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LOMA LINDA UNIVERSITY
School of Science and Technology
in conjunction with the
Faculty of Graduate Studies

Myelomeningocele and the Neuropsychological Functioning of Bilingual Children

by

Claudia Venessa Resendiz

A Dissertation submitted in partial satisfaction of
the requirements for the degree
Doctor of Philosophy in Clinical Psychology

September 2011

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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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“The LORD gives me strength. He makes my feet as sure as those of a deer, and He helps me stand on the mountains” Habakkuk 3:19.

CONTENT

TABLES

Tables Page

ABBREVIATIONS

ADHD	Attention Deficit Hyperactivity Disorder
ANCOVA	Analyses of Covariance
CM	Chiari Malformation
CPS	Cocktail Party Syndrome
CSF	Cerebrospinal Fluid
HC	Hydrocephalus
IQ	Intelligence Quotient
MANCOVA	Multivariate Analyses of Covariance
MM	Myelomeningocele
MM-HC	Myelomeningocele and Hydrocephalus
NVLD	Nonverbal Learning Disorder
NTD	Neural Tube Defect
SB	Spina Bifida
VP	Ventriculoperitoneal

ABSTRACT OF THE DISSERTATION

Myelomeningocele and the Neuropsychological Functioning of Bilingual Children

by

Claudia Venessa Resendiz

Doctor of Philosophy, School of Science and Technology
Loma Linda University, September 2011
Dr. Susan A. Ropacki, Chairperson

Myelomeningocele is the most common and most severe form of spina bifida, affecting the brain and spinal cord of millions of children. Children of Hispanic background have the highest prevalence rate of this condition. Despite this fact, research that examines the cognitive profiles of Hispanic children with myelomeningocele is limited. A review on bilingualism and neurocognitive performance suggests that a cognitive advantage is present among those who are able to learn and utilize two languages. Although some have investigated the neuropsychological performance of children with myelomeningocele, research has yet to examine whether a bilingual cognitive advantage is present among bilingual children with this condition. Furthermore, it is unknown whether bilingualism gives a cognitive advantage to those who undergo additional brain insults such as multiple shunt revisions, which are commonly seen in those with myelomeningocele and hydrocephalus (MM-HC). Therefore, this study aimed to examine the neurocognitive profiles of bilingual Hispanic children with myelomeningocele and evaluate whether they benefit from the bilingual cognitive advantage. Twenty seven monolingual children and 22 bilingual children with MM-HC were administered a neuropsychological battery to assess various cognitive domains. In addition, the influence of cultural variables (such as level of language fluency, acculturation, parental income and education) was also considered. Analyses of Covariance indicated that after controlling for cultural variables, the scores of bilingual and monolingual children with MM-HC in the domains of General Intellectual Abilities, Verbal abilities, Motor Abilities, Processing Speed and Executive Functions were not significantly different. However, significant differences were found in the domains of Visual Memory/Abilities and Verbal/Working Memory, indicating that monolingual children with MM-HC significantly outperformed their bilingual counterparts. Subsequent analyses among those who had undergone additional shunt related surgeries revealed no significant differences between bilingual and monolingual children with MM-HC who had a history of shunt revisions. Results from this study suggest that the cognitive advantage seen among bilinguals with intact brains (i.e., no previous brain insults/traumas) is <u>not</u> present among bilingual children with MM-HC. Several explanations of these findings are discussed.

Introduction

Spina bifida (SB) is among the most common types of neural tube defects (CDC, 2008). For unknown reasons, this condition is more pervasive among children of Hispanic background who have a 50-200 percent higher risk than those of non-Hispanic whites (CDC, 2002). In addition to physical and medical problems, the sequela of SB extends to a wide range of cognitive and neuropsychological impairments (Del Bigio, 1993; Wills, 1993). Although Hispanic children have the highest risk for developing this condition and thus experiencing cognitive and neuropsychological impairments, research has failed to capture the neuropsychological implications of SB among this particular group.

Research on the effects of bilingualism on specific areas of cognitive functioning suggests that bilingual individuals might be at an advantage. Studies have found that compared to monolinguals, bilinguals have superior flexibility using symbol reorganization tasks (Peal & Lambert, 1962), have a better understanding of the arbitrary nature of numeric symbols (Saxe, 1988), ignore misleading features of number concept tasks (Bialystok & Codd, 1997), have a better understanding of object constancy (Feldman & Shen, 1971), have superior performances on spatial problems (Bialystok & Majumder, 1998) and perform well on nonlinguistic tests of creativity and geometric design (Ricciardelli, 1992).

This bilingual advantage has been primarily studied on healthy and cognitively intact individuals (Bialystok, 2007; Carlson & Meltzoff, 2008; Chuneyeva, 2009; Kormi-Nouri, Moniri & Nilson, 2003). It appears that the mechanisms used to learn and efficiently utilize two languages enhance the cognitive processes of bilingual individuals (Bialystok, 2001). However, it is unknown whether the bilingual advantage develops in individuals that suffer from some type of brain insult early in life, such as the damage created by the different forms of SB.

The purpose of the present study is to identify whether a cognitive advantage is present among bilingual children of Hispanic background that suffer from myelomeningocele (the most common and most severe form of SB) and to assess for differences in their neuropsychological profiles as compared to monolingual English speaking children with the same condition. Examining the neuropsychological profiles of Hispanic children with myelomeningocele and a possible bilingual cognitive advantage is expected to contribute to a better understanding of cognitive functions among this group.

Overview

Neural tube defects (NTDs) are the second most common type of birth defects in the United States, after congenital heart defects (CDC, 2008). Spina Bifida, the most common type of NTD, involves a "developmental malformation in which bony coverings of the vertebral arches fail to close and encase the spinal cord" (Shine, 1998, p. 616). Spina Bifida can be classified according to the degree of severity and as to whether the defect is concealed (spina bifida occulta), involves only the meninges (meningocele), or involves the meninges as well as the spinal cord (myelomeningocele).

Spina Bifida occulta is the mildest form of SB. Spina Bifida occulta is characterized by a manifestation of a small cavity between two vertebrae without abnormalities in the meninges. Individuals with this type of defect are typically asymptomatic and lack neurologic signs (Hynd, Morgan & Vaughn, 1997; Kinsman & Johnston, 2007). Meningocele is a moderate form of SB where there is a protrusion of the membranes that cover the spinal cord through the spinal column. However, the spinal cord is typically normal and the defect is covered with skin, posing minimal threat to the patient (Kinsman & Johnston, 2007).

Myelomeningocele (MM) represents the most common and most severe form of SB, affecting approximately one thousand infants in the United States each year (CDC, 2004). Myelomeningocele is a neural tube defect where the bones of the spine fail to form and cause an incomplete spinal canal. This results in a protruding fluid-filled sac which contains the spinal cord and meninges (Kinsman & Johnston, 2007). At birth, part of the spinal cord is visible. Thus, surgical intervention needs to follow immediately after birth to diminish neurological deficits and to prevent infections and possible death.

The etiology of MM is mostly unknown. However, the contribution of multiple factors such as deficiencies in folic acid, maternal obesity and diabetes, mother’s use of anticonvulsants during pregnancy, mutations of enzymes, chromosome abnormalities, and socioeconomic difficulties are thought to contribute to the development of this condition (CDC, 1992; Kinsman & Johnston, 2007; Shaer et al., 2007). The types of dysfunctions associated with this condition generally include impairments in ambulation, gastrointestinal complications, bowel and bladder incontinence, urinary tract infections secondary to catheterization, symptomatic hypercalcemia, polydyspia, neurocognitive deficits, Chiari II malformations and hydrocephalus (Kinsman & Johnston, 2007). Although these deficits may vary in each patient, the two most common dysfunctions seen in children with MM are Chiari II malformations and hydrocephalus (Kinsman & Johnston, 2007).

Chiari malformations. There are four types of Chiari malformations with Chiari II malformations (CM-II) being the most common in individuals with MM (Stevenson, 2004). Type I consists of displacement of the cerebellar tonsils through the foramen magnum with the fourth ventricle remaining it its normal position. Type III and IV are the most rare, but have the highest mortality rate. Here, the cerebellum fails to develop normally (Menkes, 2000; Victor & Ropper, 2001). Type II, the most common among individuals with MM, in fact, it has been documented that is virtually present in every child born with MM (Shaer, Chescheir & Schulkin, 2007; Stevenson, 2004). Although hydrocephalus is associated with MM and CM-II, prenatal imagining has allowed researchers to observe that CM-II may be present prior to the appearance of hydrocephalus (Stevenson, 2004). In fact, it has been documented that 10 to 20% of children with MM and CM II may never develop hydrocephalus. However, in those that do develop hydrocephalus, they do as a result of Chiari II malformations that are associated with inferior displacement of the brainstem and fourth ventricle through the foramen magnum into the vertebral canal (Stevenson, 2004).

Hydrocephalus. It has been reported that about 80-90% of children with MM will develop hydrocephalus (Fobe et al., 1999; Kinsman & Johnston, 2007). Hydrocephalus (HC) is the excessive accumulation of cerebrospinal fluid (CSF) within the cranium which may lead to increased intracranial pressure, dilation of cerebral ventricles and displacement of adjacent brain structures (Golden & Bonnemann, 2007).

Under normal functioning, CSF follows a particular pathway (CFS is circulated from the ventricular system, to the lateral ventricles, through the foramen of Monro into the third ventricle, through the aqueduct of sylvius into the fourth ventricle, out the paired foramina of Luschaka and single foramen of Magendie, through the basal cisterns and spinal subarachnoid space and reabsorbed through the arachnoid villi) (Barrow, 2000). It is when there is an obstruction or decreased absorption of CSF along this pathway that HC occurs.

Hydrocephalus can be categorized into noncommunicating (obstructive) and communicating (nonobstructive) forms. Noncommunicating HC results from an obstruction within the ventricular system, whereas communicating HC results from obliteration of the subarachnoid cisterns or malfunction of the arachnoid villi and the obstruction is outside the ventricular system (Barrow, 2000; Kinsman & Johnston, 2007).

Shunting. Ventriculoperitoneal shunting (the insertion of a catheter and valve into one of the lateral ventricles which then drains CSF into the abdomen) is the standard form of treatment for HC (Kinsman & Johnston, 2007; Shaer et al., 2007; Victor & Ropper, 2001). In fact, it has been reported that when shunting is not implemented, the mortality rate is 45% to 53% (Del Bigio, 1993). Although ventriculoperitoneal shunting is the standard treatment for HC, significant problems are likely to occur. Shunt malfunctions and infections are the most common complications seen in patients treated for HC (Fried & Epstein, 1994). Shunt malfunctions occur in approximately 70% of shunted children, and are most commonly due to occlusions of the catheter (Fried & Epstein, 1994; Menkes, 2000). Shunt infections are also a notable complication caused by bacteria that enters the cranium during the shunt placement surgery (Drake et al., 1998).

Drake and collaborators (1998) reported that in North America, individuals shunted for HC have an infection rate averaging 8 to 10%. Shunt malfunctions and infections produce the need for surgical corrections (i.e., revisions) and placement of new shunts (i.e., replacements). Other causes for shunt revisions include slit ventricle syndrome, abdominal complications, seizures, and lengthening of the catheter to compensate for growth (Fried & Epstein, 1994). Despite the complications that may arise from ventriculoperitoneal shunting, this procedure continues to be implemented as the formal treatment for HC and continues saving the lives of those suffering from this condition.

Effects of Shunt Revisions and/or Replacements on Cognition

Shunt malfunctions and infections produce the need for surgical corrections (i.e., revisions) and placement of new shunts (i.e., replacements). Some researchers report no correlations between the shunt revisions/replacements and patient's cognitive performance (McLone et al., 1983; Wills, 1993). However others indicate that the surgical procedures required to place a shunt have been associated with diminished cognitive performances such as a decline in intellectual performance (IQ) and cognition (Fobe et al., 1999; Jackson et al., 2008). For example, in 1999, Fobe and associates examined a group of 45 children with MM who had been shunted to treat HC. Their results revealed that children who underwent shunt revision surgeries were noted to have lower IQs than those with no shunt revisions. Furthermore, a study by Jackson and colleagues (2008) found that multiple shunts were significantly related to progressive declines in cognitive functioning. More specifically, they found a significant relationship between the number of shunt revisions and declines in IQ as well as declines in both verbal and nonverbal memory. Thus, these studies suggest that the number of shunt revisions is a significant predictor of cognitive decline and intellectual performance among those with myelomeningocele and hydrocephalus (MM-HC).

Myelomeningocele and Neuropsychological Functioning

Because of the increased intracranial pressure caused by HC, a disruption of white matter and distortion in the development of the cortex is likely to occur (Del Bigio, 1993). As a result, the distortions of the cortex can lead to a wide range of cognitive, neuropsychological and motor impairments, even after HC has been treated by shunting procedures (Del Bigio, 1993; Wills, 1993). Thus, HC as well as shunt revisions/replacements have been found to affect several neuropsychological domains including general intellectual abilities, attention and executive functions, memory, verbal, visuospatial and motor abilities. These various areas of impairment will be presently discussed.

General intellectual abilities. A general consensus for a decline of intellectual abilities exists among researchers in this area (Fletcher et al., 1992; Friedrich et al., 1991; Holler et al., 1995; Hommet et al., 1999). Although the global IQ scores of individuals shunted for MM-HC are in the “average range” and remain stable across their lifespan, their IQs are likely to be lower than those seen in normal controls (Fletcher et al., 1992; Friedrich et al., 1991; Holler et al., 1995; Hommet et al., 1999). For example, in 2001, Jacobs, Northam and Anderson examined 19 children shunted for MM-HC and compared them to a healthy control group that was matched for age and gender. Their results indicated that children shunted for MM-HC had poorer global cognitive skills, including intellectual and educational skills, as compared to the control group. Several other studies have found similar results where individuals shunted for MM-HC have significantly lower IQs as compared to normal controls (Fletcher, Francis, Thompson, Brookshire, Bonah, Landry, et. al., 1992; Friedrich, Lovejoy, Shaffer, & Shurtleff, 1991; Scott, Fletcher, Brookshire, Davidson, Landry, Bohan, et. al., 1998). The lower global IQ scores among those with MM-HC have been attributed to score discrepancies between verbal and performance IQ.

Investigators have found a discrepancy between the verbal sections of the IQ test (usually falling in the “average” to “above average” range) and the performance sections (usually falling in the “below average” range) among individuals with MM-HC (Brookshire et al., 1995 and Fletcher et al., 1992). Conversely, others have failed to find discrepancies between verbal and performance scores of children shunted for MM-HC and believe that deficits tend to be more global (Hommet et al., 1999; Jacobs, 2001; and Scott et al., 1998), arguing that verbal and performance IQs are equally poor among patients shunted for MM-HC.

Nonverbal learning disorders (NVLDs) have been examined as possible causes for the discrepancies between verbal IQ and performance IQ scores among individuals with MM-HC (Matte & Bolaski, 1998; Rourke, 1995). A common cause for NVLDs is a disruption of neuropathways in the right hemisphere as a result of excess CSF (Rourke, 1995). The excess of CSF in the right hemisphere diminishes and/or disrupts the processing of nonverbal information and production of nonverbal behaviors (Erickson, 2001; Rourke, 1995). Those with NVLDs experience problems in tactile perception, visual-spatial perception, psychomotor coordination and attention to novel stimuli (Matte

& Bolaski, 1998; Rourke, 1995). In addition, Rourke (1995) also noted secondary deficits in visual attention, physical functioning, memory for nonverbal material, ability to internalize feedback, and problem-solving strategies. As a result, general intellectual abilities and academic achievement are negatively affected (Matte & Bolaski, 1998; Rourke, 1995).

Nonverbal learning disorders may account for part of the discrepancy in scores between verbal IQ and performance IQ sometimes seen in children with MM-HC (Brookshier et al., 1995 and Fletcher et al., 1992; Matte & Bolaski, 1998; Rourke, 1995). As a result, individuals with MM-HC may be able to have an “average” to “above average” range on the verbal sections of IQ tests, but may score in the “below average” range on the performance (i.e., nonverbal/visual) sections. Nonetheless, the argument of whether discrepancies between verbal vs. performance scores truly exists continues. A reason as to why some have found discrepancies whereas others have failed to do so has not yet been identified. Nevertheless, investigators in this area agree that individuals affected by MM-HC do have significantly lower overall IQs than the normal population.

Attention and executive functioning. Individuals with MM-HC have been found to have problems with attention and executive functioning (Fletcher et al., 1996; Loss, Yeates & Enrile, 1998; Snow, 1999; Wills, 1993). It is argued that damage to the frontal sub-cortical white matter circuits, which is associated with HC, disrupts communication between the prefrontal cortex and other areas of the brain, resulting in problems with attention and executive dysfunction (Fletcher et al., 1996; Wills, 1993). Loss, Yeates and Enrile (1998) studied four elements of attentional functioning (i.e., encode, sustain, focus/execute, and shift) among 64 children with MM-HC and 27 of their un-affected siblings. Results revealed that children with MM-HC exhibited deficits across the four elements of attentional functioning as compared to their un-affected siblings. Interestingly though, the magnitude of the deficits seen among children with MM varied depending on whether or not there was the presence of HC. Group differences were more pronounced among children with a history of shunting than those without shunts. The results are consistent with other studies which suggest that deficits in attention are more pronounced in children with MM and a history of shunted HC than among those with no history of HC (Fletcher et al., 1995 and 1996).

Furthermore, Snow (1999) examined the executive functions of children with MM-HC and compared them to children with learning disabilities, children with attention deficit hyperactivity disorder (ADHD) and a control group. The Wisconsin Card Sorting Test and Trail Making Test (part A and B) were used to assess executive function. When the four groups were compared, children with MM-HC showed severe deficits on measures of visual planning and visual sequencing. Their performance was below that of normal children but was also significantly below those with ADHD and learning disabilities. Furthermore, Snow added that children with MM-HC were perseverative in their response style, showing deficits with mental flexibility. Several others have also confirmed the deficits in attention and executive function among children with MM-HC which reveal problems with focused attention, selective attention and problem-solving skills (Fletcher et al., 1996; Horn, Lorch, Lorch, & Culatta, 1985; Wills, 1993).

Individuals with MM-HC have also been found to have a higher incidence rate of ADHD than those in the normal population. Ammerman et al., (1998) found an ADHD prevalence rate of 33% in a sample of children with MM-HC. This rate is higher than the general population, where ADHD prevalence rates are three to five percent (Ammerman et al., 1998). The attentional difficulties found in children with MM-HC are marked by inattention and distractibility instead of the impulsivity and hyperactivity components more commonly observed in the general ADHD population (Ammerman et al., 1998).

Memory. Hydrocephalus may lead to compression of the temporal lobe, hippocampus and other subcortical structures associated with memory functioning, resulting in memory deficits (Scott et al., 1998). Mild memory deficits have been found in encoding, retrieval and recognition of new information as well as serial learning and spontaneous recall (Hommet et al., 1999; Jacobs et al., 2001; Loss et al., 1998). A study conducted by Yates and colleges (1995) compared the verbal memory functions of children with MM and no shunts, children with MM-HC with shunts and a control group on the California Verbal Learning Test for children (i.e., a list learning task). Results revealed that although children with MM-HC and shunts recalled the same number of words as controls on their first learning trial, their overall recall of words was lower/poorer. In contrast, the performance of children with MM (no shunts) was not significantly different from the control group, but they did demonstrate better long-delay free recall than children with MM-HC and shunts. Hence this study suggests that verbal memory problems are more prevalent in children with MM that have been shunted for HC (as they experienced significant retrieval problems) than in children with MM-no shunts and/or controls.

