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Language Development Among Preschool Age Children Born Prematurely

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LANGUAGE DEVELOPMENT AMONG PRESCHOOL AGE CHILDREN BORN PREMATURELY

by

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CHAPTER 1: INTRODUCTION

Premature births, as defined by births occurring before 37 weeks gestation, have been gradually increasing over the past 20 years. It has been estimated that in 2005, approximately 13 million children were born prematurely worldwide, and North America had the second highest rate of premature births at 10.6 percent (Beck et al., 2010). The increased use of assisted reproduction techniques, environmental factors, and increasing maternal age at birth are factors which researchers have hypothesized to be contributing to the increase in the rate of preterm births.

According to a review conducted by McCormick, Litt, Smith and Zupancic (2011) premature birth is one of the leading causes of infant mortality, and these children who survive beyond birth have shown to exhibit health, psychological, and behavioral difficulties. More specifically, children born preterm are more susceptible to cognitive deficits, fine and gross motor delays, learning disabilities, inattention, and hyperactivity. Preterm born children have also shown to have a higher rate of language deficits compared to controls, with increasing difficulties with complex language skills as they grow older (Noort-van der Spek, Franken, & Weisglas-Kuperus, 2012). Rates of autism spectrum disorders are also higher among very low birth weight infants than children of higher birth weights, indicating deficits with pragmatic language, or the social use of language and nonverbal communication (McCormick et al., 2011; Limperopoulos et al., 2008). Although it is understood that preterm born children are more likely to experience neurocognitive deficits as a group, there is much variability in functional outcomes during the early school years, and the factors that make preterm-born children more susceptible to specific neuropsychological skill deficits are not yet fully understood. This study focused on perinatal factors that may potentially account for variability within the preterm-born population in preschool language outcome.

Literature Review

There were 23 studies since 1986 that reviewed language functioning in preterm-born children. Twenty of these studies used cohorts born after 1990, and were thus served in the modern neonatal intensive care unit (NICU). The modern NICU is characterized by the use of more “gentle” ventilators and the administration of surfactant for the treatment of neonatal respiratory distress syndrome, and therefore, the period after 1990 is often referred to as the “surfactant” or “post-surfactant” era (Bland, 2005). To facilitate inspection of the main methodological features of these studies, the characteristics of studies that examined the language performances of children born prematurely are coded in Table 1. The tables present sample characteristics (i.e., inclusion and exclusion criteria, comparison group characteristics, outcome measures used, covariates, and results). Because multiple studies also examined intellectual performance, I also included these findings in the table and summarized them below.

Comparisons between Preterm and Full Term Children

Language performance. Prior to the examination of perinatal correlates of language deficits *within* preterm-born children, it is necessary to establish whether this group differs in language performance from full-term born children. In this section I review the literature pertaining to this topic. As Table 1 shows, 21 of the 23 studies examined compared the language abilities of preterm children to full term born children. Although the preponderance of the studies (16) reported significant language deficits in the preterm group, several (5) investigations were unable to show group differences.

Infants and toddlers. Seven studies compared language performance between full term and preterm children aged 1 - 18 months, with four studies finding significant differences. Very preterm children performed significantly lower on expressive language measures than their full term peers at 9, 11, 12, 13, 14, 16, and 18 months of age (Bühler, Limongi, & Diniz, 2009). Casiro et al. (1990) demonstrated that at one year of age, a sample of toddlers born very prematurely exhibited significantly lower language quotients than full term controls. In regard to vocabulary size at the age of two, toddlers born very prematurely were shown to have significantly smaller vocabulary sizes than full term peers (Gayraud & Kern, 2007). Similarly, among a sample of toddlers of 23 to 25 months of age, in comparison to full term born toddlers, the preterm- born toddlers had smaller vocabulary sizes, produced fewer verbs, expressed more utterances without content, and produced smaller mean length of utterances (MLUs; Seidman, Allen, & Wasserman, 1986). The preterm and full term born toddlers performed similarly on measures of pragmatic skills (specifically in the frequency of functional utterances, or utterances that were purposeful in a conversational context) and in their mean number of utterances (Seidman et al., 1986). In comparison to the four studies that documented group differences, three failed to show differences in language performance between full term and preterm infants and/or toddlers. Toddlers who were born either extremely or very prematurely had comparable vocabulary sizes to full term children, although the investigators also noted that the preterm group was over-represented at the lower end of the vocabulary size range (Foster-Cohen, Edgin, Champion, & Woodward, 2007). Similarly, Stolt et al. (2007) found that two-year-old preterm toddlers had similar vocabulary sizes to full term controls; however, the preterm born toddlers with vocabularies greater than 425 words used significantly less nouns and grammatical function words than their full term born counterparts. At 2 ½ years of age, preterm and full term born children have shown to exhibit comparable language abilities on measures of total words produced, vocabulary composition, grammatical development, and MLUs (Sansavini et al., 2006).

In sum, four of the seven studies examined (Bühler et al., 2009; Casiro et al., 1990; Gayraud & Kern, 2007; Seidman et al., 1986) found significant differences between preterm and full term infants or toddlers (from birth to around 2 years old) on measures of expressive language, while three studies (Foster-Cohen et al., 2007; Stolt et al., 2007; Sansavini et al., 2006) failed to find significant differences between the groups on measures of expressive language focusing on vocabulary and/or grammatical skills.

Preschool age. Five studies compared the language performances of preterm and full term children during the preschool years, four of which found significant differences. Briscoe, Gathercole, and Marlow (1998) studied preschoolers aged three to four using a comprehensive language battery (i.e., British Picture Vocabulary Scale, McCarthy Scales of Children's Abilities-Oral Vocab, & Bus Story Test). Children born prematurely obtained lower scores than full term controls on the British Picture Vocabulary Scale (a receptive language measure) and on the Information component of the Bus Story Test (an expressive language measure), although performances on the remaining measures (i.e., Bus Story Average Sentence Length and Naming Vocabulary) were comparable between groups (see Table 1). In addition, the preterm group exhibited more at-risk language development (as indexed by a cut-off score of 5 or below on the Bus Story Information score), and those who were categorized as "at-risk" performed more poorly than controls on all language measures (both receptive and expressive measures). In another study, four-year-old preterm children performed significantly worse than full term controls on receptive and expressive language measures, and were twice as likely to have a clinically significant mild to severe language delay (Foster-Cohen, Friesen, Champion, and Woodward, 2010). Similar results were reported in three-year-olds, where children born extremely prematurely were shown to exhibit significantly lower receptive and expressive skills in comparison to full term controls (Van Lierde, Roeyers, Boerjan, & De Groote, 2009). At the ages of 3 ½ and five years, preterm children have been shown to produce significantly fewer verbs (an expressive language measure) than full term controls (Le Normand & Cohen, 1999). In contrast to the above described findings from five investigations of preschool–aged children, the findings from a single study did not reveal significant differences on overall language measures between preterm and full term children during the preschool years. Sansavini et al. (2010) found that at the ages of 2 ½ and 3 ½, preterm and full term children performed similarly on expressive language measures of lexical and grammatical development. Nonetheless, the investigators also reported that the preterm children exhibited a wider range of scores and had a significantly higher risk of having a language impairment at 3 ½ years of age.

