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Bilingualism and executive functioning in children born very low birth weight and normal birth weight

Natalia Carr Moss
University of New Mexico - Main Campus

Sarah Erickson
University of New Mexico - Main Campus

Jean Lowe
University of New Mexico - Main Campus

Steven Verney
University of New Mexico - Main Campus

Judy Ho
Pepperdine University

Natalia Moss
Candidate

Dissertation (Psychology Department)
Department

This dissertation is approved, and it is acceptable in quality and form for publication:

Approved by the Dissertation Committee:

Sarah J. Erickson, Ph.D., Chairperson

Jean R. Lowe, Ph.D.

Steven Verney, Ph.D.

Judy Ho, Ph.D., ABPP, CFMHE

BILINGUALISM AND EXECUTIVE FUNCTIONING IN CHILDREN BORN VERY LOW BIRTH WEIGHT AND NORMAL BIRTH WEIGHT

by

NATALIA C. MOSS

B.A., Psychology, University of California, Los Angeles, 2008
M.A., Psychology, Pepperdine University, 2012
M.S., Psychology, University of New Mexico, 2016

DISSERTATION

Submitted in Partial Fulfillment of the
Requirements for the Degree of

Doctor of Philosophy
Psychology

The University of New Mexico
Albuquerque, New Mexico

July 2019

ACKNOWLEDGMENTS

I would like to acknowledge my faculty mentor and dissertation chair, Dr. Sarah Erickson, and my dissertation committee, Drs. Jean Lowe, Steven Verney, and Judy Ho, for investing their valuable time and energy into my training.

I wish to thank my family, whose love and guidance are with me in whatever I pursue; and a special thanks to my husband, Natan and daughter, Shia for their wise counsel, inspiration, and unwavering support.

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Ph.D., Psychology, University of New Mexico, 2019

ABSTRACT

Research has documented an advantage on executive functioning in bilingual compared to monolingual children, suggesting that bilingual children may develop inhibitory control earlier than their monolingual peers. There are no known studies examining the differences between monolingual and bilingual children who were born very low birth weight (VLBW). Children born VLBW are at greater risk for difficulties with attention and inhibition. Executive functioning abilities were measured at 3-4 years and at 5-7 years. Caregivers reported sociodemographic information. Bilingualism was measured by self-report and observation of unstructured mother-child play. Executive functioning abilities were measured using the Bear Dragon (inhibition and working memory 3-4 years), Memory for Location 2 (working memory 3-4 years), Gift Delay (inhibition 3-4 & 5-7 years), WJ-III Memory for Words (working memory 3-4 & 5-7 years), Color Form (inhibition and task switching 5-7 years), and the DCCS (inhibition and task switching 5-7 years). Children born normal birth weight (NBW) performed significantly better on tasks involving working memory (3-4 years), and inhibition (5-7

years). Monolingual children born NBW performed better on tasks of working memory (3-4 years) and inhibition (5-7 years) compared to bilingual children born VLBW. Modest evidence for a bilingual (parent reported but not observational) advantage on one of three inhibition tasks (Gift Delay) emerged at school age (5-7 years). Children born NBW performed better on executive functioning measures beginning at the preschool age (3-4 years). Evidence for developmental differences between these groups helps to provide a broader understanding of the development of early executive processes.

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Chapter 1

Introduction

The cognitive effects of learning more than one language in childhood have been an area of interest among researchers for many years. Bilingualism has been defined in many ways and there are varying degrees of bilingualism among those who identify as bilingual. The Pew Research Center assesses level of bilingualism by asking participants to rate their own language abilities, and by asking how well they are able to converse, read and write in each language (Krogstad & Gonzalez-Barrera, 2013). Bilingualism in the U.S. may be classified in several different ways including English dominance, other language dominance, or balanced proficiency in both languages. Distinctions have also been made between those who acquire a second language early in life (before age 12) compared to late in life (after age 12) (Puente & Ardila, 2000). Other areas to consider when assessing for bilingualism may include language of academic instruction, contexts in which the two languages are used, and personal attitudes towards each language (Puente & Ardila, 2000). Currently there is no accepted, objective standard for classifying children as bilingual (Carlson, 2005). Children become bilingual for many reasons; in the U.S. children who are bilingual often have non-native parents who speak a language other than English in the home and their children become bilingual when they begin school where the instruction is in English.

Early research warned that the bilingual experience could negatively impact learning based on evidence of monolingual children outperforming bilingual children on various tasks of cognitive abilities (Hakuta, 1986). However, many of these early studies did not consider the effects of confounding variables that are known to negatively impact measures of cognitive abilities such as socioeconomic status (SES), living conditions, and quality of education (Adesope, Lavin, Thompson & Ungerleider, 2010). It may be particularly valuable to continue studying children who have been exposed to more than one language within their socioeconomic context to more accurately understand how the bilingual experience may impact cognitive development. Several studies have documented differences between monolingual and bilingual children suggesting bilingual individuals show an advantage on tasks of executive functioning including, theory of mind, inhibition, task switching, nonverbal perceptual reasoning, and cognitive flexibility (Bialystok & Craik, 2010; Gold, Kim, Johnson, Kryscio, & Smith, 2013). Past research has also suggested that bilinguals experience more difficulty with word retrieval and vocabulary acquisition (Gollan, Montoya, Cera, & Sandoval, 2008; Bialystok & Luk, 2012). However, there are no known studies to examine the differences between monolingual and bilingual children who were born very low birth weight (VLBW).

A large number of children born VLBW or preterm have been found to be at risk for neurodevelopmental disabilities including reduced cognitive test scores and behavior difficulties entering school age (Bhutta, Cleves, Casey, Cradock, & Anand, 2002). Incidence of learning disabilities, low cognitive abilities, attention deficits, and behavior problems occur in as many as 50%-70% of children born VLBW (Taylor, Klein, & Hack, 2000). Long term delays have been found in cognitive functioning, language development and executive functioning skills in children born VLBW (Smith, Landy, & Swank, 2000). However, bilingual participants in these studies were not analyzed separately and therefore it is unknown if these findings generalize to bilingual children born VLBW as well. This is of particular interest because some of the documented cognitive deficits associated with prematurity (e.g., attention, executive functioning) are areas strength in bilingual children.

The preschool to school-age period is particularly of interest in this population because it is a time of rapid change in neural development and self-regulation (Clark et al., 2013; Bayless & Stevenson, 2007). During this time children show substantial growth in their executive functioning abilities, self-control over behavior, emotions and thoughts (Carlson, 2005). Dowsett and Livesey (2000) discuss observed improvements in inhibitory control from ages three to five years that may be attributed to maturation in the prefrontal cortex. Although preschoolers may have the cognitive capacity for inhibitory control, they appear to have difficulty displaying inhibitory control through motor responses (Dowsett & Livesey, 2000). There is some evidence to suggest that bilingual children may develop inhibitory control earlier, around age three, whereas these abilities are not generally seen in monolingual children until they are closer to four or five years old (Diamond, Carlson & Beck, 2005). Assessing children over time may help to better understand differences in the development of executive functioning abilities in bilingual children.

Diversity Considerations

America's growing cultural diversity must be considered in research to best serve increasingly diverse populations. Recent statistics state that Hispanics are the largest minority group within the U.S. and make up about 17% of the population followed by African Americans (13%), American Indian/Alaska Natives (1%), Asians (6%), and Pacific Islanders (<1%) (U.S. Census Bureau, 2015). The 2015 American Community Survey found that about 64.5 million or 21.5% people living in the U.S. spoke a language other than English at home. About 60% of individuals who speak a language other than English at home also reported being bilingual indicating that they speak English “very well” (American Community Survey, 2015). Spanish is the most prevalent non-English language spoken in the U.S. with estimated 40 million speakers of variable English proficiency (American Community Survey, 2015). The population of bilingual children has steadily increased over the past decades and is estimated to be around 25% (Migration Policy institute, 2014). It is clear that there is great heterogeneity among individuals living in the U.S. with respect to ethnic identity and languages spoken.

