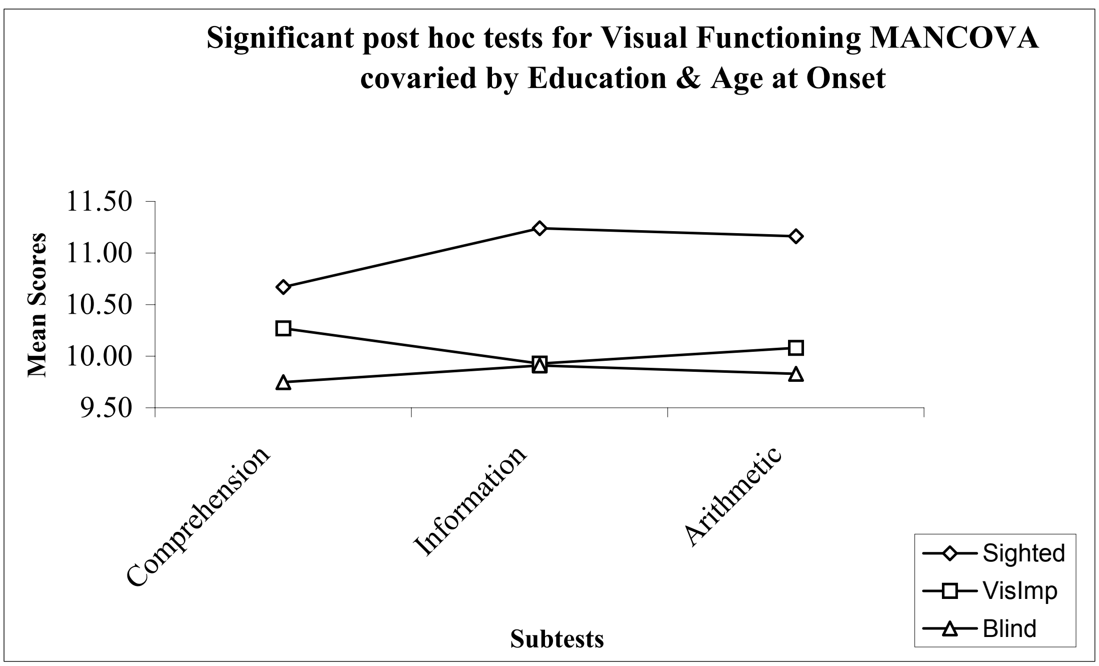

Figure 1: Tukey's HSD significant post hoc analysis of interaction effects for Visual Functioning covaried by both Education and Age at Onset

Once the effects of the combination of both education and age at onset of visual impairment had been discerned, a second analysis of covariance (ANCOVA) was conducted to analyze just the covariant effects of education alone. Table 7 indicates that, once the effects of the age of onset had been removed, there were significant main effects on every subtest of both the CTB and the WAIS-R. Again, similar outcomes were noted for those subtests that were similar in nature, as was observed with the prior, combined covaried analysis. Post hoc analyses were only significant for the CTB subtests of Letter-Number Learning and Category Memory, both complex measures of executive functioning. In each case, the St group again performed better than either the VI or Bld groups, suggesting that vision is indeed essential despite one's educational opportunities. In fact, it appears as though education does become a major influence in cognitive development, especially in terms of priming and accommodating for complex information and processing. Table 8 lists the post hoc analyses for visual status covaried only by education.

Table 7 ANCOVA for Visual Status covaried by Education

Variable	Sighted (n=39)	VI (n=47) Means/SD	Blind (n=286)	F	Sig.
WAIS-R					
Comprehension	10.88 3.26	10.27 2.64	9.74 2.89	9.11	.003**
Information	11.63 2.37	9.93 3.32	9.91 2.87	7.87	.005**
Digit Span	10.03 2.54	10.22 2.73	9.87 2.91	29.57	.000***
Arithmetic	11.15 2.33	10.08 3.44	9.87 2.82	10.34	.001***
Similarities	12.08 3.12	10.35 2.75	9.73 2.77	9.89	.002**
Vocabulary	12.18 3.14	9.56 2.79	9.68 2.73	5.61	.018*
CTB					
Auditory Analysis	10.49 2.22	10.89 2.44	9.98 3.01	53.45	.000***
Immediate Digit Recall	10.24 2.39	10.17 2.76	9.91 2.84	45.51	.000***
Language Comp.& Memory	11.76 2.68	10.11 2.60	10.14 2.90	24.29	.000***
Letter-Number Learning	8.91 2.26	9.82 2.20	10.00 2.94	49.32	.000***
Vocabulary	11.92 3.03	9.91 2.84	9.96 2.88	5.68	.018*
Category Learning	10.23 2.89	9.82 3.26	10.03 2.81	57.33	.000***
Category Memory	8.75 3.29	9.62 2.79	10.06 2.88	58.84	.000***
Memory Recognition	9.97 3.03	9.96 2.54	9.59 2.92	88.34	.000***
Pattern Recall	9.89 2.98	9.99 2.72	10.13 2.74	76.12	.000***
Spatial Analysis	9.69 3.01	10.10 2.53	9.98 3.00	89.55	.000***

*p<.05 **p<.01 ***p<.001

Table 8

Significant Post hoc Analyses for ANCOVA of Visual Status covaried by Education

Subtest	Sighted	VI	Blind	Tukey's HSD	
		Means			
CTB Letter-Number Lrng	8.91	9.82	10.00	St < VI	.03*
				St < Bld	.001**
CTB Category Memory	8.75	9.62	10.06	St < Bld	.01**

*p<.05 **p<.01 ***p<.001

Once the effects of education had been isolated, further analysis examined the effects of the age at onset of visual impairment on cognitive functioning. Again, an ANCOVA analysis of the level of visual functioning was performed, this time using the subject's age at onset of VI as the covariate. Table 9 lists the results of that analysis and Table 10 lists the post hoc analyses. An analysis of the main effects revealed a strong influence insofar as the results for each subtest were significant at the p <.001 level. Post hoc analyses again showed that the St group outperformed both the VI and Bld groups on tasks of executive processing (CTB Language Comprehension and Memory), and general word knowledge (WAIS-R and CTB Vocabulary). The St group also outperformed the Bld group on tasks of social perception and judgment (WAIS-R Comprehension). The VI group did better than the combined Bld group on tasks of abstract reasoning (WAIS-R Similarities) and incidental memory (CTB Memory Recognition). As with the case of education, the effects of visual functioning certainly appear to favor the sighted, especially on tasks involving a high degree of imagery or complex cognitive processing.