In summary, both receptive and expressive deficits have been recorded in preschool aged children born prematurely compared to their full term born peers. Three studies documented receptive language deficits (Briscoe et al., 1998; Foster-Cohen et al., 2010; Van Lierde et al., 2009), four found expressive language deficiencies (Briscoe et al., 1998; Foster-Cohen et al., 2010; Van Lierde et al., 2009; LeNormand & Cohen, 1999), and two (Briscoe et al., 1998; Sansavini et al., 2010) found significantly elevated risk for the presence of language delays in comparison to term born controls.

Early school age. As Table 1 shows, seven studies compared preterm to full term children during the early school years, of which six found significant differences in language performance between the groups. In a sample children age 4 to 6 years old, preterm children exhibited poorer performance than full term born controls on a comprehensive language battery, the TOLD Test of Oral Vocabulary (Gonzalez & Robison , 2001)). Guarini and colleagues (2009) demonstrated that at age six, Italian preterm birth children made more vocabulary and grammatical errors, and produced a greater number of incorrect responses on a test of phonological awareness at the syllabic level (phonological), but the groups performed similarly on phonological awareness at the phonemic level on an Italian phonological battery. Preterm born children at six years of age have exhibited poorer performance than full term controls on Understanding Directions (Woodcock-Johnson III Tests of Achievement), and two out of five measures of early literacy skills (Pritchard et al., 2009) . The preterm group was also two to three times more likely to receive below average ratings from teachers on language comprehension. Six-year-old children born extremely preterm have also been shown to score significantly lower on the Preschool Language Scale-3 and Phonological Abilities Test (receptive language, expressive language, and phonological skills measures), to exhibit significantly higher rates of phonological disorders, to use less appropriate speech sounds, and to have more disturbances in speech fluency than full term controls (Wolke, Samara, Bracewell, & Marlow, 2008). Wolke and Meyer (1999) also demonstrated that at the age of six, children born very prematurely obtained lower scores than full term controls on articulation, quality of speech, and number naming (an expressive language measure). A single study failed to find significant differences, when a sample of eight-year-old preterm and full term born children performed similarly on all language measures (Guarini et al., 2010).

In summary, deficits in both receptive and expressive language have been illustrated in early school age preterm-born children. Five studies showed receptive and/or expressive deficits (Gonzalez & Robison, 2001; Guarini et al., 2009; Pritchard et al., 2009; Wolke et al., 2008;

Wolke & Meyer, 1999) three showed phonological deficits (Gonzalez & Robison, 2001; Guarini et al., 2009; Wolke et al., 2008), one showed grammatical deficits (Guarini et al., 2009), and one showed deficits in early literacy skills (Pritchard et al., 2009).

Older children and adolescents. As Table 1 illustrates, the two studies comparing language performance between preterm and full term adolescents showed significant group differences. Between the ages of 9 – 16, preterm children performed more poorly than controls on measures of receptive and expressive language, syntactic comprehension, linguistic processing speed, verbal memory, decoding, and reading comprehension (Lee, Yeatman, Luna, & Feldman, 2011). A study conducted by Caldú et al. (2006) showed that at the age of 13, preterm children exhibited lower semantic verbal fluency (expressive language measure) scores than full term controls.

In summary, the two studies conducted to date in older children and adolescents reveal in preterm children deficits in multiple language domains, including receptive and expressive language, among others.

Cognitive abilities.

Fifteen of the studies that examined language abilities among preterm children also found global cognitive differences, except for four cases mentioned below.

Infants and toddlers. Four of the studies compared cognitive abilities between infants and/or toddlers and full term controls, and all four reported significant group differences (Bühler et al., 2009; Casiro et al., 1990; Foster-Cohen et al., 2007; & Stolt et al., 2007). Bühler et al. (2009) tested children born very prematurely monthly from 1 to 18 months of age, and found that the preterm children had lower cognitive abilities than the full term controls from 6 months on (based on the Cognitive portion of the Protocol for Expressive Language and Cognition

Development Observation). In two other studies, children at one and two years obtained significantly lower developmental quotients (as measured by the Gessell Developmental Scales and the Bayley Scales of Infant Development, Second Edition) than full term controls (Casiro et al., 1990 & Foster-Cohen et al., 2007). Stolt and colleagues (2007) found that at two years, the group of preterm children whose cognitive abilities (indexed by the Bayley Scales of Infant Development, Second Edition) were in the upper ranges of their respective group's performance, obtained significantly lower cognitive scores than full term controls.

Preschool age. Three studies compared preterm to full term born children's cognitive abilities at the preschool age, and two found significant group differences. Sansavini and colleagues (2010) found that at 3 ½ years old, preterm children scored significantly lower than full term controls on cognitive measures, but there were no differences at 2 ½ years of age. Another study found that three year old preterm children had significantly lower cognitive abilities than full term controls (Van Lierde et al., 2009). One study found no significant differences in cognitive abilities between preterm children and full term controls at 3 – 4 years of age, although the same investigators were able to document significant language differences (Briscoe et al., 1998).

Early school age. Six studies compared the cognitive abilities of preterm and full term early school aged children, with three reporting significant group differences. Pritchard and others (2009) discovered that in comparison to children born full term, six-year-old children who had been born very prematurely exhibited significantly higher rates of severe cognitive delay. Wolke and colleagues (2008) reported similar findings, in that at the age of 6, children born extremely prematurely obtained significantly lower cognitive scores than full term children. Additionally, another study (Wolke & Meyer, 1999) reported that a group of six year olds born very preterm produced significantly lower scores than a full term born comparison group on a global cognitive index (German version of the Kauffman Assessment Battery for Children). Additionally, the high-risk group exhibited significantly higher rates of mild and severe intellectual impairment, and had specific difficulties with complex information processing tasks. In contrast, a study by Gonzalez and Robison (2001) found that in a group of six to eight year old children, those born prematurely did not differ significantly from full term born peers on cognitive measures, although some differences on language measures were nonetheless found (as discussed previously). Guarini and colleagues (2009, 2010) also failed to detect differences in cognitive abilities between preterm and full term children at six years, and at seven to eight years.