Scott and Colleagues (1998) evaluated verbal and nonverbal (visual) memory among 157 children with arrested HC (no shunts), shunted HC and no hydrocephalus. Children with shunted HC were found to have deficiencies on measures of verbal and nonverbal memory when compared to those with arrested HC and no HC. More specifically, children with shunted HC performed poorly on encoding and retrieval of a verbal serial learning task as well as a verbal recognition task as compared to the arrested HC and no HC group. Both the arrested and shunted HC groups displayed significant encoding and retrieval problems in the nonverbal serial learning task as compared to controls, however, the shunted HC group's performance was still significantly lower than the arrested HC group.

The findings in general suggest that HC negatively impacts memory functions, particularly among those who undergo shunting procedures to treat HC. Thus the placement of shunts can have a detrimental impact on memory functions.

Verbal abilities. Speech development in children with MM-HC typically follows normal development and basic verbal abilities tend to be spared. Conversational speech has been noted to be normal in intonation, rate, fluency, repetition and articulation (Barnes & Dennis, 1998; Culatta, 1993; Fletcher, Barnes & Dennis, 2002). However, a slow response speed for word-finding and difficulties in grammatical comprehension has been noted (Fletcher, Barnes & Dennis, 2002). The "Cocktail Party Syndrome" (CPS) has also been observed in about 30% of children with MM-HC (Hurley et al., 1990; Wills, 1993). Cocktail Party Syndrome refers to fluent and grammatically correct expressive language with high frequency of irrelevant and inappropriate bizarre utterances as well as poor explanatory or descriptive speech (Wills, 1993). However, not every child with MM-HC develops CPS. This phenomenon is more prevalent in those with HC, low IQ scores (especially when Performance IQ is much lower than Verbal IQ), attentional difficulties and higher lesion levels (Anderson & Spain, 1977; Wills, 1993). In fact, research suggests that CPS is specific to children with solely HC and that it does not occur in children with MM who do not develop HC (Badell-Ribera et al., 1966; Tew, 1979; Wills, 1993).

Although children with MM-HC may score within the normal range on language measures, the possibility of CPS exists. In addition, these children may display difficulties with word finding and grammatical comprehension (Dennis et al., 1981; Hadenius et al., 1962; Horn et al., 1985; Parson, 1968).

Visuospatial/visual-motor skills. Abundant evidence of visuospatial deficits among children with MM-HC exists. Several factors influence this deficit. First, children with MM-HC are likely to have oculomotor deficits such as poor visual tracking, nearsightedness, and strabismus due to compression or malformation of cranial nerves (Anderson et al., 2006; Lennerstrand & Gallo, 1990). Second, motor disorders may be present among individuals in this group due to malformation of the cerebellum as a result of Chiari malformations (Stevenson, 2004). Third, movement of the hands, arms and legs are controlled by pyramidal systems which may be disturbed by HC (Turner, 1986; Wallace, 1973). And fourth, children with MM experience a lesion of the spinal cord which can impair fine control of hand and arm movement (Jansen-Osmann, Wiedenbauer, and Heil, 2008; Lomax-Bream, 2007). A combination of these factors affects the performances of individuals with MM-HC on visuospatial and visual-motor integration tasks.

Dennis, Rogers and Barnes (2001) compared children with MM-HC with age-matched peers on the ability to perceive visual illusions and multistable figures. Children with MM-HC were significantly impaired in the perception of multistable figures that involved figure-ground reversals, illusory contours and paradoxical figures when compared to the control group. Although several studies state visuospatial deficits among children (Friedrich et al., 1991; Hommet et al., 1999; Wills et al., 1990), it is important to note that most of these studies relied on tests that required visual-motor integration rather than tests that assessed pure visuospatial ability. Thus, additional research is needed to determine whether these deficits can be attributed to pure aspects of visuospatial abilities once the role of visual-motor impairments is controlled for, or if there is a significant amount of shared variance among visuospatial and visual-motor abilities.

Motor skills. Myelomeningocele is commonly associated with fine and gross motor deficits as well as gross motor problems in the lower limbs (Fletcher et al., 1995, Shine, 1998 and Wills, 1993). As previously reviewed, motor deficits may be a result of Chiari malformations, disruption in pyramidal systems and lesions of the spinal cord due to MM (Jansen-Osmann, Wiedenbauer, and Heil, 2008; Lomax-Bream, 2007; Stevenson, 2004; Turner, 1986; Wallace, 1973). A study by Muen & Bannister (1997) compared children with HC (no MM), children with MM (no HC) and a group of healthy controls. Findings revealed that children with MM had poorer fine motor control and weaker power in the muscles controlling hand functions than healthy controls. There were no statistically significant differences between healthy controls and those with HC (no MM), suggesting that motor deficits are not attributed to HC, but to MM. However, complications with HC, such as shunt infections or shunt malfunctions have been found to negatively impact motor performance among individuals with MM-HC. For example, a study by Mazur et al. (1998) found that individuals with MM-HC had poorer performances than normal controls and individuals with HC (no MM) on hand functioning tasks. These motor deficits were related to spinal lesion level as well as the number of shunt replacement surgeries. Thus, the findings of these studies suggest that motor deficits can be in part accounted for by damage to the spinal cord as a result of MM as well as shunt revision surgeries.

A Cognitive Advantage

Neurocognitive and neuropsychological research on MM has mainly focused on detailing the deficits seen as a result of HC and shunt revisions. But what if individuals with MM-HC could do something to recover functions that have been lost or enhance areas that are lacking? Within the last four decades, the idea of "bilingualism" as a cognitive advantage has emerged. In this study, a definition of bilingualism suggested by Grosjean (1992) has been adopted: bilingualism is the regular use of two (or more) languages and bilinguals are those who need and use two (or more) languages in their everyday life. Bilingualism has been found to engage individuals in early usage of executive functions, facilitate the resolution of complex problems, and diminish cognitive decline associated with aging among many other advantages (see Bialystok, 2001 for a review).

In 1962, a study by Peal and Lambert was the first to suggest a positive influence of bilingualism on cognitive abilities. Peal and Lambert found that bilingual children (French-English) performed better than monolinguals (English only) on verbal and nonverbal intelligence tasks after controlling for socioeconomic class, sex, age and school/school system. These findings were contrary to previous research which proclaimed that bilingualism posed a detrimental effect on cognitive performance (Peal &

Lambert, 1962). However, Peal and Lambert pointed out that previous studies failed to control for additional variables (such as demographic factors) that were essential in the evaluation of bilinguals. Since this study, examinations of specific areas of cognitive functioning suggest that bilingual children may have a better understanding of object constancy (Feldman & Shen, 1971), superior performance on spatial problems (Bialystok & Majumder, 1998) and nonlinguistic tests of creativity and geometric design (Ricciardelli, 1992) and others (see Bialystok, 2001 for a review).

Bilingualism and Neuropsychological Functioning

Executive functions. Bilingual speakers are believed to have two representational systems that are rich in detail and structure (Bialystok, 2007). The two representational systems are simultaneously active and available during all language use activities even if only one of the systems is in use (Bialystok, 2007). Because of this constant competing linguistic system between two active languages, bilinguals need a mechanism to control and direct their attention to the required language, ignore the other language system not in use, and constantly shift their attention because they may need to adjust the language they are using depending on the setting they are in. Therefore, the necessary control of the language systems in bilinguals requires constant attention, inhibition, monitoring and switching, all aspects of executive function (Bialystok, 2007).

Bialystok and collaborators (1986, 1988, 1999, 2004 & 2007) proposed that the constant use of attention, inhibition, monitoring and switching in the management of multiple language systems may alter and modify the development and utilization of executive function processes among bilinguals. More specifically, Bialystok and colleagues found that bilingual children have advantages in executive function which are maintained into adulthood, and these processes show a slower decline with aging as compared to monolinguals (Bialystok 1986, 1988, 1999 and Bialystok & Martin 2004).

In two studies (1986 and 1988), Bialystok and colleagues assessed monolingual and bilingual children's attentional control by having them identify grammatical errors in several sentences (e.g., apples growed on trees), and later focus their attention only on grammar and ignore misleading anomalies in the meaning of sentences (e.g., apples grow on noses). Monolingual and bilingual children had the ability to identify the sentences with grammatical errors. However, the ability to focus their attention only on grammar and ignore misleading anomalies in the meaning of a sentence (an executive function process) was diminished among monolingual children as compared to the bilingual counterparts.

Furthermore, Bialystok (1999) and Bialystok & Martin (2004) used the "dimensional change card sort task" (Zelalo & Frye, 1997), in which children are asked to sort images first in one dimension (e.g., shape) and later in another (e.g., color). Typically, children find it difficult to reclassify the pictures once they have already sorted them according to the first dimension. This is because in order for a new type of sorting to occur, the previous dimension (e.g., shape) needs to be ignored, and attention must shift and focus to a new dimension (e.g., color), all aspects of executive function. However, when this task was given to monolingual and bilingual children, Bialystok (1999) and Bialystok & Martin (2004) found that bilingual children were able to solve this problem more easily than comparable monolinguals. More recently, Carlson & Meltzoff (2008) examined inhibitory control skills and other executive functions among

50 kindergarten children. Three language groups were selected, bilinguals (Spanish-English), monolinguals (English), and English speakers enrolled in second-language immersion kindergarten. After statistically controlling for demographic factors (age, parents' education and income level), bilingual children were found to perform significantly better on executive function tasks that required an inhibition of attention to a distracting response as compared to the other two groups.

These studies reveal a consistent pattern where bilingual children appear to develop the ability to control, focus and shift their attention and ignore misleading information more efficiently than monolingual children. The constant attention, inhibition, monitoring and switching processes used by bilinguals in their attempt to have efficient management of two languages appears to promote and bolster their executive function abilities.

Memory. Recent research on the effects of bilingualism and memory suggests a positive effect of dual-language knowledge on memory functions. Kormi-Nouri, Moniri and Nilsson (2003) compared 60 monolingual (Swedish) and 60 bilingual (Iranian-Swedish) children on episodic and semantic memory tasks. All testing was conducted in Swedish. Findings revealed that in both semantic and episodic memory, bilingual children had better recall than monolingual children. The authors argued that language can serve as a means for organizing information. Bilingual children are repeatedly integrating and/or organizing the information of two languages; thus, the repeated process of integrating and organizing information creates an advantage for bilinguals in terms of encoding information and enhancing memory abilities.

More recently, Kormi-Nouri and collaborators (2008) expanded the 2003 study. They included a larger sample, assessed children with different cultural backgrounds and controlled for additional variables (i.e., intelligence, achievement and socioeconomic status). The results of the 2008 study support the previous 2003 study, which indicated that bilingual children outperformed monolingual children in various types of memory tasks.

Although four decades of cognitive studies have shown a positive influence of bilingualism on the cognitive abilities of children, the relationship between bilingualism and memory has just begun to be explored. Recent studies show a positive effect of bilingualism on children's semantic and episodic memory (Kormi-Nouri, Moniri and Nilsson, 2003; Kormi-Nouri et al., 2008). However, additional studies are warranted to further explore the effects of bilingualism on the various mechanisms of memory.

Visuospatial functions. Even fewer studies have looked at the role of bilingualism and its relation to visuospatial/visuoconstruction abilities. However, emergent research is finding a positive relationship between bilingualism and visuospatial/visuoconstruction abilities. One of the first studies in this area was done by Gorrell and collaborators (1982). They examined twenty bilingual first grade children (10 Vietnamese-English and 10-Spanish-English) and twenty monolingual children on the Wechsler Intelligence Scale for Children-Revised (WISC-R) Block Design task, which assesses individuals' visuospatial and visuoconstruction abilities. Results indicated that bilingual children (Vietnamese and Spanish speaking participants) outperformed their monolingual counterparts in the Block Design task, suggesting an advantage for the bilingual groups.

In 2003, McLeay used a series of visuospatial test items (diagrams of like and unlike pairs of knotted and unknotted ropes at varying orientations, which varied in complexity), to test 11 bilinguals (Welsh and English) and 30 monolinguals (English). The results indicated that bilinguals performed the task faster than monolingual subjects, and bilinguals were particularly adept at solving the more complex items. Furthermore, Chuneyeva (2009) examined the visuospatial functions of 32 Russian-English bilinguals and 32 English monolinguals using the Porteus Maze Test (PMT). The results of this study indicated that the Russian-English bilinguals were faster and committed fewer errors on the visuospatial tasks as compared to the English monolinguals. These studies suggest that spatial tasks that involve some method of mental manipulation or rotation are performed more efficiently by bilinguals.

The limited amount of research regarding bilingualism and visuospatial or visuoconstruction abilities suggests a positive relationship between them. A possible explanation for this advantage suggests that bilinguals rely more heavily on visual or spatial strategies (non-verbal representations) than verbal strategies, as non-verbal representations are considered less ambiguous (Ransdell & Fischler, 1991). However, a conclusive answer has yet to be reached. Although a visuospatial advantage for bilinguals over monolinguals is apparent, an explanation and/or theoretical framework of this relationship remains to be established. Additional research is warranted to confidently acknowledge the advantage of bilingualism on visuospatial abilities.

Verbal abilities. Verbal fluency tasks are often used in neuropsychological research; however, the effects of bilingualism on verbal fluency are not well understood. A recent study by Rosselli and collaborators (2000) found that Spanish-English bilinguals performed worse relative to age-matched monolinguals on semantic fluency tasks, but not phonemic fluency tasks. Gollan and colleagues (2002) also found the same pattern as Rosselli and collaborators, where Spanish-English bilinguals performed relatively worse than their monolingual counterparts on a semantic fluency task. Recently, Portocarrero, Burright and Donovick (2007) assessed the vocabulary and verbal fluency among English monolingual and bilingual (Spanish-English) college students. The bilinguals' receptive and expressive English vocabularies were found to be in the average range; however, their vocabularies were still lower than their monolingual counterparts. In addition, the investigators found that both groups had similar performances on phonemic fluency, but the bilingual group performed significantly lower in semantic fluency as compared to monolinguals. Thus a pattern in the verbal abilities of bilinguals emerged, where verbal fluency for phonemic material is comparable to that of monolinguals, however, verbal fluency for semantic information is diminished among bilingual individuals.

Several explanations have been offered for this occurrence. First, it is suggested that cross-language interference occurs, where language processing centers are active for both languages, thereby competing with one another and delaying the retrieval of a single item in one language (Gollan et al., 2002; Rosselli et al., 2000). More specifically, categories of semantic fluency (e.g., animals) include only the recall of concrete words (e.g., elephant), as opposed to phonetic fluency which is not limited by concrete words (e.g., any word that begins with "F"). Thus, semantic categories are constrained by the availability of only concrete words. Second, it has been suggested that concrete words share more elements in their representations among two languages than non-concrete words, giving rise to a cross-language interference. Hence, cross-language interference tends to have a greater impact on semantic fluency than on phonetic fluency (Gollan et al., 2002; Rosselli et al., 2000).

Although the idea of cross-language interference has been suggested as a possible explanation for the diminished semantic verbal fluency among bilinguals, it contradicts previous findings on executive functions of bilinguals. Previous studies have documented a superior advantage of executive abilities among bilinguals, where executive functions should be able to successfully inhibit languages from interfering with one another. However, verbal ability researchers argue that this is not the case for semantic fluency processes. There is still no conclusive answer in this area. Additional studies are warranted to clarify the effects of bilingualism on verbal abilities.

Conclusions regarding the effects of bilingualism. Several advantages have been identified regarding the effects of bilingualism on cognitive functions. A well documented advantage is the relationship between executive functions and bilingualism. For example, studies suggest that bilingual children have advantages in executive function which are maintained into adulthood, and these processes show a slower decline with aging (Bialystok 1986, 1988, 1999 and Bialystok & Martin 2004). In addition, emergent research on memory and visuospatial abilities also suggests a bilingual advantage. However, the mechanisms by which bilinguals outperform monolinguals on memory and visuospatial abilities are not well understood. Furthermore, several questions remain in the area of the verbal abilities of bilinguals as this area has not been fully explored. Despite the infancy of research regarding the relationship between bilingualism and neurocognitive abilities, a trend indicating a cognitive advantage is present.

Hispanic Children and MM-HC

As previously reviewed, research demonstrates that children with MM-HC experience an array of neuropsychological and motor impairments. Despite the emergent research on bilingualism as a cognitive advantage, a study that examines the effects of bilingualism on cognitive functions among children with MM-HC remains to be executed. In order to investigate this relationship, a group of individuals with MM-HC that speak and understand two languages is necessary.

Latinos/Hispanics (these terms will be used interchangeably) in the United States have the opportunity to learn and use English and Spanish in their various interactions. Such a group can be assessed for the possible effects of bilingualism on cognitive performance. In addition, although the latest data from the Centers for Disease Control and Prevention (CDC) indicates a decline in SB birth-prevalence rates in the US, the birth-prevalence rate of SB still remains the highest for Latinos (CDC, 2002). Latinos have been found to have neural tube defect risks 50-200 percent higher (9-16 per 10,000 live births) than those of non-Hispanic Whites (6 per 10,000 live births) (Lary & Lary, 1996; Shaw et al., 1994).

Contributions of multiple risk factors have been identified as reasons for the high prevalence rate of NTDs among Latinos. Some of these factors are maternal factors and include diminished health care access, poor nutrition, diabetes, obesity, work related risks (e.g., agricultural jobs that continually expose women to pesticides), religion (stigma towards early termination of pregnancy), lack of education, and lower socioeconomic conditions (Hendricks, Simpson and Larsen, 1999; Shaw, Velie & Wasserman, 1997; Williams et al., 2005).

Despite the increased interest in examining the neurocognitive functions among children with MM-HC, a need for examining the neurocognitive functions among Hispanic children with MM-HC still remains, especially since this is the ethnic group most commonly affected by this condition. To date, studies have examined medical and/or psychological variables among Hispanic children with MM-HC. However, a formal study that examines the neuropsychological functioning of Hispanic children with MM-HC is still needed. It is possible that such absence of research is due to the difficulties in assessing the cognitive abilities of bilingual/bicultural individuals, which has deterred researchers in their quest to understand the neurocognitive profiles of Hispanic children with MM-HC.

Examining Cognitive Functions in Bilinguals

Several limitations have been observed in the neuropsychological assessment of bilinguals. These include level of acculturation, language barriers (such as limited language proficiency), and lack of measures that are appropriately developed and normed for Latinos (Ponton, 2001). These will be briefly discussed.

Acculturation is defined as “an individual’s ability to understand and maneuver outside the culture that he or she was raised in and is most familiar with” (Berry, 1997, p. 7). It is still not fully understood how acculturation affects cognitive functioning (Ponton & Ardila, 1999). However, recent evidence suggests that acculturation may impact familiarity of testing situations and test performances (Herrera, Ponton, Corona, Gonzalez & Higareda, 1998). For example, US born native English-speakers (i.e., those who are fully acculturated) are familiar with testing experiences in school, which usually require speed and efficiency on the part of the test-taker. In contrast, some Hispanics (i.e., those who may not be acculturated to the US mainstream culture), may not think of speed and efficiency as important aspects of the testing process, but place more importance in other aspects such as developing a personal relationship with the examiner. The discrepancy between what the Hispanic test-taker sees as important from what is expected in an evaluation can impact test performance and result in lower test scores (Ponton, 2001). Therefore the lower the levels of acculturation will result in substandard test performances.