Table 9 ANCOVA for Visual Status covaried by Age at Onset

Variable	Sighted (n=44)	VI (n=60) Means/SD	Blind (n=188)	F	Sig.
WAIS-R					
Comprehension	10.67 3.23	10.72 3.04	9.73 2.90	391.37	.000***
Information	11.24 2.15	9.95 3.19	9.94 2.90	449.15	.000***
Digit Span	10.15 2.62	9.93 3.14	9.83 2.91	687.78	.000***
Arithmetic	11.16 2.45	10.11 3.23	9.82 2.81	433.21	.000***
Similarities	11.88 3.21	10.64 3.23	9.69 2.77	518.10	.000***
Vocabulary	11.91 3.11	9.71 3.23	9.69 2.74	689.72	.000***
CTB					
Auditory Analysis	10.36 2.21	10.54 2.66	10.00 3.00	831.74	.000***
Immediate Digit Recall	10.37 2.46	9.93 3.38	9.87 2.83	752.34	.000***
Language Comp.& Memory	11.63 2.74	10.09 2.96	10.13 2.88	834.74	.000***
Letter-Number Learning	8.90 2.31	10.33 3.18	9.97 2.94	878.71	.000***
Vocabulary	11.64 2.95	10.07 3.36	9.97 2.89	676.32	.000***
Category Learning	10.05 2.94	10.20 3.20	9.96 2.85	799.09	.000***
Category Memory	8.70 3.25	9.91 3.17	10.03 2.89	658.56	.000***
Memory Recognition	10.09 3.05	11.01 2.77	9.58 2.96	796.76	.000***
Pattern Recall	9.86 3.08	10.10 3.31	10.06 2.74	786.76	.000***
Spatial Analysis	9.88 3.02	10.30 2.90	9.96 3.01	822.95	.000***

*p<.05 **p<.01 ***p<.001

Table 10 Significant Post hoc Analyses for ANCOVA of Visual Status covaried by Age at Onset

Subtest	Sighted	VI	Blind	Tukey's HSD	
WAIS-R		Means			
Comprehension	10.67	10.72	9.73	VI > Bld	.006**
Similarities	11.88	10.64	9.69	St > Bld	.001***
				VI > Bld	.03*
Vocabulary	11.91	9.71	9.69	St > VI	.001***
				St > Bld	.000***
CTB					
Lang Comp/Memory	11.63	10.09	10.13	St > VI	.004**
				St > Bld	.001***
Vocabulary	11.64	10.07	9.97	St > VI	.03*
				St > Bld	.006**
Memory Recognition	10.09	11.01	9.58	VI > Bld	.000***

*p<.05 **p<.01 ***p<.001

Since these analyses were performed at the subtest level, it was important to ensure that the trends observed carried on to the factor level and were not unduly influenced by any other confounding factors. Therefore, the same combined MANCOVA analysis of level of visual functioning covaried by both education and age at onset of visual impairment was conducted. The results listed in Table 11 reveal significant differences for all factors at the 99.9% confidence interval for the intercepted covariances of the main effects. That effect was noted on the CTB Language Factor, which is derived from the Auditory Analysis, Vocabulary, and Language Comprehension subtests.

Therefore, as with the subtest-level analyses, the significant effects were likely the combined effects of significant differences in the Vocabulary and the Language Comprehension subtest, which would be akin to the Comprehension subtest on the WAIS-R. The difference here is that the VI group performed better than the St group but that the St group performed better than the Bld group. It should be noted that the St group had a standard deviation of 24.91 while the VI group had a standard deviation of 13.36 and the Bld group had a standard deviation of 14.72, even though the means were similar to within about one point in either direction. Table 12 lists the only significant post hoc analysis. Since similar trends were derived at the factor level as were observed for the subtests, no further breakdown of main effects at the factor level was performed. Based on concepts of test construction and previous research on both the WAIS-R and CTB, it was predicted that similar findings would be noted for the factor scores as were noted for the subtests. The results of this particular analysis seem to support those predictions.

Table 11 Factor-level MANCOVA for Visual Status covaried by Education and Age at Onset of Blindness

Variable	Sighted (n=44)	VI (n=41) Means/SD	Blind (n=298)	F (2, 298)	Sig.
WAIS-R					
Verbal IQ	109.02 13.43	100.33 14.92	99.14 14.09	79.23	.000***
CTB					
Total Standard	97.30 14.60	98.23 12.65	98.72 14.05	185.88	.000***
Verbal Standard	97.57 20.10	100.47 12.66	99.17 14.34	152.24	.000***
Performance Standard	94.18 16.97	98.63 12.87	99.35 14.22	271.13	.000***
Conceptual Standard	94.68 15.44	100.02 14.18	100.06 14.39	281.48	.000***
Verbal Learning Standard	96.10 12.12	98.06 13.50	100.01 14.08	254.52	.000***
Verbal Memory Standard	103.98 12.33	100.62 13.46	100.09 14.20	197.72	.000***
Non-verbal Memory Standard	94.90 19.80	97.95 12.37	99.14 13.82	254.44	.000***
Language Standard	99.93 24.91	100.96 13.36	99.38 14.72	113.99	.000***
Spatial Standard	99.26 15.15	100.34 12.25	100.12 14.68	333.75	.000***

*p<.05 **p<.01 ***p<.001

Table 12

Significant Post hoc Analyses for factor-level MANCOVA of Visual Status covaried by Education and Age at Onset

Subtest	Sighted	VI	Blind	Tukey's HSD	
		Means			
CTB					
Language factor	99.93	100.96	99.38	VI > St	.04*
				St > Bld	.035*

*p<.05 **p<.01 ***p<.001

Analysis of Age on Onset

The second research question dealt with the issue of what cognitive differences exist, if any, among individuals with some type of visual impairment. This stage of analyses also used the ANCOVA procedure to examine the differences in cognitive functioning between those individuals born with the impairment as compared to those individuals who acquired a visual impairment or blindness at various stages later in life. Four arbitrary age delineations were established based on previous vision research as well research on cognitive development. Those stages were the congenitally blind, the early blind, school-age blind, and adult blind. Detailed descriptions of these four groups may be found in the Methods section of this study. The various groups were initially examined to determine any intercepted main effects of the age at onset of blindness acquisition while attempting to account for age at time of evaluation, gender, and ethnic differences inherent in any cognitive assessment. Further attempts were made to statistically account for the influence of education and the person’s level of visual functioning at the time of testing.

The first analyses were performed through a MANCOVA of the effects of education and level of visual functioning. At the subtest level of analysis, significant main effects were noted for virtually all subtests of both the CTB and WAIS-R, with the exception of the Information, WAIS-R Vocabulary, and CTB Vocabulary subtests. Table 13 lists the main effects of that analysis with associated Tukey's HSD post hoc analyses presented in Table 14. A graphic representation of these results may be found in Figure 2.