In sum, 3 of the 6 studies (Pritchard et al., 2009; Wolke et al., 2008; Wolke & Meyer, 1999) that included cognitive measures in language comparisons of full term and preterm born children tested during the early school years found significant increases in the rates of cognitive delay or a significant deficit in global cognitive skill levels in the preterm group.

Older children and adolescents. Two studies have investigated the language abilities in older children and adolescents who have been born preterm. Both studies showed that older children and/or adolescents who had been born preterm scored lower on both perceptual and verbal indices of cognitive measures (Lee et al., 2011; Caldú et al., 2006).

Cognitive abilities versus language performance: conclusion. In brief, 11 out of 15 studies comparing cognitive performance between full term and preterm children found significant group differences. Of the four studies that failed to find significant differences in cognitive performance, three reported differences in language performance (Briscoe et al., 1998; Gonzalez & Robison, 2001; Guarini et al., 2009), suggesting that language measures may be more sensitive to perinatal insults associated with preterm birth. Conversely, only two of the studies that did not find language differences found cognitive differences (Foster-Cohen et al., 2007 & Stolt et al., 2007).

Examination of variables associated with lower performance within the preterm population

Language. Thirteen of the studies comparing full term and preterm birth children also attempted to determine the source of individual differences in outcome amongst the children born prematurely. Thus, they examined the relationships between perinatal risk factors and language performance within the preterm group. In each of these studies, significant relationships were documented between either gestational age, birth weight, or other perinatal risk factors and language outcome.

Infants and toddlers. Five studies examined correlates of language performance within the preterm population, all which found significant associations with perinatal risk.

Of the five studies, two examined the relationship between gestational age and language performance. Foster-Cohen and colleagues (2007) compared children at two years who had been born extremely preterm and very preterm, and found a positive relationship between gestational age and vocabulary size (an expressive language measure). Also, in regard to grammatical skills, a dose-response relationship was observed. The extremely preterm group performed significantly lower than the very preterm group, and the very preterm group performed significantly lower than the full term born group. Gayraud and Kern (2007) compared three preterm groups (extremely, very, and moderately preterm) at two years, and also found that in terms of vocabulary size (an expressive language measure), the extremely preterm group had significantly smaller vocabulary sizes than the very preterm and moderately preterm groups, and that first-borns had significantly larger vocabulary sizes than those who were not first-borns.

Additionally, the extremely preterm group exhibited significantly shorter MLUs (an expressive language measure) than the other groups, and the very preterm group exhibited significantly shorter MLUs than the moderately preterm group, again, a dose- response relationship observed within preterm-born children.

Two of the studies examined the relationship between birth weight and language performance. Stolt and others (2007) found at age two, both birth weight and maternal education were significantly related to vocabulary size (expressive language measure), but no statistical effects of sex or growth retardation on vocabulary size were found. Sansavini and colleagues (2010) produced similar results among children ages 2 ½ to 3 ½, finding that males with birth weights ≤1,000g produced significantly less words than preterm females regardless of weight on an Italian test of repetition of noun-phrases and sentences (an expressive language measure).

A single study of preterm toddlers found significant gender effects, and significant interactions between gender and gestational age. Sansavini and colleagues (2006) reported that in a sample of 2 ½ year olds, preterm males produced significantly less words than females. Additionally, males with a birth weight of 1,000 grams or less produced fewer words than females of all birth weights. They also found a significant interaction between gender and gestational age, with males born prior to 31 weeks gestation having significantly lower MLU scores than males with a GA of 31 weeks or greater.

In summary, two of the five studies examining perinatal correlates of language performance in infants or toddlers found relationships between gestational age and language skills, two studies found relationships between birth weight and language skills, and one study reported gender differences in language skills. Specifically, these correlates were found to be related to expressive language skills.

Preschool age. Four studies examined correlates of language outcome in preschool children born preterm, with all of the studies finding significant relationships between perinatal risk factors and language performance. Schirmer, Portuguez and Nunes (2006) found that children born prior to 32 weeks gestation were three times more likely than those of higher gestational ages to exhibit delayed language acquisition at the age of three, as indexed by a composite score comprised of gestational age, Denver scores at 12 and 24 months, and an altered Bayley Scales of Infant Development-III behavioral score. Mikkola and colleagues (2005) examined differences between appropriate (AGA) and small (SGA) for gestational age preschoolers who were born preterm. They reported that at the age of five, children who were extremely preterm but who were AGA scored significantly higher on language measures than did the children who were SGA, and that those born before 27 weeks gestation and who were SGA had significantly lower scores than those who were AGA. In contrast with expectations, Le Normand and Cohen (1999) found that among groups of 3 ½ and 5 year olds, the degree of prematurity had no effect on verb usage and production (Le Normand & Cohen, 1999; expressive language measure). Foster-Cohen and colleagues (2010) found that at age 4, increased social risk, moderate to severe white matter abnormalities on neonatal MRI, and undesirable parental behavior were significantly related to increased risk of later language delay in preschoolers born prematurely. They found no significant effects of gestational age, birth weight, neonatal complications, or family factors on language performance of these high-risk preschoolers.

In sum, all four studies examined found significant associations between perinatal risk factors and language performances within the preterm group during the preschool years. Significant associations were found between specific risk factors (e.g., gestational age, intrauterine growth rate, social risk factors, moderate to severe white matter abnormalities, and undesirable parental behavior) and prevalence of language delay, expressive language performance, as well as overall language measures.

School age. Three studies have analyzed language skills in school age children born preterm, and each detected significant relationships between perinatal risk factors and language performance. Guarini and colleagues (2009) found that at age 6, intraventricular hemorrhage grade I or II was significantly related to grammar skills, but that there was no relationship between medical complications (e.g., broncho-pulmonary dysplasia & intra-ventricular hemorrhage Grade I or II) and vocabulary size (an expressive measure) or phonological awareness. Head size has been shown to be negatively related to receptive language performance at age 8 (Hack et al., 1991). Boys have been found to exhibit significantly higher rates of language impairment than girls (as determined by the overall Preschool Language Scale-3 scores, and the scores from the Auditory Comprehension, Expressive Communication, and Articulation scales; Wolke et al., 2008).