Language proficiency can also impact the test results of bilingual individuals. For example, some individuals may have mastered conversational English and appear to be fluent during conversations. However, they may be deficient in other language-related skills, such as reading and writing, and may not possess the same level of proficiency as their conversational skills (Ponton, 2001). Furthermore, even when bilingual individuals have mastery in all aspects of both languages, their fluency in the second language may diminish when placed in a stressful situation such as an interview or evaluation (Peck, 1994).

Perhaps the foremost and leading limitation in the assessment of Hispanics is the lack of measures that are appropriately developed and normed for this group. Due to the lack of measures that assess cognitive functions among Latinos, many practitioners will turn to translating the test and/or use translators. However, many problems arise from this practice. First, there may be linguistic idiosyncrasies between the original language of the measure and the language to which it is being translated. Second, the cultural familiarity and meaningfulness of tests can result in differences in performance. Third, the use of inexperienced and untrained translators may contaminate the performance of the individual being assessed (Echemendia and Julian, 2002). Another major issue limiting the assessment of Hispanics is that despite the exponential growth of Hispanics in the US, few tests have been normed for this group (Ponton, 2001). In addition, even though a miniscule number of tests have been normed for this group, they are typically normed for a particular Hispanic subgroup (e.g., Puerto Ricans, Colombians, Mexicans). Thus, the heterogeneity of the Hispanic population also makes it difficult for measures to be appropriately normed.

Many of these issues have discouraged and prevented researchers from examining neurocognitive processes in bilingual groups, such as Hispanics. However, the need to investigate neurocognitive functions among bilingual groups despite these limitations is absolutely warranted.

Although limitations in the neuropsychological assessment of bilingual individuals exist, Ponton (2001) has offered a number of possible solutions in order to overcome and/or diminish said limitations. First, the individual's degree of language proficiency needs to be determined. This can be done by determining where along the "continuum of language functioning among Hispanics" an individual falls (Ponton & Leon-Carrion, 2001). The degree of language proficiency may be viewed as falling anywhere in the continuum of "English-dominant" on one end, "balanced bilingual" in the middle, and "Spanish-dominant" at the other end of the spectrum (Ponton & Leon-Carrion, 2001). The degree of language proficiency needs to take into account the individual's ability to speak and understand the language(s). It is then recommended that only those individuals who are "balanced bilinguals" or "English-dominant" be assessed using instruments developed and normed for monolingual (i.e., English only) individuals (Ponton, 2001). Furthermore, after determining an individual's level of language proficiency, researchers can then use this variable to examine its influence on cognitive processes.

Acculturation level has also been found to be a significant moderator variable in the performance outcomes of neuropsychological assessments (Ponton, 2001). Thus an individual's level of acculturation needs to be taken into account when interpreting neuropsychological data of bilingual individuals.

Demographic variables such as ethnicity, income and education are also often associated with and at times overlap with culture (Betancourt & Lopez, 1993). Furthermore, individuals' culture variables (e.g., income and education) can affect his/her performance on neuropsychological tests (Ponton, 2001). Therefore cultural variables need to be taken into account when examining the neuropsychological performances of Hispanics. More specifically, level of education and socio-economic status are important cultural variables that need to be considered in the neuropsychological evaluation of Hispanics.

Difficulties may emerge in the assessment of Hispanics due to the heterogeneity of the group and limitations of testing procedures. Nevertheless, it is imperative that neuropsychological research among this group continues to advance, as this minority group continues to grow and continues to be in need of professional services. Some potential solutions in overcoming limitations in the assessment of this group include controlling for cultural variables that influence the cognitive performance of individuals. By controlling variables such as level of language proficiency, acculturation, education and SES, fewer errors will be introduced when assessing the cognitive performances of these individuals (Ponton, 2001).

Myelomeningocele and Latino Children - Preliminary Research

Preliminary research suggests that English-speaking and Spanish-speaking children with MM and HC differ in their neuropsychological profiles. Jackson and collaborators (2008) examined the cognitive profiles of monolingual-English and bilingual-English/Spanish children some with only MM and other with MM-HC and found that bilingual children performed significantly better than their counterparts on verbal memory tasks. Previous research on memory functions among bilinguals suggests such an advantage among individuals with intact cognitive abilities (i.e., no previous brain insult/trauma). As seen in the study by Jackson and colleagues, this advantage appears to remain despite the insult that MM has on the brain. In addition, Jackson and associates reported that bilingual children with MM displayed a better understanding of information than their monolingual counterparts when it was visually presented. These findings also support previous research on bilingualism and the cognitive functions of individuals with intact (i.e., no previous brain insult/trauma) abilities. Overall, being bilingual brings a cognitive advantage in visual functions.

On the other hand, Jackson and colleges (2008) found that bilingual children with MM had poorer performance on tasks of visual memory when compared to monolingual children with MM. Although bilingual children with MM seemed to understand visually based information better than monolingual children, this was not the case for tasks that assessed visual memory. Thus the question is raised as to why a visual advantage would be present among bilingual children with MM in some functions (visual comprehension of information) and not others (visual memory)? Although Jackson and colleagues' study has begun to shed light on a previously unexplored area, the need to formally examine additional cognitive abilities between monolingual and bilingual children with MM-HC still remains.

In addition, the effects of shunt revision and/or replacement surgeries on the cognitive abilities of bilingual children are yet to be examined. Jackson et al. (2008) investigated the impact of shunt revisions (due to malfunctions or infections) on the neuropsychological functioning of children with MM-HC. Although bilingual children were included in his study, these investigators did not further investigate the impact of shunt revisions/replacements on this particular group and whether they differed from monolinguals. Hence the impact of shunt revisions/replacements on the neuropsychological functioning of bilingual children with MM-HC remains to be explored. In addition, research needs to evaluate whether being bilingual brings an advantage for those that have undergone additional brain insults such as surgeries for shunt revisions and/or replacements.

Finally, although Jackson and colleges began to investigate the neurocognitive functions between monolingual and bilingual children with MM, the study failed to control for demographic backgrounds such as language proficiency, acculturation, education and socioeconomic status, which have been found to influence the scores of bilingual individuals. Thus, future studies that examine the cognitive functions of bilingual children with MM-HC should be attentive to these demographic variables.

Controlling for the effects of these variables will introduce fewer errors when assessing the neurocognitive performance of bilingual individuals.

Conclusions

Myelomeningocele and hydrocephalus affect thousands of children in the United States each year. Despite a recent decline in the rate of MM-HC, children of Hispanic background continue to have the highest prevalence rate of any ethnic group. Several cognitive deficits have been documented as a result of MM-HC. Children with MM-HC experience deficits in overall intellectual functioning, attention, memory, executive functions, visuospatial and motor abilities.

Emergent research on bilingualism has found several advantages for those who are bilingual. Research supports the findings that the repeated use and management of two languages enhances the executive functions and attention processes of those who are bilinguals. Although in its beginning stages, some support has also emerged indicating a positive effect of bilingualism on memory and visuospatial functions. Thus, it appears that the process of learning and using two languages gives the brains of bilinguals an advantage, as cognitive functions are enhanced by the processes used to effectively manage the two languages. Although this cognitive advantage seems to be present among healthy and cognitively intact bilinguals, it is unknown as to whether this advantage is able to develop after some type of brain insult, such as MM-HC.

Furthermore, if the bilingual cognitive advantage does develop, despite a brain insult such as MM-HC, a study that explores said advantage among bilingual children with MM-HC remains to be done. Although research has found cognitive deficits among children with MM-HC, it is unknown as to whether these deficits differ between monolingual and bilingual children with this condition. If the bilingual cognitive advantage observed in cognitively intact children also remains in children with MM-HC (in spite of the brain insult), wouldn't the cognitive functions of bilingual children with MM-HC be better than those of the monolingual children with MM-HC? This question remains to be answered. However, if research reveals that bilingual children with MM-HC appear to have better cognitive performances than those of monolingual children with MM-HC, then it would be reasonable to suggest that the mechanisms underlying the learning and execution of two languages may be responsible for enhancing the cognitive abilities of those who have undergone a brain insult such as MM-HC. This could certainly have an impact on future treatments, as one can possibly implement the learning of a second language as an early intervention to enhance cognitive processes among children with MM-HC. Thus, a study that examines the possible cognitive advantages that bilingualism brings among children with MM-HC is warranted.

As previously reviewed, preliminary research has found some differences between bilingual and monolingual children with MM-HC (see Jackson et al., 2008). However, the cognitive domains examined were restricted to verbal/visual comprehension and memory. Nevertheless, attention, executive function and visuospatial/motor dysfunction, which are deficits commonly seen in children with MM-HC, remain to be examined in regards to the possible influence of bilingualism. Furthermore, it is unknown as to whether being bilingual gives a cognitive advantage to those who undergo <u>additional</u> brain insults, such as shunt revisions/replacement surgeries, which are commonly seen in those with MM-HC. Therefore, examining the cognitive profiles of those who have undergone shunt revisions provides an adequate context to study the effects of bilingualism on cognition and whether a cognitive advantage exists despite additional brain trauma.

Aim and Hypotheses

The aim of this study was to investigate whether a cognitive advantage exists among bilingual children with myelomeningocele and hydrocephalus.

It was hypothesized that:

1. Bilingual children with MM who have been shunted for HC would have less cognitive deficits than monolingual children with MM who have also been shunted for HC.
2. Bilingual children with MM-HC who underwent shunt revision and/or replacement surgery/surgeries would have less cognitive deficits than their monolingual MM-HC counterparts.

Methods

Participants

The target population for this study is monolingual and bilingual children with MM-HC. Participants were recruited from the Loma Linda University Spina Bifida Clinic. The clinic is open once a week and sees approximately 20 patients each day it is open. Children between the ages of six and 17 were selected for this study. Inclusion criteria for the monolingual group included: (1) diagnosis of MM; (2) prior placement of ventriculoperitoneal (VP) shunt; and (3) functional mastery of the English language. Inclusion criteria for the bilingual group included: (1) diagnosis of MM; (2) prior placement of ventriculoperitoneal (VP) shunt; (3) functional mastery of the English language; (4) functional mastery of the Spanish language. Exclusion criteria for both groups included: (1) physical disabilities of movement that may comprise standardization of testing, and (2) presence of neurological illness or condition not directly related to MM or HC.

Measures

Demographic information. Participants and/or parents/legal guardians were asked to provide information regarding participant's age, date of birth, place of birth, grade level, whether the participant was bilingual, number of shunts, age of first shunt, number of shunt infections, age of first shunt infection, number of shunt revision surgeries, ages of all shunt related surgeries, date of last shunt related surgery, location of MM lesion, and weeks of gestation. Gathered medical information was corroborated with available medical records. Additional information regarding household income and grade level completed by parent/legal guardian with the highest level of education was also collected. (See Appendix A).

Neuropsychological measurements. Cognitive functions were assessed by utilizing various neuropsychological measures. These measures included the following: Wechsler Intelligence Scale for Children – Fourth Edition (WISC-IV, 2003), the Controlled Oral Word Association Test (COWAT) FAS subtest (1976), the Animals semantic fluency test (1976), the California Verbal Learning Test-Children's version (CVLT-C, 1994), the Rey Complex Figure Test with Recognition Trial (RCFT, 1941 & 1944), the Grooved Pegboard test (1964), the Trail Making Test part A and B (TMT, 1944), and the Wisconsin Card Sorting Test abbreviated form (WCST-64, 1948). A description of these measures is provided below.

Wechsler Intelligence Scale for Children – Fourth Edition (WISC-IV). The WISC-IV is a test for assessing intelligence of children aged 6 through 16 years old. The test is comprised of 10 core subtests and five optional subtests. The 10 core subtests yield five indices: Verbal Comprehension Index (VCI), Perceptual Reasoning Index (PRI), Working Memory Index (WMI), Processing Speed Index (PSI) and a Full Scale Intelligence Quotient (FSIQ). These indices can be interpreted individually, and/or can be combined to make the FSIQ. The FSIQ and all indices are based on a mean of 100 and a standard deviation of 15. Furthermore, the 10 core subtests (which were utilized for this study) include Block Design (examinee is required to replicate a set of modeled two-dimensional geometric patterns within a specified time limit), Similarities (examinee is required to describe how two words are similar), Digit Span (Digit Span Forward:

examinee is required to repeat numbers verbatim and on Digit Span Backward the examinee is required to repeat numbers in the reverse order), Picture Concepts (examinee is required to choose one picture from among two or three rows to form a group with a common characteristic), Coding (examinee is required to copy symbols that are paired with either geometric shapes or numbers within a specified time limit), Vocabulary (examinee is required to provide definitions for words), Letter Number Sequencing (examinee is read a number and letter sequence and is required to recall numbers in ascending order and letters in alphabetical order), Matrix Reasoning (examinee is required to complete the missing portion of a picture matrix by selecting one of five options), Comprehension (examinee is required to answer a series of questions based on his/her understanding of general principles and social situations), and Symbol Search (examinee is required to scan a search group and indicate the presence or absence of target symbols within a specified time limit). The subtests are based on a mean of 10 and a standard deviation of 3.

Tests of Verbal Fluency. The FAS from the Controlled Oral Word Association is a verbal phonemic fluency test in which the examinee has to say as many words as possible that begin with a particular letter (i.e., F, A, and S) within an allotted time. In addition, the Animals test is utilized to assess verbal semantic fluency. In this task, the examinee is required to say as many words as possible from a given category (in this case animals) within an allotted time. Results obtained from FAS and Animals are standardized and later compared to age-appropriate normed data.

California Verbal Learning Test- Children's version. The CVLT-C assesses immediate learning and delayed recall of a list of words that are semantically related. In this test the participant is asked to learn a list of words throughout five trials. An interference task is given followed by a short-delay free (and cued) recall trial (this trial assesses immediate learning). After a 20-minute delay, a free recall (and cued recall) trial is administered (this trial assesses delayed recall of words). In addition a word-recognition trial is also administered. The CVLT-C measures verbal memory, learning rate, learning strategies and retention of information over short and long delays. Results are standardized and compared to age-appropriate normed data. Although all trials of the CVLT-C were administered to the participants of this study, only the total number of words learns after the five trial presentation, the short delay free recall and the long delay free recall scores were examined.

Rey Complex Figure Test. The Rey Complex Figure Test (RCFT) is a test normed for individuals 6 to 89 years of age. In this test, the examinee is asked to copy a complex figure design and then reproduce the figure from memory three-minutes, and 30 minutes later. There is also a recognition trial following the 30 minutes delay. Examinees' scores are standardized and compared to age-appropriate norms. Although all trials of the RCFT were administered to the participants of this study, only the copy, three minute delay and 30 minute delay trials were examined.

Grooved Pegboard Test. The Grooved Pegboard test is used to assess speeded motoric function. In this test, the examinee is required to place key-like pegs into holes using only their dominant hand, and then using their non-dominant hand. A score is then determined based on the time needed to place all the pegs in the holes. Scores are standardized and compared to age appropriate norms.

Trail Making Test- Part A and B. The TMT part A requires the examinee to draw a line from one circled number to another in numerical order. In part B, the examinee is required to connect a series of numbers and letters in alternating sequential order (e.g., number then letter). Both tasks (part A and B) are timed. Scores are standardized and compared to age-appropriate norms.

Wisconsin Card Sorting Test. The WCST consists of four stimulus cards and 64 response cards. The examinee is asked to match each of the response cards to one of the four stimulus cards. The examinee is not told how to match each response card, but is told whether it is a correct or incorrect response. After a set number of correct responses, the matching principle is changed. Then, the examinee is to use the feedback (correct or incorrect) to determine the new matching principle. This test has been normed for individuals ages 6 through 89. Examinees' scores are standardized and compared to age-appropriate norms.

Cultural measurements. Language proficiency and acculturation level among bilinguals was measured by using a self-report measure (Gasquoine et al., 2007) and the Brief Acculturation rating Scale for Mexican Americans-II for Children and Adolescents (Bauman, 2005), respectively.

Language proficiency. Bilinguals' level of language proficiency was assessed using Gasquoine and collaborators' self-report measure (2007) (see Appendix B). Participants were asked their preferred language for conversation from amongst the triad "Spanish," "English," or "Both." Additionally, participants were asked to rate their current ability to speak and understand Spanish, as well as their ability to speak and understand English on a five-point Likert scale with the anchors of "minimal" to "high."

These ratings were then collapsed into a single difference score by subtracting the sum of the two English fluency ratings (ability to speak and ability to understand English) from the sum of the two Spanish fluency ratings (ability to speak and ability to understand Spanish). A score between “-8” and “-3” was utilized to select those with greater self-rated proficiency in English (Monolinguals), while a score between “-2” and “5” indicated greater self-rated proficiency in both English and Spanish (Bilinguals). (See Appendix B for scoring instructions).

Acculturation. The Brief Acculturation Rating Scale for Mexican Americans-II for children (Brief ARSMA-II for children) was used to assess levels of acculturation among bilingual participants (Bauman, 2005) (see Appendix C). The Brief ARMSA-II for Children and Adolescents uses a multidimensional approach by measuring cultural orientation toward the Mexican culture and the Anglo culture independently. The measure is comprised of 12 items (containing 6 for the Mexican Oriented scale (MOS), and 6 for the Anglo Oriented Scale(AOS)) and has a response on a Likert-type scale ranging from one (not at all) to five (almost always/extremely often). Each item is written in Spanish and English on the same form, so all participants receive the same form. In order to obtain a mean for each scale (MOS and AOS), the average of each scale is calculated by summing each item on the scale and dividing the total score by six. Subsequently, the mean of the MOS scale is subtracted from the mean of the AOS scale. The score indicates the level of acculturation. Level 1 is classified as “very Mexican oriented”, Level 2 “Mexican oriented or balanced bicultural”, Level 3 “slightly Anglo oriented bicultural”, Level 4 “strongly Anglo oriented”, and Level 5 “very assimilated, Anglicized”.

Procedure

Medical records from the Loma Linda University Spina Bifida Team Clinic were reviewed to identify potential participants who met inclusion criteria. The parents/legal guardians of children who had been diagnosed with MM-HC were subsequently approached by the primary investigator during one of the patient's routine appointments. They were informed that the study was examining the cognitive abilities of monolingual and bilingual children with MM-HC. Those parents who verbally consented to have their children participate were then invited to travel to the Loma Linda University Department of Psychology, where all the testing procedures took place. Upon arrival, participants were provided with assent forms (Appendix D). Parents/legal guardians were provided with written consent forms and the California experimental subject's bill of rights, in either English (Appendix E and F) or Spanish (Appendix G and H), depending on their preference. Additional questions regarding the purpose and procedures of the study were answered before proceeding with the evaluation.

An intake interview was conducted with participants and their parents/legal guardians to obtain background information. Subsequently, the participants were given the neuropsychological assessment battery and cultural measures mentioned above.

Confidentiality of data. All participant information was held confidential and available only to those directly involved in the study. Participants and their parents/legal guardians were provided with a summary of the results pertaining to cognitive strengths and weaknesses. Participants and their parents/legal guardians were not given their IQ scores or percentile rankings of cognitive functioning.

Results

Data Screening

Prior to hypothesis testing, the data were screened to verify assumptions of analysis of covariance (ANCOVA). ANCOVA analyses are sensitive to missing data, multivariate normality, outliers, linearity, and homogeneity of variance matrices. Thus the data were screened for accuracy of input, missing data, univariate and multivariate outliers, univariate and multivariate normality and linearity and homogeneity of variance. An alpha level of .01 was used for this screening.

