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Differences in IQ and Memory of Monolingual/Bilingual Children who Suffered a TBI

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Differences in IQ and Memory of Monolingual/Bilingual Children who Suffered a TBI

by

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Each person whose signature appears below certifies that this dissertation in his/her opinion is adequate, in scope and quality, as a dissertation for the degree Doctor of Philosophy.

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ABBREVIATIONS

TBI	Traumatic Brain Injury
GCS	Glasgow Coma Scale
CDC	Center for Disease Control
IQ	Intelligence Quotient
VIQ	Verbal Intelligence Quotient
PIQ	Performance Intelligence Quotient
FSIQ	Full Scale Intelligence Quotient
WASI	Wechsler Abbreviated Scale of Intelligence
CMS	Children’s Memory Scale

ABSTRACT OF THE DISSERTATION

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Pediatric traumatic brain injury (TBI) occurs at an average rate of 180 per 100,000 children who are hospitalized for head injury within the United States (Schwartz et al., 2003).

Bilinguals are a large proportion of the population living in the United States and in Southern California, particularly. If children who are bilingual incur a TBI, will they have even more difficulty than monolinguals with language tasks because they have a smaller vocabulary base? This study aims to further elucidate whether verbal memory will be more severely impacted than nonverbal memory in this same bilingual pediatric TBI population. 18 children (M age =11.67 years (SD =3.7), 61% males, 50% bilingual) were assessed as part of a longitudinal study evaluating neuropsychological outcomes in moderate/ severe pediatric TBI at 3 m (Time 1) & 12 m (Time 2) post-injury. Multiple mixed design ANCOVA's were conducted in order to assess differences within and between bilingual/monolingual IQ's and verbal and nonverbal memories. Overall this study has shown that bilinguals do not appear to have a significant difference between their VIQ/PIQ splits. The bilingual brain does not appear to have significant changes in VIQ, immediate, or delayed verbal memory. More significant improvements are seen

within the monolingual brain. The greatest recovery for both bilinguals and monolinguals appears to occur over time with immediate and delayed nonverbal memory.

CHAPTER ONE

INTRODUCTION

Pediatric traumatic brain injury (TBI) occurs at an average rate of 180 per 100,000 children who are hospitalized for head injury within the United States (Schwartz et al., 2003). In children younger than 14 years, TBI results in 2,685 deaths, 37,000 hospitalizations, and 435,000 emergency department visits annually (Centers for Disease Control and Prevention, 2007). These statistics do not include individuals who may have had a TBI but did not seek medical help. It is startling to read these numbers and realize how many children in the United States incur a TBI. It has been shown that children who acquire TBI's have long-lasting cognitive and neuropsychological consequences that significantly and negatively impact their academic achievement over time (Ewing-Cobbs et al., 2006). Nonetheless, despite the high incidence of TBI and its adverse impact on cognition, there is a lack of research that informs our understanding of the relationship between pediatric brain injury and outcome. Based on functional models of the brain, we can predict what specific deficits may be observed in the brain of a child with TBI. However, we do not know what specific deficits may be observed in the brains of children whose brains may be functionally different. Bilingualism, for example, has been shown to create certain differences in functional brain organization between bilinguals and monolinguals (Marrero, Golden, & Espe-Pfeifer, 2002). It might be expected that the consequences of injury to a bilingual brain may be different from those of a monolingual brain. Given the ever-increasing bilingual population, it has become critical to understand the neuropsychological sequelae of bilingual children who receive a TBI to more appropriately identify any possible risk factors for long-term outcome.

In order to investigate the effects of TBI, we must begin by defining it. A traumatic brain injury (TBI) is defined as a blow to the head or a penetrating head injury that disrupts the function of the brain (Centers for Disease Control and Prevention, 2007). The severity of a TBI can range from "mild," i.e., a brief change in mental status or consciousness, to "moderate," i.e., a loss of consciousness for greater than 30 minutes but less than 24 hours, to "severe," i.e., an extended period of unconsciousness or amnesia after the injury (Centers for Disease Control and Prevention, 2007). Babikian & Asarnow (2009) conducted a meta-analysis on pediatric TBI and its neurological consequences and revealed that the Glasgow Coma Scale (GCS) was the most commonly utilized measure of TBI severity. What has become the norm in the most recent studies has been to use the GCS to define the severity of TBI. The CDC describes the main use of the GCS as a measure to assess the depth and duration of a coma and/or unconsciousness (Glasgow, 2010). The GCS is a 15-point scale that measures motor response, eye opening response, and verbal response in order to come up with a measure of the overall level of dependence on others (Symptoms, 2006). A GCS score of 13-15 constitutes a mild TBI, a GCS of 9-12 constitutes a moderate TBI, and a GCS of 3-8 constitutes a severe TBI (See Appendix A). Mild TBI is generally classified as having no loss of consciousness or less than 30 minutes of a loss of consciousness. To classify as a moderate TBI, the GCS must fall within 9-12 points. In general, an individual with a moderate TBI will also have a loss of consciousness that lasts for more than 30 minutes but less than 24 hours. The symptomatology of a severe TBI indicates the individual is in a comatose state (Symptoms, 2006; Glasgow, 2010).

It has been shown that TBI can cause significant changes that can affect an individual's thinking ability, language, sensation, and emotion. The most common causes of TBI are falls, car accidents, being struck by something, and assaults. The two age groups that are at the highest risk for experiencing a TBI are 0-4 years old and 15-19 years old (Centers For Disease Control and Prevention, 2007). These statistics demonstrate the importance of investigating pediatric TBI and the effects it can have on a child's developing brain.

Research on pediatric TBI is sparse, and moreover there is an even greater shortage of research that focuses on the neuropsychological and intellectual consequences of TBI in children. Currently, there are very few articles available on the topic. Searching "pediatric TBI" on PubMed, for example, yields only 420 hits. These articles encompass many different aspects of TBI, from generic long-term effects of pediatric TBI (Schwartz et al., 2003), to the impact on IQ over time in bilateral brain damage (Bava, Ballantyne, &Trauner, 2005), to academic performance over time after suffering from pediatric TBI (Ewing-Cobbs, 2004). If the search is narrowed down to "pediatric TBI and language," the number of hits decreases dramatically to a total of 22. These articles tend to focus on language production and social interaction, rather than on neuropsychological tests of language or the impact of TBI on verbal intelligence.

One important question that is not addressed in these studies is whether incurring a TBI or lesion in one hemisphere contributes more to demonstrated language delays or deficits than does an injury to the other hemisphere. Given empirical evidence that language may be lateralized to the dominant hemisphere, this seems to be a logical and critical issue. Research by Bates et al. (2001) suggests there may be a relationship between laterality and language skills in pediatric TBI. These researchers looked at 38 children who received early unilateral brain injury, 14 of whom had right hemisphere damage while the remaining 24 had left hemisphere damage. All children were between 5-8 years old and had congenital injuries. Using free speech analysis, the researchers found no significant difference in language production between the injured children. However, it is important to note that these children had congenital injuries and not TBI's incurred after birth. Research by Ballatyne, Spilkin, & Trauner (2007) provides support for the impact of brain injury on language functions. This group found that regardless of where a lesion occurs, there are complex language deficits in school age children with TBI.

Sorting out the effects of pediatric TBI on language functions becomes more complicated in the context of those who are bilingual. In regards to the bilingual's brain, there has been great debate as to which hemisphere learns, processes, and stores the second language. While some studies have found that the second language originates in various areas of the left hemisphere (Berthier, Starkstein, Lylyk, and Leiguarda, 1990), others (Marrero, Golden, & Espe-Pfeifer, 2001) have found that the second language can be found in both the left and right hemispheres. Berthier, Starkstein, Lylyk, and Leiguarda (1990) reported that multilinguals' languages are stored within the verbal-dominant perisylvian region of both hemispheres. The second language may be organized within the central sylvian core while the first language may be better represented in more distal perisylvian areas. At this point, there is no definitive answer to the question of laterality of language in the bilingual brain, but it seems that language ability in bilinguals may be found in both hemispheres, suggesting that language may be more widespread in the bilingual brain than in the monolingual brain. Thus, it is possible that TBI in bilingual children may have greater adverse affects towards the bilingual's language abilities as both languages are more widespread than one language in the monolingual brain. This could, consequently, cause bilinguals to have lower VIQ's and verbal memory scores than monolinguals.

Impact of Severity of TBI on Neuropsychological Function

Severity of injury appears to be an important variable in regard to lasting deficits over time. In a meta-analysis of studies of TBI, Babikian & Asarnow (2009) found that the majority of studies of mild TBI showed few to negligible differences between mild TBI and controls in regard to full scale intelligence quotient (FSIQ), performance intelligence quotient (PIQ), working memory, problem solving, visual immediate memory, and visual perceptual functioning. The most significant difference was that processing speed was slowed in children with mild TBI's compared to controls, but these were small to moderate effects. They also found that those with moderate TBI were similar to those with severe TBI in regards to measures of intellectual functioning and processing speed 0-5 months post injury (time 1). Ultimately, they found that individuals with moderate TBI's and individuals with severe TBI's tend to have a significant decrease in their intellectual functioning and processing speed when first assessed after incurring a TBI. Babikian & Asarnow (2009) also found that approximately two years after injury, general memory and visuoperceptual skills in individuals with moderate TBI were similar to those of control subjects who had not received a TBI. Individuals with moderate TBI, however, seemed to still have significant deficits in their intellectual functioning and attention, even two years post injury. This suggests that individuals with moderate TBI tend to regain their memory and visuoperceptual skills after a two-year period, but that significant deficits in intellectual functioning and attention remain.

Babikian & Asarnow's (2009) meta-analysis also revealed that individuals with severe TBI do not appear to make developmentally appropriate gains. In other words, those with severe TBI are affected so drastically they do not reach the developmentally appropriate point or average for their age group compared to their same aged peers. This has become known as the "double hazard" injury model. Not only do these individuals fail to catch up to their developmental peer group, they seem to fall even further behind in their developmental progression over time. The current study proposes to look only at moderate to severe TBI's since they appear to have neurocognitive changes and consequences over time compared to mild TBI.

Factors that Impact Recovery from TBI

Unfortunately, there have been many inconsistencies among studies that describe recovery from neurocognitive impairment following pediatric TBI (Babikian & Asarnow, 2009). Babikian & Asarnow (2009) state that these inconsistencies occur among studies due to differences in age at injury and study design (longitudinal studies versus cross-sectional studies). The majority of the literature on the effects of age at injury on TBI has been conducted on adults; showing that the older the adult the poorer the recovery and the greater the lesions after TBI (Schonberger, Ponsford, Reutens, Beare, & O'Sullivan, 2009; Senathi-Raja, Ponsford, & Schonberger, 2010). There appears to be an opposite effect for the pediatric and adult TBI populations in regards to recovery over time after receiving a TBI. Specifically, they showed the younger age at injury groups had more significant score discrepancies over time compared to controls versus older age at injury groups. Additionally, Anderson, Morse, Catroppa, Haritou, & Rosenfeld (2004) conducted a study looking at outcomes of TBI that occurred in early childhood. The subjects were 2-7 years of age when the injury occurred. They completed acute, 12, and 30-month evaluations. They used the Bayley Infant Scales of Development, Wechsler Preschool and Primary Scale of Intelligence (WPPSI), and the Wechsler Intelligence Scale for Children 3rd edition (WISC-III) to assess for intelligence. These researchers found that children who obtained moderate to severe TBI's did not show improvement over time on their verbal intelligence quotient (VIQ) or PIQ scores. Furthermore, they showed that recovery of VIQ and/or PIQ is absent if the TBI occurred in early childhood (between the ages of 2-7 years old). In general, the little research that is available on pediatric TBI has shown that children who incur TBI's at an early age have poorer recovery compared to children who incur a TBI at later ages (Anderson, Morse, Catroppa, Haritou, & Rosenfeld, 2004; Anderson & Moore, 1995; Babikian & Asarnow, 2009).

Designs vary between studies that are looking at the neuropsychological and/or neurological effects TBI can have on a person's cognitive functioning making it difficult to compare studies (Babikian & Asarnow, 2009). Some studies focus on only one time point while other studies are longitudinal and focus on multiple time points. Some studies have subjects complete a neuropsychological battery one week after incurring a TBI (Govind et al., 2010), other studies are longitudinal- testing subjects over time (Ewing-Cobbs et al., 2004), while others look at the predictability that MRI results may have on cognitive functioning over time (Babikian et al., 2006). Lastly, other studies only assessed for post traumatic amnesia and focused on MRI results not assessing any other neuropsychological deficits that may be occurring (Schonberger, Ponsford, Reutens, Beare, & O'Sullivan, 2009). It becomes difficult to attempt to compare studies that may have different methodologies, time points of assessment, and subject ages.

Neuroanatomical Changes in TBI

Jonsson, Smedler, Ljungmark, & Emanuelson (2009) examined what neurological changes occurred in children after severe TBIs. Of note, these children had such severe TBI's that they had cerebral bleeds and swelling, which were treated with neurosurgery. Neuroanatomically, they found that that these individuals had a late maturation in the frontal and temporal lobes (measured by a loss of cortical grey matter). The loss of cortical grey matter was a result of synaptic pruning due to TBI (Jonsson, Smedler, Ljungmark, & Emanuelson, 2009). This loss was still present in the temporal lobe at the age of 19. Consequently, they also found that the TBI groups had significantly lower IQ's and memory scores compared to the controls. This shows that there is empirical support that traumatic brain injury causes a neurological impact, which in turn translates into deficits of IQ and memory.

Ewing-Cobbs et al. (2008) looked at the changes in the corpus callosum of individuals who incurred a moderate to severe TBI classified using the Glasgow Coma Scale (GCS). In this study, the researchers found that individuals with a TBI had a significantly smaller posterior body and isthmus of their corpus callosum compared to the controls of the study. Their overall conclusion was that there was arrested development of the corpus callosum in children who had incurred a TBI. Furthermore, they also assessed neuropsychological domains to see what differences were present in individuals with TBI compared to the controls. They found that children who incurred a TBI demonstrated worse performance on all of the cognitive domains assessed, which included IQ, reading comprehension, memory, fine motor skill, processing speed, and calculation.

Bilingualism in the United States

The United States is an ever-growing country full of multicultural individuals and communities. Mindt et al. (2008) reports that one-third of the U.S. population is part of a racial/ethnic minority group. Furthermore, it is expected that racial/ethnic minority groups will climb to about one-half of the U.S. population in 2050 (U.S. Census Bureau, 2002).

As people from other countries continue to come to the U.S. in hopes of finding and fulfilling the American dream, this country's bilingual population continues to increase. Whether an individual learns a second language because they recently immigrated to the U.S. and need to communicate in a new country, or if an individual has monolingual parents that speak a language other than English, bilingualism is constantly increasing within the United States.

According to the U.S. Census Bureau (2007) at the time of the 2000 U.S. Census, 18% of individuals in the U.S. spoke a language other than English at home. More than 25% of the population in seven states speaks a language other than English at home. In California, 39% of the state's population reports speaking another language at home (U.S. Census Bureau, 2007). It is expected that a greater portion of U.S. residents will speak a non-English language by the time the 2010 U.S. Census is completed (U.S. Census Bureau, 2007). Of these non-English languages, Spanish is the most common language spoken in the United States, with 28 million U.S. residents speaking it (U.S. Census Bureau, 2007).

Latinos are an important group to study because, as of 2006, they continue to be the largest ethnic/racial minority group in the United States. Latinos comprise 15% of the U.S. population, which equates to 44.3 million Hispanics living in the U.S. (Owens, 2006). Between 2000 and 2006, Hispanics accounted for more than one half of the nation's population growth and their growth rate of 24.3% was more than triple that of the U.S. growth rate of 6.1% (Owens, 2006). As of 2006, in California alone there were 13,074,156 Hispanics living in the state (Owens, 2006). Between 2000 and 2006 in California alone, there was a 2 million-person increase in the Hispanic population (Owens, 2006). In 2005, it was shown that the U.S. had the third largest Latino population in the world following Mexico and Colombia (U.S. Census Bureau, 2007). Seventy-eight percent of the U.S. Latino population (ages 5 and older) reports speaking Spanish in the home (U.S. Census Bureau, 2000). These statistics speak to the large prevalence of bilingualism, particularly Spanish-English bilingualism, in the United States and within California, specifically.

Bilingual Theories

Mindt et al.'s (2008) "reduced-frequency-of-use hypothesis" (also known as the "weaker links account") posits that because a bilingual speaks two different languages, they use each language less frequently than a monolingual. Monolinguals thus become extremely proficient in one language compared to bilinguals' reduced proficiency in two languages. To support this theory, Mindt et al. point to the well-established connection between proficiency of language and lexical ability. Frequently used words can be accessed more quickly than words that are not used as frequently. In a similar way, as bilinguals end up using both languages they end up being less proficient in identifying and using higher frequency words compared to monolinguals because they are concentrating and constantly switching between two different lexical dictionaries. Based on this theory it would be expected that on tests such as vocabulary, on any of the Wechsler intelligence batteries, that bilinguals should obtain lower scores than monolinguals because the words become more difficult and are less commonly used words as the subtest progresses.

The interference theory has also been used to explain how brain activation patterns in bilingual individuals may impact language and verbal processing (Mindt et al., 2008). Research has shown that both languages tend to be active all the time in the bilingual brain. Therefore, the individual must control the activation of the second language (Mindt et al., 2008). The study adds that the need for language control is most necessary when a bilingual speaks in the "non-dominant" language or the language that is spoken less in the individual's day-to-day life. In theory, the dominant language will be more accessible and will need to be subdued, hence interfering with the individual's ability to access the non-dominant language. However, Mindt et al. (2008) report that bilinguals tend to have no interference from the non-dominant language because it is less active than the dominant language. The results of the neuropsychological assessments will depend on which language is used more. Since this study is focusing on a pediatric population, it is probable that the children speak one language at school and another at home. It is possible that there may not be one language that is more dominant than the other although Spanish, in the case of this study, may have been the first language learned but now English and Spanish may both be used on a daily basis. If Spanish is the dominant language then, based on the interference theory, Spanish will constantly have to be subdued throughout the assessment leading the child to have difficulty pulling up their non dominant language, English. Consequently, this may lead to lower VIQ and verbal memory scores compared to monolinguals.

Mindt et al. (2008) discuss both the cognitive disadvantages and advantages of being bilingual. One of the disadvantages is in regards to vocabulary size. While the bilingual individual technically has a larger vocabulary because they speak two separate languages, in reality they have two names for the same concept. As such, when compared to monolinguals, bilinguals end up having a much smaller vocabulary size than the monolinguals do. Gollan and Brown (2006) demonstrated that bilinguals struggle more when trying to recognize difficult vocabulary words compared to monolingual individuals.

Thomas and Collier (2002) showed that greater proficiency in the first acquired language helps the individual gain greater proficiency in the second language. This is contrary to the interference theory discussed in the Mindt et al. (2008) study. What this shows is that dual language programs or classes will be more efficient and more helpful to students rather than monolingual programs. Monolingual programs will over-tax the individual by forcing them to focus on the less proficient language and not allowing them to use their more proficient language. Hence, a greater disparity is created between both languages and there is much more difficulty in trying to learn the second language. Students who are put in English immersion classes in the U.S., for example, may end up working much harder than native English speakers, and they may need many more years to catch up to the proficiency of native English speakers (Mindt et al, 2008). This is especially true when they are not allowed to use their second language in the classroom.

There are also cognitive advantages for bilinguals. Green (1998) discusses that bilinguals have better ability to use inhibitory control compared to monolinguals because they are constantly having to inhibit their dominant language. Green (1998) states that the inhibitory control is suppressed by the same executive functions that control attention and inhibition. Moreover, many studies have shown that the cost of switching from one language to the other is greater from the stronger dominant language than the weaker non dominant language (Green, 1998; Mindt et al., 2008). It was shown in Mindt et al. (2008) that bilinguals outperform monolinguals on tasks of inhibitory control of attention. Due to this need for inhibitory control, bilinguals have more practice with and expertise in controlling what they attend to (Mindt et al., 2008). However, it is important to note that the bilinguals used in this study were from Canada with the languages being French and English. Mindt et al. (2008) stated that future studies need to be conducted that compare bilingual Latinos in the US with monolinguals, which is what this study intends to do. Mindt et al. (2008) continue to state that bilingual children have earlier development of their executive function ability- usually around the age of three, compared to monolinguals who develop their executive function ability between the ages of four and five. As bilinguals have more practice with the use of executive functions, particularly of inhibition and attention, it is expected that that bilinguals will do better on non verbal tasks that assess more attention and executive functions (i.e., block design and matrix reasoning).