Post hoc analyses reveal that the Adult onset (AB) group performed much better than the congenitally blind group (CB) on tasks of mental computation and general word knowledge, and that the school-age (SB) onset group also outperformed the CB group on tasks of mental computation and social awareness and better than the AB on a task of incidental haptic learning. However, the CB group performed better than the AB on tasks of alphanumeric sequencing, memory recall, spatial recall, and spatial analysis; all measures of attention and concentration. Rather than relate to academic learning of these tasks, they reflected a more astute level of attentiveness, concentration, and cognitive efficiency. Based on theories of cognitive development, it may then be ascribed to differences in sensory stimulation and acquisition, as well as a more efficient cognitive processing. Once the effects of education and level of visual functioning have been removed, the differences were greatest between the congenitally blind and adult blind, with those differences being heavily dependent on certain qualitative aspects of learning and cognitive processing.

Table 13 MANCOVA for Age at Onset covaried by Education & Visual Status

Subtest	CB	EB	SB	AB	F	Sig.
	Means/SD					
WAIS-R						
Comprehension	9.34 2.82	8.62 2.18	10.87 2.71	10.38 2.89	4.92	.028*
Information	9.59 3.05	10.07 2.59	9.73 3.02	10.51 2.66	2.41	0.122
Digit Span	10.08 3.01	9.65 2.11	9.47 2.10	9.73 2.97	8.40	.004**
Arithmetic	9.43 2.78	8.49 2.36	10.73 2.33	10.44 3.12	6.20	.014*
Similarities	9.80 2.66	7.35 2.56	9.95 3.12	9.89 2.82	5.40	.021*
Vocabulary	9.67 2.88	9.24 3.41	9.24 2.59	9.85 2.49	1.61	0.206
CTB						
Auditory Analysis	10.33 2.94	9.57 3.31	9.92 2.92	9.85 2.95	28.32	.000***
Immediate Digit Recall	10.16 2.95	10.14 2.41	9.60 2.21	9.62 2.84	12.74	.000***
Lang. Comp./Memory	10.31 2.78	9.28 3.59	9.54 2.66	10.13 2.94	7.60	.006**
Letter-Number Learning	10.45 2.95	10.45 3.21	9.85 2.41	9.12 2.63	23.51	.000***
Vocabulary	9.93 2.99	10.14 3.16	9.35 2.59	10.18 2.75	2.07	0.151
Category Learning	10.32 3.03	10.26 2.61	9.55 2.34	9.48 2.63	35.19	.000***
Category Memory	10.20 2.96	9.76 2.17	10.31 2.82	9.49 2.79	33.09	.000***
Memory Recognition	9.75 3.07	9.15 2.65	9.83 2.47	9.35 2.73	46.40	.000***
Pattern Recall	10.26 2.93	10.43 2.49	10.46 2.34	9.56 2.45	51.28	.000***
Spatial Analysis	10.36 2.82	9.74 3.42	10.33 2.95	9.26 2.98	50.28	.000***

*p<.05 **p<.01 ***p<.001

Table 14

Significant Post hoc Analyses for MANCOVA of Age at Onset covaried by Education & Visual Status

Subtest	CB	EB	SB	AB	Tukey's HSD	
WAIS-R			Means			
Comprehension	9.34	8.62	10.87	10.38	CB < SA	.003**
Arithmetic	9.43	8.49	10.73	10.44	CB < SA	.01**
					CB < AB	.009**
CTB						
Letter-Number Lrng	10.45	10.45	9.85	9.12	CB > AB	.000***
Vocabulary	9.93	10.14	9.35	10.18	CB < AB	.02*
Category Memory	10.2	9.76	10.31	9.49	CB > AB	.002**
Pattern Recall	10.26	10.43	10.46	9.56	CB > AB	.03*
					SA > AB	.05*
Spatial Analysis	10.36	9.74	10.33	9.26	CB > AB	.002**

*p<.05 **p<.01 ***p<.001

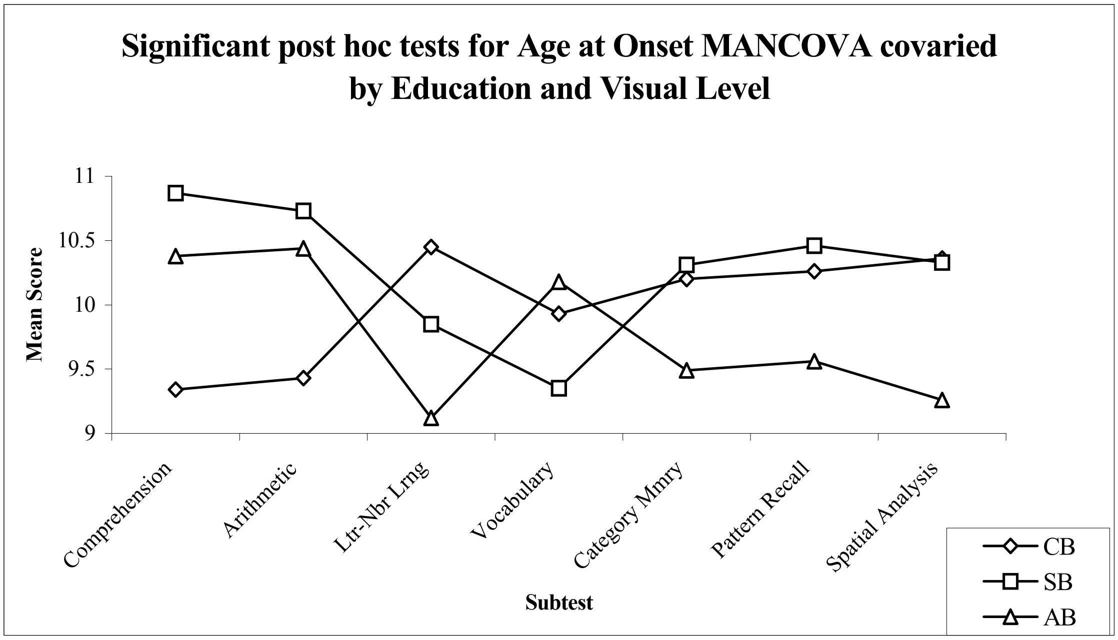

Figure 2: Tukey's HSD post hoc for interaction effects for Age at Onset covaried by both Education and Visual Functioning

The next level of analysis was to isolate the effects of education only. An ANCOVA was performed using education as the only covariate. Table 15 identifies that there were significant main effects for every subtest of both the WAIS-R and the CTB, as was the case with the visual status analysis of education effects. The post hoc analyses listed in Table 16 basically followed the same trend as that observed for the multiple covariance of education and visual status. These analyses identified that school age onset blind and adult onset blind performed better than the congenitally blind on tasks of social awareness, general fund of information, and mental computation; all subtests of the WAIS-R. For both the Information subtest as well as the Arithmetic subtest, as with previous analyses, education is known to play a highly significant role in effecting a person's performance. For the Comprehension subtest, understanding the intricacies and subtleties of interpersonal relations is often heavily dependent on visual cues, gestures, and voice inflections. Without prior experience with all of these aspects, certain deficits would be expected in one's perception and assessment of normal social interactions. As for the CTB subtests, the CB again performed better than the AB on tasks of alphanumeric sequencing, abstract and incidental haptic learning, spatial orientation, and attention and concentration. Again, it appears as though significant differences are being noted between the CB group and the AB group in terms of neuropsychological processing, especially on those tasks related to non-verbal abstract development and measures of attention and concentration.