Older children and adolescents. One study analyzed language skills in older children and adolescents born pre term. Between the ages of 9 and 16, the degree of prematurity has been found to be a significant predictor of linguistic processing speed and syntactic comprehension, even after controlling for PIQ and SES (Lee et al., 2011). Linguistic processing speed was measured by the reaction time from the TROG-R.

Summary. Each of the 13 studies examined that analyzed language differences within the preterm population found significant relationships between perinatal factors and language skills. Four of the studies found significant relationships between language performance and gestational age (Foster-Cohen et al., 2007; Gayraud & Kern, 2007; Schirmer et al., 2006; Lee et al., 2011), two studies found significant relationships between language performance and birth weight (Stolt et al., 2007; Sansavini et al., 2010), and four other studies (Sansavini et al., 2006; Mikkola et al., 2005; Foster-Cohen et al., 2010; Guarini et al., 2009; Hack et al., 1991; Wolke et al., 2008) reported significant relationships between language performance and additional factors (i.e., SGA, medical complications, head size, & gender); however, three of the studies that found relationships between such factors and language performance also failed to find relationships between other early risk factors (i.e., sex, intrauterine growth retardation, degree of prematurity, bronchopulmonary dysplasia, intraventricular hemorrhage I or II) and language skills (Stolt et al., 2007; LeNormand & Cohen, 1999; Guarini et al., 2009).

Summary of literature on preterm language and cognitive abilities

Between 1986 and 2012, there were 22 studies that examined language abilities in children born preterm, and 18 of the studies also examined cognitive functioning. Fourteen of the 18 studies that examined cognitive functioning found significant differences between groups. Of the 4 studies that did not find cognitive differences between and/or within groups, 3 of these studies found language differences. This suggests that language measures may be more sensitive that cognitive measures to the neuropsychological deficits present in children born preterm.

Methodological Critique of Literature

The major methodological shortcomings in studies of language development in preterm children of preschool and school age are listed below.

Insufficient exclusionary criteria. A number of studies were unclear about their exclusionary criteria, while others failed to control for conditions such as cerebral palsy (CP), periventricular leukomalacia (PVL), or intraventricular hemorrhage (IVH) grades III and IV (e.g., Hack et al., 1991; Foster-Cohen et al., 2010; Mikkola et al, 2005). In addition, some studies excluded children who were at the low end of the distribution in regard to cognitive skills, which is problematic because their samples were not adequate representations of the preterm population (e.g., Casiro et al., 1990).

Failure to examine individual differences within the preterm group. The majority of studies completed to date compared the preterm groups' language performance to that of children born full term. Only 13 of the 23 studies examined conducted any within group analyses to investigate language outcome differences within the preterm groups (Foster-Cohen et al., 2010; Foster-Cohen et al., 2007; Gayraud & Kern, 2007; Guarini et al., 2009; Hack et al., 1991; Lee et al., 2011; LeNormand & Cohen, 1999; Mikkola et al., 2005; Sansavini et al., 2006; Sansavini et al., 2010; Schirmer et al., 2006; Stolt et al., 2007; Wolke et al., 2008). This is problematic because these comparisons do not provide any insight into why specific children within the preterm group might perform better or worse on specific tasks than others.

Failure to consider background perinatal risk-factors in studies examining language correlates within the preterm population. Many of the studies that examined correlates of language performance within the preterm group did not statistically adjust for gestational age, for the medical status of the infant (perinatal complications), or for intrauterine growth rate (e.g., Briscoe et al., 1998; Van Lierde et al., 2009, etc.). Additionally, several studies only looked at groupings (i.e., VLBW, or VPT, or ELBW, or EPT) and neglected to examine gestational age as a continuum (e.g., Schirmer, 2006; Le Normand & Cohen, 1999; etc.).

Inadequate matching of preterm and control groups. Of the studies that included control groups and specified their recruitment mechanism, only three of the studies used hospital- or health center-matched control groups (Foster-Cohen et al., 2010; Foster-Cohen et al., 2007; Pritchard et al., 2009); however, the majority of the studies used community- or school-matched controls, or children who were recruited by friends and relatives of the preterm children (e.g., Wolke et al., 2008; Lee et al., 2011; etc.). This is problematic because this type of matching does not sufficiently account for other relevant factors, such as socioeconomic status and other background variables that may be associated with SES.

Failure to perform proper adjustment for sociodemographic factors. Most studies examined controlled for SES, yet several studies failed to do so (e.g., Schirmer, 2006; Briscoe et al., 1998; Guarini et al., 2009, etc.).

Failure to use complex or broad language measures. The studies examined differed in the breadth of the measures that were used to analyze language skills, and in the functions of interest. Of the studies examined, few utilized comprehensive language batteries evaluating receptive, expressive and pragmatic language skills (e.g., CELF, Reynell Developmental Language Scales, etc.). Many of the studies used measures of circumscribed language skills (e.g., transcribed verbal interactions, selected NEPSY subtests, Bus Story Test, etc.).

Limited generalization due to use of birth weight cutoff. Most of the studies used gestational age cutoffs to define who would be included in their preterm groups, but several studies used birth weight cutoffs (e.g., Foster-Cohen et al., 2010; Mikkola et al., 2005, etc.). The problem with using birth weight as a cut-off is that children who are small for gestational age (SGA) may be overrepresented in the sample. This is problematic because overrepresentation of children with SGA biases the sample toward lower performance in the low birth weight group, as children with SGA have demonstrated poorer outcome than preterm children who are AGA (Casiro et al., 1990; Mikkola et al., 2005).

Questionable adjustment for IQ. Several studies statistically adjusted for IQ during examination of the associations between prematurity and language outcome (e.g., Guarini et al., 2009). This does not make complete theoretical sense because language and cognitive performances are correlated, and language skills are a component of composite IQ scores. Moreover, the same factors which cause intellectual deficits may also reduce language performance.

Critique of Seven Studies Examining Early Correlates of Language Outcome within Preschool and School-Age Preterm-Born Children

Limitations of language studies in preschool children born preterm. Schirmer and colleagues (2006) did not exclude children with CP, IVH > Grade II (i.e., severe bleed), or periventricular leukomalacia. They also used a brief (i.e., circumscribed) language measure (Nicolosi Sequence of Language Development), and they did not control for factors such as SES, gender, or medical complications. Mikkola and colleagues (2005) used a birth weight cutoff instead of a gestational age cutoff, thus probably including children of higher gestational ages and growth restriction. They also did not use a complete language battery, and they excluded children with moderate to severe cognitive impairments, lending to a sample that is not representative of the preterm population. The researchers also failed to statistically adjust for factors such as SES, gender, or medical complications. LeNormand and Cohen (1999) did not control for or exclude children with CP or severe IVH, and did not use standardized language measures. The inclusion criteria in a study by Foster-Cohen and colleagues (2010) required that the participants meet either low gestational age or low birth weight criteria, thus apparently including in the sample full term born children with growth restriction. The researchers also did not exclude CP, IVH or PVL.