In regards to other cognitive buffers, bilinguals seem to obtain a stronger cognitive reserve against dementia. Bialystok, Craik, and Freedman (2007) have found a protective effect of bilingualism against cognitive decline in healthy aging individuals and those with Alzheimer's Disease. They looked at a sample of individuals who were diagnosed with Alzheimer's Disease. Fifty-one percent of the sample was bilingual. They found that bilingual individuals showed the onset of symptoms of dementia four years later than the monolinguals.

Age and acquisition of language may be factors that impact language organization and therefore may account for some of the discrepancies among studies of TBI and language. Illes et al. (1999) stated that the organization of the second language changes during the acquisition process. In early stages of learning a second language, words are processed primarily through their association with their translation equivalents in the first language. However, this differs when looking at later stages of learning. In later stages of learning, the second language is more concept-mediated, or equivalently, the words of the second language are compared to the words of the first language based on their individual meanings rather than the association of the translation equivalents (Illes et al., 1999). This meaning or concept mediated way of comparing words is a process mediated by the left hemisphere, which may explain why the left hemisphere is more active when learning a second language. Different regions and hemispheres of the brain are activated when learning a second language.

Illes et al. (1999) tells us the younger the learner when first learning both languages, the more similar the localization of those languages within the brain. Semantic activations for both languages, English and Spanish, were observed in the left inferior frontal gyrus with smaller or weaker activation also observed in the right inferior frontal gyrus (Illes et al., 1999; Holland et al., 2007). In general, most language functions occur in the neocortical areas in the inferior frontal and posterior temporoparietal areas (Holland et al., 2007). Moreover, Mindt et al. (2008) report that prefrontal and frontal structures have the most neural activity in the bilingual brain. There is an interplay between cortical and subcortical structures when an individual is inhibiting one language and using inhibitory control. The activation of the inferior frontal gyri in both the left and right hemispheres shows evidence for a common semantic network that spans both hemispheres.

Age of acquisition of a second language may be one factor that impacts language lateralization in the bilingual brain. Marrero, Golden, & Espe-Pfeifer (2002) found that individuals who had an earlier age of acquisition of their second language showed more significant left-hemisphere advantage for processing words; those who had an older acquisition age displayed increased right hemisphere involvement. Marrero, Golden, & Espe-Pfeifer (2002) theorized that a critical period for second-language acquisition exists and that the right hemisphere becomes more active with later acquisition age of language. Marrero, Golden, & Espe-Pfeifer (2002) also stated that left hemisphere involvement increases in the later stages of learning any language when there is increased automaticity and over-learning involved. This study suggests that when one is first learning a language, there will be more right hemisphere activation and as the language becomes more automatic and more over-learned, the activity will switch over and the left hemisphere will become more active.

Another finding of Marrero, Golden, & Espe-Pfeifer (2002) was that the method by which a second language was learned may impact language localization in bilinguals. They compared those with formal acquisition of a second language (i.e., learned in a classroom and governed by rules and grammar) to those with informal second language learning (when one learns a language by using it with friends and family in a more casual setting through modeling, exposure, and repetition). Ultimately, they discovered that the left hemisphere is more involved in formal language learning while the right hemisphere is more involved in informal language learning. The authors explained that when one begins to learn a second language, even if they do so formally, the left hemisphere as well as the right would be active. The right is activated because the information is new and the left is activated because certain ideas and activities of learning a second language are automatic and repetitive.

It appears that language dominance is dependent on automaticity and degree of fluency in the two languages. Age of acquisition seems to have a significant effect on localization, with later age of acquisition creating greater activation in the right hemisphere while early age of acquisition of the second language seems to create greater activation in the left hemisphere. Age and acquisition of language may therefore be critical variables to consider in a bilingual's neuropsychological profile as they may have adverse effects on the bilingual's verbal scores.

Neuropsychological Test Performance in Bilinguals

Research suggests that in general, adult bilinguals tend to perform more poorly than monolinguals on neuropsychological tests. A study by Gaquoine, Croyle, Cavazon-Gonzlez and Sandoval (2007) found, for example, that there was a significant difference in bilinguals' visual perceptual intelligence versus their language (verbal) achievement, and that bilinguals had a significantly higher visual perceptual intelligence than language/verbal achievement. They also found that the language of administration did not affect the bilinguals score if the individual had the same level of fluency and proficiency in both languages. This appears to be a common theme throughout the research in that bilinguals tend to have higher visuospatial or performance abilities compared to their verbal abilities.

Gollan and Brown (2006) also showed that bilingual adults tend to name pictures at a slower rate than monolingual adults. They demonstrated that bilingual individuals tended to name fewer pictures correctly on standardized naming tests. Bilinguals appear to have slower processing speed when they are attempting to retrieve words from their vocabulary in their minds.

Neuropsychological Functioning of the Traumatized Brain

Ballantyne, Spilkin, & Trauner (2007) demonstrated that children who have a focal lesion during the perinatal stage of development tend to have difficulty with more complex language tasks that require either mental flexibility or the ability to follow multi-task demands. Interestingly, they found that these children were capable of performing at average levels using their basic language abilities such as defining single words. However, children with focal lesions performed in the low to below average range on all other expressive and receptive indices of the Clinical Evaluation of Language Fundamentals –Revised (CELF-R). It is probable that single word language is the simplest and most over-learned form of language and as such, the least impacted by brain damage. Single word vocabulary may also only tax one part of the brain while more structured language tasks would require use of multiple brain regions (i.e., frontal and temporal lobes). Based on this information, it is reasonable to speculate that children who incur a TBI will experience more difficulty with tasks that require use of verbal abstract reasoning, mental flexibility, and executive functions, as these types of tasks are more complex higher order verbal functions.

Ewing-Cobbs et al. (2008) used the Wechsler Abbreviated Scale of Intelligence (WASI), Sentence Span, and the rapid letter naming subtest of the Comprehensive Test of Phonological Processing to assess children who had incurred TBI's between the ages of zero and 15 years. IQ was calculated as a composite score made up of a visual reasoning task (the Matrix Reasoning subtest) and a verbal expression task (the Vocabulary subtest). Overall, the TBI group performed more poorly than the control (non-TBI) group on tasks of rapid letter naming, verbal working memory, and the IQ composite score.

Ewing-Cobbs et al. (2006) compared the intellectual and academic outcomes in children who received a TBI before the age of six years to a non-TBI control group. This study assessed the child's long-term academic achievement and IQ level approximately five years after they had their TBI. They also assessed each child's IQ (using the Stanford Binet Intelligence Test 4) at two, 12, and 24 months post TBI. On average, the TBI group had significantly lower Full Scale IQ scores when compared to the control group. They found that 48% of children who had incurred a TBI had IQ's that fell below the 10^{th} percentile. The TBI group also had significantly lower scores on the vocabulary subtests of the Stanford Binet compared to the control group. Ewing-Cobbs et al. (2006) also found that children who incurred a TBI and were tested five years after their TBI still showed significant delays/deficits in their cognitive/neuropsychological domains or did not improve since their first neuropsychological assessment a few months after their TBI. Ewing-Cobbs et al. (2006) stated that there seems to be significant restrictions on the neural and cognitive plasticity that occurs in the developing brain of a child who has incurred a TBI.

Other studies have also focused on differences found between VIQ (verbal IQ) and PIQ (performance IQ) in children over time after they had received a TBI. Jonsson, Smedler, Ljungmark, & Emanuelson (2009) found that the VIQ scores of children who received a TBI were significantly lower than their PIQ scores. Subjects underwent one neuropsychological assessment about six years after their TBI.

Another cognitive factor that could be affected by TBI is memory. Jonsson, Smedler, Ljungmark, & Emanuelson (2009) found that verbal memory was highly impacted in children who had a TBI. They found that verbal memory was one of the lowest scores that children who received TBI's obtained in their assessment battery. Wirsen and Ingvar (1991) conducted a study that looked specifically at memory deficits that may occur in individuals who have had a head injury. Participants consisted of 18 males who had suffered a head injury and age matched controls. Of the 18 participants, six were classified has having a severe injury, one as having a moderate injury, one as having a mild injury (Wirsen and Ingvar, 1991). Verbal memory was assessed using a list learning subtest, digit span from the WAIS-R, story recall, and thirty word pairs. Nonverbal memory was assessed using a block span test, the Rey-Osterrieth Complex Figure Test (3 minute delay), and the Benton Visual Retention Test. Wirsen and Ingvar (1991) found a significant difference between general or total memory scores in individuals who experienced a head injury compared to controls. They further broke down the results to see if there were differences between head injury (HI) patients and controls in regards to verbal and nonverbal memory. They found that those who had a HI had significantly lower scores on verbal memory than controls. No significant difference was found on nonverbal memory between HI and controls.

Lowther and Mayfield (2004) conducted a study on the effects of TBI on memory in a pediatric population. The sample consisted of 70 children who had a moderate or severe TBI and 70 age-matched controls. All participants ranged in age from five to 19 years old. Lowther and Mayfield (2004) used the test of memory and learning (TOMAL) to assess memory. The TOMAL consists of a verbal memory index, a nonverbal memory index, and a composite memory index. Lowther and Mayfield (2004) found that children who incurred a moderate or severe TBI performed worse than controls across all of the indices. Specifically, children with TBI had significantly worse scores on immediate and delayed verbal memory tasks and immediate recall of a nonverbal memory task. However, the TBI sample performed as well as the matched controls on a task of delayed visual recall. Moreover, when the moderate and severe TBI groups were compared to one another, no significant differences were found (Lowther and Mayfield, 2004).

These results seem to show that memory is indeed impacted if an individual incurs a TBI. However, Wirsen and Ingvar (1991), found that nonverbal memory scores were not significantly different from matched controls while Lowther and Mayfield (2004), found that both nonverbal and verbal memory were significantly lower in the TBI group compared to controls. This research suggests that children who have incurred TBI's may experience long term deficits in their verbal and nonverbal skills. Overall, TBI seems to result in significant VIQ-PIQ discrepancies, with VIQ being significantly lower than PIQ especially in children who have undergone TBI (Jonsson, Smedler, Ljungmark, & Emanuelson, 2009; Iverson, Mendrek, & Adams, 2004; Bava, Ballantyne, & Trauner, 2005).

Neuropsychological Functioning of the Bilingual Traumatized Brain

There is very little information available on the how the bilingual brain is affected by TBI. In fact, a search for "bilinguals and traumatic brain injury" in Pubmed yielded a single hit - a case study conducted by Tavano et al. (2009). In this single case study, Tavano et al. (2009) reported on a bilingual child who received a severe left hemisphere TBI when he was seven months old. He was given the Wechsler Preschool and Primary Scale of Intelligence (WPPSI) when he was 5 years, 2 months old. Consistent with previously cited research, this child had a significantly lower VIQ than PIQ. Notably, he had extreme difficulty with both expressive and receptive language. In fact, his speech was "hardly intelligible" according to Tavano et al. (2009). After undergoing a five week cognitive rehabilitation program, the child was tested again at age 73 months. His cognitive scores improved from a FSIQ = 59, VIQ = 57, PIQ = 70 to a FIQ= 64, VIQ =

64, PIQ = 81; however, the difference between the child's VIQ and PIQ was even more significantly different after rehabilitation.

Problem Statement and Hypotheses

Pediatric traumatic brain injury (TBI) occurs at an average rate of 180 per 100,000 children who are hospitalized for head injury within the United States (Schwartz et al., 2003). In children younger than 14 years, TBI results in 2,685 deaths, 37,000 hospitalizations, and 435,000 emergency department visits annually (Centers for Disease Control and Prevention, 2007). Little is known about the effects of TBI on the pediatric brain. It is apparent that language is one of the functions that is generally compromised after incurring a TBI.

What has been shown is that there is a significant difference between VIQ and PIQ, with lower VIQ's, being found in individuals who have undergone a TBI. What is not apparent is whether a significant difference exists in the verbal IQ's of monolingual and bilingual children who have experienced a TBI. Bilinguals are a large proportion of the population living in the United States and in Southern California, particularly. The number of bilinguals continues to increase annually. If children who are bilingual incur a TBI, will they have even more difficulty than monolinguals with language tasks because they have a smaller vocabulary base? Will bilinguals perform better on PIQ measures that focus on executive functions and attention because of their strength with inhibitory control and attention in accordance with the interference theory? The purpose of this study is to investigate whether a significant difference exists between a bilingual child's VIQ and PIQ after they have incurred brain damage. This study aims to further elucidate whether verbal memory will be more severely impacted than nonverbal memory in this same bilingual pediatric TBI population. We know that verbal memory is more adversely affected in individuals who have undergone a head injury than nonverbal memory. However, will there be the same discrepancy in an individual who is bilingual? Due to smaller vocabulary that bilinguals have compared to monolinguals, they may have more difficulty remembering verbal or language based information especially on subtests that have no context such as unrelated word pairs. This study will differ from previous research in that the comparison group will be monolingual children who have sustained a TBI. This will allow the researcher to begin to gain an understanding of whether there are significant cognitive differences between the injured monolingual and bilingual brain in a pediatric population. Based on the previous research stated presently, the expectation is that there will be significant differences with lower VIQ's and more adversely affected verbal memories. As such, it is hypothesized that a TBI in a bilingual child will further exacerbate the VIQ/PIQ split.

Hypotheses

1. It is hypothesized that bilingual children who have had a traumatic brain injury will have significantly lower VIQ's compared to their own PIQ's when controlling for age of language acquisition and age when TBI was obtained.
2. It is hypothesized that bilingual children who had a traumatic brain injury will have greater splits between their VIQ and PIQ's (with PIQ being the higher value) compared to monolingual children who have incurred a traumatic brain injury when controlling for age of language acquisition and age when TBI was obtained.

3. It is hypothesized that bilingual children who have had a traumatic brain injury will have a significant discrepancy (> 1SD) between their verbal and nonverbal memory scores (with verbal having a lower standard score) when controlling for age of language acquisition and age when TBI was obtained.
4. It is hypothesized that bilingual children who have had a traumatic brain injury will have a greater discrepancy (> 1SD) between their verbal and nonverbal memory scores (with verbal having a lower standard score) compared to monolingual children who have had a traumatic brain injury when controlling for age of language acquisition and age when TBI was obtained.

CHAPTER TWO

METHODS

Participants

The targeted study population consists of monolingual and bilingual children who have incurred a moderate to severe TBI. The sample was recruited from the Loma Linda University Children's Hospital Level-1 Trauma Center's emergency department. The data utilized in this study is archival data from an NIH funded grant # 5 RO1 NS 054001-02 that was approved at the Loma Linda University Children's Hospital (Ashwal, 2005).

Inclusion Criteria

It was determined whether the TBI was considered to be mild, moderate, or severe by staff in the Emergency Department. TBI participants received a moderate (GCS score of 9-12) or severe (GCS ≤ 8) TBI as defined by their best GCS score prior to the administration of sedative or paralytics within the first 24-hour period (See Appendix A). TBI severity was also determined using the Mayo TBI Severity Classification System (See Appendix B). The Mayo TBI Severity Classification System is broken into three different classifications: Moderate-Severe (Definite) TBI, Mild (Probable) TBI, and Symptomatic (Possible) TBI. Participants were included in the study who met criteria for the Moderate-Severe (Definite) TBI categorization (Malec et al., 2007). All participants were between 5 and 17 years of age.

Exclusion Criteria

Children with a history of known central nervous system malformation, developmental disability, and/or previous brain injury were excluded from the study. Patients with non-accidental trauma (NAT) were also excluded from the study because children with NAT have a pattern of injury that is different than accidental TBI (as evidenced in Ashwal et al., 2000; and Brenner, Freier, Holshouser, Burley, & Ashwal, 2003).

Measures

Neuropsychological Measures

Intelligence was assessed using the Wechsler Abbreviated Scales of Intelligence (WASI). The WASI is an abbreviated and reliable measure of intelligence made up of 4 subtests (vocabulary, block design, similarities, and matrix reasoning) that yields three indices: verbal IQ, performance IQ, and full scale IQ (Wechsler, 1999). The WASI takes approximately 30-45 minutes to administer. Standardization included 2,245 individuals (ages 6 to 89) considered representative of the current U.S. census. The test-retest reliability coefficient for these ages was .93 for full scale IQ, .88 for performance IQ, and .92 verbal IQ. Content validity indicates that the WASI full scale IQ is significantly correlated with the Wechsler Intelligence Scale for Children-Third Edition (WISC-III) FSIQ (Wechsler, 1999).

Memory and learning were assessed using the Children's Memory Scale (CMS) for all the children (ages 6 to 16). The CMS is the most commonly utilized comprehensive measure of learning and memory in children (Cohen, 1999). The CMS takes approximately 60 minutes to administer and yields immediate and delayed indices for visual and verbal memory as well as learning with repetition and delayed recognition.

Standardization included 1,000 children representative of children in the United States according to the U.S. Census Bureau (Cohen, 1999). Split-test reliability coefficients ranged from .71 to .91. Test-retest reliability ranged from .29 (immediate visual memory for 13 to 16 year olds) to .86 (overall memory for 9 to 12 year olds). Validation studies indicate appropriate content, construct and criterion-related validity, with correlations between subtests within domains higher than correlations between subtests across domains (Cohen, 1999). Subjects were given a larger battery of tests that included the Test of Everyday Attention for Children (TEA-CH) however, due to the focus of the present study, these data will not be considered.

A self-report questionnaire that assesses language fluency was also administered (See Appendix C). Given that there is not a language proficiency questionnaire that is standardized with children, this questionnaire was modified for use with children. The questionnaire was administered to a parent of every child. A questionnaire was also administered to all children aged 8 or older. It was expected that children this age would have adequate reading capacity so as to be able to answer the questions reliably. Gaquoine, Croyle, Cavazos-Gonzalez, & Sandoval (2007) conducted correlations to assess whether an individual's self report of language proficiency and fluency was highly correlated with their performance on the Woodcock-Munoz Language Survey. They found that self-report was highly correlated with performance ($r = 0.77$, $p < .001$), signifying that bilingual individuals are accurate reporters of their language abilities in both languages. This questionnaire was intended to help identify the age of second language acquisition as well as the frequency of use of each language. There is a question that specifically asks both the parent and the child at what age the child first learned their second language. A composite variable was created based on the parent and child report of language acquisition. The language acquisition variable will consist of five different levels acquiring language in infancy, at age three, at age four, at age five, or at age six. It is expected that six will be the latest age that the second language was learned as six is the average age to enter first grade.

Procedure

After a child received a TBI and had been brought to the Loma Linda University Children's Hospital, it was determined whether the TBI was considered to be mild, moderate, or severe by staff in the Emergency Department. If the child met criteria for a moderate to severe TBI according to GCS ratings and/or the Mayo Classification System, the parents were approached by the study's research coordinator and asked if they would like their child to be in the study. Parents then provided informed consent while the child was hospitalized at the Loma Linda University Children's Hospital and when possible the child provided assent (Ashwal, 2005).

All participants underwent neuropsychological evaluations at 3 months and 12 months post injury. These evaluations were conducted at the Loma Linda University Healthcare Department of Pediatric Psychology Research. The 3-month time period was determined to be the earliest that neuropsychological measures would be stable as a result of variation in post-traumatic amnesia and coma (Ashwal, 2005). The 12-month time period was selected so that data could be analyzed in conjunction with magnetic resonance spectroscopy imaging; however, the imaging data will not be used in this study (Ashwal, 2005). The specific neuropsychological measures that were used included the

Wechsler Abbreviated Scale of Intelligence (WASI) and the Children's Memory Scale (CMS). These assessments are well standardized and have been used at Loma Linda for follow-up testing in children who have undergone traumatic brain injury.

Participants were contacted for their 3-month and 12-month neuropsychological assessment appointments by the neuropsychological post-doctoral fellow and/or research assistant. Each participant's IQ and memory was assessed using the WASI and CMS. The assessor then scored and interpreted the results of the assessment. A brief report was written up that included recommendations and referrals when appropriate. Oral feedback was provided to the parent of the participant an average of one week after the child was assessed after both the 3 and 12 month evaluations. After feedback was completed, the child's report was mailed to the parents to keep for their own records. As the language fluency questionnaire was not included in the original study, in conjunction with IRB approval, parents and participants were contacted via telephone and the questionnaire was administered orally.