In addition to ethnic and language heterogeneity among bilinguals in the U.S., there is diversity among factors such as immigration status, country of origin, quality of education received, religious practices, SES, culture, and level of acculturation that may impact performance and interpretation of performance on measures of cognitive abilities. Children from bilingual homes are more likely to have parents with less than a high school education, be lower income, and be raised in a cultural context that differs from mainstream U.S. culture (Espinosa, Fatas, & Ubeda, 2015). Additionally, immigrant mothers are more likely to be married, have larger families, and be less likely to be depressed than mothers born in the U.S. (Mistry, Biesanz, Chien, Howes, & Benner, 2008). Researchers must consider the potential impact of resiliency and risk factors associated with socio-cultural differences between monolingual and bilingual children when assessing cognitive abilities.

Demographic Factors and Assessment Outcomes

In the U.S., ethnic minority populations are disproportionately, negatively impacted by a wide range of health disparities including lower quality of education, few years of education, lower literacy rates, increased poverty, and limited access to health care services (Mindt, Byrd, Saez & Manly, 2010). Level and quality of education received has been found to impact cognitive test performance on both verbal and nonverbal tests (Manly et al., 1999; Rosselli & Ardila, 2003). Throughout preschool and K-12 education, bilingual children have historically underperformed in comparison to their monolingual, English-speaking peer (Espinosa, 2010).

SES is often measured through a combination of income, education, and occupational attainment. Past research has consistently found that poverty is negatively correlated with scores on measures of cognitive ability and school achievement (McLoyd, 1998). Children living in lower income neighborhoods have less access to quality public and private services (e.g., parks, community centers, daycare, education) and are more likely to encounter environmental stressors (e.g., violence, homelessness, substance use) (McLoyd, 1998). Although there is great variability within minority groups, low SES and minority status have historically been intertwined in our society. Immigrants in the U.S. are more likely to live below the poverty line and work as laborers or equipment operators (U.S. Census Bureau, 2014). Discrimination and marginalization are some significant barriers to overcoming poverty for minorities in the U.S. (Corcoran & Nichols-Casebolt, 2004). Mindt and colleagues (2010) found increased false-positive errors in diagnoses following a neuropsychological evaluation in Latino communities in comparison to Non-Hispanic white communities. In a review of multicultural assessment of children researchers found that test performance patterns might be differentially impacted by socioeconomic factors such that children from high SES homes score significantly higher across a variety of domains (Byrd, Arentoft, Scheiner, Westerveld & Baron, 2008).

The Bilingual Experience

Bilingualism has been found to impact cognitive processing through various different mechanisms. One hypothesis involves the inhibitory control model, which states that bilingual individuals must constantly manage competition/interference between both languages using multiple levels of control (Mindt et al., 2008; Green, 1998). For example, when an individual has access to two languages and is asked to name a picture there is competition between responses in that they must select between response options in either language (Green, 1998). It was previously thought that when bilinguals were speaking in one language the other language was "turned off." More recent research proposes that both languages are always active and bilinguals are actively inhibiting the use of the second language (Mindt et al., 2008). When individuals are speaking in their dominant language it may be easier to inhibit their nondominant language. However, when one is speaking in their nondominant language it is significantly more difficult to suppress the dominant language, which is more easily accessible and therefore the individual may experience more interference (Green, 1998). This hypothesis implies that bilingualism requires increased cognitive control, especially when speaking in one's nondominant language, or when frequently switching back and forth between languages. Because switching between languages is thought to involve inhibiting the previous language spoken it may reduce one's speed of response but it may also strengthen executive functioning abilities such as inhibition (Green, 1998).

Cognitive disadvantages of bilingualism. Much of the past research on the cognitive effects of learning multiple languages in childhood has focused on the negative impacts of bilingualism (Carlson & Beck, 2009). For example, the weaker links hypothesis suggests bilinguals experience more difficulty with word retrieval. One explanation for this effect is that there is a positive correlation between frequency of word use and speed of retrieval, and bilinguals use each individual language less often than a monolingual individual uses their one language (Gollan et al., 2008). Another hypothesis proposes that it is easier to inhibit one's nondominant language in comparison to inhibiting their dominant language because it is less accessible; therefore, bilinguals will be most disadvantaged when required to produce high-frequency words because they require more effortful control to inhibit (Green, 1998).

Research with preschoolers frequently shows that children who learn two languages simultaneously may acquire vocabulary more slowly than monolingual preschoolers (Collier, 1995). Because bilingual children know two labels for many words their vocabulary is very large compared to monolingual individuals when considering both languages but not when assessing each language individually. When comparing their expressive and receptive vocabulary in each language separately, bilingual children appear to have a smaller vocabulary in comparison to monolingual children and this effect remains into adulthood (Bialystok, Craik, & Luk, 2008). A bilingual disadvantage is often seen on tasks that depend on vocabulary level, even when the bilingual individual is being assessed in their dominant language (Bialystok & Luk, 2012). Young adult bilinguals whose receptive language was assessed using the Peabody Picture Vocabulary Test (PPVT; Dunn & Dunn, 1997) and Boston Naming Test (Kaplan, Goodglass, &

Weintraub, 2001) showed more retrieval failures than monolinguals (Gollan & Brown, 2006; Bialystok & Luk, 2012). Bilinguals have also been found to name pictures more slowly and with more errors when using their dominant language than monolinguals (Gollan, Montoya & Fennema-Notestine, 2005). Bilingual individuals also experience the tip-of-the-tongue phenomena more often when naming pictures that have a similar label in both known languages (Gollan & Acenas, 2004). Although there is evidence to suggest some disadvantages in verbal abilities, there is also evidence to suggest cognitive advantages associated with learning and maintaining multiple languages at once.

Cognitive advantages of bilingualism. It has been suggested that speaking two languages since childhood may reduce age-related declines in cognitive processes seen in older adults. For example, switching between languages may strengthen task switching abilities and executive control processes (Bialystok & Craik, 2010). Previous research has also found a bilingual advantage for nonverbal perceptual reasoning tasks and cognitive flexibility (Bialystok & Craik, 2010; Gold, Kim, Johnson, Kryscio, & Smith, 2013). Cognitive flexibility has been described as one's ability to adapt thoughts and behavior to meet the individual's goals while living in a constantly changing environment (Miller & Cohen, 2001). Pons and colleagues (2009) suggested that bilingual preschoolers outperform monolingual preschoolers on theory of mind tasks. In a study comparing early second language acquisition in children compared to monolingual children, researchers reported more effective semantic processing, in early second language learners (Pliatsikas, Moshchopoulou & Saddy, 2015). Gold and colleagues (2013) found bilingual older adults were more efficient at switching between perceptual reasoning tasks, and they showed decreased activation in the left lateral frontal cortex and the cingulate cortex suggesting better neural efficiency for cognitive control processes than their monolingual peers.

Executive Functioning

Executive functioning refers to a complex set of cognitive processes such as working memory, reasoning, task flexibility, inhibition, problem solving, planning, and execution and has been shown to be a predictor of school readiness in preschool aged children (Espy et al., 2002). Deficits in executive functioning have been found to be associated with a variety of psychological and developmental problems such as aggression (Séguin & Zelazo, 2005), ADHD (Clark, Pritchard, & Woodward, 2010), and autism (Pennington & Ozonoff, 1996). As a result, identifying factors that underlie individual differences in children's executive functioning constitutes an important target for developmental research. It has been suggested that individual differences in executive functioning may have implications for long-term social, academic and behavioral outcomes (Clark et al., 2013).