Limitations of language studies in school-age children born preterm. Guarini and colleagues (2009) did not control for SES or use a measure of pragmatic language skills in their battery. In a study by Hack and others (1991), the researchers used a birth weight cutoff, thus potentially including children who were born full term in the sample, and a disproportionate number of children who were classified as SGA (20%). They did not exclude CP, IVH, or PVL, and they did not use a comprehensive language battery. Wolke and colleagues (2008) did not exclude CP, IVH, or PVL and they did not control for SES.

Hypotheses and Rationale

The majority of studies reviewed compared preterm to full term children, with only seven examining differences in neuropsychological functioning within the preterm-born group at the preschool or school-age. As the differences between the two groups are well established on almost every preschool and school performance measure, it is far more important, not to mention interesting, to examine individual differences within the preterm group. Such an investigation will potentially enhance our understanding about the causes of vulnerability or resilience, in this high-risk population. Thus, the current study focused on the biological factors, or medical variables that could influence intellectual functioning in general, and language performance, in particular.

1. It was hypothesized that intrauterine growth rate, expressed as a *z*-score reflecting birth weight standardized by gestational age and sex (Kramer et al., 2001), would have a significant association with performance measures in the current study. One study by Mikkola and colleagues (2005) found that preterm born children who are SGA (i.e., IUGR) have significantly lower language scores than those who are AGA. Yet they did not examine whether intrauterine growth rate, in general, is related to language outcome measures. Thus, in the current investigation, intrauterine growth was treated as a continuum, rather than a dichotomous variable.

2. It was hypothesized that children with lower gestational age (< 30 completed weeks) would perform more poorly on outcome measures even after taking into account the total number of complications, intrauterine growth rate, presence of multiple gestation, sex, and socioeconomic status. Gestational age or birth weight, two highly correlated variables, have typically been treated as proxy variables, representing the multiple medical complications in the background of each preterm infant. Yet a recent study found that gestational age accounts for a unique portion of the variance in intellectual functioning in a group of extremely preterm children < 27weeks gestation even after accounting for background medical complications (Raz, DeBastos, Newman, & Batton, 2010). The current study attempted to extend this finding to a group with a higher gestational age limit, and to a different outcome measure, i.e., language performance. The variable “gestational age” was treated both as a binary variable, and as a continuous dimension in the current study.
3. Based on previous findings, it was hypothesized that degree of immaturity (operationalized as gestational age) would be linearly related to outcome in specific language domains.
    a. It was hypothesized that expressive language, but not receptive language, would be particularly sensitive to immaturity. Many studies have found expressive language deficits among preterm born children when compared to full term born children (e.g., Bühler et al., 2009; Caldú, et al., 2006; Gonzalez & Robison, 2001; Guarini et al., 2009, etc.); however, only four studies examined correlates of expressive language deficits within the preterm born group, and reported the degree of immaturity to be related to the severity of such deficits (Foster-Cohen et

al., 2007; Gayraud & Kern, 2007; Sansavini et al., 2006; Schirmer et al., 2006); however, all of these studies have examined language abilities among preterm born toddlers. In contrast, I attempted to extend these findings to preschool aged children.

b. It was also hypothesized that measures of pragmatic language (indexed by NEPSY - Affect Recognition & the Descriptive Pragmatics rating scale from the CELF-P2) would be associated with degree of gestational immaturity. This hypothesis was based on the observation of higher rates of autism, a disorder characterized by significant pragmatic language deficits (Lam & Yeung, 2012), in preterm birth children (McCormick et al., 2011; Limperopoulos et al., 2008).

4. It was hypothesized that preterm-born boys would obtain significantly lower scores than girls on language and cognitive measures. Based on the literature, however, it appears that sex differences are somewhat selective (e.g., Wolke et al., 2008; Sansavini et al., 2006). The following specific predictions were made:

   a. Based on findings from Wolke and others (2008), it was expected that boys would obtain lower scores on both the verbal (VIQ) and performance (PIQ) domains of intelligence. In other words, I expected both verbal and nonverbal intelligence scores to be significantly lower in boys than in girls.

   b. It was hypothesized that boys will also obtain significantly lower expressive language scores than girls. This hypothesis is based upon the results of previous studies in which boys born preterm were found to have higher rates of language impairment than girls (as determined by expressive and receptive measures) and to have impaired language development in comparison to girls born preterm (Wolke et al., 2008; Sansavini et al., 2006).

CHAPTER 2: METHOD

Participants

Fifty subjects were recruited for the current study. The children were recruited as a part of a larger investigation titled Neuropsychological Outcome in Preschool and School Aged Children with Perinatal Complications and with Various Degrees of Exposure to Prenatal Steroids, approved by both William Beaumont Hospital (WBH) and Wayne State University (WSU) internal review boards. The parents of children born before 33 weeks gestation who were born and treated in the NICU at William Beaumont Hospital (Royal Oak, Michigan) between 2007 and 2009 (N = 40), were contacted to determine interest in participating. The inclusion and exclusion criteria for the study are provided in detail below.

Inclusion criteria. Participants for this segment of the study were recruited from a cohort of preterm born infants (less than 33 weeks of completed gestation) who were born and treated in the Neonatal Intensive Care Unit (NICU) at William Beaumont Hospital in Royal Oak, Michigan. Participants were children who were born between September 2007 and March 2009, who were between the ages of 3 and 4 years (adjusted for prematurity) at the time of recruitment. The recruitment rate for the study is approximately 20-25% depending on the birth year.

General exclusion criteria. Infants were excluded from this segment of the Steroid Study under the following circumstances: death, gestational age greater than 32 weeks, presence of major congenital anomalies (e.g., spina bifida, cleft palate, etc.) or chromosomal disorders, children with perinatal neonatal meningitis, and children who required mechanical ventilation at discharge from the NICU. Infants were also excluded if they had been transported to Beaumont from a different hospital (i.e., “outborn”). It is thought that during transport from one hospital to another, infants may receive insufficient respiratory support (Lee et al., 2003). Additionally, children whose parents had reported on the Background Questionnaire that the child have a history of severe head trauma with loss of consciousness, severe cerebral palsy, or uncorrected sensory deficits (e.g., blindness, deafness) were excluded.