CHAPTER THREE

RESULTS

Preliminary Analyses

Normality was assessed based on observation of histograms to assess for outliers (See Figs 1-16). Also, assumption of sphericity was used. Sphericity assumes that the relationship between experimental conditions is equal. It is similar to the assumption of homogeneity of variance in a between group ANOVA. Using Mauchly's test on SPSS, which tests the hypothesis that the variances of the differences between conditions are equal, sphericity can be assessed. If the test is significant, then there are significant differences between the variances and sphericity is not met. If the assumption is not met, the Greenhouse-Geisser correction can be used to correct the sphericity violation. In all cases of possible violation of the sphericity assumption, the conservative Greenhouse-Geisser correction has been used. In presenting the results, the uncorrected degrees of freedom are reported along with the corrected p-value. Homogeneity of variance was all assessed when running the mixed model ANOVA's by looking at the Box's Test. If the Box's Test is insignificant then homogeneity of variance is present. All Box's Tests were insignificant signifying that no corrections had to made to the data.

Participant Characteristics

A total of 18 participants that ranged in age from five to 17 years (M=11.67 years) were obtained for this study. All participants had incurred either a moderate or severe TBI and were recruited from Loma Linda University Medical Center and Children's Hospital. Of the 18 participants, nine were bilingual (Spanish-English) and nine were monolingual (English). Of the bilingual participants, four were female and five were male. Of the monolingual participants, three were female and six were male. All participants were age matched for comparison between monolingual and bilingual groups. A total of 20 bilingual patients qualified to be a part of this study. Of the 20, only nine consented to answer the language fluency questionnaire. Of the 11 who did not participate, six did not return phone calls after three messages were left, three had parents who were bilingual but children who were monolingual, and two telephone numbers had been disconnected.

Table 1.

Demographic Characteristics of Participants

	Demographic Characteristics	Percentage (Raw #)	Mean (SD)
Bilinguals			
	Gender		
	Female	44.4 (4)	
	Male	55.6 (5)	
	Age		11.67 (3.74)
	Parent Reporter		
	Mothers	89 (8)	
	Fathers	11 (1)	
Monolinguals			
	Gender		
	Female	33.3 (3)	
	Male	66.7 (6)	
	Age		11.67 (3.61)

A power analysis was conducted *a priori*, using G power 3 (Faul, Erdfelder, & Buchner, 2007), which showed that in order to obtain an effect size of 0.20 and power of 0.80 the experiment would need 16 participants (eight participants in each group) if a mixed model ANOVA is to be conducted.

This study is a quasi-experimental correlational design that aims to determine if there are significant differences in IQ and memory between a bilingual child who has incurred a TBI and a monolingual child who has incurred a TBI. This study also aims to determine if there are significant differences in the VIQ and PIQ and/or verbal and nonverbal memory in bilingual children who have experienced a TBI. All ANOVA's were conducted using age when TBI was obtained as a covariate. This variable was used as a covariate as previous research has shown that it can account for substantial variance in this subpopulation (Babikian & Asarnow, 2009).

Statistical Analyses: Hypotheses Examined

Hypothesis One

It is hypothesized that bilingual children who have had a traumatic brain injury will have significantly lower VIQ's compared to their own PIQ's when controlling for the age when TBI was obtained. Analyses include a within subjects ANCOVA measuring the repeated measures for Time 1 (3 month) and Time 2 (12 month) with the dependent variables of VIQ and PIQ while controlling for age when TBI occurred.

A repeated measures ANCOVA was conducted utilizing the age when TBI was obtained as a covariate. There were no significant main effects of time that were found, p's > .05. No significant interactions were found, p's > .05 (see table 2).

Table 2.

ANCOVA of Bilingual IQ Scores Across Time

Sources of Variation	**SS**	**Df**	**MS**	**F**	***P*-Value**
IQ Time 1	32.09	1	32.09	0.93	0.37
IQ Time 2	25.56	1	25.56	0.51	0.50
Age	428.88	1	428.88	0.85	0.39

A paired samples t-test was conducted to assess whether a significant difference existed between a bilingual's VIQ at Time 1 (3 month) compared to their VIQ at Time 2 (12 month) and their PIQ at Time 1 compared to their PIQ at Time 2. On average, bilingual TBI participants did not have a significant difference between their VIQ (M = 91.11, SE = 3.94) and VIQ2 (M = 94.67, SE = 4.49), $t(8) = -1.042$, $p = 0.33$. On average, bilingual TBI participants did not have a significant difference between their PIQ (M = 91.56, SE = 6.06) and PIQ2 (M = 99.56, SE = 2.46), $t(8) = -1.649$, $p = 0.14$.

A paired samples t-test was conducted to assess whether a significant difference existed between a bilingual's VIQ at Time 1 (3 month) compared to their PIQ at Time 1 (12 month) and their VIQ at Time 2 compared to their PIQ at Time 2. On average, bilingual TBI participants did not have a significant difference between their VIQ (M = 91.11, SE = 3.94) and PIQ (M = 91.56, SE = 6.06), $t(8) = -0.08$, $p = 0.93$. On average, bilingual TBI participants did not have a significant difference between their VIQ2 (M = 94.67, SE = 4.49) and PIQ2 (M = 99.56, SE = 2.46), $t(8) = -1.629$, $p = 0.14$.

Hypothesis Two

It is hypothesized that bilingual children who had a traumatic brain injury will have greater splits between their VIQ and PIQ's (with PIQ being the higher value) compared to monolingual children who have incurred a traumatic brain injury when controlling for age when TBI was obtained. Analyses included a within-between subjects mixed design ANCOVA measuring the repeated measures for Time 1 (3 month) and Time 2 (12 month) with the dependent variables of VIQ and PIQ and the between subjects variable of monolingual/bilingual while controlling for age when TBI occurred.

No significant main effects were found when comparing bilingual's VIQ and PIQ scores at Time 1 and Time 2 to monolingual VIQ and PIQ scores at Time 1 and Time 2 (*p*'s > .05) (see table 3).

Table 3.

ANCOVA of Bilingual/Monolingual IQ Scores Across Time

Sources of Variation	**SS**	**Df**	**MS**	**F**	***P*-Value**
IQ Time 1	1.78	1	1.78	0.05	0.82
IQ Time 2	45.79	1	45.79	0.67	0.43
Age	162.18	1	162.18	0.26	0.62
Language Spoken	5.01	1	5.01	0.01	0.93

However, a significant interaction was present between bilingual/monolingual and IQ at Time 2 (12 month) $F(1, 15) = 4.83$, $p = 0.04$, r = 0.54. This indicates that the effect on IQ at the 12 month evaluation was impacted by language (monolingual vs bilingual) status. Monolinguals appear to have a greater difference between their VIQ (M = 89.11, SE = 4.09) and PIQ (M = 100.39, SE = 4.65) at their 12 month evaluation compared to the difference evident in bilinguals' VIQ (M= 92.89, SE = 4.09) and PIQ (M = 95.56, SE = 4.65). Monolinguals appear to have significantly lower VIQ's compared to their PIQ's while bilinguals do not at Time 2 (See Fig. 17).

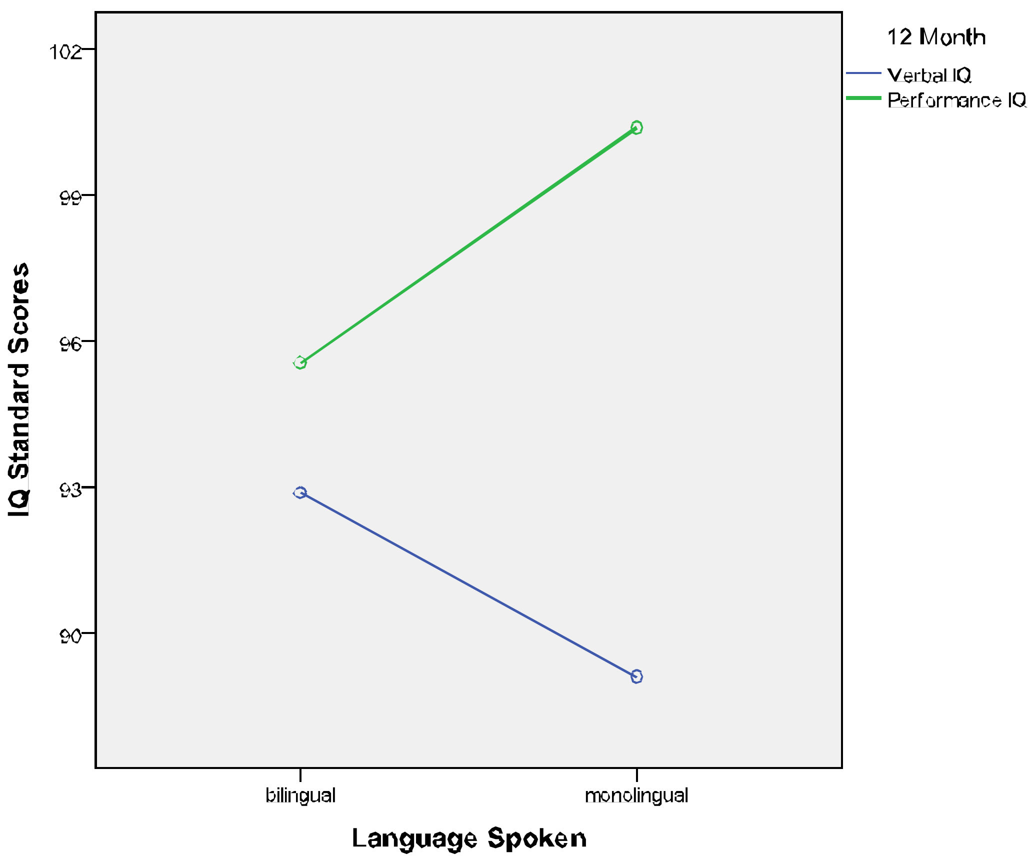


Figure 17. IQ of Monolingual and Bilingual children at 12 Month Evaluation

There was an interaction approaching significance between age of TBI acquisition and IQ score at Time 2 (12 month) $F(1, 15) = 3.63$, $p = 0.08$, r = 0.43. The effect is linear suggesting the older the individual the higher their IQ scores should be.

Hypothesis Three

It is hypothesized that bilingual children who have had a traumatic brain injury will have a significant discrepancy (> 1SD) between their verbal and nonverbal memory scores (with verbal memory having a lower standard score) when controlling for age when TBI was obtained. Analyses included a within subjects ANCOVA measuring the repeated measures for Time 1 (3 month) and Time 2 (12 month) with the dependent variables of verbal and nonverbal memory while controlling for age of second language acquisition and age when TBI occurred.

In order to assess for both immediate and delayed memory, two separate repeated measures ANCOVA's were conducted – one that assessed both verbal and nonverbal immediate memory and another that assessed both verbal and nonverbal delayed memory.

Immediate Memory

There were no significant main effects of immediate memory across time that were found (all *p*'s > .05) (see table 4).

Table 4.

ANCOVA of Bilingual Immediate Memory Scores Across Time

Sources of Variation	**SS**	**Df**	**MS**	**F**	***P*-Value**
Immediate Memory Time 1	333.03	1	333.03	2.29	0.17
Immediate Memory Time 2	13.46	1	13.46	0.10	0.76
Age	380.73	1	380.73	0.77	0.41

However, a significant interaction was present between immediate memory at Time 1 (3 month) and immediate memory at Time 2 (12 month) $F(1, 7) = 7.45$, $p = 0.03$, r = 0.65. This indicates that bilinguals' verbal immediate memory scores (M = 92.56, SE = 5.24) and nonverbal immediate memory scores (M = 93.89, SE = 6.17) at Time 1 (3 month) were significantly lower than their verbal immediate memory scores (M = 98.33, SE = 4.23) and nonverbal immediate memory scores (M = 114.56, SE 3.77) at Time 2 (12 month). At Time 1 there appears to be a very small discrepancy between verbal and nonverbal memory compared to the much larger discrepancy apparent at Time 2 between verbal and nonverbal memory (See Fig. 18).

Also there was a three way interaction approaching significance between age that TBI was obtained, immediate memory scores at Time 1 (3 month), and immediate memory scores at Time 2 (12 month) $F(1, 7) = 4.83$, $p = 0.06$, r = 0.47. The effect is linear suggesting the older the individual, the higher their immediate memory scores should be at both Time 1 and Time 2.

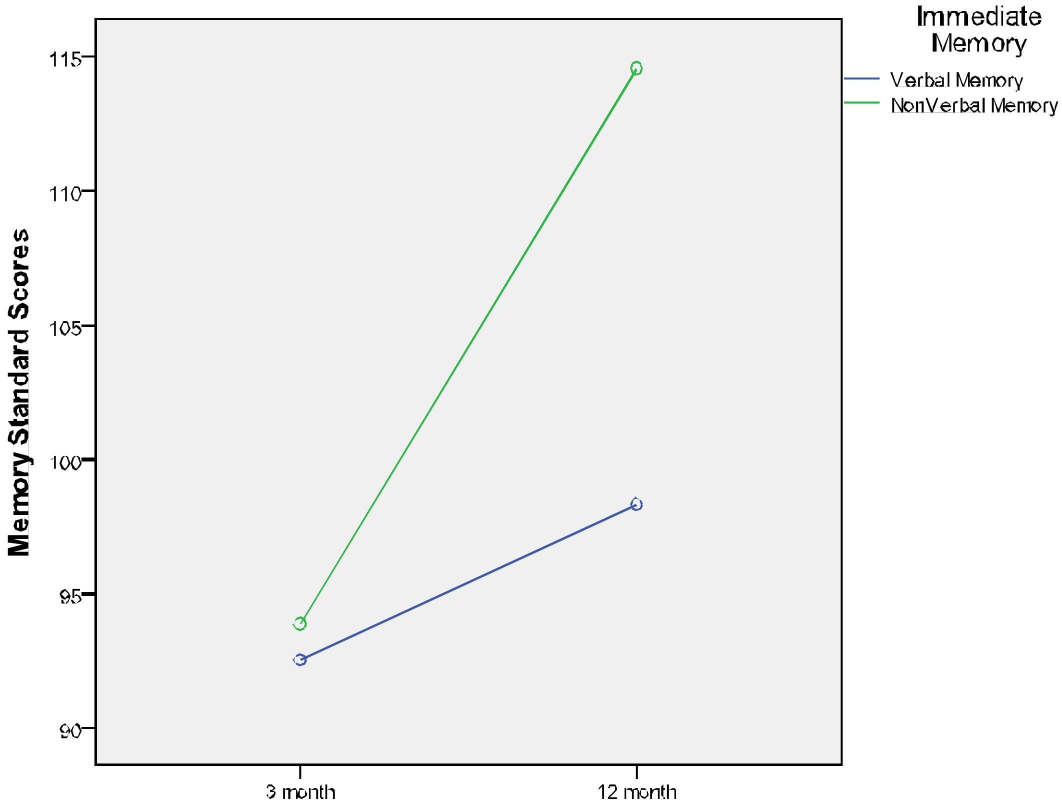


Figure 18. Immediate Memory for Bilinguals Across Both Time Points

Lastly, a paired samples t-test was conducted to assess whether significant differences existed between a bilingual's immediate verbal memory at Time 1 (3 month) compared to their immediate verbal memory at Time 2 (12month evaluation) and their immediate nonverbal memory at Time 1 compared to their immediate nonverbal memory at Time 2. On average, bilingual TBI participants did not have a significant difference between their immediate verbal memory at Time 1 (M = 92.56, SE = 5.63) and immediate verbal memory at Time 2 (M = 98.33, SE = 4.07), $t(8) = -1.954$, $p = 0.09$. On average, bilingual TBI participants had a significant difference between their immediate nonverbal memory at Time 1 (M = 93.89, SE = 5.92) and immediate nonverbal memory at Time 2 (M = 114.56, SE = 4.16), $t(8) = -2.764$, $p = 0.03$, r = 0.69. Bilinguals' nonverbal immediate memory score at Time 2 was significantly higher compared to their nonverbal immediate memory score at Time 1.

A second paired samples t-test was conducted to assess whether a significant difference existed for bilinguals between immediate verbal memory and immediate nonverbal memory at Time 1 as well as if a significant difference exists between immediate verbal memory and immediate nonverbal memory at Time 2. On average, bilingual TBI participants did not have a significant difference between their immediate verbal memory (M = 92.56, SE = 5.63) and immediate nonverbal memory at Time 1 (M = 93.89, SE = 5.92), $t(8) = -0.199$, $p = 0.85$. On average, bilingual TBI participants had a significant difference between their immediate verbal memory (M = 98.33, SE = 4.07) and immediate nonverbal memory at Time 2 (M = 114.56, SE = 4.16), $t(8) = -3.623$, $p < 0.01$, r = 0.79. On average, bilinguals had significantly lower immediate verbal memory scores compared to their immediate visual memory at Time 2.

Delayed Memory

There was a significant main effect of age $F(1, 7) = 5.44$, $p = .05$, r = 0.52 on delayed memory scores across time. This suggests that the age when TBI occurred has a significant effect on delayed memory scores. However, there were no significant interactions of delayed memory across time that were found (all p's > .05) (see table 5).

Table 5.

ANCOVA of Bilingual Delayed Memory Scores Across Time

Sources of Variation	**SS**	**Df**	**MS**	**F**	***P*-Value**
Delayed Memory Time 1	39.33	1	39.33	0.37	0.56
Delayed Memory Time 2	289.55	1	289.55	2.29	0.17
Age	1450.08	1	1450.08	5.44	0.05

A paired samples t-test was conducted to assess whether significant differences existed between a bilingual's delayed verbal memory at Time 1 (3 month) compared to their delayed verbal memory at Time 2 (12 month evaluation) and their delayed nonverbal memory at Time 1 compared to their delayed nonverbal memory at Time 2. On average, bilingual TBI participants did not have a significant difference between their delayed verbal memory at Time 1 (M = 97.89, SE = 4.04) and delayed verbal memory at Time 2 (M = 101.00, SE = 4.18), $t(8) = -.703$, $p = 0.50$. On average, bilingual TBI participants had a significant difference between their delayed nonverbal memory at Time 1 (M = 96.22, SE = 5.47) and delayed nonverbal memory at Time 2 (M = 112.56, SE = 3.83), $t(8) = -4.123$, $p < 0.01$, r = 0.82. Bilinguals' delayed nonverbal memory score at Time 2 was significantly higher compared to their delayed nonverbal memory score at Time 1.

A third paired samples t-test was conducted to assess whether a significant difference existed for bilinguals between delayed verbal memory and delayed nonverbal memory at Time 1 as well as if a significant difference exists between delayed verbal memory and delayed nonverbal memory at Time 2. On average, bilingual TBI participants did not have a significant difference between their delayed verbal memory (M = 97.89, SE = 4.04) and delayed nonverbal memory at Time 1 (M = 96.22, SE = 5.47), $t(8) = 0.360$, $p = 0.73$. On average, bilingual TBI participants had a significant difference between their delayed verbal memory (M = 101.00, SE = 4.18) and delayed nonverbal memory at Time 2 (M = 112.56, SE = 3.83), $t(8) = -2.859$, $p = 0.02$, r = 0.71. On average, bilinguals had significantly lower delayed verbal memory scores compared to their delayed visual memory scores at Time 2.

Hypothesis Four

It is hypothesized that bilingual children who have had a traumatic brain injury will have a greater discrepancy (> 1SD) between their verbal and nonverbal memory scores (with verbal having a lower standard score) compared to monolingual children who have had a traumatic brain injury when controlling for age of language acquisition and age when TBI was obtained. Analyses included a within-between subjects mixed design ANCOVA including the between participants factors of bilingual or monolingual, repeated measures for Time 1 (3 month) and Time 2 (12 month) with the dependent variables of verbal memory and nonverbal memory while controlling for age of second language acquisition and age when TBI occurred.

In order to assess for both immediate and delayed memory, two separate mixed model ANCOVA’s were conducted that assessed both verbal and nonverbal immediate memory and another that assessed both verbal and nonverbal delayed memory. When running the mixed model ANCOVA, only the age when TBI was obtained was used given that the age of language acquisition was very similar for all participants. Due to the small sample size and in order to preserve power, only the age when TBI was obtained was used as the covariate.

Immediate Memory

There were no significant main effects of immediate memory across time that were found (all *p*'s > .05) (See Table 6).

Table 6.

ANCOVA of Bilingual/Monolingual Immediate Memory Scores Across Time

Sources of Variation	**SS**	**Df**	**MS**	**F**	***P*-Value**
Immediate Memory Time 1	182.14	1	182.14	1.00	0.33
Immediate Memory Time 2	73.30	1	73.30	0.26	0.62
Age	1215.21	1	1215.21	2.93	0.11
Language Spoken	501.39	1	501.39	1.21	0.29

However, a significant interaction was present between immediate memory at Time 1 (3 month evaluation) and immediate memory at Time 2 (12 month) $F(1, 15) = 11.59$, $p < .01$, r = 0.89. This indicates that as a group, monolinguals/bilinguals' verbal immediate memory scores (M = 93.39, SE = 4.22) and nonverbal immediate memory scores (M = 98.78, SE = 4.22) at Time 1 (3 month) were significantly lower than their verbal immediate memory scores (M = 99.39, SE = 4.28) and nonverbal immediate memory scores (M = 118.33, SE 2.64) at Time 2 (12 month). At Time 1 there appears to be a very small discrepancy between verbal and nonverbal memory compared to the much larger discrepancy apparent at Time 2 between verbal and nonverbal memory (See Fig. 19).