Specific tasks that have been found useful in assessing preschool aged children include delayed response tasks because of the nonverbal component, simple demands, and their sensitivity to age related differences (Espy et al., 2002). Other skills often included in the assessment of executive functioning include the ability to inhibit goal-irrelevant impulses or attention responses and the ability to adapt flexibility to changes in the environment (Anderson & Doyle, 2008). Previous studies have suggested that parent–child interactions play an important part in the development of prefrontal cortical systems that support executive control (Hackman & Farah, 2009). As a result, socioeconomic factors such as maternal education and income are relevant to consider when interpreting individual differences in executive functioning (Bernier, Carlson, & Whipple, 2010). Recent studies have found children from lower SES families perform worse on working memory and executive control at 6-14 months (Lipina, Martelli, Vuelta, & Colombo, 2005), and executive attention at 6 years (Mezzacappa, 2004).

Executive Functioning Children Born VLBW. In a meta-analysis Mulder and colleagues (2009) found executive functioning to be a weakness for children born preterm in areas of selective attention, sustained attention, inhibition, working memory, planning, and verbal fluency across studies and age groups. Similarly at the age of five children born preterm with average IQ displayed significantly higher rates of impairments on executive functioning tasks (Aarnoudse-Moens, Smidts, Oosterlaan, Duivenvoorden, & Weisglas-Kuperus, 2009). In a study comparing MRI measures of working memory in two year olds born full term and preterm, clear differences were found between the groups such that the preterm group had marked deficits in working memory (Woodward, Clark, Pritchard, Anderson, & Inder, 2011). Given the central role of executive functioning in a variety of domains including learning, problem solving, and language development these deficits are likely to impact their academic and social performance later in life.

Executive Functioning and Bilingualism. Past research has suggested that bilingual individuals show an advantage across lifespan on tasks requiring executive control. A comprehensive review on cognitive difference between bilingual and monolingual children found evidence to suggest that inhibitory control develops earlier in bilingual children (Bialystok, 2001). Green (1998) proposed that bilingual children have more opportunities to practice inhibitory control than monolingual children by using their executive functions to suppress their second language. Bialystok and Martin (2004) explain that encoding and interpreting vocabulary in two languages compared to one requires greater effort in areas of attention and inhibition on a regular basis. Attending to a set of labels known for an item in one language while ignoring the labels known in the second language requires increased attention and inhibition.

Bialystok and Martin (2004) assessed bilingual and monolingual 5-year-old children using a computerized dimensional change card sort (DCCS) task. This DCCS task is a measure of executive functioning where children are asked to sort cards by, color, shape, object or function. On tasks requiring moderate demands of inhibition (sorting by color-shape & color-object), bilingual children outperformed monolingual children (Bialystok & Martin, 2004). Researchers proposed that bilingual children at this age might have greater cognitive flexibility and attention strategies from managing two languages, which enable them to outperform monolingual children on this type of task. The bilingual four year olds performed similarly to the monolingual five year olds (Bialystok & Martin, 2004).

Cognitive benefits seen in bilinguals such as cognitive flexibility and improved executive functioning may be related to structural differences in their neuroanatomy. Past studies have found different patterns of brain activation in bilinguals compared to monolinguals. Mechelli and colleagues (2004) looked at Italian-English speaking bilinguals and found an increase in grey matter density in the left-inferior parietal cortex that was correlated with, acquiring a second language at an early age, and with increased second language proficiency. In another study comparing early second language acquisition to monolinguals, researchers reported significant differences in several white matter tracts involved in language processing in the bilingual group (Garcia-Penton, Perez, Iturria-Medina, Gillon-Dowens & Carreiras, 2014). These white matter differences may be explained by the constant need for bilinguals to select between the use of one language and another.

Bilingualism in Children Born VLBW

In previous studies bilingual children have outperformed monolingual children on measures of executive functioning. Similarly children born NBW have outperformed children born VLBW on measures of executive functioning. Although there are no known studies comparing bilingual children who were born VLBW, to the monolingual children born NBW to see if bilingualism is a protective factor regarding executive functioning in children who were born VLBW, there are studies that examined bilingualism in other populations of children at-risk for executive function deficits. Previous studies have suggested that children with language impairments are at greater risk for deficits in executive functioning abilities (Henry, Messer, & Nash, 2012). A study looking at bilingualism and executive functioning in children with language impairments found that bilingual children with language impairments performed similarly to typically developing monolingual children on tasks of selective attention and inhibition (Engel de Abrreu, Cruz-Santos & Puglisi, 2014). This may suggest that bilingualism is a protective factor for children who are at-risk for executive functioning deficits.

Difficulties of Measuring Bilingualism

The bilingual experience is dynamic and difficult to study. As mentioned previously there are many different ways to categorize bilingualism. Some studies ask participants to self report on the presence or absence of a second language while others use more formal questionnaires and assessments in combination with self-rating scales of language proficiency and demographic information to more precisely measure the level of bilingualism. Because there is such variability within bilingualism it is often difficult to determine what the observed differences between bilingual and monolingual group might be attributed to. For example, differences observed may be due to age of second language acquisition, frequency of language use, cultural differences or demographic variables that are often difficult to tease apart rather than a clear difference between bilinguals and monolinguals. Given that bilingualism is not a categorical variable it may be better defined as a matter of degree (Carlson, 2005). Developmental research has found that the degree of bilingualism is crucial in determining the cognitive implications of bilingualism (Bialystok, McBride-Chang, & Luk, 2005).

In addition to difficulties with defining and measuring bilingualism, there are also many confounding variables to consider such as differences in SES that have also been shown to correlate with differences on measures of cognitive abilities across a variety of domains. Studies that match bilinguals and monolinguals on various demographic characteristics such as income and level of education were more likely to report cognitive advantages in bilinguals than studies that were unable to match participants in this way (Gold et al., 2013). Often times when studies did not match participants on demographic variables, the bilingual group was confounded with also being a lower SES group making it difficult to determine whether cognitive differences were due to the bilingual experience or the risk factors associated with having a lower SES.

Bilingual children are often found to show some language based deficits early on that may look like impairments but are actually quite normative when compared to other bilingual children (Friesen, Luo, Luk & Bialystok, 2015). Kieffer (2008) found that children who entered kindergarten in an English-only school with limited English proficiency showed lower reading achievements by the fifth grade compared to students who were native English speakers or bilingual with high English proficiency entering kindergarten. However, upon further analysis, this study also found that when researchers controlled for SES (i.e., parent's education, parent's occupation and household income), these group differences were much smaller over time. Numerous studies have warned that members of Hispanic and African American communities are at greater risk for being false-positive errors n measures of cognitive abilities than Non-Hispanic white examinees when socioeconomic factors are not considered in the interpretation of test results (Norman, Evans, Miller, & Heaton, 2000; Taylor & Heaton, 2001). These inherent difficulties in studying bilingualism must be considered when interpreting and generalizing results.

Aims and Hypotheses

Past research has suggested that bilingual individuals show an advantage on tasks requiring executive control. Similarly, bilingual children are thought to develop executive functioning abilities, particularly cognitive flexibility, selective attention and inhibitory control, earlier (3 years) in comparison to monolingual children (4-5 years) (Diamond et al., 2005). This study sought to extend our understanding of the possible effects of bilingualism on executive functioning abilities in children who were born VLBW, a population that has previously been found to show deficits in executive functioning abilities at school age (Bhutt et al., 2002; Taylor et al., 2000; Smith et al., 2000).

Researchers compared executive functioning abilities on tasks requiring working memory, inhibition, and task switching at the preschool (3-4 years) and school age (5-7 years). Executive functioning is a critical component of cognitive and social development, and research on bilingual children born VLBW has implications for understanding the development of executive functioning in medically at risk populations, and the relationship between executive functioning and early bilingual exposure in children.

Some challenges identified by past researchers in this area include defining bilingualism, and considering the impact of socioeconomic variables often confounded with bilingual children. As mentioned previously, bilingualism is not a categorical variable and is better defined by degree of bilingualism. To address definitional challenges of bilingualism, this study measured bilingualism in two ways: 1) by self report of primary and secondary language spoken in the home whereby participants are classified as either bilingual or monolingual; and 2) by percent of English compared to another language spoken in 5 minute unstructured mother-child play interactions at 3-4 years and 5-7 years. To address the challenge of potentially underestimating the abilities of bilingual children due to confounding variables, SES, gestational age, and test age were used as covariates in primary analyses. Evidence for developmental differences between the two groups may help to further understand the effect of bilingualism on children’s cognition, and provide a broader understanding of the development of these cognitive processes.