Table 15 ANCOVA for Age at Onset covaried by Education

Variable	CB	EB	SB	AB	F	Sig.
	Means/SD					
WAIS-R						
Comprehension	9.34 2.82	8.62 2.18	10.87 2.71	10.38 2.89	9.98	.002**
Information	9.59 3.05	10.07 2.59	9.73 3.02	10.51 2.66	11.75	.001***
Digit Span	10.08 3.01	9.65 2.11	9.47 2.10	9.73 2.97	28.68	.000***
Arithmetic	9.43 2.78	8.49 2.36	10.73 2.33	10.44 3.12	11.63	.001***
Similarities	9.80 2.66	7.35 2.56	9.95 3.12	9.89 2.82	9.10	.003**
Vocabulary	9.67 2.88	9.24 3.41	9.24 2.59	9.85 2.49	8.66	.004**
CTB						
Auditory Analysis	10.33 2.94	9.57 3.31	9.92 2.92	9.85 2.95	47.39	.000***
Imdt Digit Recall	10.16 2.95	10.14 2.41	9.60 2.21	9.62 2.84	42.83	.000***
Lang. Comp./Mem.	10.31 2.78	9.28 3.59	9.54 2.66	10.13 2.94	19.90	.000***
Letter-Number Lrng	10.15 2.95	10.45 3.21	9.85 2.41	9.12 2.63	62.64	.000***
Vocabulary	9.93 2.99	10.14 3.16	9.35 2.59	10.18 2.75	9.51	.002**
Category Learning	10.32 3.03	10.26 2.61	9.55 2.34	9.48 2.63	57.73	.000***
Category Memory	10.20 2.96	9.76 2.17	10.31 2.82	9.49 2.79	63.51	.000***
Memory Recog.	9.75 3.07	9.15 2.65	9.83 2.47	9.35 2.73	86.04	.000***
Pattern Recall	10.26 2.93	10.43 2.49	10.46 2.34	9.56 2.45	85.41	.000***
Spatial Analysis	10.36 2.82	9.74 3.42	10.33 10.33	9.26 9.26	90.44	.000***

*p<.05 **p<.01 ***p<.001

Table 16

Significant Post hoc Analyses for ANCOVA of Age at Onset covaried by Education

Subtest	CB	EB	SB	AB	Tukey's HSD	
WAIS-R		Means				
Comprehension	9.34	8.62	10.87	10.38	CB < SB	.003**
					CB < AB	.006**
Information	9.59	10.07	9.73	10.51	CB < AB	.02*
Arithmetic	9.43	8.49	10.73	10.44	CB < SB	.01**
					CB < AB	.009**
CTB						
Letter-Number Lrng	10.45	10.45	9.85	9.12	CB > AB	.000***
Category Learning	10.32	10.26	9.55	9.48	CB > AB	.02*
Pattern Recall	10.26	10.43	10.46	9.56	CB > AB	.04*
					SB > AB	.04*
Spatial Analysis	10.36	9.74	10.33	9.26	CB > AB	.002**
					SB > AB	.05*

*p<.05 **p<.01 ***p<.001

Once the effects of education had been isolated, another ANCOVA was conducted to determine the effects of the level of visual functioning on cognitive functioning dependent on the individual's age at which the blindness occurred. Table 17 lists that all subtests had significant main effects at the 99.9% confidence interval. As before, post hoc analyses (Table 18) show that the CB group performed better than the AB group in terms of alphanumeric sequencing, abstract reasoning and incidental haptic memory, delayed spatial recall, pattern recognition and recall, and spatial orientation. The

CB performed better than the early blind (EB) group on tasks of verbal abstract reasoning, immediate numeric recall, auditory perception and analysis, verbal comprehension, as well as alphanumeric sequencing and incidental haptic memory. As with the previous analyses, the AB performed better than the CB on tasks of mental computation. Finally, the SB performed better than the EB on a task of mental computation and better than the AB on a task of spatial orientation. Therefore, perhaps more so than just education itself, it appears as though there are numerous and major differences between the congenitally blind and the adult adventitiously blind in many tasks requiring a high degree of attention and concentration, as well executive cognitive processing skills. Since there were more differences noted in this analysis without the effects of education and solely dependent on age at onset and level of visual functioning, it may be surmised that organic neuropsychological differences do indeed exist between the CB and the AB, thereby highly supporting the notion of the creation and use of alternate neurocognitive pathways to achieve similar results by the two groups. Indeed, there does appear to be substantial evidence to suggest that the congenitally blind do process certain types of information differently than the adult onset blind.

Table 17 ANCOVA for Age at Onset covaried by Visual Functioning

Variable	CB	EB	SB	AB	F	Sig.
	Means/SD					
WAIS-R						
Comprehension	9.69 3.00	9.44 2.93	10.87 2.71	10.38 2.89	129.98	.000***
Information	9.68 3.10	10.16 2.66	9.73 3.02	10.51 2.66	78.45	.000***
Digit Span	10.11 3.13	8.72 2.13	9.47 2.10	9.73 2.97	103.41	.000***
Arithmetic	9.60 2.84	8.80 2.96	10.73 2.33	10.44 3.12	112.30	.000***
Similarities	10.05 2.86	8.49 3.52	9.95 3.12	9.89 2.82	117.40	.000***
Vocabulary	9.78 3.03	8.77 3.02	9.24 2.59	9.85 2.49	103.88	.000***
CTB						
Auditory Analysis	10.43 2.87	9.14 3.05	9.92 2.92	9.85 2.95	159.44	.000***
Imdt Digit Recall	10.18 3.16	8.99 2.64	9.60 2.21	9.62 2.84	105.44	.000***
Lang. Comp./Mem.	10.35 2.79	9.06 3.57	9.54 2.66	10.13 2.94	132.19	.000***
Letter-Number Lrng	10.66 3.09	9.10 3.19	9.85 2.41	9.12 2.63	133.18	.000***
Vocabulary	10.06 3.15	9.46 3.13	9.35 2.59	10.18 2.75	105.90	.000***
Category Learning	10.46 3.06	8.97 3.16	9.55 2.34	9.48 2.63	160.43	.000***
Category Memory	10.26 3.03	9.13 2.89	10.31 2.82	9.49 2.79	138.12	.000***
Memory Recog.	10.23 3.11	9.91 3.25	9.83 2.47	9.35 2.73	237.04	.000***
Pattern Recall	10.28 3.10	9.71 3.13	10.46 2.34	9.56 2.45	177.99	.000***
Spatial Analysis	10.44 2.85	9.45 3.43	10.33 2.95	9.26 2.98	169.79	.000***