This data included several missing values in three particular variables. These were: FAS (missing data for 8 subjects), Animals (missing data for 8 subjects), and Rey Complex Figure Test- three minute recall (missing data for 8 subjects). Scores for missing data were imputed using group mean substitution. Thus, the mean for a particular missing value was computed by averaging the scores of participants who were similar in age, gender, language preference, grade level, and history of additional shunt surgeries.

Screening for univariate outliers was conducted by examining scores that had a z-score greater than "3." Analyses revealed the presence of no univariate outliers. Skewness and kurtosis analyses revealed normality among all dependent variables used in the analyses with the exception of Trail Making Test part B (TMTB). The TMTB test showed significant skewness and kurtosis. Transformation of values for the TMTB was not performed in order to preserve the meaningfulness of original data obtained; however it should be noted that because of the violated normality, the effect sizes might be deflated. Furthermore, none of the variables of relevance to the hypotheses showed evidence for multicollinearity. The assumption of homogeneity of variance was tested through the Levene's Test of Error Variances which was within acceptable ranges for all variables.

Sample Characteristics

Statistical analyses were performed on 49 children with MM-HC. Of note, ten of the participants' data were obtained from archival data collected approximately 15 months prior to the current study. The same protocol and measures were used for those in the archival data with the exception of the two verbal fluency measures, one condition of the Rey Complex Figure Test (three minute delay) and the two cultural measures. An attempt was made to contact all of the ten subjects to re-evaluate them. However, only two of the ten subjects were available to be re-evaluated. As previously explained, mean data imputation procedures were used to calculate the scores of the eight remaining participants.

The participant's ages ranged from six to 17 years of age, while their grade level extended from first to 12th grade. Fifty-five percent of the participants were male and over half of them (57.1%) had undergone an additional shunt surgery due to a shunt infection and/or malfunction. The majority of the participants were right handed (65.3%) and the two most frequent location of myelomeningocele were at the Mid Lumbar or Lumbosacral level (38.8% and 26.5%, respectively).

The bilingual group was composed of 22 participants, with a mean age of 12.81 and mean years of education of 7.22. Fifty percent of the participants were male, and 51.9% of them had undergone an additional shunt surgery. The majority of participants were born in the United States (90.9%). Furthermore, 72.7% of the bilingual participants spoke both English and Spanish at home. The majority of the bilingual participants' annual family income was below $39,999 (77.3%), and the mean for the parents with the highest level of education was 10.27 years. Additionally, none of the children in the bilingual sample sustained a MM injury at the low lumbar level.

In contrast, the monolingual group was composed of 27 participants, with a mean age of 11.67 and mean years of education of 6.07. Fifty nine point three percent of the monolingual participants were male, and 63.6% of participants in this group had undergone an additional shunt surgery. None of the monolingual children reported myelomeningocele injury levels in the thoracic or high lumbar areas. The majority of the monolingual's annual family income was above $25,000 (74%) and the mean level of education for the parent who completed the highest level of education was 13.70 years.

Statistically significant differences were found between bilingual and monolingual children in regards to weeks of gestation, (bilinguals having longer gestational periods, $t(47) = -2.07$, $p = .04$), parental level of education (monolinguals having parents with higher levels of education, $t(47) = 3.63$, $p = .001$), location of myelomeningocele (bilinguals having more children with thoracic and high lumbar lesion levels, and monolinguals having more children with mid lumbar lesion levels, X^2 (5, N=49) = 23.66, $p < .01$), household income (bilinguals reporting a higher percentage of income in the $15K-$24,999 bracket than monolinguals, X^2 (4, N=49) = 7.81, $p = .01$), and handedness (monolinguals having more right handed children than bilinguals, and bilinguals having more left handed children, X^2 (1, N=49) = 4.13, $p = .04$). See Table 1 for additional details.

Table 1

MM-HC Demographics - Means, Standard Deviations (SD) & Percentages

	Total (49)		Bilingual (22)		Monolingual (27)	
	Mean (SD)	%	Mean (S.D)	%	Mean (S.D)	%
Age (Yrs)	12.18 (3.59)		12.81 (3.35)		11.67 (3.75)	
Education (Yrs)	6.59 (3.65)		7.22 (3.68)		6.07 (3.62)	
Num of Shunts	1.65 (1.07)		1.68 (.78)		1.63 (1.28)	
Weeks of Gestation	38.59 (2.00)		39.23 (1.57)*		38.07 (2.20)*	
Parental Level of Education	12.16 (3.54)		10.27 (3.91)*		13.70 (2.30)*	
Language Proficiency	-4.14 (3.85)		-.27 (1.64)**		-7.30 (1.46)**	
Gender (%)						
Male		55.1		50		59.3
Female		44.9		50		40.7
Shunt Infection (%)						
Yes		16.3		13.6		18.5
No		83.7		86.4		81.5
Shunt Malfunction (%)						
Yes		46.9		50		44.4
No		53.1		50		55.6
Additional Surgery (%)						
Yes		57.1		51.9		63.6
No		42.9		48.1		36.4
Location of MM (%)						
Thoracic		6.1		13.6*		0*
High Lumbar		14.3		31.8*		0*
Mid Lumbar		38.8		13.6**		59.3**
Low Lumbar		8.2		0		14.8
Lumbosacral		26.5		36.4		18.5
Sacral		6.1		4.5		7.4
Household Income (%)						
$0-$14,999		24.5		27.3		22.2
$15K-$24,999		14.3		27.3*		3.7*
$25K-$39,999		26.5		22.7		29.6
$40K-$59,999		14.3		4.5		22.2
$60+		20.4		18.2		22.2
Handedness (%)						
Right		65.3		50*		77.8*
Left		34.7		50*		22.2*
Immigration Status						
US Born		0		90.9		0

Table 1. *Continued*

Foreign Born	0	9.1	0
Language Spoken at Home			
English	0	4.5	0
Spanish	0	22.7	0
Both	0	72.7	0
Level of Acculturation			
- Very Mexican Oriented	6.1	13.6*	0*
- Mexican Oriented or Balanced Bilingual	6.1	13.6*	0*
- Slightly Anglo Oriented/Bicultural	30.6	59.1**	7.4**
- Strongly Anglo Oriented	14.3	13.6	14.8
- Very Assimilated/ Anglicized	42.9	0**	77.8*

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

Analyses were also completed for those who have had additional shunt related surgeries as a result of shunt infection and/or shunt malfunction. The majority of additional shunt surgeries were due to shunt malfunctions (82.1%) as opposed to shunt infections (28.6%). In addition, the majority of those who underwent additional shunt surgeries had mid lumbar level lesions (39.3%).The majority of those with additional surgeries were males (57.1% bilinguals and 71.4% monolinguals). Statistically significant differences were found between bilinguals and monolinguals in regards to parental level of education, location of myelomeningocele and handedness. The parents of monolingual children who have had additional shunt related surgery had higher level of education (t (26) = 2.83, $p = .01$). Furthermore, monolingual children with additional shunt related surgeries also tended to have more mid-lumbar and low lumbar lesions than their bilingual counterparts (X^2 (5, N=28) = 14.60, p = .01). Finally, There were significantly more right handed monolingual children and significantly more left handed bilingual children (X^2 (1, N=28) = 5.60, p = .02). See Table 2 for additional demographic information.

Factor Analyses

After the administration of the neuropsychological measures, data were scored and compared to age-appropriate norms. Subsequently, all data was converted to the same metric by standardizing raw scores into z-scores. Z-scores are based on a mean of "0" and a standard deviation of "1."

The scores (i.e., z-scores) from the various neuropsychological tests were factor analyzed using factor analysis with Varimax (orthogonal) rotation. A minimal loading value of .30 was selected for the analyses. The analysis yielded six factors explaining a total of 70.27% of the variance for the entire set of variables. Factor 1 was labeled "Verbal Abilities" due to the high loadings by the following tests: Vocabulary, Comprehension, Picture Concepts, Digit Span, Similarities, and Animals. This first factor explained 16.65% of the variance. The second factor derived was labeled "Visual Memory and Abilities" and contained the following tests: Rey Complex Figure test (RCFT)-3 minute delay, RCFT-30 minute delay, Letter Number Sequencing, Matrix Reasoning, and FAS. This factor accounted for 13.61% of the variance. The third factor was labeled "Motor Abilities" and was composed of Grooved Pegboard- dominant hand, Grooved Pegboard- non-dominant hand, RCFT-copy, and Block Design. This third factor accounted for 13.55% of the variance. The fourth factor was comprised of the California Verbal Learning Test for children (CVLT-C) total score, CVLT-C Short Delay Free

Table 2

Additional Surgeries Demographics - Means, Standard Deviations (SD) & Percentages

	Total Sample with additional Surgeries (28)		Bilinguals with additional surgeries (14)		Monolinguals with additional surgeries (14)	
	Mean (S.D)	%	Mean (SD)	%	Mean (S.D)	%
Age (Yrs)	11.86 (3.64		12.5 (3.50)		11.21 (3.79)	
Education (Yrs)	6.29 (3.80)		6.93 (3.83)		5.64 (3.79)	
Num of Shunts	2.14 (1.21)		2.07 (.73)		2.21 (1.58)	
Weeks of Gestation	38.36 (2.28)		38.79 (1.85)		37.93 (2.64)	
Parental Level of Education	12.36 (3.74)		10.57 (3.94)*		14.14 (2.60)*	
Language Proficiency	-3.79 (4.04)		-.07 (1.73)**		-7.5 (1.09)**	
Gender (%)						
Male		64.3		57.1		71.4
Female		35.7		42.9		28.6
Shunt Infection (%)						
Yes		28.6		21.4		35.7
No		71.4		78.6		64.3
Shunt Malfunction (%)						
Yes		82.1		78.6		85.7
No		17.9		21.4		14.3
Additional Surgery (%)						
Yes		100		100		100
No		0		0		0
Location of MM (%)						
Thoracic		7.1		14.3		0
High Lumbar		17.9		35.7		0
Mid Lumbar		39.3		14.3*		64.3*
Low Lumbar		7.1		0*		14.3*
Lumbosacral		25		28.6		21.4
Sacral		3.6		7.1		0
Household Income (%)						
$0-$14,999		28.6		21.4		35.7
$15K-$24,999		21.4		35.7		7.1
$25K-$39,999		17.9		21.4		14.3
$40K-$59,999		7.1		0		14.3
$60+		25		21.4		28.6
Handedness (%)						
Right		64.3		42.9*		85.7*
Left		35.7		57.1*		14.3*

Table 2. *Continued.*

Immigration Status			
US Born	0	92.9	0
Foreign Born	0	7.1	0
Language Spoken at Home			
English	0	0	0
Spanish	0	28.6	0
Both	0	71.4	0
Level of Acculturation			
- Very Mexican Oriented	7.1	14.3	0
- Mexican Oriented or Balanced Bilingual	7.1	14.3	0
- Slightly Anglo Oriented/Bicultural	32.1	57.1*	7.1*
- Strongly Anglo Oriented	10.7	14.3	7.1
- Very Assimilated/ Anglicized	42.9	0*	85.7*

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

Recall, CVLT-C Long Delay Free Recall, and Symbol Search. This factor was labeled "Verbal and Working Memory" and accounted for 12.37% of the variance. Factor number five was labeled "Processing Speed" and was comprised of the Trail Making Test (TMT) part A, TMT part B, and Coding. This factor accounted for 7.83% of the variance. Finally, the sixth factor was labeled "Executive Functions" explaining 6.26% of the variance. This factor was comprised of the Wisconsin Card Sorting Test-64 cards. (See Table 3 for a detailed description of the factor analyses).

Adjustments to factor one "Verbal Abilities" and factor two "Visual Memory and Abilities" were made. Variables that comprised factor one are related to comprehension/knowledge of verbal material and language related processes. However, Picture Concepts, which loaded onto this factor, is a measure of non-verbal fluid reasoning and perceptual organization and does not theoretically fit on to the verbal

Table 3

Factor Loadings from Factor Analysis with Varimax Rotation

Item	Factor Loading					
	1	2	3	4	5	6
Vocabulary	**.758**	.294	-.188	-.022	.264	.056
Comprehension	**.732**	-.143	.034	.106	.333	-.015
Picture Concepts	**.699**	.107	.263	.005	.036	.126
Digit Span	**.690**	.082	.282	.223	-.014	.087
Similarities	**.657**	.344	-.279	.112	-.056	.221
Animals	**.461**	.220	.163	.262	.165	.268
RCFT 3 minute delay	.090	**.880**	.220	.048	.111	-.108
RCFT 30 minute delay	.061	**.796**	.240	.135	.177	.071
Letter Number Sequencing	.374	**.549**	-.045	.186	.061	.371
Matrix Reasoning	.318	**.540**	.496	.273	-.296	-.024
FAS	.447	**.529**	-.285	.185	.194	-.243
Grooved Pegboard Dominant	.065	-.055	**.787**	.018	.240	.190
RCFT Copy	-.029	.238	**.782**	.068	.077	-.154
Grooved Pegboard Non-Dominant	.084	.229	**.741**	-.002	.243	.323
Block Design	.419	.370	**.463**	.359	-.128	-.020
CVLT SDFR	-.002	.051	.025	**.936**	.024	.094
CVLT LDFR	.122	.155	.199	**.835**	.227	.150
CVLT Total	.295	.144	-.263	**.619**	.135	.354
Symbol Search	.447	.238	.139	**.551**	.227	-.243
Trail Making Test A	.247	-.034	.436	.087	**.683**	.155
Coding	.112	.246	.190	.286	**.659**	-.080
Trail Making Test B	.256	.374	.032	.124	**.499**	.277
WCST	.167	-.064	.204	.201	.075	**.770**
Eigenvalue	7.49	2.75	1.91	1.76	1.2	1.05
% of Total Variance	16.65	13.61	13.55	12.37	7.83	6.26
Total Variance						70.27

abilities construct, thus this variable was dropped from this factor. As it did not load to a sufficient level on any other factor, it was eliminated from all analyses. Furthermore, FAS (which is a measure of verbal fluency) loaded on to factor two, which is comprised of items that assess visual memory and visual abilities. However, it was deemed more appropriate for FAS to be moved to factor one (i.e., Verbal Abilities), a move justified by its sufficient loading on that factor as well. Letter-Number Sequencing (LNS) was loaded on to factor two. However, LNS is a test that involves ordering numbers and letters presented in an unordered sequence, which requires aspects of attention and executive function skills. This test was deemed more appropriate to be part of factor 6 (Executive Functions), and loaded to a sufficient level to this factor, hence it was moved. See Table 4 for a description of the final neurocognitive components used for analyses.

Following the factor analyses, the z-scores of each variable from each factor were summed, allowing for a mean z-core to be calculated for each particular factor. The six factors resulting from the factor analyses represent the six different cognitive domains that will be assessed among monolingual and bilingual children with MM-HC. In addition to these six cognitive domains, the Full Scale IQ (FSIQ) scores were also included in the analyses to represent the domain of "General Intellectual Abilities." Table 5 contains the means and standard deviations of the seven cognitive domains for bilingual and monolingual children with MM-HC (Hypothesis 1) and Table 6 contains the means and standard deviations of the seven cognitive domains for bilingual and monolingual children with MM-HC that have undergone additional shunt-related surgeries (Hypothesis 2).

Table 4

Final Components

Name of Component	Subtests
General Intellectual Abilities	FSIQ
Verbal Abilities	Vocabulary
	Comprehension
	Digit Span
	Similarities
	Animals
	FAS
Visual Memory and Abilities	RCFT 3 min delay
	RCFT 30 min delay
	Matrix Reasoning
Motor Abilities	Grooved Pegboard Dom
	Grooved Pegboard Non Dom
	RCFT Copy
	Block Design
Verbal and Working Memory	CVLT Total
	CVLT SDFR
	CVLT LDFR
	Symbol Search
Processing Speed	TMT A
	TMT B
	Coding
Executive Functions	WCST
	Letter Number Sequencing

Analyses of Covariance

Hypothesis One. Hypothesis one stated that bilingual children with MM who have been shunted for HC would have less cognitive deficits than monolingual children with MM who have also been shunted for HC. This hypothesis was rejected. Analyses of covariance were performed to determine whether differences between bilingual children with MM-HC and monolingual children with MM-HC were present across the seven cognitive domains after covarying for participant's level of language proficiency, participant's level of acculturation, parental income level, and parental level of education.

Table 5

Z-score Means and SDs of Neurocognitive Components for Children with MM-HC

	Total (49)		Bilingual (22)		Monolingual (27)	
	Mean	SD	Mean	SD	Mean	SD
General Intellectual Abilities	-1.82	0.79	-1.63	0.78	-2.06	0.74
Verbal Abilities	-1.29	0.69	-1.48	0.65	-1.14	0.70
Visual Memory and Abilities	-1.74	0.72	-1.97	0.65	-1.55	0.73
Motor Abilities	-1.62	0.92	-1.76	0.82	-1.51	0.99
Verbal and Working Memory	-1.40	0.83	-1.57	0.79	-1.25	0.84
Processing Speed	-2.06	0.74	-2.17	0.84	-1.97	0.64
Executive Functions	-1.09	0.87	-1.12	0.77	-1.06	0.95

Table 6

Z-score Means and SDs of Neurocognitive Components for those with Additional Surgeries

	Total Sample with Additional Surgeries (28)		Bilinguals with Additional Surgeries (14)		Monolinguals with Additional Surgeries (14)	
	Mean	SD	Mean	SD	Mean	SD
General Intellectual Abilities	-1.91	0.75	-2.17	0.58	-1.64	0.81
Verbal Abilities	-1.36	0.61	-1.58	0.44	-1.14	0.69
Visual Memory and Abilities	-1.74	0.75	-1.96	0.64	-1.51	0.80
Motor Abilities	-1.72	1.01	-1.9	0.84	-1.54	1.17
Verbal and Working Memory	-1.42	0.79	-1.67	0.72	-1.18	0.8
Processing Speed	-2.20	0.62	-2.37	0.56	-2.05	0.65
Executive Functions	-1.13	0.83	-1.09	0.71	-1.17	0.95

After adjustment by covariates, the component of “Visual Memory and Abilities” was significantly different between bilingual and monolingual children with MM-HC (F (1, 43) = 4.59, p = .04, η^2 = .10). In contrast to what hypothesis one stated, monolingual children (M = -1.55, SD = .73) had better performances in this cognitive domain than their bilingual counterparts (M = -1.98, SD = .65). Furthermore, analyses revealed that monolingual children with MM-HC (M = -1.25, SD = .84) performed significantly better than bilingual children with MM-HC (M = -1.57, SD = .79) in regards to Verbal and Working Memory abilities (F (1, 43) = 6.3, p = .02, η^2 = .13). This was also in contrast with what hypothesis one proposed.

No statistically significant differences were found between bilingual and monolingual children with MM-HC in regards to their General Intellectual Abilities (F (1, 43) = 1.28, p = .26), Verbal Abilities (F (1, 43) = 1.18, p = .28), Motor Abilities (F (1, 43) = .30, p = .59), Processing Speed (F (1, 43) = .02, p = .91), and Executive Functions (F (1, 43) = .52 p = .47). Again, this is also contrary with what was initially hypothesized.