Hypotheses. The primary goal of this study was to understand how differences in language (monolingual vs. bilingual) may relate to executive functioning abilities in children born VLBW compared to children born normal birth weight (NBW) between the preschool (3-4 years) and school age (5-7 years) time period. Measures of executive functioning included the Bear Dragon (inhibition/working memory), Gift Delay (inhibition), WJ-III Memory for Words (working memory), and Memory for Location 2 (working memory) at 3-4 years and the Gift Delay, WJ-III Memory for Words, Color Form (inhibition/task switching) and the Dimensional Change Card Sort (DCCS) (inhibition/task switching) at 5-7 years. As a preliminary hypothesis, we assessed if Children born VLBW scored significantly lower than children born NBW on tasks of executive functioning (Bear Dragon, Gift Delay, Color Form, DCCS, Memory for Location 2, & Memory for Words). Main hypotheses included that: 1) It was predicted that bilingual children who were born VLBW would perform similarly to monolingual children born NBW on executive functioning measures of inhibitory control (Bear Dragon, Gift Delay, Color Form, DCCS) at both time points. 2) There would be a bilingual advantage, for those who self-reported as bilingual (VLBW & NBW), at both time points on executive functioning measures of inhibitory control (Bear Dragon, Gift Delay, Color Form & DCCS) and would perform more similarly to their monolingual peers on tasks of working memory (Memory for Location 2 & Memory for Words). 3) Bilingual children, by maternal self-report, would show inhibitory control earlier (3-4 years), as evidenced by performance on the Bear Dragon and Gift Delay than their monolingual peers who would show inhibitory control later (5-7 years) as evidenced by performance on Gift Delay, Color Form and DCCS. 4) Videos that showed the greatest degree of bilingualism (i.e., closer to 50% English and 50% a second language) would show the greatest bilingual advantage on executive functioning tasks of inhibitory control

(Bear Dragon, Gift Delay, Color Form, DCCS), but would perform similarly to their monolingual peers on tasks of working memory (Memory for Location 2 & Memory for Words) at both time points.

Chapter 2

Methodology

Participants

The University of New Mexico's Human Research Review Committee provided review and approval for this study, which was in compliance with institutional research standards for human research. Participants included children born VLBW, children who were born NBW and had an uneventful newborn course, and their maternal caregiver. Children were evaluated at ages 3-4 years, and then again at ages 5-7 years. There were 93 children evaluated at the 3-4 year time point (M age = 3 years 10 months; range = 3 years 6 months-4 years 10 months; females = 47). There were 78 children who were evaluated at the 5-7 year time point (M age = 6 years 1 month; range = 5 years 6 months-7 years 6 months; females = 41). Of the 93 3-4 year old participants, 67 children also participated in the 5-7 year data collection. Children were excluded if they were prenatally exposed to illicit substances, had vision/hearing impairment, or had a genetic abnormality. To recruit participants, pediatric nurses from the University of New Mexico Hospital Clinical and Translational Science Center identified eligible participants. Graduate students then called the caregivers of the eligible preschoolers to provide a brief description of the study and schedule an assessment if mothers were interested in participating with their child.

All caregivers provided informed consent at the start of their scheduled assessment, prior to filling out questionnaires, participating in testing, or being video recorded. Completion of questionnaires, evaluation of the child's cognitive abilities, and the video recording took place at the MIND Research Network in Albuquerque, New Mexico or at the University of Utah, Utah. Medical information was obtained for the VLBW cohort through hospital record review.

Bilingual preschool aged group. The bilingual preschool aged (3-4 years) group consisted of 44 children. Within this group, 29 children were born VLBW and 15 children were born NBW. The children in this bilingual, preschool aged group had exposure to English and a second language in their home as indicated by the maternal caregiver on a demographic questionnaire. Most parents (n = 23) reported English as the primary and Spanish as the secondary language spoken in the home; 12 reported Spanish as the primary and English the secondary language; 7 reported English as the primary and a Native Language (Navajo, Tewa, or Crow) as the secondary language; 1 reported a Native Language as the primary and English as the secondary language; and 1 reported English as the primary and French as the secondary language.

Monolingual preschool aged group. The monolingual preschool aged (3-4 years) group consisted of 49 children. Within this group, 40 children were born VLBW and 9 children born full term with exposure to only English in their home as indicated by mothers on a demographic questionnaire.

Bilingual school aged group. The bilingual school aged (5-7 years) group consisted of 29 children. Within this group, 16 children born VLBW and 13 were born NBW. The children in this bilingual, school aged group had exposure to English and a second language in their home as indicated by the maternal caregiver on a demographic questionnaire. Most parents (n = 14) reported English as the primary and Spanish the secondary language spoken in the home; 8 reported Spanish as the primary and English the secondary language; and 7 reported English as the primary and a Native Language (Navajo, Tewa, or Crow) as the secondary language.

Monolingual school aged group. The monolingual school aged (5-7 years) group consisted of 49 children. Within this group, 42 children born VLBW and 7 children born full term with exposure to only English in their home as indicated by mothers on a demographic questionnaire. Tables one and two contain detailed demographic information for the bilingual and monolingual groups at each time point.

Measures

Sociodemographic variables. Demographic variable data collected through maternal caregiver's report included child's ethnicity, gestational age, birth weight, household income, number of people living in the home, and maternal education. Maternal caregivers indicated income by selecting one of eight choices for annual household income: 1) from $0 to $10,000, 2) income between $10,001 and $20,000, 3) income between $20,0001 and $30,000, 4) income between $30,001 and $40,000, 5) income between $40,001 and $50,000, 6) income between $50,001 and $60,000, 7) income between $60,001 and $70,000 and, 8) income greater than $70,000. Maternal education was indicated as one of seven different choices: 1) less than 12th grade, 2) high school graduate, 3) 1 year of college, 4) an Associate's degree, 5) a Bachelor's degree, 6) some graduate school, or 7) Masters degree or higher.

Bilingualism. Bilingualism was measured in two ways. The first measure of bilingualism was obtained through maternal caregiver's report of primary and secondary (if applicable) languages spoken in the home on a demographic questionnaire. Secondly mother and child dyads were video recorded for 8 to10 minutes with a standard set of toys including pretend food, a cash register and blocks at the 3-4 year evaluation, and with a puzzle at 5-7 year evaluation. Five minutes of the video recorded mother-child interaction was coded for percentage of English and another language spoken by both the mother and the child. The highest degree of bilingualism possible would be 50% (50% of the time speaking in one language 50% of the time speaking in another language). For example, if a participant spoke 20% of the time in English and 80% of the time in another language, their interaction was coded as 20% bilingual exposure. Similarly if a participant spoke 80% of the time in English and 20% of the time in another language their interaction would again be coded as 20% bilingual exposure. The videos were coded this way to capture bilingualism rather than comparing Spanish speaking to English speaking participants. The difficulty of measuring bilingualism is a theme throughout bilingualism research and in this study, researchers are exploring a new way of measuring bilingualism and comparing it to a frequently used measure of bilingualism, self report.