Additional exclusion criteria for the Prematurity Language Study. In addition, children were excluded from the Prematurity Language Study if they sustained a severe intracranial hemorrhage (grades 3 or 4), a hemorrhage that originated outside the Germinal Matrix, or had been diagnosed with periventricular leukomalacia.

Sample characteristics. Altogether, 50 participants were recruited for the study; however, we excluded 3 children from the study who were untestable due to low functioning and/or who were uncooperative with most of the assessment. Thus, 47 children were included in this study. The participants were divided into two groups based on gestational age at birth. The lower gestational age group consists of children born at 30 weeks gestation or earlier (M = 28.508, SD = 1.893) and the higher gestational age group consists of children born after 30 weeks gestation (M = 31.964, SD = 0.540). The demographic and socio-familial characteristics of each group are presented in Table 3. No significant group differences were observed in race, gender, adjusted age at testing, proportion of multiple gestation, maternal and paternal education, maternal VIQ (as measured by the WAIS-IV Information, Vocabulary, and Similarities subtests), and socioeconomic status (Hollingshead, 1975).

The antenatal, perinatal, and neonatal complications by gestational age group are depicted in Table 4. In regard to antenatal complications, the groups did not differ significantly in antenatal risk, including relative frequency of placental abruption, chorioamnionitis, maternal diabetes or hypertension. Additionally, there were no significant group differences in maternal age or intrauterine growth, as indexed by the intrauterine growth z-score. The intrauterine growth *z*-score was calculated according to norms published by Kramer et al. (2001), which requires calculating the deviation of an infant's birth weight from the mean weight of his or her normative group, as defined by both gestational age at birth and sex.

With respect to perinatal risk factors, as expected, the lower gestational age group had significantly lower birth weight, $t(43) = -5.809$, $p < .001$, shorter birth length, $t(44) = -4.967$, $p < .001$, and smaller head circumference at birth $t(43) = -5.809$, $p < .001$, than the higher gestational age group (see Table 4). By definition, the groups differed significantly on gestational age, $t(45) = -8.263$. The groups also significantly differed on 1 minute Apgar scores, $t(45) = -2.189$, $p < .05$, and 5 minute Apgar scores, $t(45) = -2.337$, $p < .05$, with the lower gestational age having lower Apgar scores than the higher gestational age group. The groups did not differ significantly in the relative frequency of abnormal presentation, need for cesarean section, use of forceps, need for general anesthesia during delivery, or in the presence of a nucal cord or fetal tachycardia.

In terms of perinatal risk, Table 4 shows that the lower gestational age group exhibited significantly more cases of apnea (Fisher exact $p = .026$), bronchopulmonary dysplasia (Fisher exact $p = .023$), and hyperbilirubinemia, (Fisher exact p = .043), than the higher gestational age group. The lower gestational group also had significantly more cases of hyaline membrane disease, χ^2 $(1, N = 47) = 7.070$, $p < .05$, and patent ductus arteriosus, χ^2 $(1, N = 47) = 5.880$, $p < .05$. In contrast, the higher gestational age group exhibited significantly higher peak bilirubin, $t(44) = -5.352$, $p < .001$. The groups did not differ significantly in the frequency of neonatal complications such as hypermagnesemia, intracranial hemorrhage, and retinopathy of prematurity.

Overall, the lower gestational age group experienced a significantly higher number of neonatal complications, $t(45) = 3.789$, $p < .001$, and total complications, $t(45) = 2.181$, $p < .05$, than the higher gestational age group. The groups were similar on total antenatal and total perinatal complications, however.

Psychological Assessment

General considerations. Each child was evaluated over 1 to 3 sessions depending upon the examiner's assessment of the child's attention and concentration. Prior to evaluation, the parents signed an informed consent form verifying that they understood the nature of the assessment and agree to the outlined terms. During the evaluation, the parents completed a background questionnaire designed to obtain information about their child's medical and developmental history as well as current behavioral functioning. Approximately two weeks after the initial child assessment, the mothers (or fathers) were contacted by phone in order to obtain an evaluation of one parent's verbal intellectual ability (in 41 of 42 cases, the reporter was the mother), and to provide verbal feedback regarding the results of their child's assessment. Finally, after feedback was completed, each parent was mailed a typed copy of a report that outlined the results of his or her child's evaluation, including recommendations for further testing as needed.

Intellectual ability. Intellectual functioning was evaluated using the Wechsler Preschool and Primary Scale of Intelligence-Third Edition (WPPSI-III; Wechsler, 2002). One subtest from the verbal subscale (Information) and one subtest from the performance subscale (Block Design) were administered to each child to obtain an estimate of overall intellectual ability (FSIQ). These two subtests were selected because they have the highest correlations with PIQ and VIQ respectively. Reliability and validity properties can be found in Table 2.

Language skills. Expressive (i.e., the ability to produce meaningful speech) and receptive (i.e., the ability to understand language) language skills were assessed using the Clinical Evaluation of Language Fundamentals—Preschool, Second Edition (CELF-P2; Wiig, Secord & Semel, 2004). For three to four year olds, the CELF-P2 provides five index scores that are comprised of the six core subtests, which are all described below. Reliability and validity properties can be found in Table 2.

The Core Language Score (CLS) is a composite measure of overall language performance. The CLS is comprised of three subtests: Sentence Structure, Word Structure, and Expressive Vocabulary. Sentence Structure requires the child to point to a picture from a choice of four that corresponds to an oral prompt (e.g., "The girl has a doll."). In Word Structure, the child is given a picture and a partial phrase, and is asked to complete the phrase based on the cues given (e.g., "Here is one house. Here are two _____" [houses]). Expressive Vocabulary is a picture naming task in which the child is shown a picture and is asked to name the object or activity shown.

The Receptive Language Index (RLI) is an index of auditory comprehension, and it is comprised of Sentence Structure, Concepts and Following Directions, and Basic Concepts. Concepts and Following Directions is a complex language comprehension task in which the child is shown a set of objects in the stimulus book, and is asked to point to specific objects in a certain order (i.e., "Point to the small blue horse then the large pink flower"). For Basic Concepts, the child is shown three to four pictures on a page and is asked to point to a concept spoken by the examiner (e.g., "point to the one in the middle," "point to the one that is flat").The Expressive Language Index (ELI) is a measure of oral language production, and it is comprised of Word Structure, Expressive Vocabulary, and Recalling Sentences. During Recalling

Sentences, the examiner presents a sentence and then the child is immediately asked to repeat the sentence verbatim. The sentences gradually increase in length and complexity. The CELF-P2 also provides a comparison score, analyzing the discrepancy between the RLI and ELI.