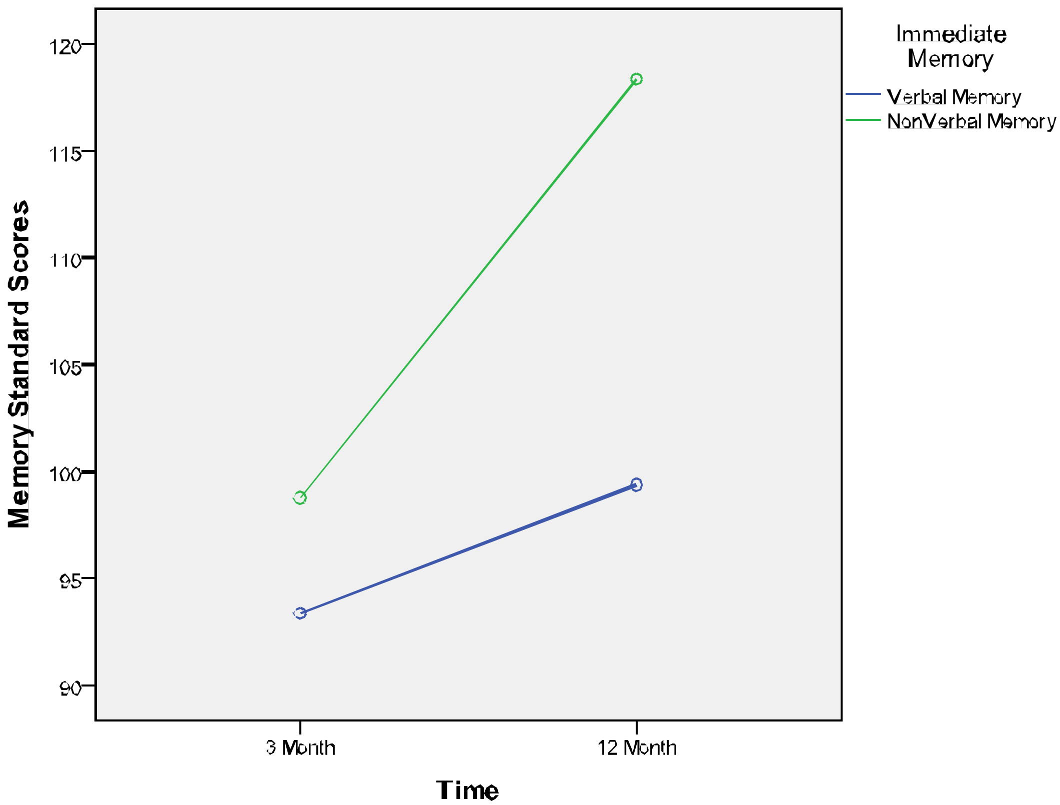
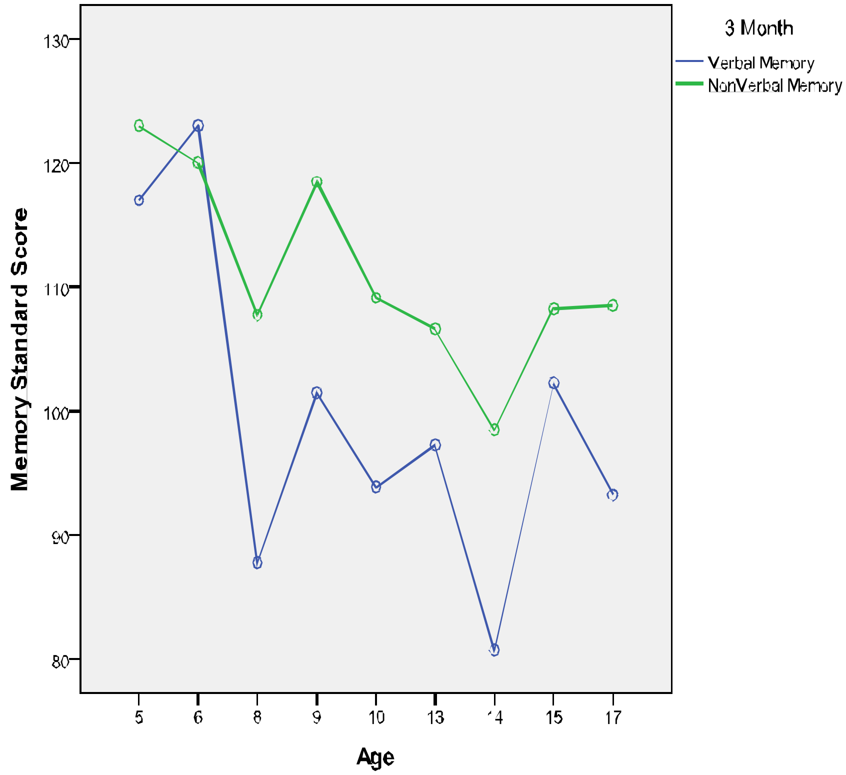


Figure 19. Immediate Memory Across Both Time Points

There is also a significant three way interaction between immediate memory at Time 1, immediate memory at Time 2, and age $F(1, 15) = 6.81$, $p = .02$, r = 0.68. It appears that younger children (specifically ages 5 and 6) do not have as many difficulties with verbal and nonverbal immediate memory at either evaluation time point. However, the older the child is when the TBI occurs, the more difficulty they have with their immediate memory. Also, verbal immediate memory appears to be more significantly impacted compared to nonverbal memory at both time points as stated above (See Fig. 20).



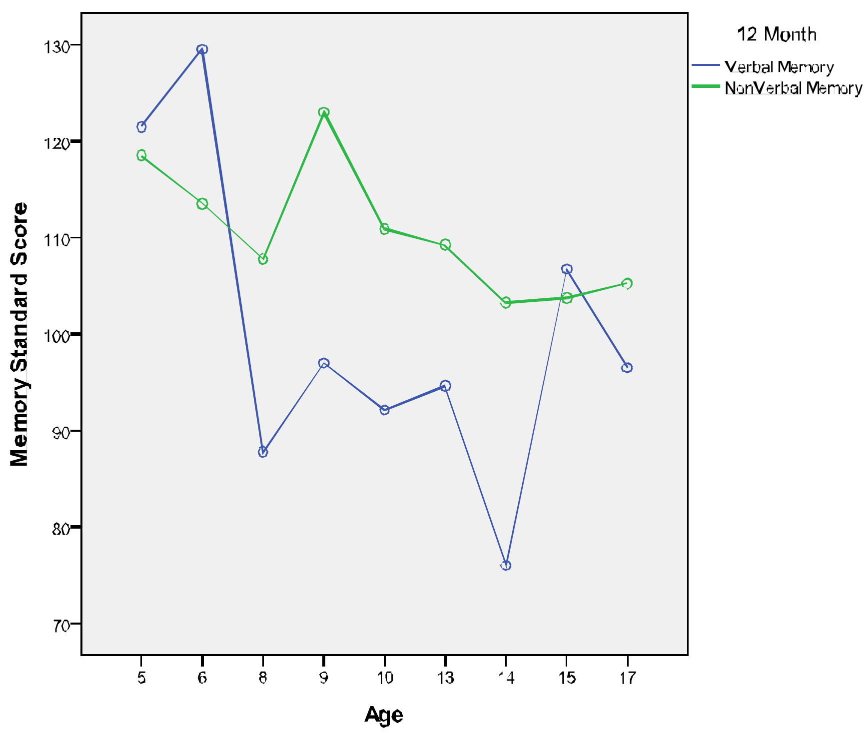


Figure 20. Immediate Memory Across Age at Both 3 Month and 12 Month Evaluations

Delayed Memory

There was a significant main effect of age on delayed memory $F(1, 15) = 8.79$, $p = .01$, r = 0.79 (See Table 7).

Table 7.

ANCOVA of Bilingual/Monolingual Delayed Memory Scores Across Time

Sources of Variation	SS	Df	MS	F	*P*-Value
Delayed Memory Time 1	48.55	1	48.55	0.63	0.44
Delayed Memory Time 2	353.01	1	353.01	1.58	0.23
Age	2940.78	1	2940.78	8.79	0.01
Language Spoken	180.50	1	180.50	0.54	0.47

Moreover, a significant interaction was present between delayed memory at Time 1 (3 month evaluation) and age $F(1, 15) = 5.59$, $p = .03$, r = 0.60. In general, monolingual/bilinguals appear to have a significantly lower delayed verbal memory at Time 1 (M = 98.14, SE = 2.37) compared to their delayed nonverbal memory at Time 1 (M = 108.86, SE = 2.41). It appears that younger children (specifically ages 5 and 6) do not have as many difficulties with verbal and nonverbal immediate memory at either time point of evaluation. However, the older the child is when the TBI occurs, the more difficulty they have with their delayed memory. Also, delayed verbal memory appears to be more significantly impacted compared to nonverbal memory at the 3 month evaluation (See Fig. 21).

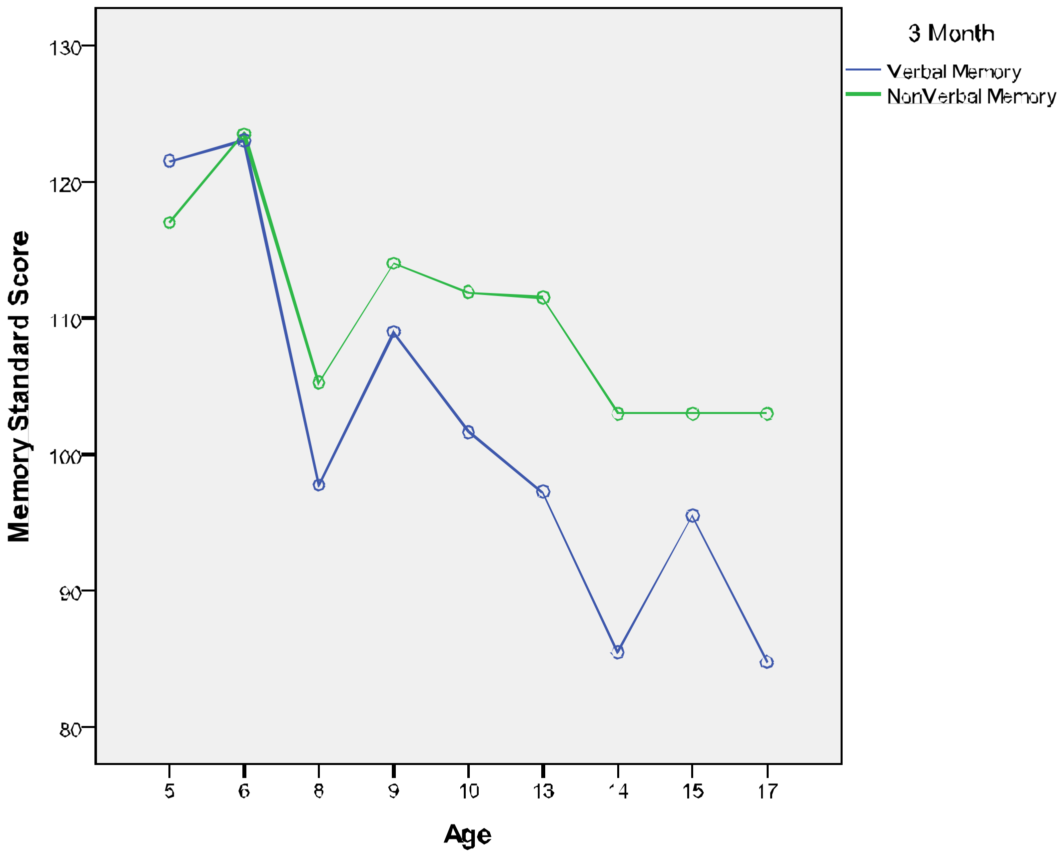


Figure 21. Delayed Memory Across Age at 3 Month Evaluation

A significant interaction was also present between delayed memory at Time 1 and delayed memory at Time 2. This indicates that as a group monolinguals/bilinguals' delayed verbal memory scores (M = 94.89, SE = 3.07) and delayed nonverbal memory scores (M = 101.39, SE = 3.47) at Time 1 (3 month) were significantly lower than their delayed verbal memory scores (M = 101.00, SE = 3.23) and delayed nonverbal memory scores (M = 116.72, SE 2.40) at Time 2 (12 month). At Time 1 there appears to be a very small discrepancy between verbal and nonverbal memory compared to the much larger discrepancy apparent at Time 2 between verbal and nonverbal memory (See Fig. 22).

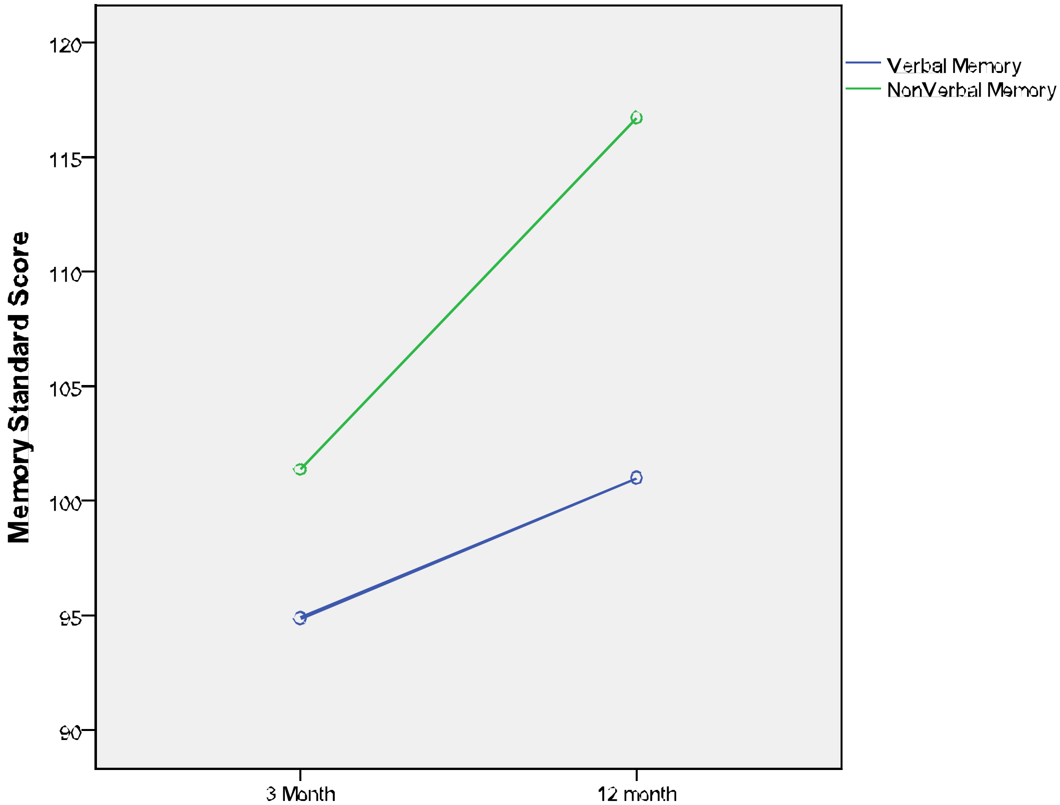


Figure 22. Delayed Memory Across Both Time Points.

CHAPTER FOUR

DISCUSSION

Little is known about the effects of pediatric traumatic brain injury on the bilingual brain. It is imperative to understand whether the bilingual brain has a different response to TBI than a monolingual in order to better serve this population with appropriate interventions throughout the recovery process. The bilingual brain is of particular interest since previous research has shown that verbal IQ tends to be significantly lower than performance IQ within the pediatric TBI population (Babikian and Asarnow, 2009; and Jonsson, Smedler, Ljungmark, & Emanuelson, 2009). With the number of bilinguals increasing annually within the United States, it becomes clinically imperative to understand what differences exist within this subpopulation in order to facilitate early identification and interventions for this subpopulation.

VIQ is a known weakness in a pediatric TBI population. What is not apparent is whether a significant difference exists in the verbal IQ's of monolingual and bilingual children who have experienced a TBI. If children who are bilingual incur a TBI, will they have even more difficulty than monolinguals with language tasks because they have a smaller vocabulary base? Will bilinguals perform better on PIQ measures that focus on executive functions and attention because of their strength with inhibitory control and attention in accordance with the interference theory? The purpose of this study was to investigate whether a significant difference exists between a bilingual child's VIQ and PIQ after they have incurred brain damage as well as if there are significant differences between a bilingual child's verbal and nonverbal memory when compared to monolingual children who have incurred a traumatic brain injury.

This study further elucidated whether verbal memory was more severely impacted than nonverbal memory in this same bilingual pediatric TBI population. We know that verbal memory is more adversely affected in individuals who have undergone a head injury than nonverbal memory. However, will there be the same discrepancy in an individual who is bilingual? Due to smaller vocabulary that bilinguals have compared to monolinguals, they may have more difficulty remembering verbal or language based information, especially on subtests that have no context such as unrelated word pairs.

This study differed from previous research in that the comparison group was monolingual children who had sustained a TBI rather than a non TBI group. This allowed the researcher to begin to gain an understanding of whether there are significant cognitive differences between the injured monolingual and bilingual brain in a pediatric population. Based on the previous research stated presently, the expectation was that there would be significant differences with lower VIQ's and more adversely affected verbal memories. As such, it was hypothesized that a TBI in a bilingual child would further exacerbate the VIQ/PIQ split as well as the verbal memory and nonverbal memory split.

This study analyzed archival data collected by the study's investigators. The data for this study included eighteen children with moderate to severe TBI from Loma Linda University's Children Hospital (11 males, 7 females) with a mean age of approximately 11 (M = 11.67), and their parents (8 mothers, 1 father). Of the 18 participants, 9 were bilingual (Spanish-English) and 9 were monolinguals (English). Of the bilingual participants, 4 were female and 5 were male. Of the monolingual participants, 3 were female and 6 were male.

Hypothesis One

It was hypothesized that bilingual children who had a traumatic brain injury would have significantly lower VIQ's compared to their own PIQ's when controlling for age of language acquisition and age when TBI was obtained. The results showed no significant findings. It is important to note that the sample size of 9 was small and it is possible that different results could come from a larger sample.

In lieu of the small sample size, a paired samples t-test was conducted and still no significant findings were present. It appears that in this sample of bilingual pediatric TBI patients significant differences do not exist between a bilingual's VIQ/PIQ at Time 1 (3 month) compared to their VIQ/PIQ at Time 2 (12 month). Also no significant differences were found between their VIQ and PIQ scores in general. This suggests that there may not be much recovery between the 3 month and 12 month evaluations after a TBI when looking at IQ because the differences between both time points are so minute. Interestingly, these findings contradict what the existing body of research regarding VIQ/PIQ splits in the pediatric TBI monolingual population. It is possible that bilinguals have a stronger cognitive barrier and may not be as drastically impacted by a TBI as the monolingual brain, as research has shown that both hemispheres appear to be active in the bilingual brain when accessing and learning language. Marrero, Golden, & Espe-Pfeifer (2002) reported that the left hemisphere is more involved in formal language learning while the right hemisphere is more involved in informal language learning. The authors explained that when one begins to learn a second language, even if they do so formally, the left hemisphere as well as the right would be active. The right is activated because the information is new and the left is activated because certain ideas and activities of learning a second language are automatic and repetitive.

According to interference theory (Mindt et al., 2008), the bilingual brain is constantly inhibiting one language in order to access the other. The combination of more areas of the bilingual brain being dedicated to language as well as the bilingual brain constantly inhibiting one language in order to access the other may create a cognitive buffer. What some research has found is that a cognitive buffer appears to exist in regards to later onset dementia in bilinguals compared to monolinguals (Bialystok, Craik, and Freedman, 2007).

Another interesting finding within this population is that bilingual's VIQ and PIQ scores at Time 1 were extremely similar with both mean standard scores falling at 91. The similarity suggests that a bilingual's verbal ability is not as negatively impacted by TBI as was hypothesized. It is probable that since previous research has shown that some of both hemispheres may be dedicated to language in a bilingual brain while only one (typically left) hemisphere is dedicated to language in the monolingual brain, that a bilingual brain has more plasticity and compensation for language deficits compared to that of a monolingual brain. For a researcher to better investigate these findings, it would be beneficial to have localization data through the use of MRI or MRS. One could compare the localization and severity of the injury to the neuropsychological assessment findings to come up with a more detailed understanding and explanation.