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

Table 18

Significant Post hoc Analyses for ANCOVA of Age at Onset covaried by Visual Functioning

Subtest	CB	EB	SB	AB	Tukey's HSD	
WAIS-R		Means				
Digit Span	10.11	8.72	9.47	9.73	CB > EB	.04*
Arithmetic	9.6	8.80	10.73	10.44	CB < AB	.03*
					EB < SB	.04*
					EB < AB	.04*
Similarities	10.05	8.49	9.95	9.89	CB > EB	.04*
CTB						
Auditory Analysis	10.43	9.14	9.92	9.85	CB > EB	.02*
Lang Comp/Mem	10.35	9.06	9.54	10.13	CB > EB	.03*
Letter-Number Lrng	10.66	9.1	9.85	9.12	CB > EB	.008**
					Cb > AB	.000***
Category Learning	10.46	8.97	9.55	9.48	CB > EB	.009**
					CB > AB	.01**
Category Memory	10.26	9.13	10.31	9.49	CB > AB	.03*
Pattern Recall	10.28	9.71	10.46	9.56	CB > AB	.05*
Spatial Analysis	10.44	9.45	10.33	9.26	CB > AB	.001***
					SA > AB	.05*

*p<.05 **p<.01 ***p<.001

An examination of the effects of education and level of visual functioning dependent on the age at onset of blindness was also conducted at the factor-level, since those scores are derived from the subtest scores noted herein. Significant main effects in the MANCOVA of factor level age at onset covaried by education and level of visual functioning were noted for every factor of the WAIS-R and the CTB. Post hoc analyses of the interaction effects were observed and noted that the CB group performed better than the AB group on every factor of the CTB, but not on the VIQ of the WAIS-R. This was a very consistent pattern as the subtest analyses for the age at onset covaried by just the level of visual functioning. Based on the results of the visual functioning factor scores noted earlier, this analysis seems to favor better, albeit alterative, cognitive processing for the CB compared to the adventitiously AB. Since the effects were so pronounced and consistent with predictions at this level, no further analyses were determined to be necessary. The results of the factor level analyses are noted in Tables 19 and 20.

Table 19

Factor level MANCOVA for Age at Onset covaried by Education and level of Visual Functioning

Factor	CB	EB	SB	AB	F	Sig.
	Means					
WAIS-R						
Verbal IQ	98.77 14.41	94.98 10.99	99.85 12.49	100.27 14.55	42.39	.000***
CTB						
Total Standard	100.33 14.84	96.38 15.94	97.67 8.87	95.96 12.85	103.73	.000***
Verbal Standard	100.77 14.77	98.23 16.02	96.84 10.71	97.76 13.66	83.38	.000***
Performance Standard	100.85 15.04	98.13 14.17	100.74 10.08	95.91 12.98	177.10	.000***
Conceptual Standard	101.90 14.87	99.60 14.77	100.18 11.78	96.65 13.79	175.35	.000***
Verbal Learning Standard	101.89 14.49	101.35 16.21	98.11 11.27	96.19 13.08	135.22	.000***
Verbal Memory Standard	101.13 14.70	98.36 15.39	97.72 10.83	99.51 13.87	88.39	.000***
Non-verbal Memory Standard	99.99 14.43	97.48 12.74	101.18 10.79	96.49 13.00	180.95	.000***
Language Standard	100.09 14.81	96.85 17.63	96.73 13.13	99.99 14.21	77.96	.000***
Spatial Standard	101.79 14.86	100.46 15.74	102.40 12.97	96.49 13.40	197.39	.000***

*p<.05 **p<.01 ***p<.001

Table 20

Significant Post hoc Analyses for factor-level MANCOVA of Age at Onset covaried by Education and level of Visual Functioning

Factor	CB	EB	SB	AB	Tukey's HSD	
CTB		Means				
Total Standard	100.33	96.38	97.67	95.96	CB > AB	.012*
Verbal Standard	100.77	98.23	96.84	97.76	CB > AB	.05*
Performance Standard	100.85	98.13	100.74	95.91	CB > AB	.005**
Conceptual Standard	101.90	99.60	100.18	96.65	CB > AB	.004**
Verbal Learning Standard	101.89	101.35	98.11	96.19	CB > AB	.001***
Nonverbal Memory Standard	99.99	97.48	101.18	96.49	CB > AB	.04*
Spatial Standard	101.79	100.46	102.40	96.49	CB > AB	.002**
					SB > AB	.02*

*p<.05 **p<.01 ***p<.001

CHAPTER 4

DISCUSSION

The present study was designed to examine the aspects of age at onset and level of visual impairment on cognitive development and functioning of persons with visual impairment or blindness. Given the paucity of research in the area of cognitive development as it relates to vision, the basic design of this study was to allow for an exploratory examination of possible effects on cognitive development while accounting for the degree of visual impairment at an individual's age at the time of onset of the impairment. Conversely, in a separate analysis, the independent effects of the age at onset on cognitive functioning were studied by controlling the degree of visual impairment. In both instances, other major intervening variables were controlled to the extent possible; e.g. level of education, ethnicity, age, and gender. The study addressed the research questions based on the notions that congenital blindness may have a discernable effect on cognitive functioning compared to onset of adventitious blindness, which occurs later in life, with differences noted primarily among school-age children and adults and that the degree of visual impairment or blindness will also affect cognitive development.

This exploratory analysis took an inductive approach in studying various cognitive abilities by first examining subtest scores of the various instruments. These subtest-level analyses were conducted among both the age at onset of visual impairment and the level of impairment groups. Although the subtest scores had been corrected for age, gender and ethnicity, significant differences were found in the predicted direction based on education. Meaning that, due to the effects of education, it was predicted that those individuals with residual vision would likely benefit more from their education than those individuals who did not have any visual input. Likewise, the effects of education would be influenced by the individual's age at the onset of blindness; suggesting that those who became adventitiously blind would have received a greater benefit from their educational experience than those who were congenitally blind. After the effects of education had been determined among the various groups, then the confounding factors of the specific level of impairment and various ages at onset were analyzed to determine whether there were any significant innate differences in cognitive abilities. Analyses of these effects were conducted initially at the subtest level, then at the more global factor levels, and finally at the overall intellectual level, often referenced as the "verbal intelligence quotient (VIQ)"on the WAIS-R and the "total standard score" on the CTB.