Executive functioning at 3-4 years. The Bear Dragon (Kochanska, Murray, Jacques, Koenig, & Vandegeest, 1996; and Kochanska, Murray, & Harlan, 2000) is a measure of inhibition and working memory in children. The examiner introduces children to a “nice” bear puppet (using a soft, high-pitched voice) and a “grumpy” dragon puppet (using a gruff, low-pitched voice). It is then explained that in this game, “we will listen to the nice bear and do what he asks us to do” (e.g., touch your head), but “we will not listen to what the grumpy dragon tells us, so we will not do what he asks us to do.” Practice trials are administered where the bear gives a command in a nice voice (“touch your nose”) and the dragon gives a command in a gruff voice (“touch your tummy”). The child passes the practice trial if they comply with the bear and do not comply with the command given by the dragon. Up to six practice trials are given, in addition to verbal rule reminders after each trial until the child passes one command by each puppet. If the child is unable to pass the practice trials they are given a score of 0. After the practice trials, there are 10 test trials with alternating bear and dragon commands. A reminder of the rules is provided halfway through the testing regardless of performance. This assessment is scored by assigning a score of 0 (fail item), 1 (wrong move), 2 (partial correct), or 3 (full correct) to each trial. Points are added to obtain a total score out of 33 possible points (3 points pretrial plus 3 points for correctly completing at least one of the practice trial items) (Carlson & Moses, 2001; Carlson, 2005).

The Gift Delay (Carlson, 2005) is a measure of inhibition in children. The child is told that the examiner has a gift for the child but they forgot to wrap it. The child is then instructed to turn away and not peek until the examiner finishes wrapping the gift. The examiner wraps the gift for one minute. Next the wrapped gift is placed in front of the child and they are told not to touch or open it while the examiner finishes making them a card. The examiner then turns her back to the child and works on a card for two minutes. No reminders are given. The task is discontinued and the child receives the gift at two minutes or when the child begins to open the gift. A score is provided for the number of seconds prior to the child peeking at the examiner, touching, and opening the gift.

The Memory for Words subtest from the Woodcock-Johnson III Normative Update Tests of Cognitive Abilities (WJ-III; Woodcock, McGrew, & Mather, 2001) was administered as a measure of short-term, auditory working memory. This test requires the child to repeat increasingly longer lists of unrelated words in the correct sequence.

The Memory for Location 2, Revised (Cossu, Antonucci, & Nava, 1999) test is a measure of spatial working memory for very young children. The child is presented with six identical cups and one toy. The examiner hides the toy under one cup and places a screen in front of all the cups for 1, 5 or 10 seconds. Once the screen is removed the participant identifies the cup under which the toy is hidden.

Executive functioning at 5-7 years. During the 5-7 year visit children were re-administered the Gift Delay and WJ-III Memory for Words subtest that were administered during the 3-4 year evaluations and described above. Additionally executive functioning was measured using the Color Form test (Sattler & D'Amato, 2002) and the Dimensional Change Card Sort (DCCS; Zelazo, Muller, Frye, & Marcovitch, 2003).

The Color Form test is a measure of attention, inhibition, visual scanning, task switching, and fine motor skills. The child is presented with a board that has geometric shapes of different colors and is asked to draw a line with their finger alternating between connecting shapes of the same color and shapes of the same figure. The child must selectively attend to one aspect of the shape (e.g., color), while ignoring the other (e.g., figure). The number of errors and time to complete the task is recorded by the examiner.

The DCCS is a measure of requires the child to sort a series of cards, first according to color (pre-switch phase), and then according to shape (post-switch phase). Children are introduced to the task with a demonstration phase where the examiner labels the two target cards using both dimensions (e.g., "Here is a blue rabbit and here is a red boat"). The child is then told they are going to play a color game where all the blue cards get stacked under the blue rabbit and all the red cards get stacked under the red boat. The child is then presented with a card by saying, "Here's a red one. Where does it go?" and the same is done with a blue card. The examiner then proceeds to the pre-switch trials, which include six cards to be sorted by color. On each pre-switch trial the examiner labels the test card by the relevant dimension only “here is a blue one, where does it go in the color game?” No feedback is given as to whether the cards were sorted correctly. For the post-switch phase new target cards are presented and the child is told “Now we are going to play the shape game. In the shape game the rabbits go here and the boats go here.” The rules are again restated after each trial but no feedback is given as to whether or not the cards were sorted correctly.

Translation of measures. Translation methods were used to administer the measures to these caregivers. Because there were no existing translation measures for the Demographic Questionnaire, Bear Dragon script, Gift Delay Peek script, Memory for Location 2, Color Form, or DCCS, a translated measure was created using a translation/back-translation procedure. A Spanish speaker created translated measures, and a second researcher back-translated the measure to English to ensure accuracy. The Spanish translation was then evaluated for readability during the interviewer-training phase and the translators made additional revisions as needed.

Chapter 3

Analyses

Demographic Characteristics

Frequency distributions, skewness, and normality was examined for all demographic variables of interest including child's age, birth weight, prematurity, and sex, in addition to mother's education, number of people living in the home, and household income (summarized in Tables 1-2). An ANOVA or t-test was used to assess differences between the monolingual and bilingual groups at 3-4 years and 5-7 years on continuous/semi-continuous demographic characteristics. A chi-square test was used to assess group differences for categorical characteristics.

Bilingualism

A regression was used to test the relationship between parental self-report of bilingualism in the home, and bilingualism as measured by percentage of English compared to another language spoken in a 5 minute video recorded mother-child interaction at both time points.

SES and Executive Functioning Abilities

Pearson correlations were used to measure the relationship among continuous/semi-continuous demographic characteristics (birth weight, yearly income, test age) and ANOVAs or t-tests were used to compare categorical demographic characteristics (child sex, maternal education) with executive functioning measures including the Bear Dragon (both time points), Gift Delay (both time points), Memory for Words (both time points), Memory for Location 2 (3-4 years), Color Form (5-7 years), and DCCS (5-7 years).

Executive Functioning Results Controlling for SES

Demographic characteristics that are significantly associated with executive functioning outcome measures were used as covariates to control for these factors in the assessment of bilingualism and executive functioning abilities. To test our preliminary hypothesis, ANCOVA analyses comparing the VLBW group and NBW group at both time points on measures of executive functioning with SES variables as covariates were conducted to determine group differences. To test hypothesis one, ANCOVA analyses comparing the monolingual NBW group and bilingual VLBW group at both time points on measures of executive functioning with SES variables as covariates were conducted to determine group differences. To test hypotheses two and three, ANCOVA analyses comparing the monolingual group to the bilingual group (as indicated by self-report) at both time points on measures of executive functioning, with SES variables as covariates, were conducted to determine differences between the groups. For hypothesis four, to assess if videos that show the greatest degree of bilingualism (i.e., closer to 50% English and 50% a second language) show a bilingual advantage on executive functioning tasks of inhibitory control (Bear Dragon, Gift Delay, Color Form, DCCS) but not on tasks of working memory (Memory for Location 2 & Memory for Words) a partial correlation (partialing out impact of relevant demographic characteristics) was completed.

Types of Executive Functioning

To assess the specific aspects of executive functioning that may be impacted by bilingualism, the four measures of executive functioning at the 3-4 year time point and the five measures of executive functioning at the 5-7 year time point were submitted to a principle component analysis.

Chapter 4

Results

Preliminary Analyses

Demographic characteristics. Demographic characteristics and parent report questionnaires are summarized in Tables 1 and 2. Regarding the 3-4 year age group, a one-way ANOVA and Chi-Square Test analyses indicated that the monolingual and bilingual groups did not significantly differ in terms of child's sex, number of people in the home, or maternal education. The monolingual and bilingual and groups reported significant differences on some measures of SES including greater gestational age F (1, 91) = 5.974, p = .016, higher birth weight F (1, 90) = 4.610, p = .034, younger test age F (1, 91) = 4.885, p = .030, and lower household yearly income F (1, 90) = 9.652, p = .003 in the bilingual group.

Regarding the 5-7 year age group, one-way ANOVA and Chi-Square Test analyses indicated that the monolingual and bilingual groups did not significantly differ in terms of child's sex, test age, household income, number of people in the home, or maternal education. Similarly to the previous data collection at 3-4 years, the bilingual group reported a significantly greater gestational age F (1, 76) = 10.080, p = .002, and higher birth weight F (1, 75) = 8.581, p = .004 compared to the monolingual group. Additionally, attrition from the first data collection (3-4 years) to the second data collection (5-7 years) was greater for the bilingual group compared to the monolingual group. Given the change in demographic characteristics, participants who were lost to follow-up were also among those with lower reported household income.