The WASI is a screener and not a full battery. Cognitive deficits and subtle language deficits may not be picked up by the Wechsler population norms and may not reveal severity of deficits compared to the normative population that was originally used to make up the norms (Massagli et al., 1996). It was shown that throughout their study (Massagli et al., 1996) when severe TBI's were compared to a control group, deficits were more significantly pronounced in the TBI group than when comparing the TBI group only to population norms from the assessment manual. This hypothesis investigates bilinguals specifically and compares their scores to the WASI norms, alone. As stated above, it is possible that deficits will not be as significant when there is not a control group for comparison. Also it is important to note that the normative population of the WASI does not have pediatric TBI patients as part of their normative sample, which may lead to underpathology of the TBI patient's cognitive deficits.

Hypothesis Two

It was hypothesized that bilingual children who had a traumatic brain injury would have greater splits between their VIQ and PIQ's (with PIQ being the higher value) compared to monolingual children who had incurred a traumatic brain injury when controlling for age of language acquisition and age when TBI was obtained.

No significant main effects were found when comparing bilinguals' VIQ and PIQ scores at Time 1 and Time 2 to monolingual VIQ and PIQ scores at Time 1 and Time 2. However, a significant interaction was present between bilingual/monolingual and IQ at Time 2 (12 month) which indicates that bilingual or monolingual status did have an effect on IQ at their 12 month evaluation. Monolinguals appeared to have a greater difference between their VIQ and PIQ during their 12 month evaluation compared to the difference evident in bilinguals' VIQ and PIQ. Monolinguals appear to have significantly lower VIQ's compared to their PIQ's while bilinguals do not at Time 2. Similarly, with bilinguals, the difference between their VIQ and PIQ at Time 1 compared to Time 2 is not significantly different. Interestingly, monolinguals appear to have the larger discrepancy at Time 2 and a significant increase in their PIQ score at Time 2 compared to Time 1. This suggests that there is ongoing recovery between the 3 month evaluation and the 12 month evaluation in regards to performance IQ, specifically within the monolingual brain. However, it appears that monolinguals do not have the same recovery for their VIQ. In this sample their VIQ improved by 3 standard score points between time points, which is not considered to be significant. It appears that once a monolingual's language is impacted, there is not much recovery that occurs over time. The bilingual brain appears to, at first, have more of a cognitive barrier to TBI. However, in regards to recovery, the bilingual brain does not experience the same significant increase in scores over time especially in regards to verbal cognitive factors. The research has shown that verbal ability tends to be lower than nonverbal ability in pediatric TBI populations (Babikian and Asarnow, 2009) which is what this study has found. It has also been shown that PIQ tends to increase significantly over time in pediatric TBI (Babikian and Asarnow, 2009).

Another prominent finding is that of the "double hazard" injury model. Children who incur a severe TBI do no reach developmentally appropriate gains when compared to their same aged peers. Not only do these individuals fail to catch up to their developmental peer group, they seem to fall even further behind in their developmental progression over time (Babikian and Aarnow, 2009). It is possible that this effect is particularly true for verbal ability when focusing on cognitive ability alone in both monolinguals and bilinguals. In regards to bilinguals' ability appearing to plateau over time, it may be that the “double hazard” injury model is supported. It may also reflect support for Mindt et al.’s (2008) explanation that bilinguals tend to have more difficulty in a monolingual class in which they are prohibited to use both of their languages. A greater disparity is created between both languages and there is much more difficulty in trying to learn the second language.

Also there was an interaction approaching significance between age at TBI and IQ score at Time 2 (12 month). The effect is linear suggesting the older the individual the higher their IQ scores should be. This is understandable, as IQ is highly influenced by education and one learns more with age. It is probable that with a larger sample size this interaction would be significant.

Hypothesis Three

It was hypothesized that bilingual children who had a traumatic brain injury would have a significant discrepancy (> 1SD) between their verbal and nonverbal memory scores (with verbal having a lower standard score) when controlling for age of language acquisition and age when TBI was obtained.

Immediate Memory

A significant interaction was present between immediate memory at Time 1 (3 month) and immediate memory at Time 2 (12 month) which indicates that bilinguals’ verbal immediate memory scores and nonverbal immediate memory scores at Time 1 (3 month) were significantly lower than their verbal immediate memory scores and nonverbal immediate memory scores at Time 2 (12 month). At Time 1 there appears to be a very small discrepancy between verbal and nonverbal memory compared to the much larger discrepancy apparent at Time 2 between verbal and nonverbal memory. It appears that bilingual participants seem to have much more recovery in their nonverbal memory from the 3 month to 12 month evaluation. Interestingly there is some recovery in their verbal memory but not as significant of a difference as their nonverbal memory. It is possible that children who experience TBI's whether bilingual or monolingual tend to have greater recovery in their nonverbal memory. This finding could be further elucidated if localization and severity of injury were specifically obtained for each individual subject. With localization of injury, the investigator would be able to understand what part of the brain is being impacted and how that portion contributes to immediate memory in this case. Severity of injury has a positive correlation with more drastic and long term consequences. The more severe the injury, the greater the negative impact on neuropsychological function (Babikian and Asarnow, 2009; Ewing-Cobbs et al., 2006). Having both localization and severity of injury information for each individual subject would allow for a clearer understanding of what processes are being disrupted in the brain and how they are being disrupted when looking at neuropsychological assessment results. Also there was a 3 way interaction approaching significance between age that TBI was obtained, memory scores at Time 1 (3 month), and memory scores at Time 2 (12 month). The effect is linear suggesting the older the individual, the higher their memory scores should be at both Time 1 and Time 2. Interestingly the same pattern is emerging for both memory and IQ although both interactions are nearing significance.

Lastly a paired samples t-test was conducted to assess whether significant differences existed between a bilingual's immediate verbal memory at Time 1 (3 month) compared to their immediate verbal memory at Time 2 (12 month) and their immediate nonverbal memory at Time 1 compared to their immediate nonverbal memory at Time 2. Bilinguals nonverbal immediate memory score at Time 2 was significantly higher compared to their nonverbal immediate memory score at Time 1. This suggests that the interaction that occurred above was highly impacted by the statistically significant difference in the bilinguals' nonverbal memory scores. A possible occurrence is that in this subpopulation there appears to be more recovery with nonverbal cognitive domains than verbal ones. It is important to note that the literature has found that individuals with low Social Economic Status (SES) tend to have lower scores on neuropsychological assessments (Keenan, Runyan, and Nocera, 2006; Haider et al., 2007; Catroppa, Anderson, Morse, Haritou, and Rosenfeld, 2008; & Taylor et al., 2008). Functional and behavioral outcomes are particularly affected by low SES. It is posited that due to low SES individuals have less access to healthcare and rehabilitative services after a TBI as well as access to overly large classrooms and poorer education. However, it is important to note that this study does not have access to the participants SES status. Future studies that focus on bilingual individuals should also consider SES as a covariate or matching participants monolingual, bilingual, and controls across SES, age, and severity/location of injury.

A paired samples t-test was conducted to assess whether a significant difference existed for bilinguals between immediate verbal memory and immediate nonverbal memory at Time 1 and Time 2. On average, bilinguals had significantly lower immediate verbal memory scores compared to their immediate nonverbal memory at Time 2. Again this appears to reinforce the recovery of immediate nonverbal memory and the plateau or flattening of immediate verbal memory across time points.

Delayed Memory

A paired samples t-test was conducted to assess whether significant differences existed between a bilingual's delayed verbal memory at Time 1 (3 month) and at Time 2 (12 month) and their delayed nonverbal memory at Time 1 and at Time 2. Bilinguals delayed nonverbal memory score at Time 2 was significantly higher compared to their delayed nonverbal memory score at Time 1. The same pattern of a significant difference with a better performance at Time 2 is occurring with delayed nonverbal memory as was seen with immediate nonverbal memory. On average, bilingual TBI participants had significantly lower delayed verbal memory scores compared to their delayed visual memory scores at Time 2. The same patterns with both immediate and delayed memory appear to be present. There appears to be significant recovery with nonverbal memory and some recovery with verbal but not a significant amount. Whether it is immediate or delayed memory the verbal memory appears to flatten or plateau between the 3 month and 12 month. The pattern of delayed verbal memory being so significantly impacted has been found before in the literature with pediatric TBI. Specifically, children with TBI had significantly worse scores on immediate and delayed verbal memory tasks and immediate recall of a nonverbal memory task. However, the TBI sample performed as well as the matched controls on a task of delayed visual recall (Lowther and Mayfield, 2004). In fact, it has been found that verbal memory appears to be the most impacted score in pediatric TBI (Jonsson, Smedler, Ljungmark, & Emanuelson, 2009; & Wirsen and

Ingvar, 1991). Verbal memory and delayed verbal memory appear to be the most impacted cognitive domain when looking at memory and ability in pediatric TBI.

Hypothesis Four

It was hypothesized that bilingual children who have had a traumatic brain injury will have a greater discrepancy (> 1SD) between their verbal and nonverbal memory scores (with verbal having a lower standard score) compared to monolingual children who have had a traumatic brain injury when controlling for age of language acquisition and age when TBI was obtained.

Immediate Memory

A significant interaction was present between immediate memory at Time 1 (3 month) and at Time 2 (12 month) indicating that as a group monolinguals/bilinguals' verbal immediate memory scores and nonverbal immediate memory scores at Time 1 were significantly lower than their verbal immediate memory scores and nonverbal immediate memory scores at Time 2. At Time 1 there is a very small discrepancy between verbal and nonverbal memory compared to the much larger discrepancy apparent at Time 2 between verbal and nonverbal memory. The pattern of increased recovery with nonverbal memory at Time 2 appears to exist within the monolinguals as well when both groups are combined. It is possible that the variance could be accounted for by the strength of this same effect that was seen in bilinguals previously in this study. However, previous literature has shown that in the pediatric TBI population there appears to be a significant decrease in verbal memory compared to visual memory overall (Jonsson, Smedler, Ljungmark, & Emanuelson, 2009; & Wirsen and Ingvar, 1991).

There is also a significant three way interaction between immediate memory at Time 1, immediate memory at Time 2, and age. It appears that younger children (specifically ages 5 and 6) do not have as many difficulties with verbal and nonverbal immediate memory at either time point of evaluation. It could be suggested that at ages of 5 and 6 there is less information to be lost since not very much has been learned as of yet. It could also be suggested that the brain may have more plasticity at a younger age. This plasticity may allow the brain to afford a significant amount of damage and recover over time. However, the older the child is when the TBI occurs the more difficulty they have with their immediate memory after their TBI. On average, there also appears to be a great discrepancy between verbal and nonverbal immediate memory in children age 7-16. Also, verbal immediate memory was significantly impacted compared to nonverbal memory at both time points as stated above. Immediate memory is more specific to learning than recall over a period of time. Ewing-Cobbs et al. (2006) showed that children who incurred a TBI performed significantly worse than non-TBI controls on tests of verbal achievement. It is possible that immediate verbal memory associated with immediate recall of word lists and stories in this study may be more severely impacted by TBI. The younger children only make up two of the subjects out of 18 which accounts for 11% of the sample. It may be that these two children happen to have higher memory scores in general due to high baseline functioning. Also, their TBI may have been more moderate compared to the more severe TBI's as this study did not differentiate between severity of injury for each individual participant.

Delayed Memory

There was a significant main effect for age on delayed memory. It appears that age plays a significant role in contributing to the variance of delayed memory. Moreover, a significant interaction was present between delayed memory at Time 1 (3 month) and age. In general, monolingual/bilinguals have a significantly lower delayed verbal memory at Time 1 compared to their delayed nonverbal memory at time 1. It appears that younger children (specifically ages 5 and 6) do not have as many difficulties with verbal and nonverbal immediate memory at either time point of evaluation. However, the older the child is when the TBI occurs, the more difficulty they have with their delayed memory. Also, delayed verbal memory appears to be more significantly impacted compared to nonverbal memory at the 3 month time point. Moreover, it is important to note that in this study only two of the participants were aged 5 and 6. As such it may be that this sample size of 2 may have simply had higher scores due to better baseline functioning before the TBI (which this study cannot assess for). However, while the majority of the literature states that more deficits and longer term consequences occur in younger children ages 2-6 after suffering a moderate TBI (Babikian and Asarnow, 2009), other literature states that younger children do not appear to have more global deficits when compared to older children (Taylor et al., 2008). A difference in Taylor et al.'s (2008) study is that the children were all younger (aged 3-6) while a majority of other studies including those reviewed in Babikian and Asarnow's (2009) meta analytic review used children of all ages in their studies. Taylor et al. (2008) also only assessed the children at 3 months after injury while other studies such as that by Ewing-Cobbs et al. (2004) looked at longitudinal assessment points over many years. In the current study, however, it was also found that younger children did not appear to have significant deficits compared to older children.

A significant interaction was also present between delayed memory at Time 1 and delayed memory at Time 2. This indicates that as a group monolinguals/bilinguals' delayed verbal memory scores and delayed nonverbal memory scores at Time 1 (3 month) were significantly lower than their delayed verbal memory scores and delayed nonverbal memory scores at Time 2 (12 month). At Time 1 there appears to be a very small discrepancy between verbal and nonverbal memory compared to the much larger discrepancy apparent at Time 2 between verbal and nonverbal memory. Again there appears to be much more recovery with nonverbal memory than verbal memory across the two time points for both groups.

Study Limitations, Clinical Significance, and Future Directions

The greatest deficit of this study is the sample size. Although this is a specialized subpopulation and it is difficult to attain a bigger sample size, a sample closer to a total of 30 participants for each group would have increased the power of the study as well as allowed for more variance in the data. For the statistical analyses that were conducted, a sample of 18 was sufficient; however, future studies should attempt to obtain larger groups. Another weakness of this study is the lack of demographic information like ethnicity and SES. These variables have played a significant role in long term consequences of behavioral functional outcome in pediatric TBI over time (Taylor et al., 2008 and Haider et al., 2007). Some of the subjects in this study may have had a history of ADHD before their TBI, which could have influenced their assessment scores particularly if they are not able to attend to the material being presented to them. It has been shown that children with premorbid ADHD before TBI perform worse than children who have incurred a TBI without a history of ADHD. Children who have premorbid ADHD and incurred a TBI have significantly worse scores on attention, executive functioning, and memory tasks (Slomine et al., 2005). Research has shown that on average 20% of children who incur a TBI have a premorbid diagnosis of ADHD (Slomine et al., 2005; Gerring et al., 1998). However, it was also found over a 2 year longitudinal study that the majority of premorbid ADHD cases were of the hyperactive type. Slomine et al. (2005) showed that over the 2 year period children with premorbid ADHD hyperactive symptoms increased after incurring a TBI. After TBI a child with premorbid ADHD would have increased hyperactive symptomatology which could be observed by the researcher administering the evaluation. It is possible that some of the participants in this study may have had a premorbid diagnosis of ADHD which could have more negatively impacted their scores on the assessment measures.

Future studies should also focus on assessing the localization and severity of the injury for each subject. While this study's participants were all moderate to severe TBI's it would have enriched the significance of the data to have associated injury location. Knowing the location and the neuropsychological assessment scores for each individual subject would allow for more specific answers and ideas regarding what organic recovery has occurred over time. This study also did not differentiate between severity for each individual participant. All participants were either moderate or severe TBI. However, it would be interesting to see if there are differences between moderate and severe TBI within the bilingual population. Babikian and Asarnow (2009) have shown that there are differences within type of severity of cognitive deficit based on severity of injury. Future studies could assess differences within each group especially the severe TBI group. Babikian and Asarnow (2009) have found that there appears to be a difference in cognitive performance even with the severe TBI group. The more severe the TBI, the poorer the performance. Addressing severity of injury would be an important step for future studies. Some of the moderate TBI's in this study may have been closer to mild leading to possibly better scores when comparing with more severe TBI's such as the 5 and 6 year old in this study. Type of injury could play a significant role as well. If the child had a closed or an open head injury; with open head injuries having a worse outcome would most likely impact their performance on neuropsychological assessment. Assessing for whether and/or how long there was intracranial pressure would be important. The more intracranial pressure that exists over extended periods of time the more brain is stressed and the worse the outcomes over time (Padayachy, Figajl, & Bullock, 2010).

Future studies could consider using a full neuropsychological battery rather than a screener (i.e., the WISC-IV instead of the WASI). This would allow the investigator to further look into the VIQ/PIQ split and specifically to further study what aspects of the PIQ are significantly increased if there are specific aspects. Using a full battery would allow for 3 to 4 subtests that make up each index instead of only two making up each index. Also a comparison could be made between working memory and immediate memory since there is a working memory index. Lastly, processing could be assessed as previous studies have found that individuals who incur a TBI tend to have significantly slower processing speeds. Future studies could also look at a non-TBI monolingual and non-TBI bilingual control groups in order to assess whether TBI affects the bilingual and monolingual brains differently across cognitive domains. Another important factor for future studies to consider would be premorbid academic functioning. The researcher could use premorbid academic functioning as a baseline of comparison. Many studies have found that IQ is positively correlated with higher academic achievement (Ewing-Cobbs et al., 2006). This would allow for at least some type of measure of premorbid functioning prior to the TBI.

The importance of early and appropriate referrals is critical to improve longitudinal outcome (Catroppa, Anderson, Morse, Haritou, and Rosenfeld, 2008). The earlier the appropriate referral is given the better the cognitive outcome overtime. In fact this author worked on a case study that was an example of this (Alberty, Arratoonian-Vedda, Pivonka-Jones, & Freier Randall, 2011). Two subjects from this study who were matched for age, severity of injury, gender, and ethnicity but were not matched on SES or premorbid academic functioning showed significantly different outcomes at both time points. The subject whose parents had greater education and higher SES ensured that their child was given rehabilitative services immediately. At her 3 month evaluation, her cognitive abilities fell in the average range. Meanwhile, the other child whose family was low SES and was not referred for any rehabilitative services, had impaired cognitive functioning even at the 12 month evaluation, albeit her premorbid academic fell in the C (average to below average) range. This speaks to the clinical significance of rehabilitative services as well as ensuring that individuals with low SES are given such services.

While it is true that it is most important to utilize neuropsychological assessments on an individualized basis to understand each patient’s specific and unique needs (as pediatric TBI patients do exhibit diverse profiles), it is as important to understand trends and themes and, perhaps even more importantly, sub populations like bilingual patients, to more effectively and accurately identify possible deficits. It has been shown that African American children experience worse clinical and functional outcomes after incurring a TBI (Haider et al., 2007). The article shows this to be true because black children are a minority that tend to fall within the low SES category leading to poorer health care and possibly poorer education. A poorer education could mean that a child's brain is not as highly developed as a same aged peer who happens to go to a small private school with more rigorous classes and expectations. It is has already been shown that in one subpopulation African American children have been impacted negatively by TBI when compared to white children who have incurred a TBI.

It is equally important to understand whether there are differences within a bilingual population. For example in the current study, Spanish English bilinguals (who are Latinos, which is another minority that tends to fall within the low SES categories), were the participants. Future studies could look to see whether there is a correlation between low SES in this minority and pediatric TBI as was found with African American children.

Overall this study has shown that bilinguals do not appear to have a significant difference between their VIQ/PIQ splits. In fact it appears that bilinguals when compared to monolinguals have a much smaller and non significant split between their VIQ/PIQ. In regards to IQ the bilingual brain does not appear to have as significant a change after TBI, although it also does not have as significant an improvement over time as the monolingual brain. The bilingual brain does not appear to have significant changes in

VIQ, immediate, or delayed verbal memory. More significant improvements are seen within the monolingual brain. The greatest recovery for both bilinguals and monolinguals appears to occur over time with immediate and delayed nonverbal memory.

It has been highlighted through this study that significant differences exist in recovery over time in the monolingual compared to the bilingual brain. Bilinguals appear to have a different trajectory and do not have significant splits between their VIQ/PIQ despite most pediatric TBI studies showing this split to be a common consequence of TBI. This study has highlighted that over time bilinguals appear to have less recovery in both their cognitive ability and memory compared to monolinguals. These differences in recovery within the bilingual brain may necessitate different types of cognitive rehabilitation and services after a TBI compared to a monolingual TBI. It is clinically imperative to understand what differences occur in order to better meet the treatment needs of the bilingual pediatric TBI population and ensure the quickest and most effective type of recovery. This study is a stepping stone in beginning to understand the bilingual brain’s unique needs after incurring a TBI.