The Language Content Index (LCI) is a measure of several aspects of semantic knowledge and skills. The LCI is comprised of Expressive Vocabulary, Concepts and Following Directions, and Basic Concepts (all explained above).The Language Structure Index (LSI) is a measure of knowledge and skills regarding word and sentence structure. The LSI is comprised of Sentence Structure, Word Structure, and Recalling Sentences (all described above). The CELF-P2 also provides a comparison score, analyzing the discrepancy between the LCI and LSI.

A supplemental subtest, Recalling Sentences in Context, was also administered. During this subtest, the child is read a story and is asked to recall certain sentences verbatim. This subtest is designed to evaluate a child's ability to internalize spoken sentence structures in order to aid in accurate recall.

Two parent rating scales were also administered. The Descriptive Pragmatics Profile is a checklist that consists of items inquiring about children's social use of language, specifically their use of nonverbal language and their ability to use language socially. The Pre-Literacy Rating Scale is a checklist a parent fills out that provides a score which represents his or her child's early reading skills (e.g., letter and sound identification). The parent is asked to respond to each item based on the frequency in which the child engages in that particular skill. The items are on a Likert scale, ranging from 1 (Never) to 4 (Always).

One subtest from the Woodcock Johnson-III (WJ-III) Tests of Cognitive Abilities (Woodcock et al., 2001), Sound Blending, was used to assess phonological skills. On Sound Blending, the child listens to a series of phonemes and is asked to blend the sounds into a word.

Four subtests from the NEPSY- Second Edition: *A Developmental Neuropsychological Assessment* (NEPSY-II; Korkman, Kirk, & Kemp, 1997) were used: Oromotor Sequences, Speeded Naming, Affect Recognition, and Word Generation. Oromotor Sequences is a subtest of oromotor coordination, and requires the child to repeat nonsense words and “tongue twisters.” Speeded Naming is a rapid naming task where the child is asked to quickly name sequences of colors and shapes. Affect Recognition is a facial expression recognition task in which the child is shown pictures of faces and is asked either to state whether they are feeling the same or different, or to point out the children who have similar expressions. Word Generation is a verbal fluency task, in which the child is given a minute to name as many objects as possible within a given category. Since single subtests were used from the NEPSY, scaled scores (range 0 to 19) were used as dependent variables as opposed to overall domain scores. Psychometric properties can be found in Table 2.

CHAPTER 3: RESULTS

Statistical Analyses

Simultaneous multiple regression analyses were used to analyze the data. The independent variables of interest were gestational age (treated as binary and continuous variable), intrauterine growth rate (*z*-score), sex, total number complications, multiplicity, socioeconomic status (SES) and adjusted age at testing. The dependent variables were performance scores on 17 language and cognitive outcome measures. A separate multiple regression analysis was run for each outcome measure, and included a set of predictors determined to be appropriate for that particular performance measure. Visual inspection of the predictor variables revealed an insignificant proportion of missing data, thus no steps were taken to replace missing values. Gestational age was found to be significantly negatively skewed, hence the variable was transformed using the reflect and square root function. The transformed gestational age variable was entered into all regression analyses in place of the original gestational age data.

Several procedures were used in order to identify demographic and perinatal variables that may contribute significant variance to the measured outcomes and subsequently, to determine additional predictors, i.e., "covariates" to include in the analyses. Group differences on demographic variables and medical complications were investigated using t-tests and chi-square analyses. As previously discussed, the two groups (based on gestational age) did not vary significantly on any of the demographic variables (see Table 3). In regard to medical complications, significant group differences were identified for several variables (see Table 4). Secondly, correlations between various demographic/medical variables and outcome variables were computed in order to identify potential confounding variables. Results of these correlational analyses led to the identification of several potential covariates. Correlations between demographic/medical variables and outcome were rather small, with the exception of the correlations between outcome and maternal education (highest r = .448, p < .01), and between outcome and days on supplemental oxygen (highest r = -.564, p < ..01). In regard to correlations between demographic/medical variables, days on oxygen was highly correlated to gestational age (r = -.851, p < .001). In addition, days on oxygen and total complications were highly correlated (r = .596, p < .001).

In order to reduce multicollinearity, only SES, multiple gestation, total complications, and adjusted age were chosen as covariates. SES was chosen because it represents a combination of both maternal and paternal factors, including both education and occupation, and because it is often found to predict outcome (Raz et al., 2010). Additionally, multiple gestation was selected as a covariate, as previous studies have shown that multiples exhibit poorer neuropsychological outcomes (Rutter, Thorpe, Greenwood, Northstone, & Golding, 2003). Because days on oxygen and total complications were highly correlated, only total complications was entered as a covariate. Adjusted age at time of testing was entered as a covariate when deemed appropriate for a particular outcome measure. In addition, one interaction between covariates was significantly related to Receptive Language outcome (SES x Multiple Gestation), hence this interaction was included in appropriate analyses. These covariates, along with the predictors of gestational age, growth rate, and sex, were entered simultaneously in all multiple regression analyses.

It was decided that SES would entered as a covariate, as previous studies have reported significant relationships between SES and performance on cognitive and language measures.

Because parental education is a component of SES, and to reduce multicollinearity, neither maternal nor paternal education were entered as covariates.

Table 6 presents the results of the multiple regression analyses for each outcome measure. For each regression, one outcome measure was entered into the equation, along with a set of several predictor variables. The predictors included gestational age, intrauterine growth rate, SES, total complications, adjusted age, multiple gestation, and sex. It should be noted that all outcome measures' scores are based upon the child's age, adjusted for prematurity.

Cognitive Functioning

Only 44 participants were included in the FSIQ analysis, as two cases had missing data (both cases were missing socioeconomic status data, and one did not understand the directions for Block Design), and one case was identified by SYSTAT as a multivariate outlier. Contrary to the hypotheses, the analyses did not reveal a significant effect of gestational age when predicting FSIQ [gestational age as continuous variable: $F(1,37) = .00$, *ns*; gestational age as binary variable: $F(1,38) = .80$, *ns*]. Intrauterine growth rate (*z*-score) and sex were also found to be non-significant predictors of FSIQ [$F(1,37) = .05$, *ns*; R^2 change = .02, $F(1,37) = .95$, *ns*, respectively]. Forty-five cases were included in the analysis of performance on Block Design and Information, as two cases were missing data (for reasons reported above). Gestational age was not found to be a significant predictor of performance on Block Design [$F(1,37) = .02$, *ns*] or Information [$F(1,38) = .03$, *ns*], respectively. There was a nonsignificant trend for a relationship between Information and Sex, with girls performing better than boys [R^2 change = .07, $F(1,38) = 3.34$, $p < .10$]. There was also a nonsignificant trend for a relationship between Information and total complications [R^2 change = .06, $F(1,38) = 2.75$, $p < .15$].