Table 1
Demographic characteristics by language group at 3-4 years

Variable	Bilingual (n = 44)	Monolingual (n = 49)	p-value
Gestational age (weeks)			
Mean (SD)	32.15 (5.41)	29.60 (4.69)	.016*
Birth weight (grams)			
Mean (SD)	1,802.49 (1,088.61)	1,357.31 (897.44)	.034*
VLBW	n=29 (66%)	n=40 (82%)	.084
NBW	n=15 (34%)	n=9 (18%)	
Sex			.179
Female	n=19 (43%)	n=28 (57%)	
Male	n=25 (57%)	n=21 (43%)	
Test Age (months)			
Mean (SD)	46.05 (3.54)	47.67 (3.56)	.030*
Yearly income			
Mean	\$30,000-\$40,000	\$40,000-\$50,000	.003**
Number of people in the home			
Mean (SD)	4.41 (1.19)	4.75 (1.62)	.256
Maternal Education			.434
<High school	n=7 (16%)	n=7 (13%)	
High school degree	n=11 (25%)	n=8 (17%)	
Some college	n=10 (23%)	n=16 (33%)	
College degree or more	n=16 (36%)	n=18 (37%)	

*p<.05 **p<0.1 ***p<.001

Table 2

Demographic characteristics by language group at 5-7 years

Variable	Bilingual (n = 29)	Monolingual (n = 49)	p-value
Gestational age (weeks)			
Mean (SD)	32.92 (5.76)	29.61 (4.36)	.002**
Birth weight (grams)			.004**
Mean (SD)	1,946.82 (1155.36)	1,261.84 (878.34)	
VLBW	n=16 (55%)	n=42 (86%)	.003**
NBW	n=13 (45%)	n=7 (14%)	
Sex			.128
Female	n=17 (59%)	n=20 (41%)	
Male	n=12 (41%)	n=29 (59%)	
Test Age (months)			.056
Mean (SD)	72.28 (3.00)	74.49 (5.68)	
Yearly income			.349
Mean	$30,000-$40,000	$40,000-$50,000	
Number of people in the home			.212
Mean	4.37 (1.28)	4.82 (1.52)	
Maternal Education			.241
<High school (%)	n=3 (11%)	n=4 (8%)	
High school degree (%)	n=7 (24%)	n=8 (16%)	
Some college (%)	n=7 (24%)	n=24 (49%)	
>College degree (%)	n=12 (41%)	n=13 (27%)	

*p<.05 **p<0.1 ***p<.001

SES and executive functioning abilities. The correlations among demographic variables and executive functioning abilities are presented in Table 3. As expected, several of the executive functioning measures were significantly related to these measures. Specifically, executive functioning scores were significantly correlated with bilingualism $r = .326$, $p < .01$ (Gift Delay 5-7 yr.), gestational age $r = .244$, $p < .05$ (Bear Dragon 3-4 yr.), $r = .276$, $p < .05$ (Gift Delay 5-7 yr.), $r = .322$, $p < .01$ (Memory for Words 3-4 yr.), $r = .234$, $p < .05$ (Memory for Words 5-7 yr.), $r = -.247$, $p < .05$ (Color Form 5-7 yr.), child's sex $r = .232$, $p < .05$ (Memory for Words 5-7 yr.), test age $r =$ -

.246, $p < .05$ (Gift Delay 3-4 yr.), income $r = .325$, $p < .01$ (Bear Dragon 3-4 yr.), $r = -.252$, $p < .05$ (Gift Delay 5-7 yr.), $r = .352$, $p < .01$ (Memory for Words 3-4 yr.), $r = .549$, $p < .01$ (Memory for Words 5-7 yr.) and maternal education $r = .299$, $p < .01$ (Bear Dragon 3-4 yr.), $r = .365$, $p < .01$ (Memory for Words 3-4 yr.), $r = .459$, $p < .01$ (Memory for Words 5-7 yr.), $r = -.280$, $p < .05$ (Color Form 5-7 yr.). All the demographic variables (bilingualism, gestational age, child's sex, test age, household income, and maternal education) were significantly correlated with at least one measure of executive functioning. Given this pattern of results and previous findings in the literature, researchers covaried gestational age, child's sex, test age, and maternal education in later analyses.

Table 3
Association among Demographic Characteristics and Executive Functioning Measures (3-4 years & 5-7 years)

	Bilingualism	Gestational Age	Sex	Test Age	Income	Maternal Education
Bear Dragon 3-4 years	-.042	.244*	.080	-.133	.325**	.299**
Memory for Location 2 3-4 years	.125	.106	.011	.811	.097	.035
Gift Delay 3-4 years 5-7 years	.140 .326**	.173 .276*	.091 .027	-.246* -.104	.192 -.252*	.185 -.088
WJ-III: Memory for Words 3-4 years 5-7 years	-.074 -.075	.322** .234*	.148 .232*	-.033 -.094	.352** .549**	.365** .459**
DCCS 5-7 years	-.201	-.122	.132	.072	.136	.151
Color Form 5-7 years	.135	-.247*	-.024	-.078	-.232	-.280*

*p<.05 **p<.01 ***p<.001
Bilingualism = As indicated by parent report
WJ-III = Woodcock-Johnson III Tests of Achievement
DCCS = Dimensional Change Card Sort

VLBW and executive functioning results controlling for SES. To test our preliminary hypothesis, we conducted ANCOVA analyses of group effects on the measures of executive functioning with gestational age, child's sex, test age, and maternal education as covariates. These analyses showed how, when controlling for SES, children born VLBW and NBW performed on measures of executive functioning. There was a significant effect of birth weight group on the WJ-III Memory for Words task at 3-4 years $F(4,86) = 6.348$, $p<.01$ such that the NBW group performed significantly better than the VLBW group. This task requires working memory. There was a significant effect of birth weight group on the Gift Delay task at 5-7 years $F(4,76) = 10.521$, $p<.01$ such that the NBW group performed significantly better than the VLBW group. This task requires inhibition. All other comparisons at 3-4 years and 5-7 years were not significant, indicating no differences between the birth weight groups.

Bilingualism. A simple linear regression was calculated to predict maternal bilingualism observed in a video recorded free play session (dependent variable), based on maternal-report of bilingualism in the home (independent variable) at both time points. Maternal bilingualism observed in a video recorded free play session was coded based on percentage of English versus Spanish spoken (with a maximum of 50%; see methods section for further detail on how this was coded). The regression equation was not significant at the 3-4 year data collection however, a significant regression equation was found at the 5-7 year data collection ($F(1,80)=8.045$, $p = .006$), with an R^2 of .091.

Similarly a simple linear regression was calculated to predict child bilingualism observed in a video recorded free play session based on maternal-report of bilingualism in the home. Again, the regression equation was not significant at the 3-4 year data collection but a significant regression equation was found at the 5-7 year data collection (F (1,80)=5.839, p = .018), with an R^2 of .068.

Bilingualism and Executive Functioning Results Controlling for SES

In the main analyses, given the influence of gestational age, child's sex, test age, and maternal education on executive functioning task performance, it was important to control for these factors in our assessment of bilingualism on executive functioning. In particular, determining whether bilingual children perform differently on measures of executive functioning may be masked by group differences in SES.

To test hypotheses two and three, we conducted ANCOVA analyses of group effects on the measures of executive functioning with gestational age, child's sex, test age, and maternal education as covariates. These analyses showed how, controlling for the above mentioned variables, monolingual and bilingual children (by self report) performed on measures of executive functioning. There was a significant effect of language group on the Gift Delay task at 5-7 years F(5,76) = 4.793, $p<.05$ such that the bilingual group performed significantly better than the monolingual group. This task requires inhibition. All other comparisons at 3-4 years and 5-7 years were not significant, indicating no differences between the monolingual and bilingual groups.