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APPENDIX A

GLASGOW COMA SCALE

Eye Opening Response

• Spontaneous--open with blinking at baseline **4 points**
• To verbal stimuli, command, speech **3 points**
• To pain only (not applied to face) **2 points**
• No response **1 point**

Verbal Response

• Oriented **5 points**
• Confused conversation, but able to answer questions **4 points**
• Inappropriate words **3 points**
• Incomprehensible speech **2 points**
• No response **1 point**

Motor Response

• Obeys commands for movement 6 points
• Purposeful movement to painful stimulus 5 points
• Withdraws in response to pain 4 points
• Flexion in response to pain (decorticate posturing) 3 points
• Extension response in response to pain (decerebrate posturing) 2 points
• No response 1 point

APPENDIX B

MAYO TBI SEVERITY CLASSIFICATION SYSTEM

A. Classify as Moderate-Severe (Definite) TBI if one or more of the following criteria apply:
1. Death due to this TBI
2. Loss of consciousness of 30 minutes or more
3. Post-traumatic anterograde amnesia of 24 hours or more
4. Worst Glasgow Coma Scale full score in first 24 hours < 13 (unless invalidataed upon review, e.g., attributableto intoxication, sedation, systemic shock)
5. One or more of the following present:
• Intracerebral hematoma
• Subdural hematoma
• Epidural hematoma
• Cerebral contusion
• Hemorrhagic contusion
• Penetrating TBI (dura penetrated)
• Subarachnoid hemorrhage
• Brain Stem Injury

B. If none of Criteria A apply, classify as Mild (Probable) TBI if one or more of the following criteria apply:
1. Loss of consciousness of momentary to less than 30 minutes
2. Post-traumatic anterograde amnesia of momentary to less than 24 hours
3. Depressed, basilar or linear skull fracture (dura intact)

C. If none of Criteria A or B apply, classify as Symptomatic (Possible) TBI if one or more of the following symptoms are present:
• Blurred vision
• Confusion (mental state changes)
• Dazed
• Dizziness
• Focal neurologic symptoms
• Headache
• Nausea

APPENDIX C

LEVEL OF LANGUAGE PROFICIENCY

1. What is your current preferred language for conversation? English / Spanish / Both
2. For how many years has this been your preferred language? _________________.
3. What language did you learn first as a child? ______________.
4. When did you begin to learn your second language? ___________________.
5. What language do you speak predominately at home? _____________.
6. Rate your current ability to speak Spanish:

1	2	3	4	5
MINIMAL		MODERATE		HIGH

7. Rate your current ability to understand Spanish:

1	2	3	4	5
MINIMAL		MODERATE		HIGH

8. Rate your current ability to speak English:

1	2	3	4	5
MINIMAL		MODERATE		HIGH

9. Rate your current ability to understand English:

1	2	3	4	5
MINIMAL		MODERATE		HIGH

Scoring: Add the two Spanish ratings (i.e., questions 6 &7). Add the two English ratings (i.e., questions 8 & 9). Subtract the English rating total from the Spanish rating total. A positive score = greater self-rated proficiency in Spanish.