Education and Level of Blindness

When analyzing the effects of years of education among the level of visual impairment, significant differences were noted between those individuals with intact vision, the sighted group, and the visually impaired group. There were also significant differences noted between the "sighted group" and those with little to no vision, the "blind group." On both the WAIS-R Comprehension subtest as well as the WAIS-R Arithmetic subtest, the sighted group performed better than the visually impaired group. This same pattern was true for the sighted group compared to the blind group, with the addition of the WAIS-R Information subtest. This level of performance was expected in that the Comprehension subtest is very often regarded as a measure of social comprehension and judgment, factors that are heavily influenced by an individual's level of maturity as well as subtle perceptions of social cues through normal interpersonal interaction. Since visually impaired and blind persons have often experienced a more isolated social involvement due to their physical limitations, it would be expected that their level of social maturity may have been somewhat different than that of a "normal," or sighted, individual. Furthermore, the absence of vision would likely negatively impact an individual's ability to discern, or even perceive, subtle physical changes in others during normal interaction; changes such as posture, facial expressions, and gesturing. Therefore, it is not surprising that the ability of visually impaired and blind individuals would be less than that of those who have experienced unimpeded social interaction throughout their lives.

In terms of the differences on the Information subtest, many aspects of mainstream classroom learning involve the integration of various methods of learning, namely visual, auditory, and tactile input. Although the Information subtest is regarded as a measure of one's general fund of knowledge, that knowledge has been gained to a major degree by the individual's educational experiences. Without the aid of vision, it is natural to assume that the experiences of a sighted individual would differ substantially from that of a visually impaired or blind individual, thereby affecting their fund of knowledge; thus, lower performance for the visually impaired/blind group on this particular standardized measure. Based on Piaget's theory of cognitive development regarding accommodation and assimilation, a lack of the basic cognitive building blocks associated with normal visual input would, subsequently, make future assimilation very difficult. The visually impaired or blind person, naturally, has less of an opportunity to create the elementary schema necessary to facilitate future learning than their sighted counterparts; thereby decreasing their overall general fund of knowledge as assessed by the Information subtest of the WAIS-R.

The Arithmetic subtest of the WAIS-R involves not only knowledge of basic mathematical abilities, but also the ability to attend and concentrate on the information being presented. Mathematical knowledge is often based on a mastery of the basic principles of addition, subtraction, multiplication, and division; skills that are generally taught early on in a child's education and mastered through repetition, a process known as "overlearning." Therefore, any breakdown in the initial learning or the overlearning stage of arithmetic mastery would likely lead to a significant level of inefficiency in one's ability to attend, concentrate, visualize, and conceptualize the presented mathematical word problems associated with the Arithmetic subtest. The modified educational experience of the visually impaired or blind child would, as in the case with the Comprehension and Information subtests, be negatively impacted in comparison to the norm, or sighted, group.

Based on fundamental theories of cognitive development, as well as the necessary modifications when educating visually impaired and blind individuals, it is understandable, and predictable, that these individuals have experienced a qualitative difference in their educational experience compared to their mainstream, sighted counterparts. As noted in the outcomes of this particular study, it does, indeed, appear as though the nature and quality of one's educational experience would impact certain cognitive abilities. As in the case of the visually impaired and blind individuals, their lack of vision has resulted in a decrease in their performance on measures of cognitive functioning that are heavily dependent on education. Even when VI/B individuals have completed advanced years of education, it is impossible to fully identify the quality of education they may have received. Additionally, since the basic elements of cognitive development have necessarily been altered, even the "overlearning" process would be impacted.

Education and Age of Onset

A multivariate analysis of the effects of education among the various ages of onset of visual impairment revealed similar results as in the level of impairment analysis. At the subtest level, there were significant differences for each of the subtests from both the WAIS-R and the CTB. Tukey's post-hoc analyses revealed the significant differences were between the congenitally blind group (birth through age 2) and the adult onset group (age 18 and over). There were no differences among the early blind or the school-age blind in comparison to the other two groups. This trend of significant main effects also held for scores at the factor level for both tests, but without any significant post-hoc interaction effects for the WAIS-R VIQ, the CTB Verbal Memory factor, and the CTB Language factor.

Here again, once the scores had been adjusted for age, ethnicity, and gender, the effects of education on cognitive performance became quite clear. There were differences regarding not only the number of years of education, but also inherent differences regarding the quality of education. As was the case in the effects of education when analyzing levels of visual functioning, it is apparent that the quality of education plays a very significant role in cognitive development, much more than the effects of age, gender, or ethnicity. The same arguments regarding the cognitive developmental process could be applied here as well.

Level of Visual Functioning

A multivariate analysis of the level of visual functioning covaried by the individual's age at onset found differences in the overall verbal intelligence quotient and in verbal memory functioning. In terms of the VIQ, sighted subjects and the totally blind performed much better than the legally blind. This same pattern held true for verbal memory. With verbal memory, the totally blind group even outperformed the sighted group. When adjusting for education, the blind group again performed better than the visually impaired group. The sighted group performed slightly better than the legally blind group, but not as well as the visually impaired or totally blind group. This again leads to the issue that educational experience does indeed play a major role in determining cognitive functioning, more so than vision.

Since both the VIQ and the CTB Verbal Memory factors were more expansive in terms of a combination of abilities, an analysis at the subtest level was performed. At this basic level of verbal cognitive functioning, the legally blind group did not do as well as the visually impaired group or the totally blind in identifying essential elements of social conventionality and the "meaningful and relevant use of facts" (Comprehension subtest) (Sattler, 1982), and verbal concept formation and logical thinking (Similarities). In fact, based on these results, there appears to be a high degree of collinearity between the theoretical assertion of logical thinking and the meaningful and relevant use of facts. If this premise holds true, then the visually impaired are more logical thinkers than their more severely afflicted counterparts. Perhaps, it better surmised that the aid of vision merely serves to increase the amount of information available to make a rational and informed decision and the loss of vision makes this information gathering more difficult, thusly impacting a logical and well-informed analysis of any given situation. However, based on the findings of the educational effects, it becomes much more apparent that these factors are highly related to educational experience as opposed to true innate cognitive differences.

Regarding working and immediate verbal memory functioning, the totally blind demonstrated better performance than any of the other groups, including the sighted. This again would lend some support to Piaget's premise of assimilation and accommodation in the formative years. Results of the present study seem to suggest that those individuals who have developed a certain set of schema regarding attention and concentration, working memory, and immediate memory recall do so without the aid of vision; especially on a task which involved the sequential recall of verbally presented digits. Still, if the individual did possess some degree of vision during the formation of these schema, then vision had become an integral part of the person's memory functioning. However, in the absence of vision, a level of accommodation occurs whereby the need for visual input has been completely eliminated and the auditory memory functioning has actually improved as a result. Auditory memory functioning appears then to be a cognitive function independent of vision. Again, the effects of education seem to suggest that memory may be improved through learning. In fact, the concept of “overlearning” deals specifically with enhancing cognitive pathways and increasing the efficiency of recall. If functions of working memory and delayed recall were emphasized and mnemonic aids employed in the educational process, this would have the natural result of improving an individual’s performance in these areas.

Other observations in terms of verbal cognitive functioning related to the degree of visual functioning were differences between the sighted group and the aggregate of persons with visual impairments or blindness. These cognitive abilities included learning ability, richness of ideas, language development, and basic expressive language; all factors directly related to one’s educational experience.