Hypothesis Two. Hypothesis two stated that bilingual children with MM-HC who underwent additional shunt related surgeries would have less cognitive deficits than their monolingual MM-HC counterparts after covarying for participant's level of language proficiency, participant's level of acculturation, parental income level, and parental level of education. After adjustment by covariates, ANCOVA analyses revealed that there were no statistically significant differences between bilingual and monolingual children who underwent additional shunt related surgeries in any of the seven neurocognitive domains: General Intellectual Abilities (F (1, 22) = .99, p = .33), Verbal Abilities (F (1, 22) = 2.46, p = .13),Visual Memory Abilities (F (1, 22) = .92, p = .35), Motor Abilities (F (1, 22) = .12, p = .73), Verbal and Working Memory (F (1, 22) = .39, p = .54), Processing Speed (F (1,22) = .10, p = .75), and Executive Functions (F (1, 22) = .28 p = .60). Hypothesis two was rejected.

Exploratory Analyses

In order to further explore the effects of shunt revisions on cognition, additional analyses were conducted among all children with MM-HC who have had additional shunt related surgeries versus those who have not had additional shunt related surgeries (i.e., they only had the original shunt placement surgery, but no additional shunt related surgeries). Results revealed that there were no significant differences between children with no additional shunt related surgeries and children with additional shunts across the seven cognitive domains (General Intellectual Abilities ($F(1, 43) = .72$, $p = .40$), Verbal Abilities ($F(1, 43) = .62$, $p = .44$),Visual Memory Abilities ($F(1, 43) = .01$, $p = .92$), Motor Abilities ($F(1, 43) = .39$, $p = .54$), Verbal and Working Memory ($F(1, 43) = .21$, $p = .65$), Processing Speed ($F(1, 43) = 2.28$, $p = .14$), and Executive Functions ($F(1, 43) = .27$ $p = .60$)). See Table 7 for additional details.

In addition, each language group (i.e., bilinguals and monolinguals) was also evaluated to assess for significant cognitive differences among the additional versus no additional surgery groups. No significant differences were found among the bilinguals with additional surgeries versus the bilinguals with no additional shunt related surgeries (Table 8). Furthermore, no significant differences were found among the monolinguals with additional surgeries versus the monolinguals with no additional shunt related surgeries (Table 9).

Exploratory analyses were also conducted at the individual tests level to further investigate potential differences in the performances of bilingual and monolingual children with MM-HC as well as bilingual and monolingual children with MM-HC and additional shunt revision surgeries.

Table 7

Analysis of Covariance for Cognitive Domains- Additional Surgery vs. No Additional Surgery- Total Sample

Source	SS	df	MS	F	p	Partial Eta Squared
General Intellectual Ability	0.44	1	0.44	0.72	0.40	0.02
Verbal Abilities	0.3	1	0.3	0.62	0.44	0.01
Visual Memory/Abilities	0.01	1	0.01	0.01	0.92	0.00
Motor Abilities	0.34	1	0.34	0.39	0.54	0.01
Verbal and Working Memory	0.15	1	0.15	0.21	0.65	0.01
Processing Speed	1.18	1	1.18	2.28	0.14	0.05
Executive Functions	0.22	1	0.22	0.27	0.60	0.01

no significant differences

Table 8

Analysis of Covariance for Cognitive Domains- Additional Surgery vs. No Additional Surgery- Bilingual

Source	SS	df	MS	F	p	Partial Eta Squared
General Intellectual Ability	0.43	1	0.43	0.65	0.43	0.04
Verbal Abilities	0.27	1	0.27	0.53	0.48	0.03
Visual Memory/Abilities	0.05	1	0.05	0.1	0.76	0.01
Motor Abilities	0.71	1	0.71	0.97	0.34	0.06
Verbal and Working Memory	0.35	1	0.35	0.51	0.49	0.03
Processing Speed	1.75	1	1.75	2.55	0.13	0.14
Executive Functions	0.04	1	0.04	0.06	0.81	0.00

no significant differences

Table 9

Analysis of Covariance for Cognitive Domains- Additional Surgery vs. No Additional Surgery- Monolingual

Source	SS	df	MS	F	p	Partial Eta Squared
General Intellectual Ability	0.03	1	0.03	0.05	0.82	0.00
Verbal Abilities	0.06	1	0.06	0.13	0.72	0.01
Visual Memory/Abilities	0.22	1	0.22	0.5	0.49	0.02
Motor Abilities	0.05	1	0.05	0.05	0.82	0.00
Verbal and Working Memory	0.45	1	0.45	0.88	0.36	0.04
Processing Speed	0.3	1	0.3	0.69	0.42	0.03
Executive Functions	0.47	1	0.47	0.5	0.49	0.02

no significant differences

t-tests. t-tests were utilized to examine differences between the various tests administered to bilingual and monolingual children with MM-HC (and also analyses among those with additional shunt revision surgeries). Table 10 summarizes the means and standard deviations of the various tests utilized for the t-test analyses among bilingual and monolingual children with MM-HC, while Table 11 summarizes the means and standard deviations of the t-test analyses among children with additional shunt revision surgeries.

Bilinguals vs. Monolinguals. Independent-sample t-tests indicated that there were significant differences between bilingual and monolingual children with MM-HC in Perceptual Reasoning Index (t (47) = 2.22, $p<.05$), Processing Speed Index (t (47) = 2.01, $p<.05$), Block Design (t (47) = 2.56, $p<.05$), Symbol Search (t (47) = 2.78, $p<.05$), and Rey Complex Figure Test- 3 minute delay (t (47) = 2.14, $p<.05$). All of these tests indicated that monolinguals had better performances than their bilingual counterparts. (See Table 10 for means and standard deviations).

Bilinguals with shunt revision/replacement surgeries vs. Monolinguals with shunt revision/replacement surgeries. In addition, independent-sample t-tests were also utilized to examine possible differences in subtest performances between bilingual and monolingual children with MM-HC who have undergone additional shunt related surgeries. Results indicated that there were significant differences between these two groups in Processing Speed Index (t (26) = 2.44, $p<.05$), Block Design (t (26) = 2.14, $p<.05$), Vocabulary (t (26) = 2.52, $p<.05$), Symbol Search (t (26) = 2.76, $p<.05$), and FAS (t (26) = 2.15, $p<.05$). Again, these results indicated a better performance among the monolingual group then the bilingual group. (See Table 11 for means and standard deviations).

Table 10

Bilingual Children with MM-HC and Monolingual Children with MM-HC- t-tests of all Neuropsychological Subtests

	Total (49)		Bilingual (22)		Monolingual (27)	
	Mean	SD	Mean	SD	Mean	SD
Full Scale IQ	-1.82	0.79	-2.06	0.74	-1.63	0.78
VCI	-1.68	0.83	-1.9	0.71	-1.5	0.88
PRI*	-1.32	0.85	-1.6	0.73	-1.08	0.88
WMI	-1.54	1.01	-1.7	1.09	-1.41	0.93
PSI*	-1.44	0.79	-1.69	0.87	-1.24	0.66
Block Design*	-1.24	0.9	-1.6	0.72	-0.96	0.95
Similarities	-1.16	0.86	-1.39	0.6	-0.96	1
Digit Span	-1.14	0.9	-1.21	1.02	-1.09	0.81
Picture Concepts	-0.91	0.98	-1.09	0.92	-0.76	1.02
Coding	-1.40	0.95	-1.55	0.97	-1.28	0.93
Vocabulary	-1.52	1.00	-1.8	-1.67	-1.28	0.99
Letter Number Sequencing	-1.45	1.20	-1.58	1.24	-1.34	1.18
Matrix Reasoning	-1.03	0.88	-1.29	0.82	-0.81	0.88
Comprehension	-1.67	0.72	-1.74	0.70	-1.62	0.74
Symbol Search*	-1.23	0.84	-1.58	0.93	-0.95	0.64
TMT-A	-2.28	1.05	-2.32	1.2	-2.24	0.94
FAS	-1.26	1.18	-1.6	1.01	-0.97	1.24
Animals	-0.99	1.13	-1.11	0.93	-0.9	1.29
CVLT-C Total	-1.58	1.14	-1.63	1.06	-1.53	1.22
CVLT-C SDFR	-1.33	0.98	-1.48	0.82	-1.19	1.06
CVLT-C LDFR	-1.46	1.12	-1.61	0.95	-1.33	1.25
RCFT Copy	-1.85	1.31	-1.84	1.38	-1.85	1.27
RCFT 3 min delay*	-2.03	0.81	-2.30	0.72	-1.82	0.83
RCFT 30 min delay	-2.16	0.85	-2.34	0.77	-2	0.9
Grooved Pegboard- dom	-1.56	1.3	-1.61	1.2	-1.52	1.39
Grooved Pegboard- non-dom	-1.82	1.21	-2.00	1.02	-1.68	1.35
WCST	-0.73	0.92	-0.67	0.76	-0.77	1.05
TMT-B	-2.51	0.85	-2.65	0.85	-2.4	0.84

*$p<.05$

FSIQ= Full Scale IQ, VCI= Verbal Comprehension Index, PRI= Perceptual Reasoning Index, WMI= Working Memory Index, PSI= Processing Speed Index, TMT= Trail Making Test, CVLT-C = California Verbal Learning Test for Children, RCFT= Rey Complex Figure Test, WCST= Wisconsin Card Sorting Test.

Table 11

Bilingual and Monolingual Children with MM-HC with Additional Shunt Related Surgeries- t-tests of all Neuropsychological Subtests

	Total (28)		Bilingual (14)		Monolingual (14)	
	Mean	SD	Mean	SD	Mean	SD
Full Scale IQ	-1.91	0.75	-2.18	0.58	-1.64	0.81
VCI	-1.78	0.71	-2.03	0.56	-1.53	0.76
PRI	-1.27	0.95	-1.56	0.77	-0.99	1.04
WMI	-1.59	1.01	-1.86	0.99	-1.34	1.00
PSI*	-1.61	0.69	-1.91	0.64	-1.33	0.62
Block Design*	-1.23	0.97	-1.60	0.75	-0.86	1.05
Similarities	-1.30	0.82	-1.48	0.49	-1.14	1.04
Digit Span	-1.16	0.96	-1.38	0.94	-0.93	0.96
Picture Concepts	-0.89	1.06	-1.05	0.93	-0.74	1.18
Coding	-1.63	0.74	-1.81	0.75	-1.45	0.72
Vocabulary*	-1.63	0.79	-1.98	0.62	-1.29	0.81
Letter Number Sequencing	-1.46	1.18	-1.55	1.22	-1.38	1.18
Matrix Reasoning	-0.93	0.96	-1.17	0.89	-0.69	0.99
Comprehension	-1.70	0.69	-1.81	0.74	-1.60	0.66
Symbol Search*	-1.32	0.84	-1.72	0.75	-0.93	0.76
TMT-A	-2.41	0.95	-2.46	1.06	-2.37	0.87
FAS*	-1.18	1.11	-1.61	0.68	-0.76	1.30
Animals	-1.16	0.94	-1.19	0.91	-1.14	1.00
CVLT Total	-1.55	1.06	-1.67	1.07	-1.43	1.07
CVLT SDFR	-1.32	1.01	-1.54	0.77	-1.11	1.20
CVLT LDFR	-1.50	1.06	-1.75	0.85	-1.25	1.22
RCFT Copy	-1.93	1.28	-2.04	1.26	-1.82	1.34
RCFT 3 min delay	-2.07	0.80	-2.35	0.66	-1.80	0.86
RCFT 30 min delay	-2.20	0.90	-2.36	0.75	-2.05	1.03
GP- Dom	-1.86	1.33	-1.94	1.28	-1.78	1.41
GP- Non-Dom	-1.87	1.27	-2.04	1.17	-1.71	1.40
WCST	-0.79	0.95	-0.63	0.76	-0.96	1.12
TMT-B	-2.57	0.77	-2.83	0.53	-2.31	0.90

$^*p < .05$

FSIQ= Full Scale IQ, VCI= Verbal Comprehension Index, PRI= Perceptual Reasoning Index, WMI= Working Memory Index, PSI= Processing Speed Index, TMT= Trail Making Test, CVLT-C= California Verbal Learning Test for Children, RCFT= Rey Complex Figure Test, WCST= Wisconsin Card Sorting Test.

Discussion

Research on bilingualism has found several cognitive advantages among those who are bilingual. For example, research suggests that the frequent use and management of two languages augments executive functions, enhances attention processes, and improves memory and visuospatial functions (Bialystok, 2001; Bialystok, 2007; Chuneyeva, 2009; Kormi-Nouir, Moniri & Nilsson 2003; Kormi-Nouri et al, 2008; and McLeay, 2003). Thus, research suggests that the processes used to effectively manage two languages give the brains of bilinguals an advantage as cognitive functions are enhanced by the process of learning and utilizing two languages. Nevertheless, this cognitive advantage has only been documented among healthy and cognitively intact bilinguals. Thus a question to be answered is: can the cognitive advantage seen among bilinguals develop despite brain insults, such MM-HC?

Several cognitive deficits have been documented as a result of MM-HC, such as deficits in overall intellectual functioning, attention, memory, executive functions, visuospatial and motor abilities (Dennis, Rogers & Barnes, 2001; Del Bigio, 1993; Fletcher, Barnes & Dennis, 1998; Fobe et al., 1999; Hommet et al., 1999; Jacobs et al., 2001; Snow, 1999; Wills, 1993). However, it is unknown how these deficits may differ in bilingual children with MM-HC who may have a cognitive advantage as compared to monolingual children with MM-HC. If the bilingual cognitive advantage also develops among bilingual children with MM-HC, then one would expect that cognitive functions among these children would be significantly better than those of the monolingual children with MM-HC. Thus, a study that examines the possible cognitive advantages that bilingualism might bring among children with MM-HC is warranted.

In addition, it is unknown as to whether being bilingual gives a cognitive advantage to those who undergo additional brain insults, such as those seen as a result of shunt revision and/or replacement surgeries. Thus, examining the neuropsychological profiles of bilingual children with MM-HC who have undergone shunt revision and/or replacement surgeries (i.e., additional surgeries due to shunt infections and/or shunt malfunctions) will elucidate whether a cognitive advantage may exist among bilingual children with MM-HC despite additional brain trauma. As a result, this study was also designed with the aim of examining whether a cognitive advantage was present among bilingual children with myelomeningocele and hydrocephalus who have also undergone shunt revision/replacement surgeries.

In order to accomplish these aims, bilingual and monolingual children with a history of MM and HC were selected, and their neuropsychological profiles were compared to assess for significant differences. More specifically, it was hypothesized that bilingual children with MM-HC would have less cognitive deficits than monolingual children with MM-HC (hypothesis 1). Secondly, the role of additional surgeries (i.e., shunt revisions and/or replacements) and its impact on cognition was examined by comparing the neuropsychological profiles of bilingual and monolingual children with MM-HC who underwent shunt revision/replacement surgeries due to shunt infections and/or shunt malfunctions. It was hypothesized that bilingual children with MM-HC who underwent shunt revision and/or replacement surgeries would have less cognitive deficits than their monolingual MM-HC counterparts (hypothesis 2).

It is noteworthy to mention that the literature on the assessment of bilinguals proposes that difficulties may emerge in the assessment of individuals with multiple languages, such as evaluating bilinguals of Hispanic background. However, several suggestions have been proposed in order to overcome limitations in the assessment of this group. These include controlling for level of language proficiency, acculturation, education, and socio-economic status as these cultural variables may influence the cognitive performance of bilinguals (Ponton, 2001). Therefore, these cultural variables were included in the analyses performed in the present study in order to reduce possible errors that may impact the assessment of cognitive functions among bilingual children.

Hypothesis One

Contrary to what was expected, results from this study revealed that bilingual children with MM-HC did not outperform their monolingual counterparts. Thus, the idea of a cognitive advantage developing in children with MM-HC was not supported. In fact, after controlling for cultural variables (i.e., language proficiency, acculturation, education and income), bilingual children with MM-HC were as equally impaired in most cognitive domains as the monolingual children with MM-HC, and in fact, bilingual children with MM-HC had significantly more deficits than their monolingual counterparts in the domains of “Visual Memory and Abilities” and “Verbal and Working Memory Abilities.” A closer look at each of these two domains follows.

The cognitive domain labeled as “Visual Memory Abilities” is composed of an immediate and long term memory test (Rey Complex Figure Test- 3 minute delay and Rey Complex Figure Test- 30 minute delay, respectively) as well as a visual abstract reasoning task (Matrix Reasoning). Thus, this component relies on aspects of visual functioning. In agreement with previous research regarding the effects of MM-HC on visual memory and visual abilities (Scott et al., 1998), both bilingual and monolingual children with MM-HC demonstrated significant deficits associated with visual memory and abilities. However, according to emergent research regarding the visual functions among bilinguals, cognitively intact bilingual children have demonstrated an advantage over monolingual children in tasks involving Block Designs and have demonstrated more efficient performance on spatial tasks that involve some method of mental manipulation or rotation (Gorell et al., 1982, McLeay, 2003). Furthermore, preliminary research by Jackson and associates (2008) suggested that bilingual children with MM-HC displayed a better understanding of information than their monolingual counterparts when it was visually presented, therefore indicating some type of cognitive advantage in visual functions for bilinguals with MM-HC. Although research regarding visual memory and visual functions among cognitively intact bilinguals, as well as cognitively compromised bilinguals(i.e., children with MM-HC) indicates that bilinguals may have a cognitive advantage, this was not the case for the bilingual group in the present study.

One explanation for this finding could be attributed to how visual functions are construed. For example, the present study combined different aspects of visual functions (i.e., visual memory and visual abstraction abilities) into one domain, whereas prior research appears to examine different aspects of visual functions (e.g., visuoconstruction and visuospatial abilities). Furthermore, some studies may use single test variables to measure a cognitive function. For example Jackson and collaborators (2008) used the Rey Complex Figure Test- Copy trial to indicate that bilingual children with MM-

HC had better performances with visually presented information than their monolingual counterparts. In contrast to the single test approach, this study aimed to utilize factors; that is, composites of various tests that measured similar aspects of a particular cognitive function. This approach (i.e., factor analysis) allows for the examination of correlations among observed variables and reduction of large number of variables to smaller number of factors. In addition, this process provides the researcher with an operational definition for an underlying process. Thus it not only reduces the number of variables in a dataset (which improves reliability and enhances statistical power), but it allows for the detection of structure, that is, how variables relate to each other.

In addition, Jackson and colleagues' preliminary research assessed cognitive functions among children with ventriculoperitoneal (VP) shunts, as well as those without shunts. Research suggests that children with MM who have undergone shunting procedures to treat HC have been noted to have lower global intellectual functioning as well as more deficits in other cognitive domains than children with MM who did not develop HC and thus needed no VP shunt placement (Fobe et al., 1999; Scott et al., 1998; Wills, 1993). The inclusion of children with, as well as children without, VP shunts in Jackson and colleagues' (2008) design makes it difficult to tease apart whether the cognitive advantages observed in bilingual children was accounted for by the children without VP shunts, as they tend to have better cognitive performances than children who have undergone shunt placement surgeries. In order to control for this possibility, the inclusion criteria for the present study required that all the participants had a diagnosis of MM and HC as well as a VP shunt.

Thus, differences in methodology and sampling used in this study may account for some of the differences in the current findings as compared to previous ones. Nevertheless, despite the differences in the approaches used, a significant finding remains. Results indicated that bilingual children do not appear to have a cognitive advantage in the areas of visual memory and overall visual processing abilities and in fact they seem to demonstrate greater deficits in this domain.