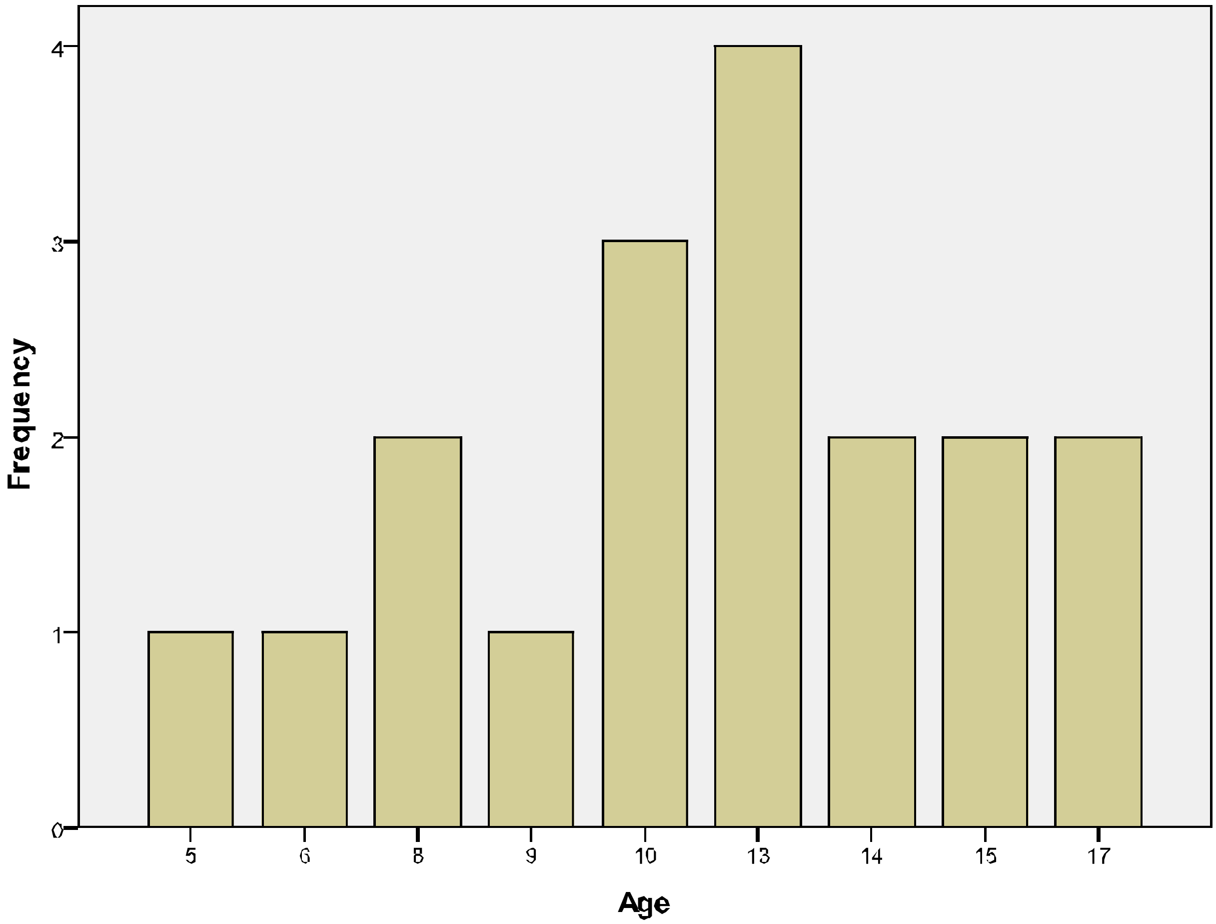

Figure 1. Ages of All 18 participants

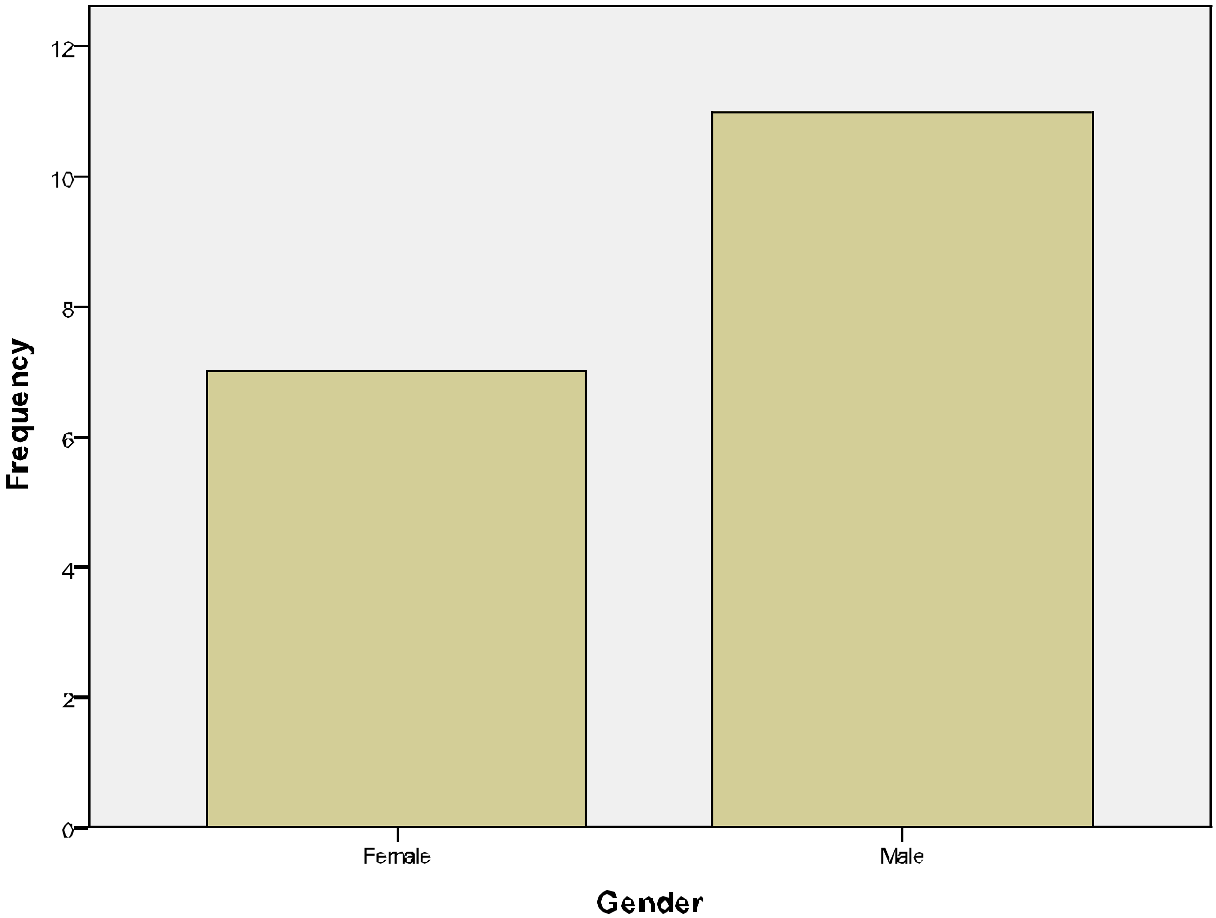

Figure 2. Gender Distribution of all 18 Participants

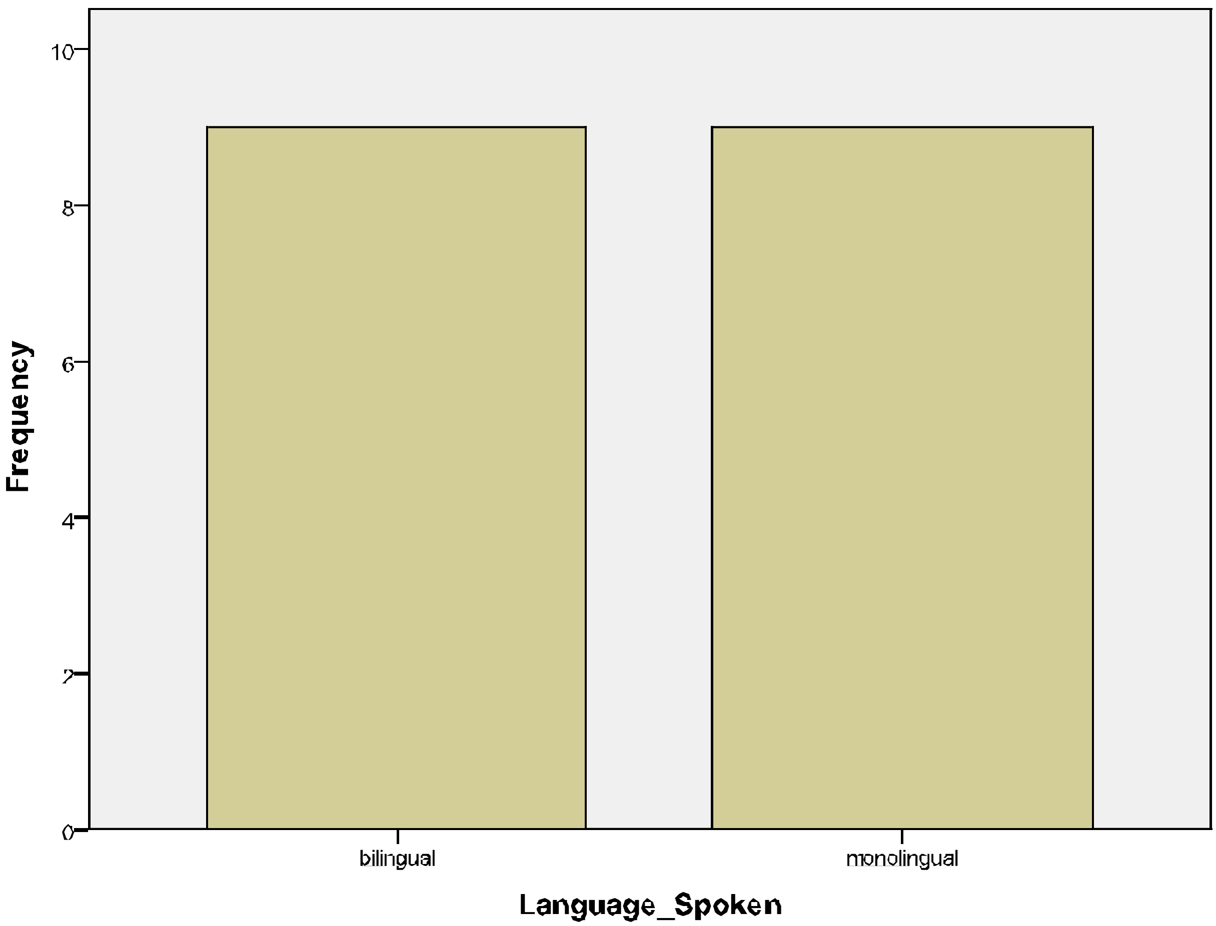

Figure 3. Number of Monolingual and Bilinguals in the Study

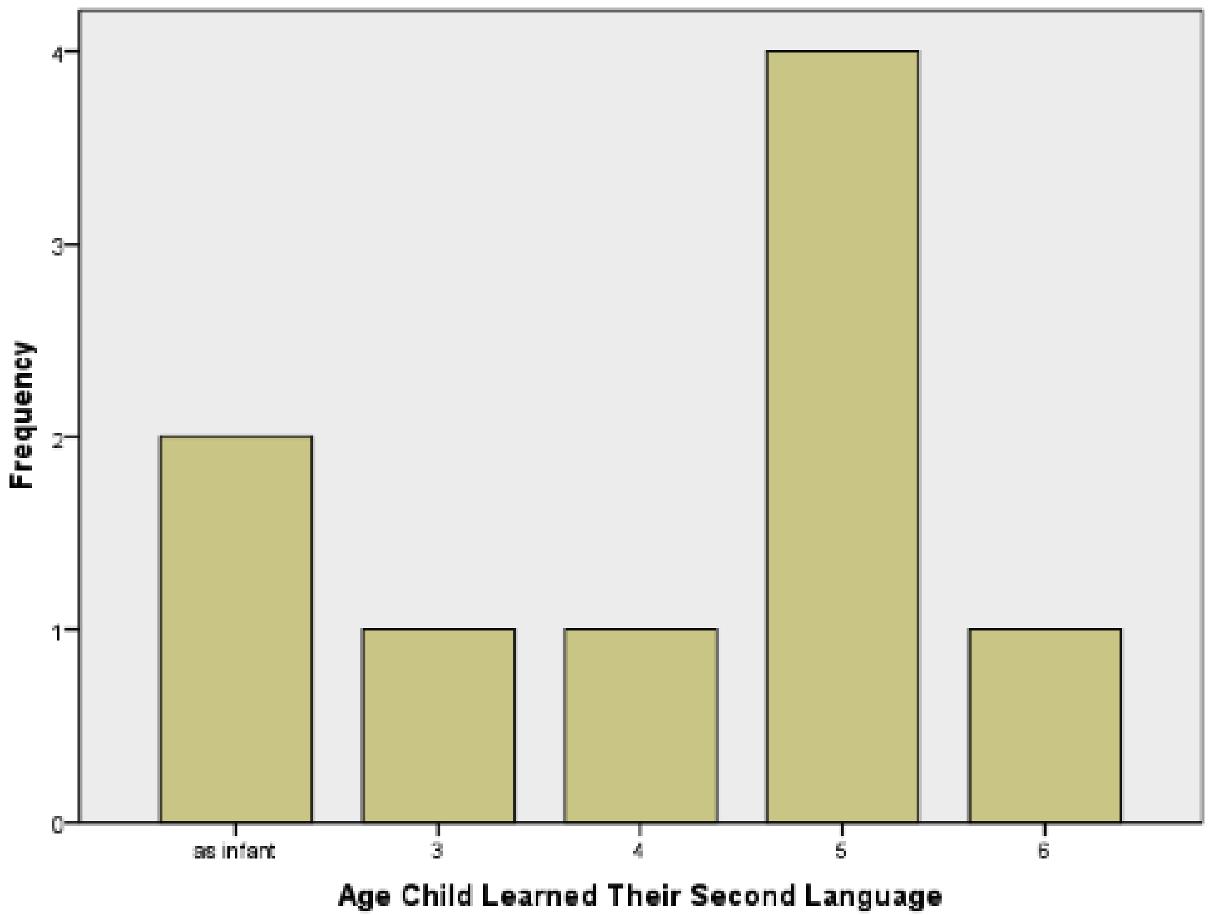

Figure 4. Age of Second Language Acquisition in Bilingual Children

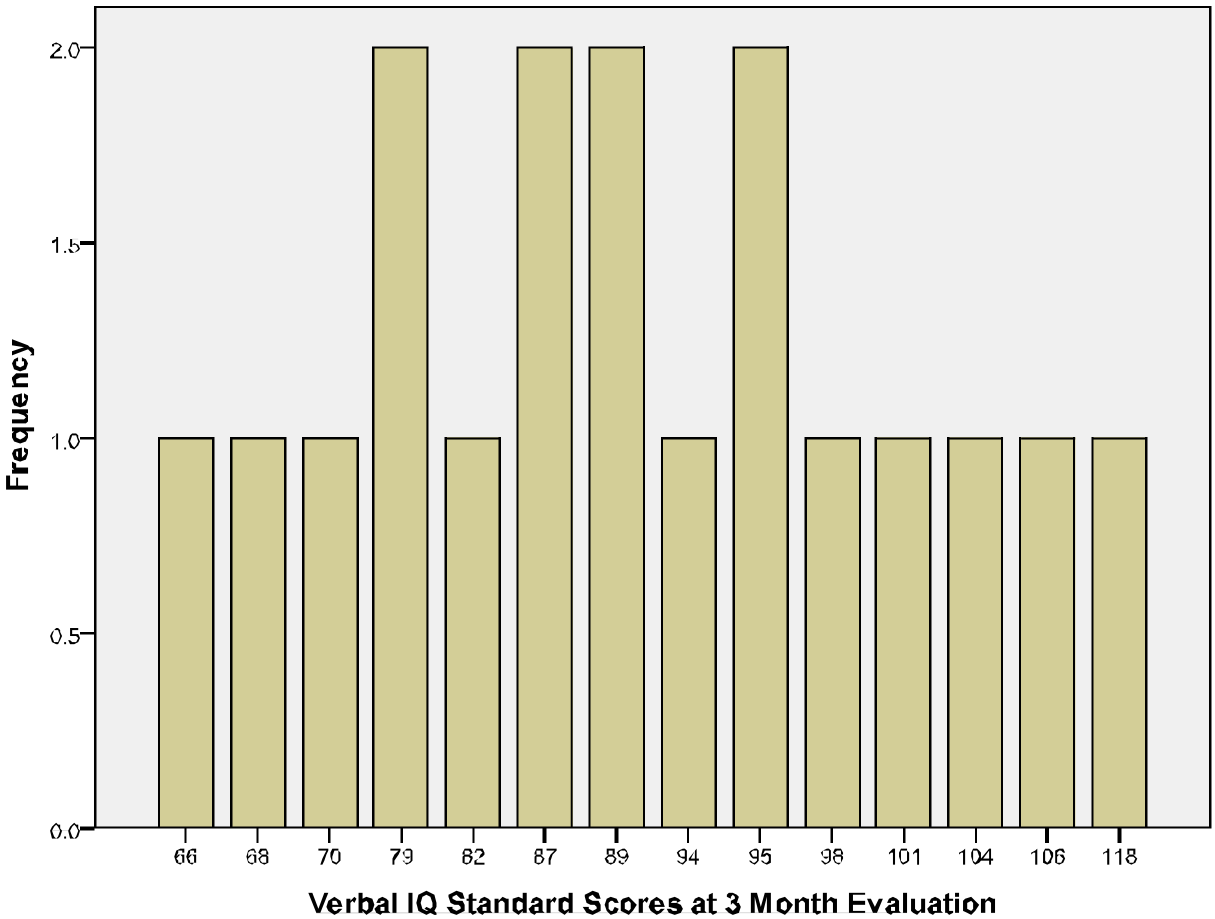

Figure 5. VIQ Scores at 3 month Evaluation of all 18 participants

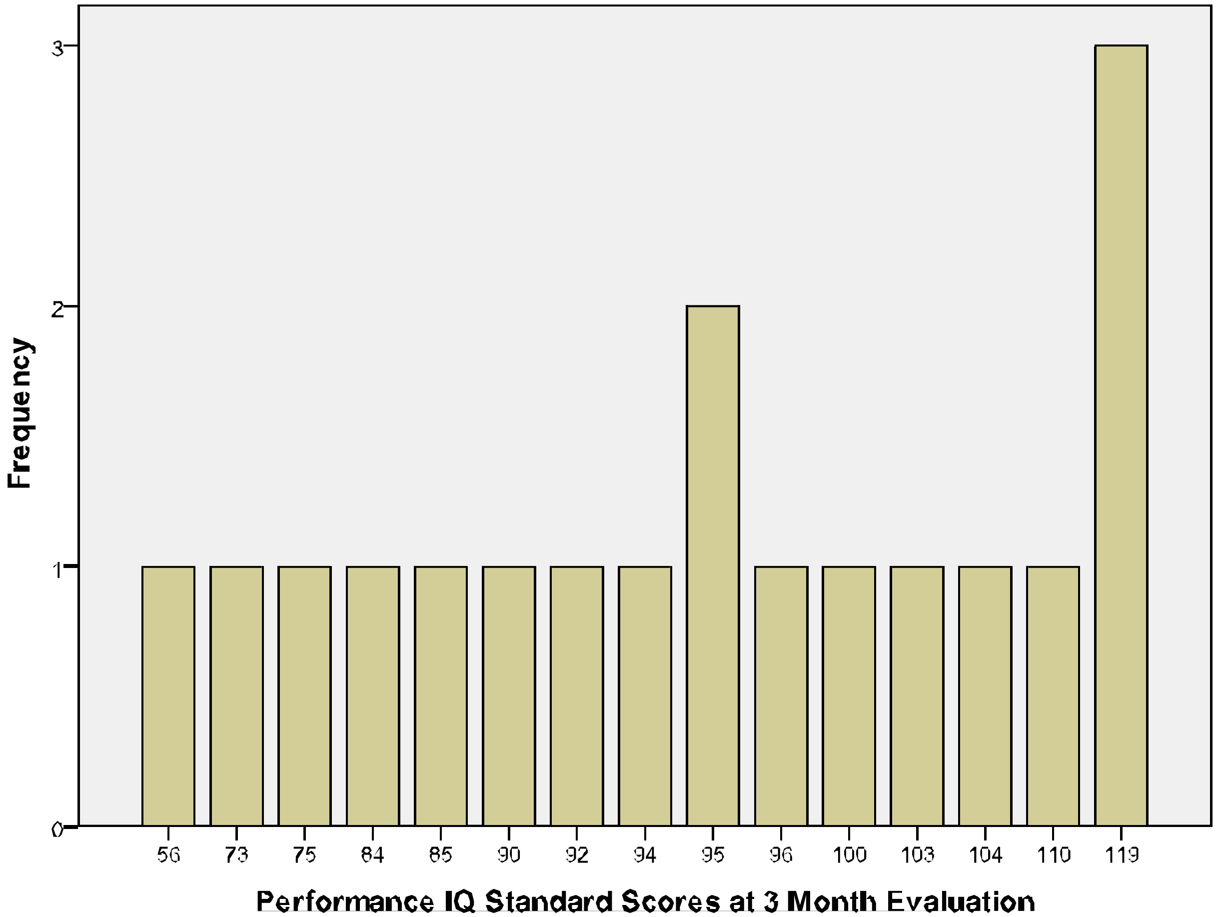

Figure 6. PIQ Scores of all 18 Participants at 3 Month Evaluation of all 18 Participants

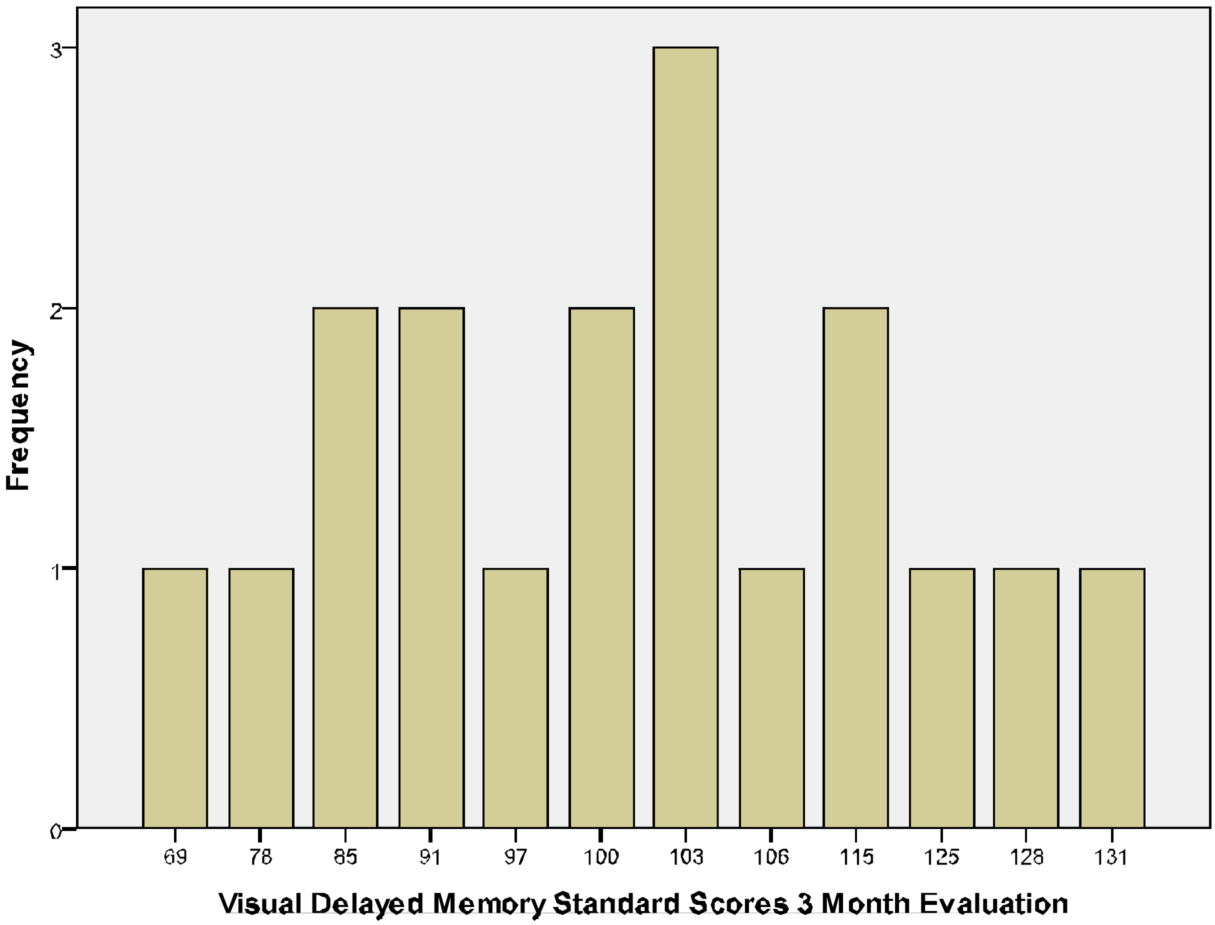

Figure 7. Verbal Delayed Memory Scores at 3 Month Evaluation of all 18 Participants

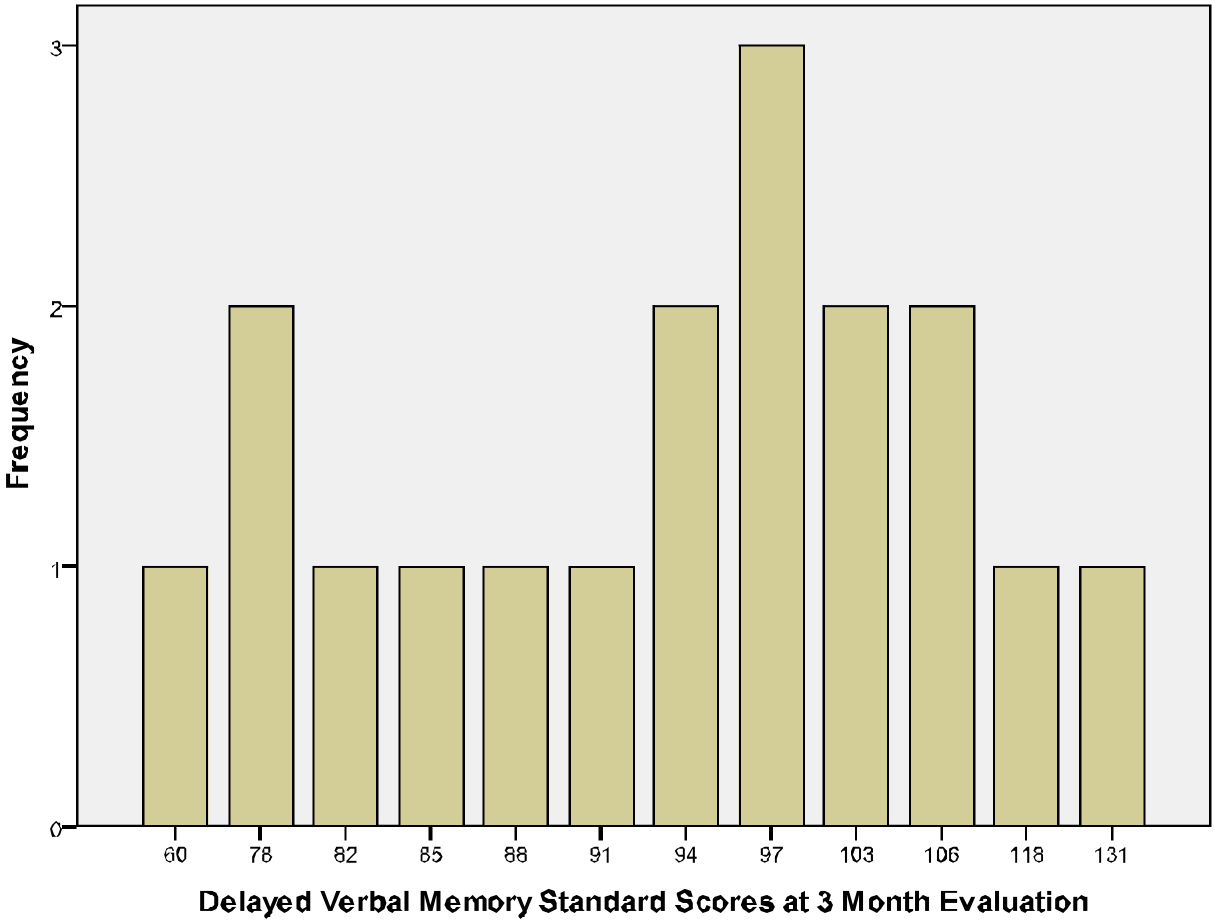

Figure 8. Delayed Verbal Memory Scores at 3 Month Evaluation of all 18 Participants

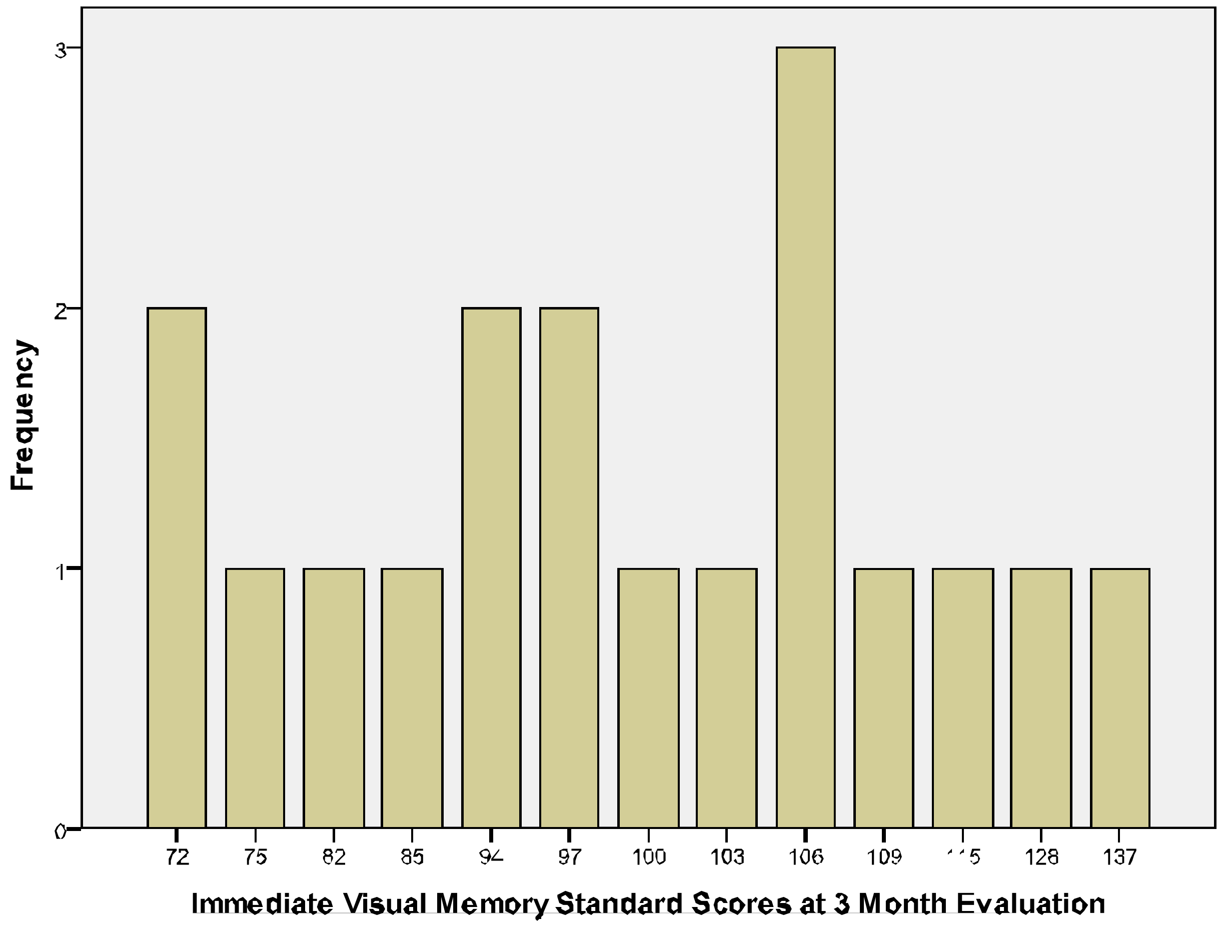

Figure 9. Immediate Visual Memory Scores At 3 Month Evaluation of all 18 Participants

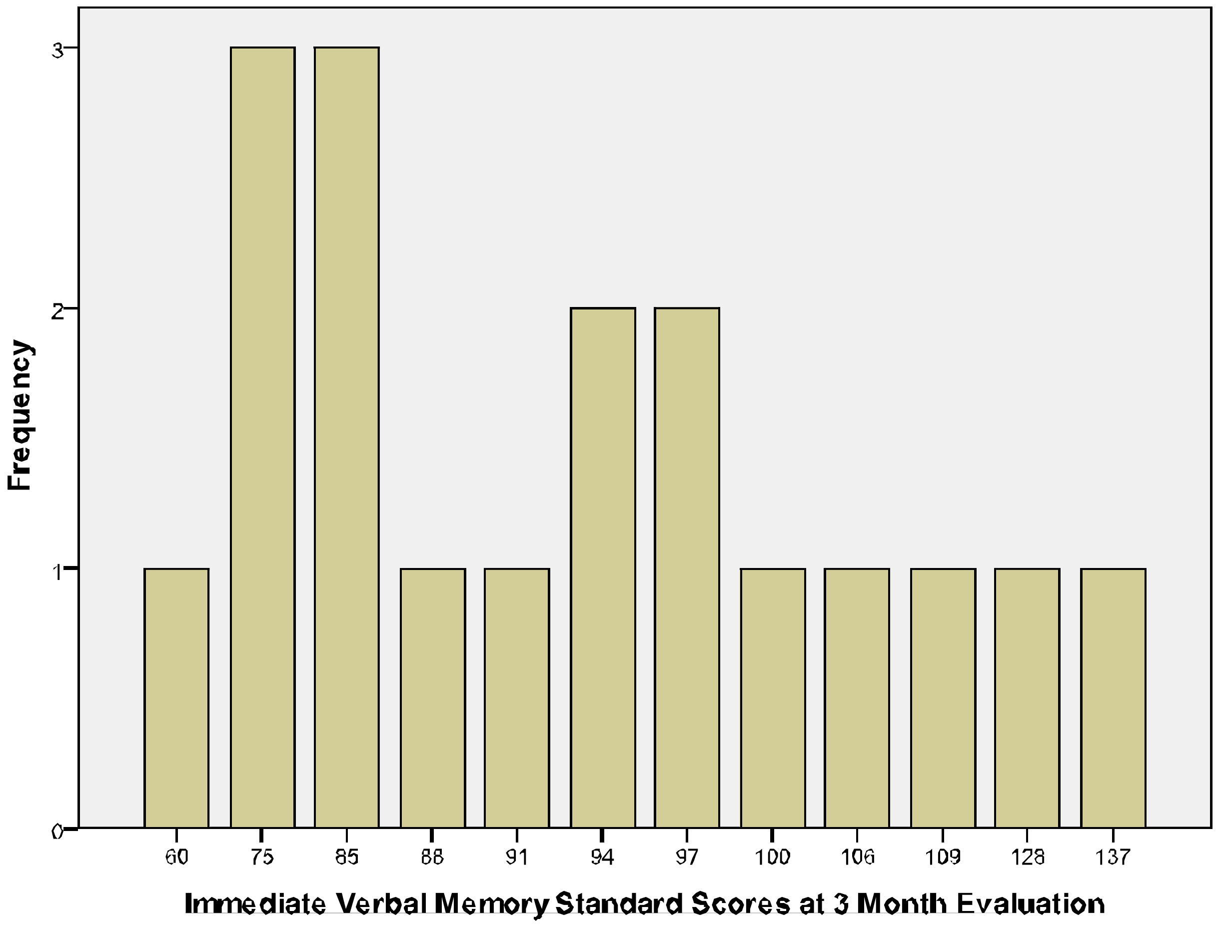

Figure 10. Immediate Verbal Memory Scores At 3 Month Evaluation of all 18 Participants