To test hypothesis four, we conducted a partial correlation to see the relationship between the child's degree of bilingualism (observed during free play) and measures of executive functioning. When controlling for gestational age, child's sex, test age, and maternal education on the relationship between degree of bilingualism exhibited by the child and measures of executive functioning, we did not find degree of bilingualism to be correlated with any of the executive functioning measures at 3-4 years. At 5-7 years we found degree of bilingualism was negatively correlated with performance on the DCCS $r = -.317$, $p < 0.05$. As a post-hoc analysis, we conducted a partial correlation to see the relationship between the amount of English spoken (observed during free play) and performance the DCCS ($p=.159$), and separately the amount of second language spoken (observed during free play) and performance the DCCS and neither were significantly correlated ($p=.159$). We did not find degree of bilingualism to be correlated with any other of the executive functioning measures at 5-7 years.

Bilingualism, VLBW and Executive Functioning Results Controlling for SES

In previous studies bilingual children have outperformed monolingual children on measures of executive functioning. Similarly children born NBW have outperformed children born VLBW on measures of executive functioning. To assess our first hypothesis, we compared the bilingual children who were born VLBW, to the monolingual children born NBW to see if bilingualism is a protective factor regarding executive functioning in children who were born VLBW. We conducted ANCOVA analyses of group effects on the measures of executive functioning with child's sex, test age, and maternal education as covariates. These analyses showed how, controlling for SES, bilingual children who were born VLBW and monolingual children who were born NBW performed on measures of executive functioning. There was a significant effect of bilingualism/birth weight group on the WJ-III Memory for Words task at 3-4 years $F(5,86) = 4.121$, $p<.05$ such that the monolingual NBW group performed significantly better than the bilingual VLBW group. This task requires working memory. There was a significant effect of bilingualism/birth weight group on the Gift Delay task at 5-7 years

$F(5,76) = 4.922$, $p<.05$ such that the monolingual NBW group performed significantly better than the bilingual VLBW group. This task requires inhibition. All other comparisons at 3-4 years and 5-7 years were not significant, indicating no differences between the groups.

Types of Executive Functioning

Finally, to begin to assess the specific aspects of executive functioning measures that may be influenced by bilingualism, we submitted the four executive functioning dependent measures from the 3-4 year age group and the four executive functioning dependent measures from the 5-7 year age group to a principle components analysis. For early executive functioning measures at the 3-4 year data collection, one component had an eigenvalue greater that 1 and captured most (48%) of the total variation in the executive functioning measures. All early executive functioning measures had a large positive association with this component (factor loading ranged from .67-.76). For early executive functioning measures at the 5-7 year data collection, one component had an eigenvalue greater that 1 and captured (35%) of the total variation in the executive functioning measures. This component had a large positive association with the Color Form and Gift Delay measures (factor loadings = .74 and .64 respectively) and a negative association with the Memory for Words and DCCS measures (factor loadings = -.59 and -.33 respectively). Overall better performance on one measure of executive functioning indicated higher scores on the other measure of executive functioning as well. The factor loadings are presented in Tables 4 and 5.

Table 4
Principle component analysis of executive functioning measures 3-4 years

Task	Factor 1 Executive Functioning
Memory for Location 2	.761
Bear Dragon	.738
WJ-III Memory for Words	.697
Gift Delay	.555

Note: n = 93
WJ-III = Woodcock-Johnson III Tests of Achievement

Table 5
Principle component analysis of executive functioning measures 5-7 years

Task	Factor 1 Executive Functioning
Gift Delay	.451
WJ-III Memory for Words	-.420
Color Form	.524
DCCS	-.231

Note: n = 78
WJ-III = Woodcock-Johnson III Tests of Achievement
DCCS = Dimensional Change Card Sort

Chapter 5

Discussion

The aims of this study were to extend our understanding of the effects of bilingualism on executive functioning abilities in children who were born VLBW. Bilingual children have previously been found to show an advantage on tasks of executive functioning (e.g., inhibition and task switching) while children born VLBW have previously been found to show difficulties with executive functioning abilities (Bhutt et al., 2002; Taylor et al., 2000; Smith et al., 2000). Researchers compared executive functioning abilities on tasks requiring working memory, inhibition, and task switching at the preschool age (3-4 years) and school age (5-7 years). Executive functioning is a critical component of cognitive and social development, and research on bilingual children born VLBW has implications for understanding the development of executive functioning in medically at risk populations as well as the relationship between executive functioning and early bilingual exposure in children.

The results showed that the language groups differed on several demographic variables that are likely to affect executive functioning abilities. In our sample, at the first data collection (3-4 years), the bilingual group reported lower yearly income, had a slightly younger mean test age, and had a greater birth weight/gestational age compared to the monolingual group. At the second data collection (5-7 years), the bilingual group no longer reported a lower yearly income compared to the monolingual group and there was no significant difference in test age. This may be a product of greater attrition of the lower SES participants in the bilingual group, which had great attrition from data collection one to data collection two compared to the monolingual group. Additionally, several of the executive functioning measures were significantly associated with demographic variables such as gestational age, child's sex, yearly income, and maternal education. To be consistent with other reports of executive function in children and the demographic differences in our populations, we controlled for gestational age, sex, test age, and maternal education on main analyses.

Some challenges identified by past researchers in this area of study include defining bilingualism, and considering the impact of socioeconomic variables confounded with bilingual children. As mentioned previously, bilingualism is not a categorical variable and is better defined by degree of bilingualism. To test alternative methods of measuring bilingualism we asked for maternal-report of bilingual exposure in addition to measuring bilingualism by coding videos of unstructured interactions between the mother and child for percentage of each language used by mother and child. We found that self-report of bilingualism was not predictive of bilingualism observed in the play interaction at the preschool age, but it was correlated at school age. One hypothesis of why there was inconsistency between maternal-report of bilingualism and observed bilingualism is that children may be exposed to another language with someone other than their mother (e.g., mother speaks with the child in English and father speaks to the child in Spanish) and therefore this bilingual influence would not be captured in the videos. Alternatively, parent report of bilingualism could over estimate the child's actual knowledge of more than one language and the observation may be a better representation of their degree of bilingualism. Additionally, when coding the videos we observed that there was variability among the videos regarding the amount of overall language used, language of mother vs. child (e.g., mother speaking in Spanish and child responding in

English), and the types of activities the mother and child participated in during the unstructured play. It is unknown how this variability may also be contributing to the relationship between language exposure and executive functioning abilities. Due to an inability to answer some of these more nuanced questions, results associated with observed bilingualism may be less reliable than the maternal report of bilingualism in our sample.

Regarding our preliminary hypothesis, when examining the relationship between birth weight and executive functioning, as expected, our results showed that children born NBW performed significantly better on the WJ-III memory for words subtest, a task involving working memory at the preschool age (3-4 years), and on the Gift Delay, a task involving inhibition at school age (5-7 years). Consistent with the literature, we found that executive functioning, including selective attention, sustained attention, inhibition, working memory, planning and verbal fluency, to be a weakness for children born preterm (Mulder et al., 2009; Aarnoudse-Moens et al., 2009; Woodward et al., 2011). Given the central role of executive functioning in a variety of domains including learning, problem solving, and language development, these deficits are important to identify as they are likely to impact academic achievement and social relationships.

When examining the relationship between bilingualism (by self report) and executive functioning, our results showed that there was a significant advantage of bilingualism on Gift Delay, a task involving inhibition at school age (5-7 years). This finding is consistent with our second hypothesis and previous studies that have suggested that bilingualism can influence further development of frontal lobe functions such as inhibition (Bialystok, 1999; Carlson & Meltzoff, 2008). Bilingual children are constantly inhibiting one language when speaking in a second language, which might generalize to a greater ability to inhibit behavior as well. In our sample, a bilingual advantage emerged at school age (5-7 years) and was isolated to an executive function measure that required inhibition. This finding showed a bilingual advantage later than predicted by hypothesis three, which predicted bilingual children would evidence more inhibitory control earlier (3-4 years) compared to their monolingual peers. Although the literature suggests that bilingual children may begin to show evidence of inhibitory control earlier, around age three years, we did not find this in our sample (Diamond, Carlson & Beck, 2005). This finding may diverge from previous literature because our sample also includes children born VLBW, which is associated with weaknesses in executive functioning abilities including inhibitory control.