The domain of “Verbal and Working Memory Abilities” was also found to be significantly better among monolingual children with MM-HC than bilingual children with MM-HC. This domain is composed of three scores from a verbal memory test (i.e., California Verbal Learning Test for Children: total score, short delay free recall score and long delay free recall score) and a working memory subtest (Symbol Search). In general, both groups were found to have significant deficits in verbal memory and working memory abilities. This is in par with research regarding the deleterious effects of MM-HC on verbal memory abilities (Hommet et al., 1999; Jacobs et al., 2001; Scott et al., 1998.)

Emerging research on memory and bilingualism supports the idea that the effects of bilingualism on memory are positive. More specifically, recent studies have shown a positive effect of bilingualism on children’s semantic and episodic memory (Kormi-Nouri, Moniri and Nilsson, 2003; Kormi-Nouri et al., 2008). In addition, preliminary research on memory and children with MM-HC also shows a positive relationship between bilingualism and memory where bilingual children with MM-HC scored significantly better on a verbal memory task (i.e., CVLT-C delay) (Jackson et al., 2008). In contrast to these research studies, the results from the present study revealed that bilingual children with MM-HC were significantly more impaired in verbal and working memory than their monolingual counterparts.

Similarly to the discrepancies found in the "Visual Memory and Abilities" domain, differences in findings between the present study and previous ones may be attributed to how the constructs of memory were defined. In the studies by Kormi-Nouri et al., (2003 & 2008), episodic memory was assessed by having children memorize sentences. For example, "read the book," "give me the spoon," "hug the doll." In addition, semantic memory was assessed by a word fluency task, that is, children were provided with a particular letter of the alphabet, and were then asked to produce as many words as possible within a time limit. Furthermore, Jackson and collaborators (2008) used only one score from the California Verbal Learning Test for Children (i.e., CVLT-delay) to assess for verbal memory. The construct of verbal memory from these studies clearly diverges from that of the present study. In the present study, a factor analysis approach was used where individual test scores were clustered together to represent a cognitive domain, such as the Verbal and Working Memory domain. In addition, the present study included only children with MM-HC who have also undergone VP shunt placement surgeries, whereas Jackson and collaborators' (2008) study included a mixture of participants with VP shunts as well as without VP shunts.

It is clear that the differences in methodology and sampling between previous studies and the present study could explain the seemingly contradictory results of the present study. However, a significant finding still remains. Results indicated that bilingual children with MM-HC did not have a cognitive advantage in the area of verbal and working memory, as their performance was significantly below that of their monolingual counterparts. Thus, it can be inferred that bilingual children with MM-HC do not have a cognitive advantage in the domain of verbal and working memory.

Results regarding the other cognitive domains assessed (i.e., General Intellectual Abilities, Verbal Abilities, Motor Abilities, Processing Speed and Executive Functions) did not reveal significant differences between monolingual and bilingual children with MM-HC. Thus, although a bilingual advantage has been observed across these domains among cognitively intact bilinguals, it can be inferred from the results of the present study that the bilingual advantage is not present among bilingual children who have had some type of brain trauma, such as the one brought forth by myelomeningocele and hydrocephalus. There are many possible reasons for this finding, though lack of control for cultural variables in previous research may provide a possible explanation.

Previous studies have found a cognitive advantage among cognitively intact bilinguals. In addition, preliminary studies have found advantages in bilinguals with MM-HC. However, these studies have failed to control for cultural variables. As previously discussed, it is imperative that consideration of cultural variables (i.e., level of language proficiency, acculturation level, education and income level) is taken into account when assessing the neuropsychological functions of bilingual individuals as these variables may influence the scores of individuals (Ponton, 2001). Therefore, failure to control for these cultural variables may have impacted findings in previous studies, and perhaps the cognitive advantage found among bilinguals would be attenuated once cultural variables were controlled for.

Hypothesis Two

Research regarding the cognitive functions of children with MM-HC has established that the surgical procedures required to treat HC (i.e., ventriculoperitoneal shunting placement) have been associated with diminished cognitive performances among these children (Fobe, 1999; Yates et al., 1995). In addition, it has been documented that shunt revision and/or replacement surgeries (e.g., additional surgeries as a result of infections or malfunctions) can impact the cognitive abilities of children with MM-HC (Fobe, 1999; Jackson, 2008). However, the effects of shunt revision/replacement surgeries on the cognitive abilities of bilingual children had yet to be examined. Thus, the present study set out to investigate whether the cognitive functions of bilingual children with MM-HC who had undergone shunt revision/replacement surgeries would differ from their monolingual counterparts. More specifically, it was hypothesized that the cognitive advantage that was observed in cognitively intact bilingual children would also be present among bilingual children with MM-HC who underwent additional shunt related surgeries and thus, their performance would be significantly better than their monolingual counterparts.

Results revealed that after controlling for cultural variables (i.e., level of language proficiency, acculturation, parental income and education) bilingual children with MM-HC who underwent shunt revision/replacement surgeries were not significantly different than their monolingual MM-HC counterparts. Thus it appears that although the mechanisms underlying the learning and execution of two languages are responsible for enhancing the cognitive abilities of bilingual individuals who are cognitively intact, this is not the case for bilingual children with MM-HC who have also undergone additional brain insults as a result of shunt revision/replacement surgeries.

There is a divergence of findings across research studies with regards to the effects of additional shunt related surgeries and cognition. Although some studies have identified deleterious effects on cognition as a result of shunt revisions/replacements (Fobe et al., 1999; Jackson et al., 2008; Scott et al., 1998), others have not (Jensen, 1987; McLone et al., 1982; Wills, 1993). Just as the latter studies, the present study failed to identify the harmful effects of shunt revision/replacements on cognitive abilities.

The divergence of findings among research studies may be explained by the inclusion of various etiologies of shunt related surgeries. More specifically, some studies may fail to detail whether a shunt revision is due to a shunt malfunction or a shunt infection. For example, a shunt revision that takes place because the shunt becomes disconnected (example of a shunt malfunction related surgery) is probably more benign than a shunt revision as a result of an infection. Thus, the underlying reasons for the revision may have a different impact on the brain and brain functions among children with MM-HC. In regards to the present study, the "additional shunt" group was comprised by both, those with shunt infections and those with shunt malfunctions. Although the underlying reason for shunt related surgeries may differ among those who undergo shunt infection vs. shunt malfunction related surgeries, this study combined both groups as no statistically significant differences in regards to cognitive functions were found between both groups.

In the present study, children with MM-HC who have had additional shunt related surgeries (i.e., as a result of shunt malfunctions and/or shunt infections) performed similarly to those who have <u>not</u> had additional shunt related surgeries across the seven cognitive domains; this was the case among solely the bilingual group, solely the monolingual group, as well as when the sample was collapsed (See Table 9, 10 and 11 for respective results). An explanation of this finding could be attributed to the age at which the participants underwent a shunt-related surgery.

Research suggests that the age of the child at the time of shunt revision can impact their overall level of cognitive functioning (Wills, 1993). More specifically, researchers have found that the number of revisions before the age of two were not associated with IQ scores, but revisions after two years of age were associated with lowered IQ scores (Hunt & Holmes, 1976; Puri et al., 1977). The majority of participants in the present study (i.e., over 64%) underwent an additional shunt related surgery before the age of two years of age. Thus it is possible that the "youngness" of this particular sample could have mitigated the detrimental effects seen as a result of additional shunt related surgeries.

It is important to note that there may be other factors that influence the relationship between additional shunt surgeries and cognitive abilities. For example, there may be a difference between a shunt revision surgery (that may require some repair of the shunt) versus a shunt replacement surgery. Although the present researcher failed to find research studies that examine the effects of shunt revisions versus shunt replacements, it is reasonable to hypothesize that a shunt revision required to simply repair a shunt is less intrusive and less intricate than having to replace an entire shunt. Furthermore, in regards to shunt replacement surgeries (i.e., removing an old shunt and placing a new one), keeping the shunt in the same location versus moving it to a different location of the brain may play an impact in how much brain matter may be disturbed by this process. Once again, the present researcher failed to find studies documenting this possible effect. The effects of shunt revision versus shunt replacements are unknown in regards to the present study as participants were only asked whether they had undergone shunt related surgeries, but not whether these involved a shunt revision and/or a shunt replacement. Nevertheless it is advised that future researchers examine the possible effects of shunt revisions versus shunt replacement and their possible role in regards to the cognitive functions of children with MM-HC.

Exploratory Analyses

Previous studies that have examined the cognitive advantage among bilinguals have typically utilized a “single test approach” (Bialystok & Martin, 2004; Gollan, Montoya & Werner, 2002; Gutierrez-Clellen, Calderon, Weismer, 2004; Kormi-Nouri, Moniri and Nilsson, 2003; Kormi-Nouri et al., 2008; Marian & Fausey, 2006 & McLeay, 2003). In these studies, the cognitive performances observed are typically assessed by comparing the performance between bilinguals and monolinguals on single test variables. As previously described, the present study opted for a factorial approach, where test variables were grouped into clusters that assessed different cognitive domains. It is possible that the methodological approach used in the previously discussed analyses contributed to the differences in findings between this study and previous ones. Thus, exploratory analyses were used to examine the cognitive performances of bilingual children with MM-HC at the individual test level, and to determine whether a cognitive advantage was present among bilinguals when this approach was used.

Bilingual vs. Monolingual Children

Results at the individual test level revealed that there were significant differences between bilingual and monolingual children with MM-HC. But contrary to what was expected, monolingual children with MM-HC outperformed their bilingual counterparts in several tests. More specifically, monolinguals with MM-HC performed significantly better on tests that measured visuospatial ability and motor skills (WISC IV- Block Design), visual perception and speed (WISC IV- Symbol Search), and short delay visual memory (RCFT- 3 minute delay) than the bilingual children with MM-HC.

Furthermore, although not a single test approach, the Perceptual Reasoning Index (PRI) and the Processing Speed Index (PSI), both derived from the WISC-IV, were compared across groups given that significant differences were found between bilinguals and monolinguals on these indices.   Each index is composed of multiple subtests.

The PRI is composed of the Block Design, Picture Concepts and Matrix Reasoning subtests. There were no statistically significant differences between monolingual and bilingual children with MM-HC in regards to their abstract categorical reasoning abilities (Picture Concepts) and visual reasoning (Matrix Reasoning). Since only the Block Design subtest was significantly different between the bilinguals and monolinguals, it seems that this subtest carries the weight of the PRI difference. The Block Design subtest measures visual-motor integration, motor dexterity/fine motor control, perceptual skills and processing speed. Examination of this subtest indicates that monolingual children with MM-HC performed significantly better than bilingual children with MM-HC. This is in sharp contrast to a study performed by Gorell and collaborators (1982) were bilingual children performed significantly better than monolingual children on a Block Design task. Thus, the advantage of better performance in this particular test which is seen among cognitively intact bilingual children (i.e., no brain insults) was not present among bilingual children who have undergone some type of brain insult (i.e., MM-HC).

One possibility for this finding is that bilinguals are thought to rely more heavily on visual or spatial strategies (non-verbal representations) than verbal strategies (Ransdell & Fischler, 1991). These functions have been found to be controlled by the right hemisphere of the brain (Erickson, 2001). As previously reviewed, HC tends to affect the right hemisphere more severely than the left hemisphere (Erickson, 2001; Rourke, 1995). Thus, HC disrupts the processing of nonverbal information and production of nonverbal behavior, including problems with tactile perception, visual-spatial perception, and psychomotor coordination. Therefore since bilinguals rely more heavily on right hemispheric functions, the impact that HC has on the right hemisphere may be significantly more taxing in bilingual children with MM-HC and hence why these children experience significantly more difficulties in these functions as compared to their monolingual counterparts.

On the other hand, the PSI measures a child's visual scanning ability, short-term visual memory, visual and motor processing, and ability to process information rapidly. The two subtests that compose this index are Coding and Symbol Search. In the present study, bilingual children with MM-HC were significantly more impaired than their monolingual counterparts in their overall PSI scores. However, when looking at the two subtest that make up this index, only Symbol Search was more significantly impaired for the bilingual children than the monolingual children with MM-HC. The performances on the Coding subtests were similar for both groups. Looking at the specific functions that each of the subtest measures provides some clarification for the differences found between both groups. First, the Coding subtest is most likely affected by motor processing speed than Symbol Search. Coding requires the examinee to handle a pencil and transcribe code symbols into empty boxes, placing a higher demand on graphomotor capacity. On the other hand, Symbol Search is not as demanding on the motor system as the examinee is only asked to draw a slash through the “yes” or “no” boxes. Thus participants who may be lacking in motor coordination may find it difficult to transcribe the coding symbols, making this subtest somewhat more demanding than Symbol Search. As evidenced in the results, all participants (monolinguals and bilinguals) in the present study had difficulties with motor abilities (i.e., they were over one and a half standard deviations below the mean when compared to peers their age, see Table 6). Thus, it is not surprising that both monolingual and bilingual children performed equally poorly on the Coding subtest as the functions of simple motor tasks and/or fine motor control have been documented to be impaired among children with MM-HC (Fletcher et al., 1995, Shine, 1998 and Wills, 1993).

On the other hand, Symbol Search is typically less affected by motor processing speed problems. In the symbols search subtest, the visual-motor coordination that is needed in the Coding subtest is removed. This leaves a purer measure of processing speed, scanning and visual perception. In this task, the bilingual children with MM-HC were significantly more impaired (over one and a half standard deviations below the mean compared to age-like peers) than monolingual children with MM-HC (who were less than a standard deviation below the mean; see table 7 for details). Thus it appears that when motor processing abilities are accounted for, bilingual children with MM-HC experience more difficulties in processing speed, scanning and visual perception than their monolingual counterparts. A similar explanation as the one made for the performance in the Block Design subtest may be able to shed some light regarding the differences between both groups. Scanning and visual perception as well as pattern recognition abilities are typically controlled by the right hemisphere (Erickson 2001). It has been argued that Bilingual children tend to rely more heavily on the right hemisphere (Ransdell & Fischler, 1991). Given that HC tends to affect the right hemisphere more severely than the left hemisphere (Erickson, 2001; Rourke, 1995), this will likely cause bilingual children with MM-HC to experience significantly more difficulties associated with right hemisphere functions than their monolingual counterparts. Therefore the fact that bilingual children evidenced significantly more difficulties in the Symbol Search subtest than their monolingual counterparts may be accounted by the "additional" injurious effects of HC on the right hemisphere of bilingual participants, which are not so pronounced among the monolingual group.

Results also revealed that monolingual children with MM-HC outperformed their bilingual counterparts in an immediate visual memory test [i.e., Rey Complex Figure Test (RCFT) - three minute delay] but not in a test of long term visual memory (i.e., RCFT- 30 minute delay). It is important to note that different areas of the brain are involved in different aspects of memory (Lezak, 2004). For example, immediate memory (also known as short term and/or working memory) is the brain's system for remembering information that is "in use." More specifically, in the RCFT-three minute task, the visuospatial sketchpad system (which manipulates visual images) appears to be in use and can hold information for a short period of time (Lezak, 2004). This type of function is controlled by the prefrontal cortex (Lezak, 2004). In contrast, information that needs to be stored for longer periods of time (e.g., information in the RCFT-30 minute delay) is typically controlled by the hippocampus (Lezak, 2004). The hippocampus then is able to process the information and store it in to long term memory (Lezak, 2004).

In the present study, immediate memory (i.e., RCFT-three minute delay) was significantly better for the monolingual children with MM-HC than their bilingual counterparts. Thus it appears that the function of the prefrontal cortex (area of the brain involved in immediate/short term memory) may be different between monolingual and bilingual children with MM-HC. Assessing the role of the prefrontal cortex can be done by examining tasks of executive functions. Interestingly, the present study revealed no differences in executive functions between monolinguals and bilinguals with MM-HC. Thus, the differences in the RCFT-three minute delay tasks may not be completely explained by differences in executive functions among the participants.

Rather, it is more likely that the deficits seen in bilingual children are the result of the effects of HC on the right hemisphere. As previously proposed, it appears that the right hemisphere among bilingual children appears to take a larger "toll" than the right hemisphere of monolingual children as a result of HC (Ransdell & Fischler, 1991 Erickson, 2001; Rourke, 1995). This toll may also be present in the RCFT-three minute delay task given the visual component that is used in this test.

In addition, monolingual children with MM-HC also demonstrated a visual-perceptual advantage over their bilingual counterparts. As previously discussed it appears that the monolingual children's better perceptual skills, visual-motor integration and motor dexterity (as suggested by their better performance on tasks requiring such skills, such as Block Design) might have helped them in initially perceiving and keeping the RCFT figure in short term memory. As would be expected, better visual perception of the figure would have naturally translated to better recall of the figure by the monolingual children with MM-HC three minutes after presentation.

In addition to the RCFT-three minute task, the RCFT also includes a 30 minute delay condition which asks participants to recall the figure 30 minutes later. No cues are provided for this task. After completion of this trial, a recognition tasks (which presents different parts of the design in a multiple-choice format) is also administered. Interestingly, both groups had significant difficulties on the RCFT- 30 minute delay condition. It can be hypothesized then, that the “free recall” of visual information (i.e., recalling information without the help of cues) among bilingual and monolingual children are similarly affected. Nevertheless, additional analyses suggest that the retrieval of visually presented information may differ between monolingual and bilingual children with MM-HC if a “multiple choice format” is presented.

Although not statistically significant, a trend appeared indicating that bilingual children had more difficulties retrieving information through a recognition format than the monolingual children with MM-HC (the *p* value reached significance at the .06 level in the RCFT-recognition task). Therefore, although bilingual and monolingual children may have similar difficulties in “freely recalling” visually presented information, the monolingual children appeared to benefit from a multiple choice/recognition format. This was likely due to the advantage that the monolinguals had as a result of better perceptual skills, visual-motor integration and motor dexterity as compared to their bilingual counterparts.

It appears that monolingual children with MM-HC outperformed their bilingual counterparts in tests of visuospatial ability and motor skills (WISC IV- Block Design), visual perception and speed (WISC IV- Symbol Search), and short delay visual memory (RCFT- 3 minute delay). A trend regarding the benefit of a multiple choice format among the monolingual children (but not the bilingual children) also appeared (RCFT- recognition trial). One explanation proposed for these findings is that provided by Ransdell & Fischler (1991) which proposes that the right hemisphere of bilingual children appears to take a larger "toll" than the right hemisphere of monolingual children as a result of HC.

Bilinguals with Shunt Revision/Replacement Surgeries vs. Monolinguals with Shunt Revision/Replacement Surgeries

As previously explained, exploratory analyses were also conducted to examine the differences between the various tests administered to bilingual and monolingual children with MM-HC who also underwent shunt revision/replacement surgery as a result of an infection or malfunction. In contrast to what was expected, results indicated that monolingual children with MM-HC who underwent a shunt revision surgery outperformed their bilingual counterparts in the Processing Speed Index, Block Design subtest, Vocabulary subtest, Symbol Search subtest and phonemic fluency test (i.e., FAS). Such findings suggest that across these two groups which have experienced additional brain trauma as a result of revision surgeries, bilingual children with MM-HC continue to experience significantly more deficits associated with visuospatial ability, perceptual skills, visual scanning ability, short-term visual memory and visual-motor integration than monolingual children with MM-HC.