Age at Onset of Visual Impairment

An analysis of the effects of the individual’s age at the time of onset of visual impairment or blindness, regardless of the level of visual impairment, did not have significant impact on the WAIS-R Verbal IQ nor the CTB Verbal factor score, but did reveal a highly significant impact on the CTB Conceptual factor as well as the Learning factor. As mentioned previously, the Conceptual factor reportedly assesses abilities such as nonverbal abstract learning and problem solving. The Learning factor reportedly assesses rote verbal and spatial learning skills. Additionally, the age of onset at time of blindness also significantly influenced the CTB Spatial factor score, which measures spatial organization and analysis abilities. As a result, the CTB Total factor score indicated a mildly significant difference for age of onset. Post hoc analyses indicated that the difference in the Total factor score was due to a moderate difference between the congenitally blind group and the adult onset group, with the congenitally blind group outperforming the adult onset every time. This pattern also held for each of the factor scores that showed a significant difference, with the most difference in performance being in the Learning factor. For the CTB Performance factor, the Conceptual factor, and the Learning factor, there were also significant differences between the congenitally blind group and the early onset group, but to a slightly lesser extent than that seen in the adult onset group.

The difference in performance of these factors between those that experienced blindness at birth, or soon thereafter, and those who became blind as adults, suggests that the congenitally blind have developed alternate methods of cognitively processing nonverbal abstract or complex information, especially if that information involved a modest degree of tactile-spatial information. Since Easton, Greene, & Srinivas (1997) provided evidence to suggest that a perceptual priming paradigm of haptic processing is experience-dependent, it is reasonable to expect that individuals who have the benefit of vision, at least partially, would have formed more traditional models of haptic structural representations. Since these more traditional models would facilitate future explorations, the process of accommodation of this material would likely be more effective. With priming, or practice, those individuals with the experience of vision would have developed a greater efficiency in integrating structural haptic information such as weight, thermal conductance, or even spatial orientation than those impaired individuals who may never have had the experience of vision. These findings seem to support Pibram's (1999) concept of “minding,” especially the “conscious and executive” functioning, as the major differences between these two groups were mostly tied to conceptualization and abstraction, both a direct function of executive cognitive processing. This level of cognitive functioning more accurately supports Thurstone’s model of intelligence (as cited in Sternberg, 1998), or “verbal comprehension,” with spatial visualization and inductive reasoning being the primary factors affected by a breakdown in the visual system. The practical implications of this help explain why these differences are not readily seen when blindness occurs later in life, but before adulthood. When a breakdown of visual processing occurs during the school-age years, the basic visual pathways have already likely been formed, and not so dependent on assimilation, as learning at this stage would be more a function of accommodation. However, when blindness occurs in adulthood, when a natural atrophy of fluid intellectual processing has already begun, the effects of visual-perceptual deprivation are more pronounced, and thus have a greater negative impact on executive functioning. Therefore, based on the findings of this study, it appears as though vision is indeed an essential element of cognitive development, especially as it pertains to abstraction and conceptualization. However, if vision is impaired from birth, it appears as though alternate cognitive pathways are formed to override the visual deficit, and new modes of assimilation are generated. In other words, congenitally blind individuals “see” differently than their sighted counterparts and develop unique methods of executive cognitive processing.

Conclusion

When removing the effects of education, the only differences in cognitive functioning appear to be in the developmental stage, or age at onset, and not by the level of visual impairment. This is a significant finding in terms of practical application insofar as the creation or exposure of alternative educational programs for the congenitally blind. Since their abilities have already been formed, the educational method would not likely have a major impact on performance, just as it would not have a major impact for those children who experience blindness for the first time during their school-age years. However, education should focus on reinforcing those idiopathic alternate pathways of the congenitally blind and not in assisting the individual to "relearn" new ways of learning. For the adult-onset-blind, educational training should focus more on adapting "life skills" and teaching the individual to cope with their impairment rather than attempting to teach these individuals "new tricks" to adjust to their condition. For the adult onset individual, training should be kept very concrete in its presentation and content and involve more of a "hands on" approach to training. This would help to maximize their entrenched methods of cognitive processing to their visual impairment and to minimize the effects of their impairment on more complex, abstract principles of thought. As a side benefit, teaching the adult onset blind to adapt would also likely ameliorate any negative emotions or frustration related to their loss of executive functioning by focusing their attention on their new successes rather than their lost or diminished abilities.

Limitations

The exploratory nature of the current study precludes any causal statements regarding these findings. Various attempts were made to match sighted subjects to the blind subjects; however, several demographic differences exist between the groups. These differences included age, gender, ethnicity, and education. Standard normative procedures were used to minimize the effects of these differences in the final analyses. Regardless, there still remain some concerns. Education, for example, was provided by self-report. Additionally, there was no distinction made regarding differences in the type of educational experience individuals may have received, such as whether that education was home-based or school-based, residential or private, standard or modified curriculum. Another possible confounding effect might have been the inclusion of congenitally blind who received some type of early childhood intervention that their later onset counterparts may not have received. Those impaired children who received early intervention may have acquired skills for accommodation that the other children may not have learned until much later, if at all. Another issue is the vast array of ages and levels of education among the school-aged children. MacCluskie (1990) raised the question as to whether educational level and performance on the WAIS-R were highly correlated, as observed in Mattarazzo (1972). Both mentioned the concern as to which predicted the other, higher intelligence was facilitated by better educational opportunities or if those of naturally higher cognitive abilities were more likely to acquire more education.

Due to limitations in sample sizes at the various levels, some combining of groups was necessary in order to include enough subjects within a cell for statistical relevance.

This artificial combining of the groups may have masked some potential differences that would have otherwise emerged at various levels of educational attainment. For example, the mean number of years of education for the sighted group was substantially higher compared to any of the visually impaired/blind groups. In fact, most of the sighted subjects had at least some college, many had obtained a bachelor's degree, and several had completed graduate-level training whereas very few of the congenitally or totally blind had even attended college. Although attempts were made to statistically minimize these differences, it would be impossible to completely eliminate any confounding effects these higher education levels would have produced in intangible or immeasurable aspects of executive cognitive functioning.

Aside from the educational limitations of this study, any subjects who had evidence of any neuropsychological impairment were excluded. Since many congenital conditions involve concomitant disease or developmental components, any remaining "neurologically clean" subjects would naturally present a bias and break from normal distributions. This bias would likely serve to enhance or magnify any strengths, thereby inflating performances across the board, but not necessarily at the same rate, especially for the congenitally blind group. In future research, etiology of blindness should be considered when attempting to explain differences between the various groups.