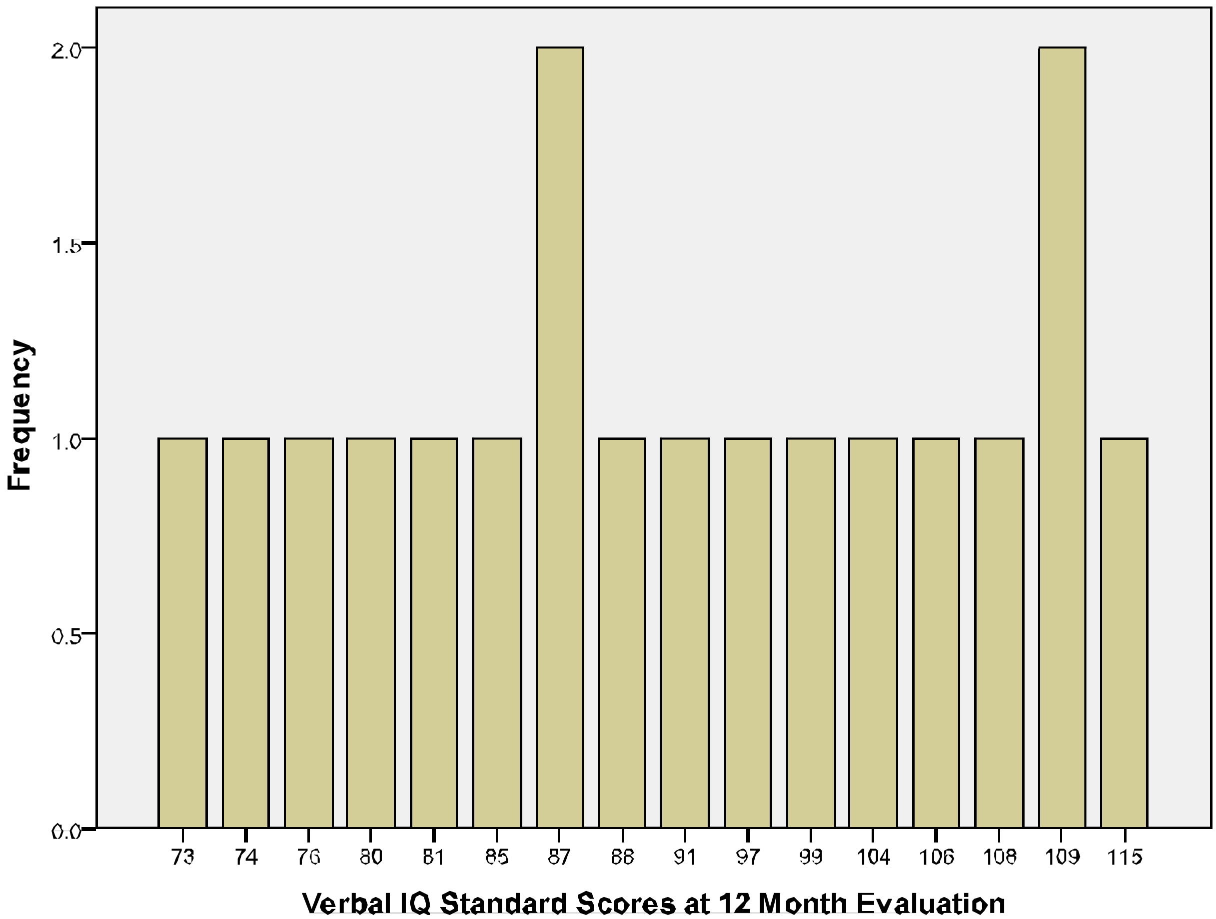

Figure 11. Verbal IQ Scores At 12 Month Evaluation of all 18 Participants

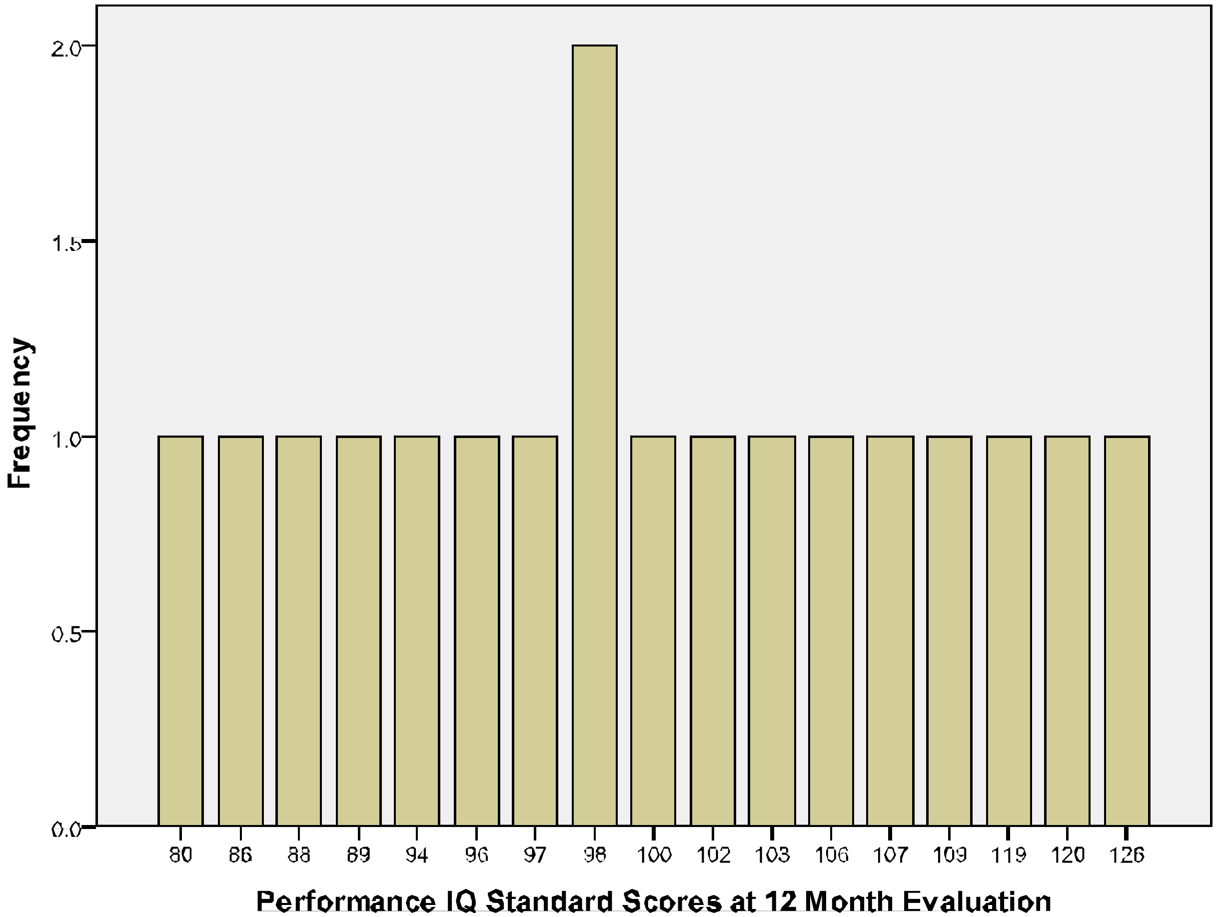

Figure 12. Performance IQ Scores At 12 Month Evaluation of all 18 Participants

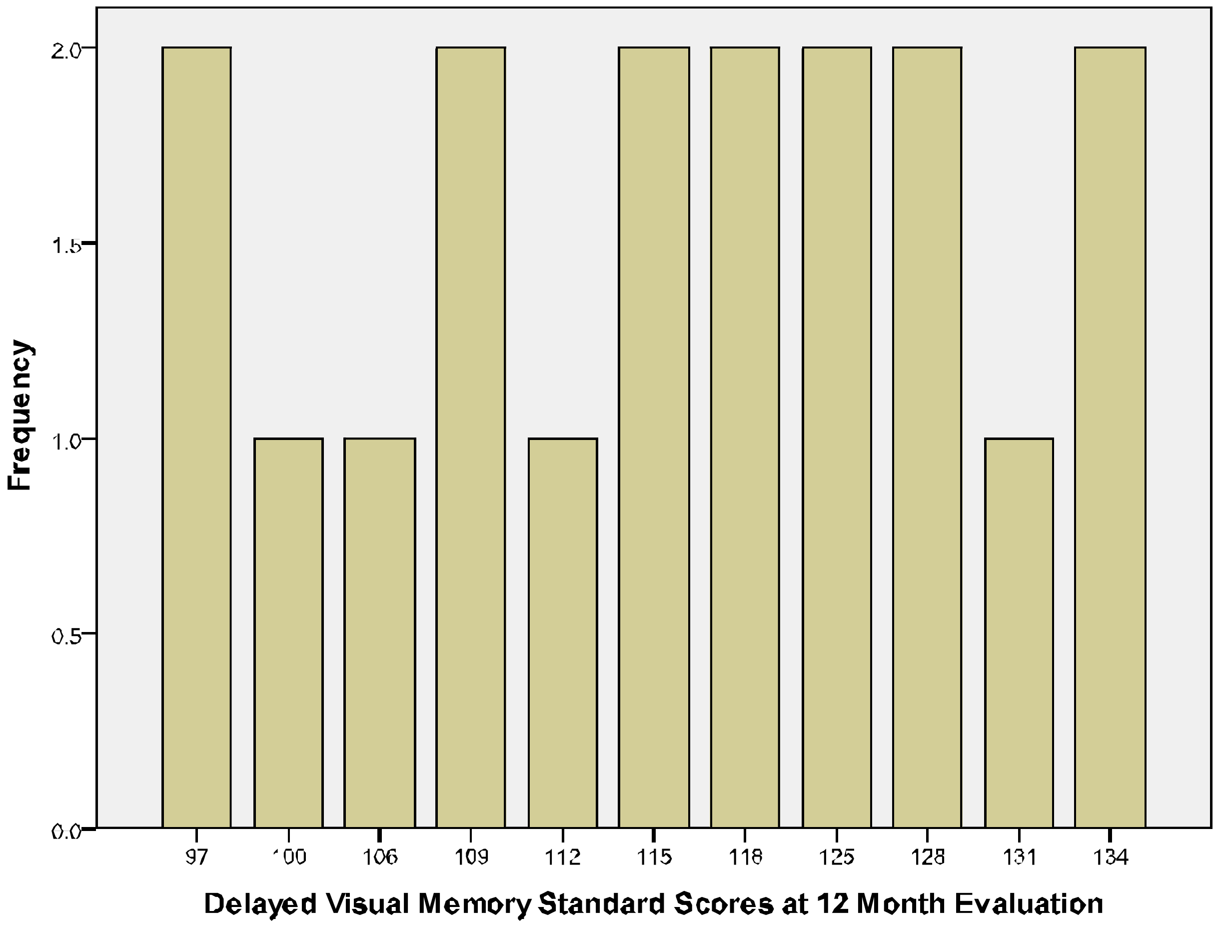

Figure 13. Delayed Visual Memory Scores At 12 Month Evaluation of all 18 Participants

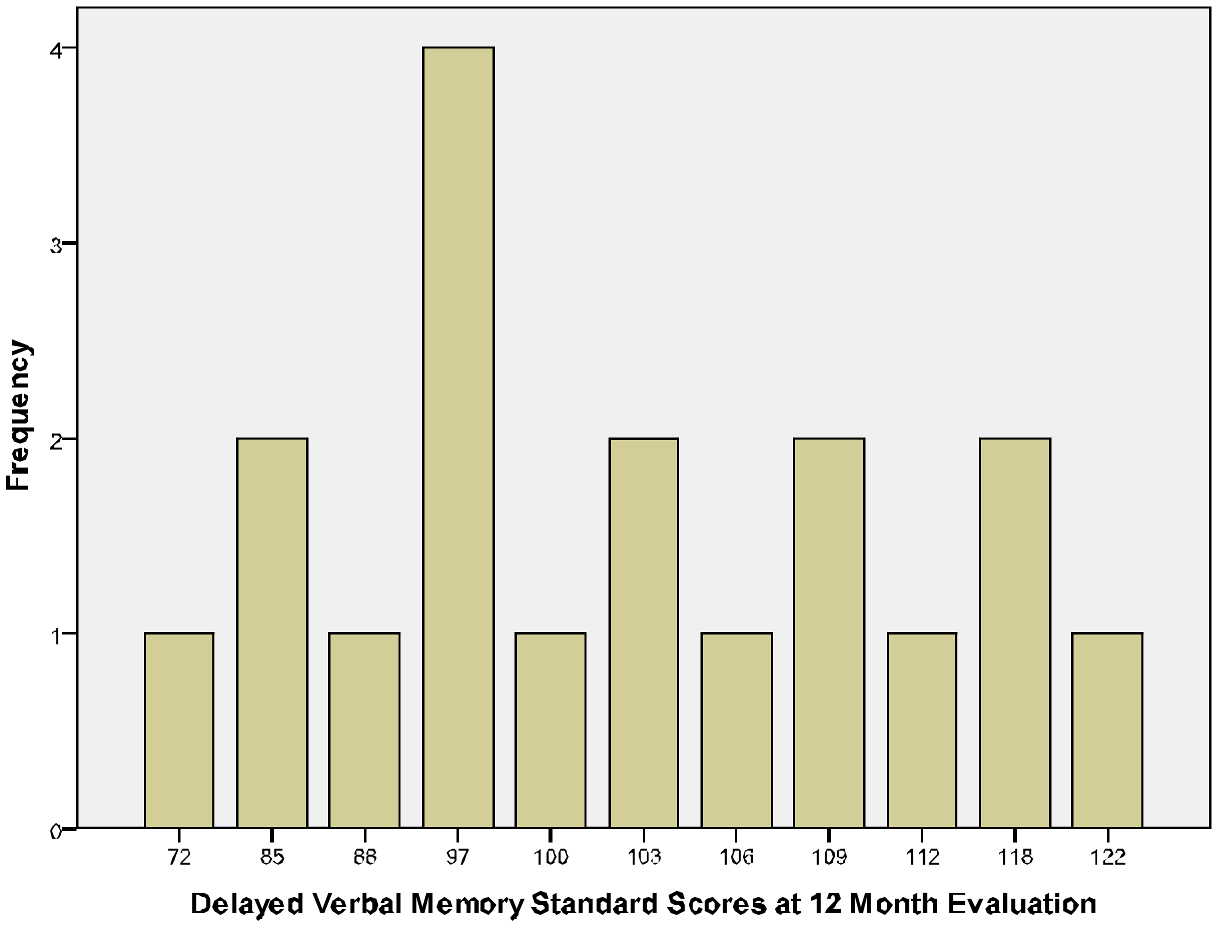

Figure 14. Delayed Verbal Memory Scores At 12 Month Evaluation of all 18 Participants

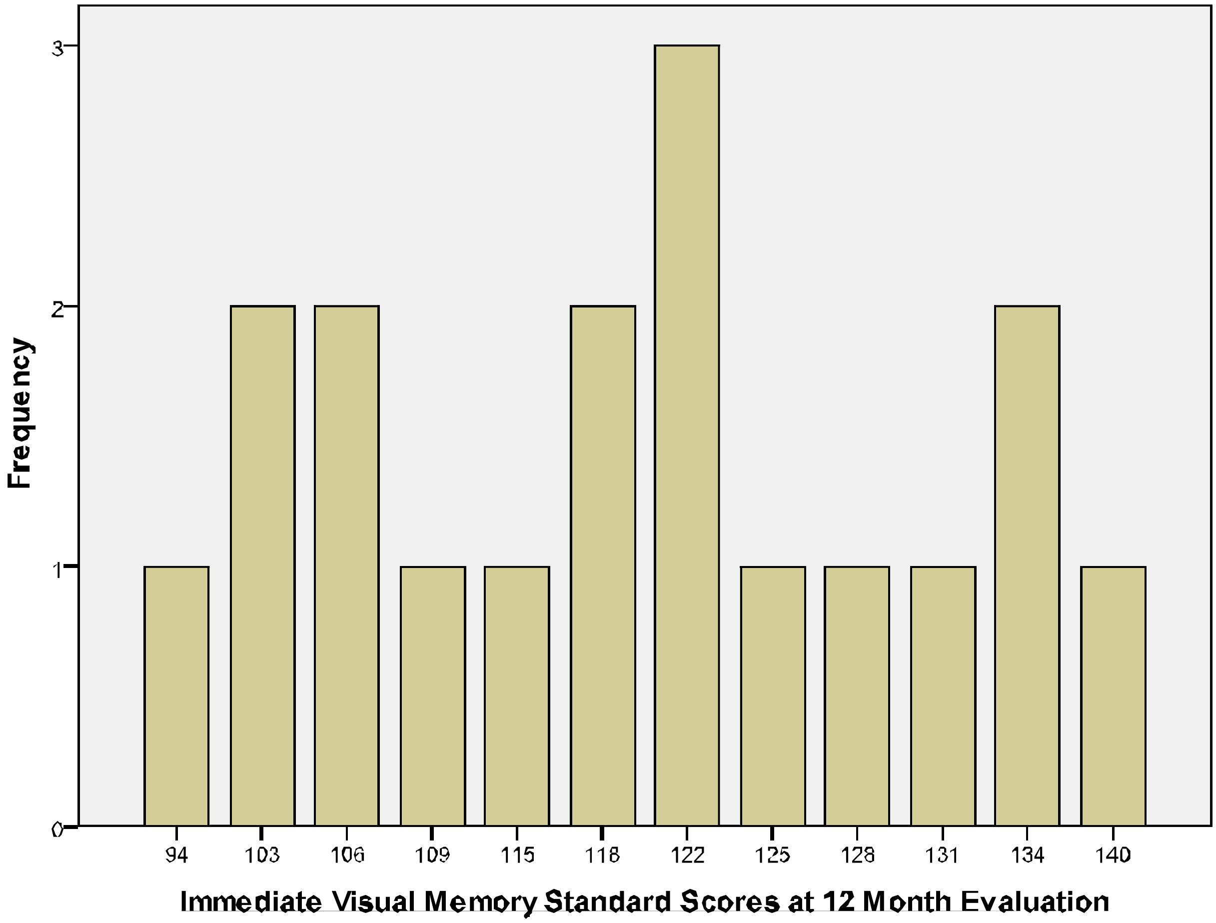

Figure 15. Immediate Visual Memory Scores At 12 Month Evaluation of all 18 Participants

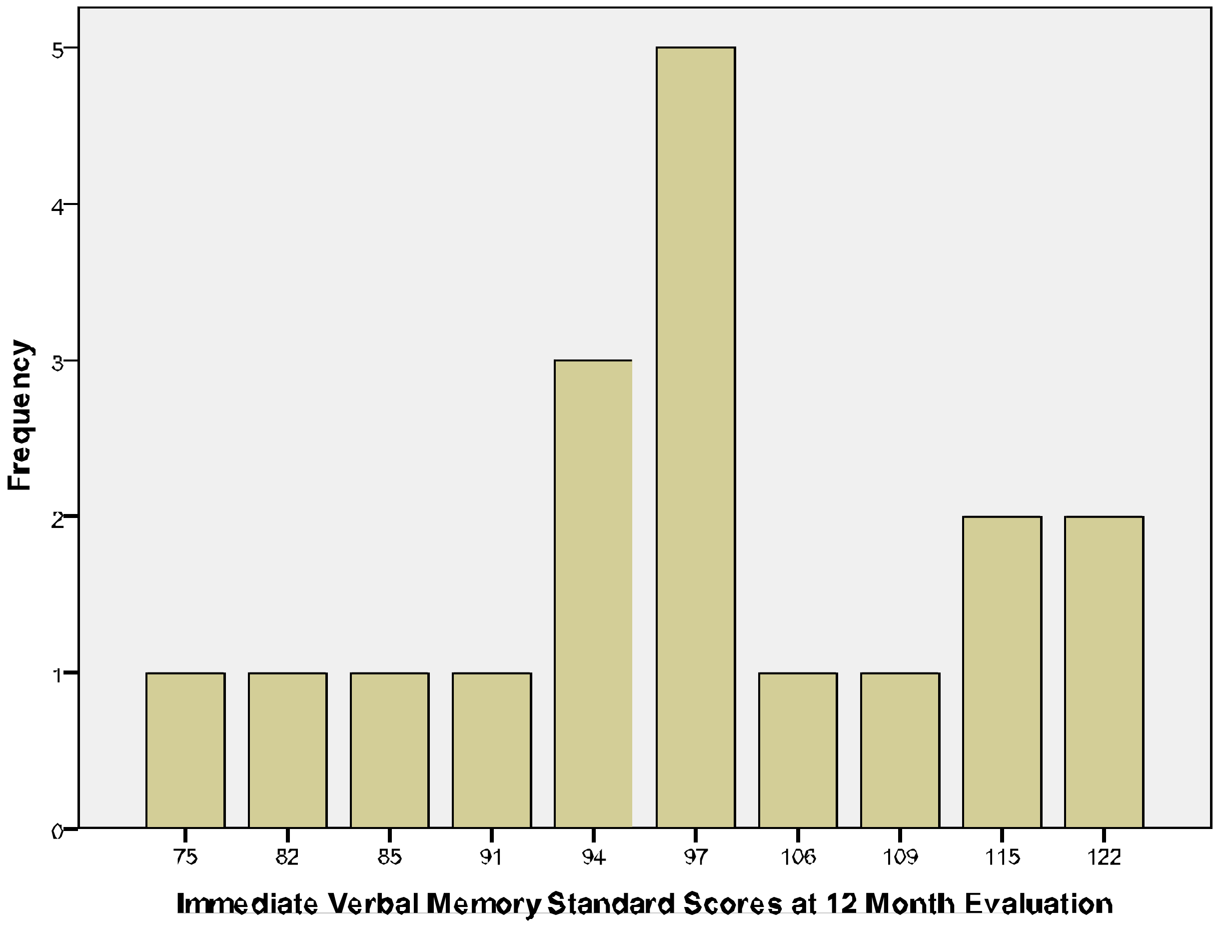

Figure 16. Immediate Verbal Memory Scores At 12 Month Evaluation of all 18 Participants