Interestingly though, differences also appeared between monolingual and bilingual children who underwent revision surgery in tests of language functions (a finding that was specific to the “additional surgery” groups). Specifically, language functions, namely the Vocabulary subtest and FAS, appeared to be significantly more impaired in bilingual children compared to monolingual children. Bilingual children with MM-HC who underwent additional shunt related surgeries were significantly more impaired than their monolingual counterparts in tasks that assessed for knowledge of words as well as phonemic fluency. This finding appears to be in line with some of the previous research revealing that bilinguals recognize fewer vocabulary words than monolinguals and have diminished phonemic fluency compared to monolinguals due to cross language interference (see Verbal Abilities section above for a review) (Gollan et al., 2002; Mindt et al., 2008; Rosselli et al., 2000). What is interesting to note is that significant differences between monolingual and bilingual children with MM-HC in the area of language appeared only among those who have had additional surgeries, and not among those who only had “the original” shunt placement surgery. One can speculate that the additional damage caused by shunt revision/replacement surgeries may play a role in the language functions of bilingual children with MM-HC and with shunt revision/replacement surgeries as these findings were prevalent only among those who underwent additional surgeries.

Differences in Handedness

Another interesting result that needs to be addressed is the significant differences found among the participants of this study in regards to handedness. As depicted in Table 1, thirty-five percent of the participants were left-handed. This proportion of left-handed participants is unusual as demographics indicate that only 5-25 percent of the population in the United States is left-handed (Mason, 2009). However, there has been research that suggests that left-hand preference is seen more frequently among children with spina bifida and hydrocephalus. Wassing, Siebelink & Luyendijk (1993) examined hand dominance among 45 patients with spina bifida and hydrocephalus (ages 13 to 25 years of age). Their results indicated that left-handedness was more frequent among those spina bifida patients who have had shunts as a result of HC than those without shunts. They proposed that the failure to establish right-handedness among these patients could be reflected by problems with lateralization, and that this may be attributable to dysfunction of the corpus callosum.

What is also interesting is that the present study revealed that there were significantly more left-handed bilingual children with MM-HC and significantly more right-handed monolingual children with MM-HC. A possible explanation could be related to the level of lesions. A study by Fletcher et al., (2005) found that children with MM-HC who sustained upper-level lesions (i.e., those with thoracic level lesions) were more likely than those with lower-level lesions to be non-right handed. Given that the majority of bilingual participants in the present study have an upper-level lesion (i.e., thoracic or high lumbar lesion level), it is possible that this may account for the finding that there are more left-handed bilingual children than monolingual children with MM-HC.

One can also look at research on bilingualism and lateralization. Unfortunately, research in the areas of bilingualism and lateralization for handedness is inconclusive. For example according to Oblert et al., (2000), “some papers demonstrate differences in lateralization between bilinguals and monolinguals; others demonstrate none. In studies with exclusively bilingual subjects, some papers demonstrate differences between the lateralization for the two languages, while others demonstrate none” (p. 354).

Nevertheless, recent research suggests a possible cognitive disadvantage for left-handers (Nicholls, 2010). In their study, Nicholls and collaborators assessed 895 individuals for the relationship between cognitive ability and handedness. Results indicated that handedness was related to cognitive ability. More specifically, right handed individuals had higher general cognitive ability test scores when compared with left-handers. Despite this finding, it is still unknown why right-handers may have a slight cognitive advantage over left-handers (Nicholls, 2010).

It is possible then, that some of the cognitive deficits associated with the bilingual children with MM-HC may be related to the cognitive disadvantage that has been observed among left-handers since 50 percent of the bilingual children in the present study were left handed. However, it is beyond the scope of the present study to determine whether the cognitive deficits associated with the bilingual children are as a result of the left-handed cognitive disadvantage theory.

Conclusions

The present study aimed to investigate the neurocognitive functions among bilingual children with myelomeningocele and hydrocephalus. As previously reviewed, research on the effects of bilingualism on various areas of cognitive functioning had suggested a cognitive advantage among bilingual individuals. Nevertheless, this bilingual advantage had primarily been studied on healthy and cognitively intact individuals. Thus a need to study whether this advantage developed in individuals that suffered from some type of brain insult, such as the damage created by myelomeningocele and hydrocephalus, had yet to be met.

Given that Latinos have been found to have the highest incidence of neural tube defects in the US (as compared to non-Hispanic Whites), bilingual children with MM-HC of Hispanic background were examined to determine whether a cognitive advantage was present in their neuropsychological profiles when compared to monolingual English speaking children with the same condition. Although limitations have been observed in the neuropsychological assessment of bilinguals, special considerations where taken to diminish these in the present study. Therefore, recommendations that have been set forth in the evaluation of bilinguals where included in this study, namely controlling for level of language proficiency, acculturation, education and income (Ponton, 2001).

The results of the present study indicated that a cognitive advantage was <u>not</u> observed among bilingual children with MM-HC. In fact, after controlling for various cultural variables, results indicated that bilingual children appeared to be significantly impaired in certain cognitive domains as compared to their monolingual peers. The results from this study suggest that although dual-language usage among bilingual individuals with intact brains may help them to augment executive functions, enhance attention processes and improve memory and visuospatial functions, this is not the case for those who have undergone some type of brain insult such as the one that children with MM-HC sustain.

Nevertheless, there may be some possibilities as to why the present study failed to find a cognitive advantage among bilingual children with MM-HC. These will now be examined. Results revealed differences between bilingual and monolingual children with MM-HC as well as between bilingual and monolingual children with MM-HC that underwent addition shunt related surgeries. However, contrary to prior research regarding a possible cognitive advantage among bilinguals with MM-HC, results revealed that monolingual children with MM-HC actually performed significantly better than their bilingual counterparts on various measures. There are several reasons that may account for these findings. First, as previously discussed, due to the high utilization of right hemispheric functions among bilingual children, the impact of HC on the right hemisphere of bilingual children with MM-HC may be more detrimental than the impact of HC on the right hemisphere of monolingual children. Therefore, the advantages seen among bilingual children (without any neurologic complications) in regards to visual-perceptual, visuo-construction and visual-motor abilities may be eliminated by the injurious effects that HC has on the brain of bilingual children with MM-HC.

Second, statistically significant differences were found between bilingual and monolingual children in regards to the location of myelomeningocele. As reported in Table 1, bilingual children had significantly more thoracic and high lumbar lesion levels than monolinguals. Monolinguals tended to have more mid lumbar lesion levels. This is a significant finding because it has been previously documented that differences in cognitive functions may vary depending on lesion levels, with higher lesions bringing more severe impairments (Fletcher et al., 2005; Wills, 1993). Fletcher and collaborators (2005) examined 268 children with MM-HC and found that children with upper-level lesions (i.e., thoracic level) had more anomalous brain development in the midbrain, tectum and corpus callosum than those with lower-level lesions (i.e., lumbar and sacral levels). Furthermore, they also found that children with upper-level lesions had less gray matter and less white matter than children with lower-level lesions. They also found that compared with children with lower-level lesions, children with upper level lesions had less gray matter in both hemispheres, but especially in the right. Children with upper-level lesions also had smaller cerebellar volumes than children with lower-level lesions. Interestingly, Fletcher and colleagues also found that upper-level lesions were more common in Hispanic than in non-Hispanic children.

The findings by Fletcher and collaborators (2005) can help explain why a cognitive advantage may have not been present among the bilingual participants with MM-HC. Similar to his study, the majority of Hispanic children in the present study (those who were bilinguals) tended to have significantly more upper level lesions (i.e., thoracic and high lumbar level lesions) than their monolingual counterparts. Applying the findings of Fletcher et al., (2005), it is likely that the bilingual group of the present study also had smaller cerebellar volumes, and had less gray and white matter. Moreover, the bilingual group in the present study could have also been similar to the one seen by Fletcher et al., (2005) in that the bilingual group had significantly less gray matter in the right hemisphere. This finding further supports the theory of the injurious effects of HC on the right hemispheres of bilingual children with MM-HC. Thus not only is it possible that bilingual children with MM-HC have more difficulties due to the deleterious effects of HC in the right hemisphere, but it is also likely that their difficulties in cognition are due to their higher rate of upper-level lesions as compared to monolingual children who evidenced more lower-level lesions. The thinner cortical mantle, decreased cerebellar volumes and diminished gray and white matter associated with upper-level lesions among children with MM-HC, may be a culprit of why bilingual children with MM-HC in the present study had significantly greater impairment in neurocognitive functions as compared to their monolingual counterparts.

Third, the findings on "handedness" may also give some additional insight as to why a bilingual cognitive advantage was not present among the bilingual children with MM-HC. As previously discussed, 50 percent of the bilingual children in the present study were left-handed. Given that emergent research has found a relationship between cognitive deficits and left-handedness, it is possible then that some of the cognitive deficits associated with the bilingual children with MM-HC were possibly related to the cognitive disadvantage observed among left-handers.

Fourth, another possible explanation for failure to find a cognitive advantage among the bilingual group is that this study sought to control for cultural variables that are often times overlooked in the research of bilingual populations. As previously discussed, it is important to consider cultural variables when assessing the neuropsychological functions of bilingual individuals. It is possible that controlling for cultural variables may attenuate the cognitive advantages found among bilingual individuals. Thus, future research regarding the neuropsychological performances of bilingual children with MM-HC needs to consider the impact that cultural variables may have on cognitive performance.

Lastly, another possibility for failure to find a cognitive advantage among bilingual children with MM-HC is the issue of test selection and norms. It is possible that some of the bilinguals in this study may have benefited from tests that were bilingual (i.e., in English and Spanish), that were developed for Spanish speakers or at least were normed for Spanish speakers. This is particularly important for bilingual children whom were higher on the Spanish speaking spectrum. This issue is a prevalent "problem" when assessing participants that are non-English speakers. The dearth of measures that have been adequately developed to assess neuropsychological performances among Spanish-speaking children continues to be a limitation. Due to the lack of measures developed for Spanish speakers, many practitioners may turn to translate the test and/or use translators. However, many problems may arise from this practice (see the "examining cognitive functions in bilinguals" section above). Thus, the selection and administration of English-only tests, as well as not having the option of more adequate norms, may have affected the results of the present study. It is possible that this limitation could have also impacted the results and thus this study failed to identify a possible cognitive advantage among bilingual children with MM-HC.

There is one unique aspect of this study. This study aimed to only include those who were diagnosed with myelomeningocele, who had experienced hydrocephalus, and who had also received a VP shunt to treat their hydrocephalus. Prior research on spina bifida has ascertained differences in cognitive performance among the different groups of spina bifida (i.e., occulta, meningocele and myelomeningocele) as well as between those who have undergone shunting procedures as a result of hydrocephalus. Thus, in order to reduce extraneous influence, this study attempted to control for these variables by only including participants with myelomeningocele type and those who had undergone shunting procedures in order to treat hydrocephalus.

Although a bilingual cognitive advantage was not found among the bilingual children with MM-HC, the present study has provided valuable data in regards to the performance of this particular group. The results gathered from the present study provide some of the first data regarding the cognitive performance among bilingual children of Hispanic background who have MM-HC.

Limitations

There are a few limitations in this study that need to be noted when interpreting the results. One of the limitations of this study is the subjectiveness of the rating scale used to determine whether a participant was bilingual or monolingual. Gasquoine and collaborators' self-report measure (2007) was used to assess level of language proficiency. This scale allows participants to rate their ability to speak and understand English as well as Spanish. The participants' scores can fall in a spectrum between "-8" (English-Monolingual) to "+8" (Spanish-Monolingual). A score of "0" depicts a "balanced bilingual." In the current sample, scores ranged from "-8" to "+5." The investigator then assigned a score between -2 and 5 to classify participants as bilingual, and a score of -8 to -3 to participants who were considered monolinguals. The selection of these scores was based on the investigators' interaction with participants and their families, as it was observed that participants with scores higher than -2 tended to speak to investigator in both languages, as well as interacted with their accompanying family members in both languages. In contrast, it was observed that participants who scored in the -8 to -3 range where only English speaking. Despite this being a subjective method for categorizing bilinguals and monolinguals, it is considered to be a better alternative than categorizing participants based on ethnicity (as a proxy to language preference), which some researchers may be inclined to do.

A second limitation of the study is the usage of Analyses of Covariance (ANCOVA) instead of other Multivariate Analyses of Covariance (MANCOVA). MANCOVA is typically used when the study aims to analyze the effect of predictor variables simultaneously on more than one response variable. The advantage of MANCOVA over a series of ANOVAS (when there are several dependent variables) is protection against inflated Type I error due to multiple tests. However, the aim of this study was to identify the effects of language (i.e., bilinguals vs. monolinguals) on single dependent variables (in this case a single cognitive component) and not at a combination of all the dependent variables. Although the possibility of Type I error exists, post-hoc power analyses reveled that utilizing an ANCOVA approach did not significantly reduced the power of the analyses (MANCOVA power =.94 ; ANCOVA power =.92).

Another limitation is the use of measures that were developed and normed for English speaking participants. As previously discussed, using English tests for bilingual participants who may be more fluent in Spanish could impact their performance and scores on the various neuropsychological aspects that were assessed.

Another possible disadvantage to this study is the inclusion of children with low IQs (i.e., FSIQ <70). The effect of mental retardation in the performance of the examined children was not accounted for. Nevertheless, this study intended to include all possible subjects regardless of IQ, as many studies that examine the neuropsychological performance of children with MM-HC tend to exclude those with FSIQ's below 70. Despite this being a limitation, it is also an unique aspect of the present study.

Future Directions

Since the current study is the first of its kind to examine the cognitive performance among bilingual children with MM-HC, additional studies are needed. As with any study of a small sample size (i.e., total N = 49, bilingual N = 22, monolingual N = 27), it is important for future studies to continue to examine the cognitive performance among bilingual children with MM-HC with a larger sample size. In addition, including bilingual individuals from different ethnic backgrounds and different language groups could reveal new insights into the research of bilingualism, language and MM-HC. Furthermore, future research with bilinguals should control for cultural variables (i.e., level of language proficiency, acculturation, education and income) when assessing for cognitive functions as these variables have been found to impact individuals' performances on cognitive tests. Future studies should also examine the relationship between myelomeningocele lesion level and cognitive functions, as findings from this study suggest that bilinguals and monolinguals differ in lesion level as well as in their cognitive functions.

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Appendix A

Demographic Information Questionnaire

1. Age: ______
2. DOB: ______
3. Place of Birth: _____________; If not US, # of years residing in the US: _________
4. Grade level: ______
5. Bilingual YES NO : Language spoken at home: ___________________
6. Number of shunts: _____
7. Age at first shunt: _____
8. Shunt infection: YES NO
9. Number of shunt infections: _____
10. Age at first shunt infection: _____
11. Number of shunt surgeries: _____
12. Age of all Shunt related surgeries: ___________________________________
13. Date of last shunt related surgery: _______
14. Location of MM lesion: ______________________________
15. Weeks of gestation: _______________
16. Weekly (yearly) household income:

    $0 - $300 ($0- 14,999) □$521- $830 ($25,000- 39,999) □> than $1,251weekly
    $301 - $520 ($15,000- 24,999) □$831- $1250 ($40,000- 59,999)□(> than $60,000)

17. Years of education by parent with highest education: _________

Appendix B

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 <u>speak</u> Spanish:

1	2	3	4	5
MINIMAL		MODERATE		HIGH

7. Rate your current ability to <u>understand</u> Spanish:

1	2	3	4	5
MINIMAL		MODERATE		HIGH

8. Rate your current ability to <u>speak</u> English:

1	2	3	4	5
MINIMAL		MODERATE		HIGH

9. Rate your current ability to <u>understand</u> English:

1	2	3	4	5
MINIMAL		MODERATE		HIGH

<u>Scoring:</u> 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.

Appendix C

The Brief Acculturation Rating Scale for Mexican Americans-II for Children and Adolescents

	Not At All/ Nada	Very Little/ Un poquito o a veces	Moderately / Moderado	Very Often/ Mucho o Muy Frequente	Almost Always/ Muchisimo, Casi Todo el Tiempo
1. I speak Spanish. Yo hablo Español.					
2. I speak English. Yo hablo Inglés.					
3. I enjoy speaking Spanish. Me gusta hablar Español.					
4. I associate with Anglos. Me asocio con Anglos.					
5. I enjoy English language movies. Me gusta ver peliculas en Inglés.					
6. I enjoy Spanish language TV. Me gusta ver programas en la television que sean en Español.					
7. I enjoy Spanish language movies. Me gusta ver peliculas en Español.					
8. I enjoy reading books in Spanish. Me gusta leer en Español.					
9. I write letters in English. Escribo (como cartas) en Inglés.					
10. My thinking is done in the English language. Mis pensamientos ocurren en el idioma Inglés.					
11. My thinking is done in the Spanish language. Mis pensamientos ocurren en el idioma Español.					
12. My friends are of Anglo origin. Mis amigos recientes son Anglo Americano.					

Appendix D

Assent Form

Child's Assent for being in a Research Study
Loma Linda University, Department of Psychology

Why am I here?

We are asking you to take part in a research study because we are trying to learn more about the way kids with spina bifida think and remember things. We are inviting you to be in the study because you have spina bifida.

Why are they doing this study?

We are doing this study because we are trying to find out if kids with spina bifida who speak two languages think differently than kids with spina bifida who only speak one language.

What will happen to me?

If you help us with this study we will give you a test that takes approximately 4 hours to do. During this test we will ask you a bunch of questions, have you play with blocks, look at pictures, and draw some pictures.

Will the study hurt?

No, you will not get hurt if you help us. You might get a little tired during the test, but you can take breaks when you want.

Will the study help me?

The test you take will help us learn about the way you think, and then we can tell your parents or school teachers how to help you learn better.

What if I have any questions?

You can ask any questions that you have about the study. If you have a question later that you didn't think of now, you can call Dr. Susan Ropacki at 909-558-8615 or Claudia Resendiz at 909-658-5483 or ask next time.

Do my parents know about this?

This study was explained to your parents and they said that you could be in the study. You can talk this over with them before you decide.

Do I have to be in the study?

You do not have to be in the study. No one will be upset if you don't want to do this. If you don't want to be in this study, you just have to tell me or your parents. You can say yes now and change your mind later. It's up to you. Writing your name on this page means that you agree to be in the study, and know what will happen to you. If you decide to quit the study all you have to do is tell the person in charge.

______________________________ ____________
Signature of Child Date

______________________________ ____________
Signature of Researcher Date

Initials________ Date_________

Appendix E

Consent Form (English)

LOMA LINDA UNIVERSITY

School of Science and Technology
Department of Psychology

11130 Anderson Street
Loma Linda, California
(909) 558-8717
Fax (909) 558-0171

INFORMED CONSENT FORM

Loma Linda University Department of Psychology

Myelomeningocele and the Neuropsychological Functioning of Monolingual and Bilingual Children

Principle Investigators:

Susan Ropacki, Ph.D.
Claudia Resendiz, M.A.
Alexander Zouros, M.D.

Your child has been asked to take part in a student research project described below. The researcher will explain the project to you in detail. The researcher will also explain the possible risks and possible benefits of being in the study. Please read the form and ask any questions you may have. Then, if you decide to allow your child to participate in the study, please sign and date this form in front of the person who explained the study to you. You will be given a copy of this form to keep.

Purpose and Procedures:

Your child is being asked to participate because he or she has myelomeningocele. Research has indicated that myelomeningocele is the most common and most severe form of spina bifida, affecting the brain and spinal cord of millions of children. Research on the effects of bilingualism on specific areas of cognitive functioning also suggests that bilingual individuals might be at an advantage as it appears that the mechanisms used to learn and efficiently utilize two languages enhance the cognitive processes of bilingual individuals. However, little is known about the effects of bilingualism on the memory, attention and other thinking skills of those with myelomeningocele. Therefore, the purpose of this research is to gain a better understanding of how bilingualism affects the memory, attention and other thinking skills of children with myelomeningocele.