When examining the relationship between bilingualism (by observation) and executive functioning, our results showed that there was a significant advantage of monolingualism on the DCCS task, a task involving inhibition and task switching at school age (5-7 years). Our findings are not consistent with our fourth hypothesis or the previous research that found bilingual children performed significantly better on the DCCS compared to the monolingual children (Bialystok, 1999). However, measuring bilingualism through observation of an unstructured play session has not been done in previous studies, and was not consistent with maternal report of bilingualism in our study, potentially accounting for our unexpected findings. Significant differences in executive functioning abilities between with bilingual (by maternal-report & observation), and monolingual groups were not found at the preschool age (3-4 years).

When examining how a combination of bilingualism and birth weight factors are associated with executive functioning abilities, our results showed that monolingual children born NBW performed significantly better on the WJ-III Memory for Words task involving working memory at the preschool age and on the Gift Delay involving inhibition at school age compared to the bilingual children born VLBW. To our knowledge, previous studies have not examined the relationship among bilingualism, birth weight and executive functioning abilities. Although group sizes were small and uneven, researchers examined these factors to see how bilingual children (expected to have better inhibitory control) who were born VLBW (expected to have difficulties with executive functioning tasks) would compare on tasks of executive functioning tasks to monolingual children who were born NBW to see if bilingualism might be a protective factor for children who are at-risk for executive functioning deficits. Contrary to our first hypothesis, our findings showed that regardless of early exposure to multiple languages, children born NBW perform better on some tasks of executive functioning including inhibition and working memory at the preschool and school age.

Our measures of executive functioning are thought to assess early inhibition, working memory, and task switching abilities. It should be acknowledged, however, that our measures of executive functioning at the preschool (3-4 years) and school age (5-7 years) time points each loaded onto only one factor, suggesting that all our measures fit into a single theoretical construct of early executive functioning abilities rather than distinct types of executive functioning skills (e.g., inhibition, working memory, switching). This finding in the 3-4 year old group is consistent with the literature that has proposed that from the early preschool to the kindergarten age, executive functioning best fits into a single-factor model (Nelson, James, Chevalier, Clark & Espy, 2016). Nelson and colleagues concluded that although there are various components of executive functioning (e.g., inhibition, shifting) which are discussed in the adult literature, executive abilities share a common foundation in early development. Differentiation of executive functioning abilities likely occurs later in childhood (Lee, Ho, & Bull, 2011). What was not expected was the negative direction of the loadings for the WJ-III Memory for Words, and the DCCS at the 5-7 year data collection, as this was not seen in previous literature. Given these findings overall, and the previous literature on measuring early executive functioning abilities in preschoolers through early childhood, it may be more beneficial to discuss executive functioning abilities as a whole, rather than breaking these abilities down further into specific types of executive functioning (e.g., inhibition, working memory, task switching). Further, it will be important to determine at what age range executive functioning shifts from encompassing a unitary dimension to including multiple dimensions.

Limitations

Because our task-based outcome measures were developed and standardized in English, caution is warranted when interpreting the difference in performance between the monolingual and bilingual participants, as many of the bilingual participants were evaluated in Spanish. First, the measures are not validated in Spanish. Further, although the tests were administered in Spanish for participants whose primary language was Spanish, it is important to consider that there are different dialects of Spanish spoken regionally and some of the words used on the measures of verbal abilities (WJ-III memory for words) may not have been familiar to all children and may not be equivalent in their difficulty to remember, calling into question the validity of this measure for the

Spanish speaking participants.

Another important limitation of this study was the inability to account for the level of acculturation, amount of bilingual exposure and by whom (e.g., parents, grandparents, siblings, school), and degree of bilingualism of participants, which may contribute to within-group variation of the bilingual groups at both time points. We were also unable to assess the quality of maternal education reported. Although the quantity, measured as reported years of education, may not have been significantly different between the monolingual and bilingual groups at either data collection, the quality of education received may have been qualitatively different. This is important because it is well documented that income is positively correlated with years of education in the United States and, as mentioned above, the two groups did significantly differ on yearly income reported at the 3-4 year data collection, with the monolingual group reporting a higher yearly income than the bilingual group.

Finally, our small sample size and uneven subsample sizes are a limitation to take into consideration, as the bilingual speaking group was significantly smaller than the English speaking group at both time points and for both VLBW and NBW groups, thereby reducing power and assumptions of equal variances in our analyses. Additionally, there was a high rate of attrition of our lower SES bilingual participants from the first to second data collection. Fifteen of the participants from the bilingual group were lost to follow-up while zero participants from the monolingual group were lost to follow-up. SES has been found to significantly impact executive functioning outcome measures in children, and in our study, the monolingual participants reported higher annual income at the 3-4 year data collection, likely contributing to the differences between the two language groups. However, the literature suggests bilingual children in the United States are not equally matched with their monolingual peers on SES (U.S. Census Bureau, 2014; Judd et al., 2009).

Conclusions and Future Study

In conclusion, our study suggests that executive functioning differences between children with early bilingual exposure compared to monolingual children begin to emerge around school age (5-7 years). We saw no differences between the monolingual and bilingual groups at the preschool age (3-4 years). A lack of standardized tools to measure early executive skills in preschoolers, and the behavioral challenges involved in assessing children of this age, may have contributed to a lack of findings at the 3-4 year data collection. It is possible that there are differences between the monolingual and bilingual 3-4 year old groups in executive functioning abilities that were not captured in the current study due to measurement difficulties. As noted previously, there was variability in language spoken by mother versus the child (e.g., mother speaking in Spanish and child speaking in English) and amount of overall language used. Future studies addressing bilingualism in children may consider investigating these variables in greater depth to assess how they impact executive functioning abilities. Overall, these findings may suggest a specific role for inhibition in the link between bilingualism and executive function.

As is the reality for many bilingual children in the United States, the bilingual children in our study were not equally matched with their monolingual peers on SES. This is an important consideration as SES has been associated with lower performance on cognitive measures. Considering these group differences, one implication of our results is that there may be protective factors associated with early bilingual exposure (possibly due to the cognitive operations involved in language switching), as evidenced by improved behavioral inhibition emerging around school age.

Consistent with the literature, children born VLBW performed significantly below their peers born NBW on measures of executive functioning beginning at the preschool age and into school age. Bilingualism was not enough of a protective factor in our participants born VLBW such that the monolingual children born NBW continued to outperform bilingual children born VLBW at the preschool and school age. The research detailing the negative effects of being born VLBW on executive functioning abilities including selective attention, sustained attention, inhibition, working memory, planning, and verbal fluency across studies and age groups is robust (Mulder et al., 2009; Aarnoudse-Moens et al., 2009; Woodward et al., 2011). There are relatively fewer studies that have documented a bilingual advantage on measures of executive functioning, and most have been primarily focused on inhibitory control, which may help to explain why the effects of birth weight were stronger than that of bilingualism in our study. Future studies may consider exploring this phenomenon in older children as well, to see if bilingualism emerges as more of a protective factor in older school-aged children (e.g., ages 9-10 years).

More research on how bilingualism contributes to brain development is needed, including measuring birth weight and bilingualism as continuous variables in order to explore more nuanced relationships between the variables. Overall findings suggest more research is needed to further explain the relationship between early bilingual exposure, birth weight and the development of early executive functioning abilities. Given the central role of executive functioning in a variety of domains including learning, problem solving, and language development, a greater understanding of these abilities in diverse populations could help to inform early intervention/recommendations and ultimately improve academic achievement and social skills later in life.

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