A similar point involves that statistical approach itself. Although multivariate techniques attempted to account for various levels of blindness, age at time of onset of blindness, and educational influences, these analyses were limited by the sample size. Overall, the study presented strong statistical power, but that power diminished significantly as the total sample was broken-down into the various subgroups. Even then, some groups included over one hundred subjects while others groups in the same analysis included less than fifty. At this level, the effects of variability would have been more influential. This also held true for differences in ethnicity, age, and gender, although these were minimized by statistical corrections, further limiting the normality of the subject pool. Finally, the initial method of this study was to analyze global factors of cognitive functioning. However, due to aberrant and unique outcomes on some factors, it was necessary to analyze performance at the individual subtest level, further limiting the size of the subject pool, increasing variability rates, and allowing for more confounding influence in terms of educational experience.

A special note should be that, although many of the findings were statistically significant, these differences were primarily statistically significant, not necessarily significant in a practical sense. Although some significant differences exist between the congenitally blind and adventitiously blind, the totally blind and the visually impaired, these differences do not necessarily dictate a massive change in rehabilitative efforts from a practical viewpoint. Again, the differences with the most practical impact are that of assimilation and accommodation between the congenitally totally blind and the adult onset blind. For those groups, modifications in rehabilitation efforts should be made, as the two groups differ to such a major degree in many neuropsychological aspects.

Improvements to this study would be to increase the sampling size at all levels of visual functioning, decrease the range of ages and years of education for the age at onset group, and more closely match subjects in terms of the total years of education and the type of education they may have received. Another area for further control or analysis would be to consider etiological and epidemiological issues of blindness. Subjects in the current study were almost completely from Texas. Future studies should include subjects in all subgroups from various parts of the country. This would help to even the field for educational experience and, for the VI/B group, to allow for differences in educational experience, as many in the current study may have served by the same state agency and followed similar guidelines for education, training, and intervention, with little influence from outside sources.

Despite these limitations, the current study is one of the most conclusive and thorough studies of the visually impaired to date. Previous research on this population has done very little to separate the levels of impairment, consider the age at onset, or to account for educational differences in any fashion. Furthermore, much of the research in the field of visual impairment is geared toward rehabilitative issues, with little or no consideration regarding the learning capabilities or concomitant neuropsychological issues of their participants. There continues to exist a strong need for more thorough analysis of theoretical issues affecting the development of the blind and visually impaired and to reevaluate “cookie-cutter” or “politically inspired” approaches to training and rehabilitation. This study was merely one step in an effort to approach these issues from a logical and scientific perspective.

APPENDIX A

Informed Consent

I agree to participate in a research study examining the performance of sighted and visually impaired persons on tests of intellectual and perceptual-motor functioning. I understand that I will be asked to provide information regarding characteristics including age, sex, ethnicity, and other information, in addition to the requirement of the testing process. I acknowledge that all information collected will be used anonymously and I will not be identified by name. I understand that there is no personal risk or discomfort directly involved with this research. I understand that I am free to withdraw my participation in this study at any time without risk or penalty. Should I have any questions regarding my participation in this study, I can call Dr. Jack Dial at (972) 570-7860.

______________________________ ____________________

Signature Date

APPENDIX B

Test Descriptions

Wechsler Adult Intelligence Scale® – Revised (WAIS-R)

The WAIS-R (Wechsler Adult Intelligence Scale and WAIS-R are registered trademarks of The Psychological Corporation, San Antonio, TX) is designed to assess general cognitive functioning and consists of a verbal scale of intelligence (VIQ) and a performance scale (PIQ) from which a full-scale intelligence quotient is derived (FSIQ). The WAIS- R consists of six verbal subtests and five performance subtests.

Since the focus of this particular study is on the cognitive differences among sighted and visually impaired persons, the WAIS-R subtests to be analyzed will be those comprising the verbal range of intellectual functioning. Those subtests include Information, Digit Span, Vocabulary, Arithmetic, Comprehension, and Similarities.

> The Information subtest consists of questions designed to assess a person's general knowledge accumulated through experiences common to our society. This test involves verbal learning ability, general knowledge, and remote memory retrieval, receptive and expressive language skills, and associative thinking abilities.
>
> The Digit Span subtest requires and individual to repeat a series of digits presented orally by the examiner. Both forward and backward sequences are included in this task. Cognitive abilities involved in this task

are immediate memory, attention, concentration, simple auditory comprehension, and numerical sequencing.

The Vocabulary subtest is generally considered the best measure of an individual's expressive language abilities whereby the individual is required to define words orally. Cognitive areas involved are auditory reception, expressive language abilities, conceptualization, and general verbal intellectual effectiveness.

The Arithmetic subtest is an oral administration of numerical operations. It is a measure of an individual's ability to integrate and utilize the abstract concept of numbers and numerical operations. This test assesses quantitative thinking, mental arithmetic operations, complex reasoning, and attention.

The Comprehension subtest requires an individual to provide oral responses to practical and relevant social situations. It is a measure of efficiency in common-sense problem solving and assesses an individual's verbal comprehension and logical problem solving.

The Similarities subtest is a measure of abstract thinking ability and requires an individual to provide responses to commonalities among items presented by the examiner. The respondent may receive scores based on the level of concrete associations among the items or more abstract relationships of those items. This test is designed to assess associative thinking in terms of qualitative aspects of relationships, verbal concept formation, long-term memory, classification and categorization, and expressive language abilities.

Cognitive Test for the Blind (CTB)

The CTB (Dial et al., 1988) is a measure of cognitive, intellectual, and information processing skills for individuals with visual impairments. The primary focus of the CTB is on active problem solving, learning, and memory. It consists of a verbal and a non-visual performance scale from which a total score is derived. In addition to a total score, the CTB also yields a priori factor scores for Conceptual, Learning, Verbal Memory, Non-Verbal Memory, Language, and Spatial abilities. Early studies of the CTB indicate very good test-retest reliability (r = .95).

Since the focus of this particular study is on the cognitive differences among sighted and visually-impaired persons, the CTB subtests to be analyzed will be Auditory Analysis and Sound Repetition, Immediate Digit Recall, Language Comprehension and Memory, Letter-Number Learning, Vocabulary, and Abstract Reasoning.

The Auditory Learning and Sound Repetition subtest requires the individual to repeat word-like sounds presented by audiotape. It is a measure of attention, auditory detection, acoustic analysis, and basic expressive language abilities.

The Immediate Digit Recall subtest is analogous to the Digit Span subtest of the WAIS-R whereby the individual is asked to repeat a series of digits either forward or backward. This test is a measure of attention, concentration, numerical recognition, and immediate memory recall.

The Language Comprehension and Memory subtest requires the individual to listen to short stories presented on audiotape and then answer some content-related questions following each story. This test is a measure of receptive language, memory for verbal detail, and basic expressive language.

The Letter-Number Learning subtest presents paired letters and numbers in a series and the individual is asked to recall the series. The individual may be presented a maximum five trials to correctly repeat the series. This test involves functions of verbal memory, learning, sequencing, attention, and concentration.

The Vocabulary subtest is analogous to the Vocabulary subtest of the WAIS-R whereby an individual is required to define words orally. This test requires word knowledge, long-term memory, and expressive language functions.

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