This study is examining monolingual patients with myelomeningocele and shunts, and bilingual patients with myelomeningocele and shunts. By comparing these two groups we can examine the impact bilingualism has on memory, attention and other thinking skills. All those participating in this study will be administered a neuropsychological assessment battery designed to measure memory, attention, problem solving skills, visuospatial skills, language, and motor skill. This neuropsychological battery is about four hours long and is a paper and pencil based test. Your child will be expected to answer questions, use small objects, and draw lines and pictures. Your child will not be placed in any machines or be subjected to any physical treatments. Some individuals become tired and/or frustrated during the testing procedure. However these symptoms are minimal and your child may take breaks as needed.

If you decide to allow your child to participate in this study, here is what will happen:

- Your child will be administered a neuropsychological assessment battery that lasts about four hours. Breaks may be taken during the testing process, and some children may chose to take different portions of the test on different days.
- Your child will be expected to answer questions, use small objects, and draw lines and pictures.
- Your child's personal information will be kept confidential and available only to those directly involved in the study or testing process. Your child will be seen by doctors and students associated with Loma Linda University. All student involvement is supervised by a licensed clinician.
- All neuropsychological assessments will take place at the Loma Linda University Psychology department located on Anderson Street in Loma Linda.
- Appointment times are very flexible and may be scheduled in the day, evenings, or weekends.
- Once your child completes the neuropsychological assessment, his/her commitment to the study is complete. It is strongly encouraged that your child completes all of the testing. However, participation in this study is voluntary and you or your child may choose to end participation at any point.
- It is anticipated that the assessment will take about four hours. However, the actual time your child needs to complete the assessment may be more or less than four hours. If you choose to have your child tested over several days, it will likely take more than four hours to complete the assessment. It is unlikely that the assessment will take more than a total of six hours to complete.
- Your child's medical records will be reviewed to confirm their history of shunts, shunt infections, and neurologic condition.
- A written outline of your child's cognitive strengths and weaknesses and appropriate recommendations will be provided to you after all testing has been completed.

Risks or discomforts:

Participating in this study exposes you to minimal risks. Some children participating in this study may become tired or frustrated during the assessment. To ease discomfort, your child will be allowed to take breaks as needed or schedule different parts of the test on another day.

Benefits:

All participants in this study will receive an outline of their thinking skills with noted strengths and weaknesses. Recommendations will be made in regards to improving weaknesses and utilizing strengths. If the child's thinking skills are thought to impair school performance, recommendations for school accommodations will be made. The results of this study will provide researchers and clinicians with new insight and understanding of how bilingualism may affect cognitive functioning in children with myelomeningocele. The data collected from this study may also be published in scholarly journals.

Participant's Rights:

Participation in this study is voluntary. Your decision whether or not to participate or terminate at any time will not affect your present or future medical care. You and your child have the right to refuse to participate in this study. You and your child have the right to withdraw from this study at any time without penalty. You and your child have the right to refuse to participate in any portion of the interview or assessment. However, if a child withdraws early from the study, no report or recommendations can be made concerning the child's strengths and weaknesses. If a child refuses to complete a portion of the assessment, a complete report and recommendations cannot be made.

Alternative Treatment:

Neuropsychological assessments may not be part of your child's standard treatment. Your child may not need a neuropsychological assessment, and your child is not assured additional treatments or resources by participating in a neuropsychological assessment. Your child may obtain a neuropsychological assessment at another location if you do not want to participate in this study. If you feel your child needs a neuropsychological assessment and you do not want to participate in this study, please contact your child's primary physician or care provider for information.

Confidentiality:

All of your child's personal information will be held confidential and available only to those directly involved in the study or assessment procedures. Your rights regarding use of your personal health information are discussed in the attached authorization form. Your name will not be associated with your test results. You will be given an identification number upon entry into the study which will be used to identify your test results. All personal information will be kept in a locked file cabinet in the Neuropsychological Assessment and Research Laboratory. All test results will be kept in a separate locked file cabinet. If recommendations for academic accommodations are being made, an additional consent must be signed to release records to the school.

Reimbursement:

Those that choose to participate in this study will receive free neuropsychological testing. Neither you nor your child will be reimbursed for your time/participation.

Impartial Third Party Contact:

If you wish to contact an impartial third party not associated with this study regarding any question or complaint you may have about the study, you may contact the Office of Patient Relations, Loma Linda University Medical Center, Loma Linda, CA 92354, phone (909) 558-4647 for information and assistance.

Informed Consent statement

a. I have read the contents of the consent form and have listened to the verbal explanation given by the investigator. My questions concerning this study have been answered to my satisfaction. I herby give voluntary consent for my child to participate in this study. Signing this consent document does not waive my rights or my child's rights, nor does it release the investigator, institution or sponsors from their responsibility. I may call Susan Ropacki Ph.D., during routine office hours at (909) 558- 8615 or Claudia Resendiz, M.A., at (909) 658-5483 if I have additional questions or concerns. ________.

b. I have been given a copy of this consent form_________.

c. I have received a copy of the California Experimental Subject's Bill of Rights and have had these rights explained to me_________.

___________________________________ ___________________________

Signature of Subject (if over 12 years old) Date

___________________________________ ___________________________

Signature of Witness Date

This protocol has been explained to my child at a level that he/she can comprehend and I give my consent for my child to participate in the study.

___________________________________ ___________________________

Signature of Parent or Legal Guardian Date

I have reviewed the contents of the California Experimental Subject's Bill of Rights and this consent form with the person signing above. The potential risks and benefits of the study have been explained to me.

_________________________________ ___________________ ____________

Signature of Investigator Phone Number Date

Appendix F

Bill of Rights (English)

CALIFORNIA EXPERIMENTAL SUBJECT'S BILL OF RIGHTS

You have been asked to participate as a subject in an experimental clinical procedure. Before you decide whether you want to participate in the experimental procedure, you have a right to:

1. Be informed of the nature and purpose of the experiment.

2. Be given an explanation of the procedures to be followed in the medical experiment, and any drug or device to be used.

3. Be given a description of any attendant discomforts and risks reasonably to be expected from the experiment.

4. Be given an explanation of any benefits to the subject reasonably to be expected from the experiment, if applicable.

5. Be given a disclosure of any appropriate alternative procedures, drugs or services that might be advantageous to the subject, and their relative risks and benefits.

6. Be informed of the avenues of medical treatment, if any, available to the subject after the experiment if complications should arise.

7. Be given an opportunity to ask any questions concerning the experiment or the procedures involved.

8. Be instructed that consent to participate in the medical experiment may be withdrawn at anytime, and the subject may discontinue participation in the medical experiment without prejudice.

9. Be given a copy of a signed and dated written consent form used in relation to the experiment

10. Be given the opportunity to decide to consent or not to consent to a medical experiment without the intervention of any element of force, fraud, deceit, duress, coercion, or undue influence on the subjects decision.

I have carefully read the information contained in the "California Experimental Subject's Bill of Rights" and I understand fully my rights as a potential subject in a medical experiment involving people as subjects.

____________________________ Date	____________________________ Patient
____________________________ Time	____________________________ Parent/Legal Guardian

If signed by other than the patient, indicate relationship:

____________________________ Relationship	____________________________ Witness

Appendix G

Consent form (Spanish)

LOMA LINDA UNIVERSITY

School of Science and Technology
Department of Psychology

11130 Anderson Street
Loma Linda, California
(909) 558-8717
Fax (909) 558-0171

FORMULARIO DE CONSENTIMIENTO PARA PARTICIPACIÓN EN UN PROYECTO DE INVESTIGACIÓN DE

LA UNIVERSIDAD DE LOMA LINDA

DEPARTAMENTO DE PSICOLOGIA

Título del estudio: Mielomeningocele y las Funciones Neuropsicológicas en Niños Monolingües y Bilingües
Investigadores principales: Susan Ropacki, Ph.D.
Claudia Resendiz, M.A.
Alexander Zouros, M.D.

Su hijo(a) está siendo invitado a participar en un estudio científico, que es parte de un proyecto de un estudiante, el cual esta descrito enseguida. Uno de los investigadores le explicara este proyecto con detalles. El investigador también le explicara posibles riesgos y posibles beneficios como resultado de participar en esta investigación. Por favor lea este formulario y haga cualquier pregunta que pueda tener. Si decide que su hijo(a) participe en esta investigación, por favor firme y anote la fecha de hoy en presencia del investigador que le explico este estudio. Una copia le será provista para su archivo personal.

Descripción del Propósito y de los Procedimientos:
Su hijo(a) ha sido invitado(a) a participar en esta investigación científica porque él o ella tiene mielomeningocele. Estudios indican que mielomeningocele es la variante de espina bífida más grave y más frecuente, la cual afecta el cerebro y la medula espinal de millones de niños. Investigaciones científicas acerca del poder hablar dos idiomas (ósea, bilingües) y áreas de funciones cognitivas sugieren que las personas bilingües pueden tener ventajas ya que los mecanismos que se usan para aprender y utilizar dos idiomas realzan los procesos cognitivos en estas personas. Sin embargo, casi no se sabe nada

acerca de los efectos del bilingüalismo en la memoria, atención y otras habilidades mentales de niños con mielomeningocele.

Esta estudio está examinando a pacientes monolingües (los que hablan un solo idioma) y bilingües (los que hablan dos idiomas) que han sufrido de mielomeningocele y también han recibido tratamientos como resultado de hidrocefalia. Al comparar esto dos grupos, podemos examinar el impacto que el bilingüalismo tiene en la memoria, atención y otras habilidades mentales en niños que han sufrido de esta condición. A todos lo que decidan participar en este estudio, les será dada una evaluación neuropsicológica que esta diseñada para evaluar la memoria, atención, lenguaje, las habilidades para resolver problemas, las habilidades visuales-espaciales, y las habilidades motoras. Esta evaluación neuropsicológica toma aproximadamente cuatro horas y requiere del uso de papel y lápiz. A su hijo(a) se le harán preguntas, usara objetos pequeños, dibujara líneas y figuras. Su hijo(a) no será evaluado con ninguna clase de maquina ni tampoco ningún tratamiento físico. Algunas personas se cansan o se frustran durante la evaluación. Sin embargo estos síntomas son mínimos y su hijo(a) puede tomar descansos conforme sean necesarios.

Si usted decide que su hijo(a) participe en este estudio, lo siguiente se llevara a cabo:

- Su hijo(a) será evaluado por medio de exámenes neuropsicológicos que duran aproximadamente cuatro horas. Descansos son permitidos durante la evaluación, y algunos niños pueden elegir tomar diferentes porciones de los exámenes en otros días.
- Su hijo(a) contestara preguntas, usara objetos pequeños y dibujara líneas y figuras.
- La información personal de su hijo(a) es confidencial y estará solamente disponibles a aquellos directamente relacionados con este estudio. Su hijo(a) será examinado por doctores y estudiantes asociados con la Universidad de Loma Linda. Todos los estudiantes envueltos en este estudio son supervisados por doctores psicólogos con licencia.
- La evaluación neuropsicológica se llevara a cabo en el Departamento de Psicología de la Universidad de Loma Linda, situado en la calle Anderson en la ciudad de Loma Linda.
- Las citas son flexibles y pueden llevarse a cabo durante el día, de noche o durante el fin de semana.
- Cuando su hijo(a) haya completado la evaluación neuropsicológica, su compromiso con este estudio habrá terminado. Es recomendable que su hijo(a) termine toda la evaluación. Sin embargo, la participación en este estudio es voluntaria y usted y su hijo(a) pueden decidir terminar con su participación en cualquier momento.
- Se anticipa que la evaluación tomara aproximadamente cuatro horas. Sin embargo el tiempo necesario para que su hijo(a) complete esta evaluación puede ser más o menos de cuatro horas. Si usted elije que su hijo(a) sea evaluado en diferentes días, lo más seguro es que se tardara más de cuatro horas para completar la evaluación. Es poco probable que se tarde más de seis horas para completar la evaluación.

- El registro medico de su hijo(a) será examinado para confirmar: historial de colocación quirúrgica de un sistema de derivación (conocido como “shunt”), infecciones en el sistema de derivación y condiciones neurológicas.
- Un reporte detallando las ventajas y desventajas cognitivas de su hijo(a), y recomendaciones le será provisto cuando toda la evaluación sea completada.

Riesgos e Inconvenientes:
El participar en este estudio expone a su hijo(a) a un riesgo mínimo. Algunos niños que participaran en este estudio podrán cansarse o sentirse frustrados durante la evaluación. Para aliviar cualquier malestar/inconveniente, le será permitido a su hijo(a) tomar descansos conformen sean necesarios, o tomar diferentes partes de la evaluación en diferentes días.

Beneficios de Participar en este Estudio:
Todos los participantes de este estudio, recibirán un reporte detallando las ventajas y desventajas cognitivas. Recomendaciones serán hechas para mejoras desventajas y enfocarse en la utilización de las ventajas. Si las habilidades mentales del niño parecen impactar el rendimiento escolar, recomendaciones para ayuda escolar serán hechas. Los resultados de este estudio le proveerán nueva información y un nuevo entendimiento a los investigadores y doctores clínicos acerca del bilingüalismo y el posible efecto en las funciones cognitivas de niños con mielomeningocele. Los datos de este estudio también podrán ser publicados en revistas científicas.

Derechos del Participante:
La participación en este estudio es voluntaria. Su decisión en cuanto a no participar o discontinuar durante cualquier momento no afectara el cuidado médico de su hijo(a) presente ni futuro. Usted y su hijo(a) tienen el derecho de rechazar la participación en este estudio. Usted y su hijo(a) tienen el derecho de retirarse de este estudio en cualquier momento sin sufrir ningún penalti. Usted y su hijo(a) tienen el derecho de rechazar su participación en cualquier porción de la entrevista o evaluación. Sin embargo, si un niño se retira prematuramente del estudio, el reporte y las recomendaciones acerca de las ventajas y/o desventajas cognitivas del niño no se podrá llevar a cabo. Si el niño(a) rechaza completar cierta parte de la evaluación, un reporte completo con recomendaciones no se podrá desarrollar.

Alternativas de Tratamiento:
Una evaluación neuropsicológica tal vez no sea parte del tratamiento habitual de su hijo(a). Tal vez su hijo(a) no necesite una evaluación neuropsicológica, y también no se le asegura que su hijo(a) obtendrá tratamientos adicionales como resultado de esta evaluación. Su hijo puede obtener una evaluación neuropsicológica en otro lugar si usted no desea participar en este estudio. Si usted piensa que su hijo(a) necesita una evaluación neuropsicológica y no quiere participar en este estudio, por favor comuníquese con el doctor o proveedor de salud de su hijo(a) para más información.

Confidencialidad:
Toda la información personal de su hijo(a) es confidencial y disponible solamente a aquellos que están directamente envueltos en este estudio. Sus derechos acerca del uso de su información personal de salud están descritos en el formulario de autorización adjunto. El nombre de su hijo(a) no será asociado con los resultados del examen. Se le dará un numero de identificación al inicio del estudio el cual será utilizado para identificar los resultados de su hijo(a). Toda su información personal será guardada en un archivo con llave en el Laboratorio de Evaluaciones e Investigaciones Neuropsicológicas. Todos los resultados de la evaluación serán guardados bajo llave en un archivo distinto. Si usted desea proveer a la escuela de su hijo(a) las recomendaciones para rendimiento escolar, usted tendrá que firmar otra forma de consentimiento.

Compensación:
Aquellos que participen de este estudio recibirán una evaluación neuropsicológica gratis. Ni usted ni su hijo(a) será reembolsados monetariamente por su tiempo o participación.

Personas a Quien Dirigirse Si Tiene Preguntas o Surge Algún Problema:
Si desea contactar a alguien que no está relacionado con este estudio acerca de preguntas o quejas, usted puede contactarse con la Oficina de Relaciones del Paciente, en la Centro Médico de la Universidad de Loma Linda, CA 92354, al teléfono (909) 558-4647 para más información y ayuda.

Consentimiento del Participante en el Estudio:

a. He leído esta forma de consentimiento y he escuchado la explicación verbal de parte del investigador. Mis preguntas acerca de esta investigación han sido contestadas a mi satisfacción. En virtud de lo expuesto en este documento, doy mi consentimiento para que mi hijo(a) participe en este estudio. El firmar este formulario de consentimiento no quita mis derechos ni los de mi hijo(a), ni tampoco exonera a los investigadores, institución o patrocinadores de su responsabilidad. Puedo llamar a la doctora Susan Ropacki, PhD., durante horas de labor al (909) 558- 8615 o a Claudia Resendiz al (909) 658-5483 si tengo otras preguntas o inquietudes.

b. Se me ha sido otorgada una copia de este formulario de consentimiento ___________.

c. He recibido una copia del formulario de la Lista de California de Derechos del Sujeto Experimental y se me ha sido explicado estos derechos _______________.

_________________________________ _______________________
Firma del Participante (si ya cumplió los 12 años) Fecha

Firma del Testigo Fecha

Este estudio ha sido explicado a mi hijo(a) en un nivel el cual él/ella puede comprender y doy mi consentimiento para que mi hijo(a) participe en este estudio.

Firma del Padre o Tutor Legal Fecha

He examinado el contenido de la Lista de California de Derechos del Sujeto Experimental y este formulario de consentimiento con la persona que firma arriba. Los probables riesgos y beneficios de este estudio me han sido explicados.

Firma del Investigador Número de Teléfono Fecha

Appendix H

Bill of Rights (Spanish)

LISTA DE CALIFORNIA DE DERECHOS DEL SUJETO EXPERIMENTAL

A usted se le ha pedido que participe como sujeto en un procedimiento clínico experimental. Antes de decidir si quiere participar en el procedimiento experimental, usted tiene derecho a:

1. Que se le informe del carácter y propósito del experimento.

2. Que se le proporcione una explicación de los procedimientos que seguirán en el experimento clínico, y cualquier fármaco o aparato que se usara.

3. Que se le provea una descripción de cualquier incomodidad y riesgos acompañantes que razonablemente se esperen como resultado de su participación en el experimento.

4. Que se le proporcione una explicación de cualquier beneficio que razonablemente se espere como resultado de su participación en el experimento.

5. Que se le proporcione información sobre cualquier procedimiento alternativo que sea apropiado, fármacos o aparatos que puedan ser de ventaja para usted y los riesgos y beneficios correspondientes a los mismos.

6. Que se le informe sobre las opciones del tratamiento clínico, si es que las hay, disponibles a usted después del procedimiento experimental, si urge alguna complicación.

7. Que se le proporcione la oportunidad de hacer cualquier pregunta concerniente al experimento clínico o a los procedimientos necesarios.

8. Que se le informe que usted puede retractar su consentimiento para participar en el procedimiento experimental en cualquier momento y que usted puede descontinuar su participación en el experimento clínico sin ningún perjuicio.

9. Que se le provea una copia de este formulario y el formulario de consentimiento escrito, firmado, y fechado.

10. Que se le dé la oportunidad de decidir si va a consentir o no al experimento clínico sin ninguna intervención de cualquier elemento de la fuerza, engaño, cohecho o influencia indebida en su decisión.

He leído cuidadosamente la información contenida arriba en la “Lista de Derechos del Sujeto Experimental de California” y entiendo plenamente mis derechos como sujeto potencial en el experimento clínico en el que personas participaran como sujetos.

____________________________	____________________________
Fecha	Paciente
____________________________	____________________________
Hora	Padre/Tutor Legal

Si lo firma otro, no el paciente, indique la relación con este:

____________________________	____________________________
Relación	Testigo