Language Functioning

Forty-five participants were included in the analysis of overall language functioning, as 2 cases were missing data on socioeconomic status. Gestational age was not significantly related to variance in Core Language performance [gestational age as continuous variable: $F(1,38) = .00$, *ns;* gestational age as binary variable: $F(1,38) = .00$, *ns*]. Growth rate and sex also were not significantly related to Core Language performance [$F(1,38) = .87$, *ns*; $F(1,38) = .44$, *ns*]. There was a nonsignificant trend for a relationship between socioeconomic status and Core Language performance [R^2 change = .09, $F(1,38) = 3.75$, $p < .10$].

Only 44 participants were included in the analysis of Receptive Language performance, as 3 cases were missing data (one due to lack of cooperation with examiner, and two due to missing socioeconomic status data). Analyses revealed a significant interaction between socioeconomic status and multiple gestation, hence this interaction term was included as a predictor. Again, gestational age was not significantly related to variance in Receptive Language outcome [$F(1,36) = .18$, *ns*]. Additionally, Receptive Language performance was not significantly related to growth rate or sex [$F(1,36) = .13$, *ns*; $F(1,36) = .93$, *ns*].

Forty-three participants were included in the analysis of Expressive Language functioning, as 3 cases were missing data (one due to lack of cooperation, and two due to missing socioeconomic status data), and one case was identified as a multivariate outlier. Neither gestational age nor growth rate were significantly related to variance in Expressive Language outcome [$F(1,35) = .00$, *ns*; $F(1,35) = .75$, *ns*]. Total complications was significantly related to Expressive Language performance [R^2 change = .10, $F(1,35) = 5.32$, $p < .05$]. There was a nonsignificant trend for a relationship between Expressive Language performance and adjusted age at time of testing [R^2 change = .07, $F(1,35) = 3.74$, $p < .10$]. There was also a nonsignificant trend for a relationship between Expressive Language and socioeconomic status [R^2 change =

.08, $F(1,35) = 2.98$, $p < .10$], as well as between sex and Expressive Language performance [R^2 change = .04, $F(1,35) = .142$, $p < .15$].

Analysis of Language Structure included 44 participants, as 3 cases had missing data (one due to lack of cooperation, and two due to missing socioeconomic status data). Results again revealed a non-significant effect of gestational age on Language Structure [$F(1,37) = .00$, *ns*]. Also, growth rate was not significantly related to Language Structure performance [$F(1,37) = .16$, *ns*]. There was a nonsignificant trend for a relationship between sex and Language Structure performance, with girls performing better than boys [R^2 change = .05, $F(1,37) = 2.20$, $p < .15$]. There was also a nonsignificant trend for a relationship between Language Structure performance and socioeconomic status [R^2 change = .10, $F(1,37) = 3.83$, $p < .10$].

Forty-four participants were also included in the analysis of Language Content performance. Neither gestational age nor growth rate were significantly related to variance in outcome [$F(1,37) = .09$, *ns*; $F(1,37) = .91$, *ns*]. Sex also was not significantly related to Language Content performance [$F(1,37) = .72$, *ns*]. There was a nonsignificant trend for a relationship between socioeconomic status and Language Content performance [R^2 change = .09, $F(1,37) = 3.65$, $p < .10$].

The analysis of performance on Recalling Sentences in Context only included 36 participants, as 11 cases were missing data (7 did not understand the task, 2 removed due to lack of cooperation, 2 were missing socioeconomic status data). Again, neither gestational age nor growth rate were significantly related to subtest performance [$F(1,29) = .40$, *ns*; $F(1,29) = .16$, *ns*]. There was a significant effect of sex, however, with girls performing significantly better than boys [R^2 change = .20, $F(1,29) = 7.67$, $p < .01$].

Analysis of parent ratings on the Pre-literacy Rating Scale included data from 43 participants, as 4 cases were missing data (2 rating forms were incomplete, and 2 cases were missing socioeconomic status data). Analyses did not find a significant relationship between scale ratings and gestational age [$F(1,35) = .03$, *ns*]. Also, growth rate and sex were not significant predictors of scale ratings [$F(1,35) = .04$, *ns*; $F(1,35) = .01$, *ns*], respectively. SES was significantly related to ratings on the Pre-Literacy Rating Scale [R^2 change = .18, $F(1,35) = 11.42$, $p < .05$]. Additionally, adjusted age at time of testing was associated with ratings [R^2 change = .11, $F(1,35) = 6.61$, $p < .05$].

The analysis of Descriptive Pragmatics Profile ratings also included only 44 participants (for the reasons reported above). Gestational age, again, was not significantly related to scale ratings [$F(1,36) = .54$, *ns*]. There was not a significant effect of growth rate [F(1,36) = 1.29, ns] or sex on scale ratings [$F(1,36) = .80$, *ns*]. There was, however, a significant relationship between adjusted age at time of testing and ratings [R^2 change = .10, $F(1,36) = 4.50$, $p < .05$].

For the analysis of performance on Sound Blending, 35 participants were included in the analysis because 12 cases were missing data (8 due to inability to understand the task, 2 due to lack of cooperation with examiner, 1 due to inability to attend a second session, and 1 due to missing socioeconomic status data). There was a nonsignificant trend for a relationship between gestational age and subtest performance [gestational age as continuous variable: R^2 change = .09, $F(1,28) = 2.98$, $p < .10$; gestational age as binary variable: $F(1,23) = 3.24$, $p < .10$]. There also was a nonsignificant trend for a relationship between socioeconomic status and subtest performance [R^2 change = .12, $F(1,28) = 3.72$, $p = < .10$]. Growth rate was not significantly related to subtest performance [$F(1,28) = 1.61$, *ns*]. Additionally, sex was not a significant predictor of performance on Sound Blending [$F(1,28) = .18$, *ns*].

Forty cases were included in the analysis of Affect Recognition performance as 7 cases were missing data (4 due to lack of comprehension of the task demands, 1 due to lack of cooperation, and 2 due to missing socioeconomic status data). Neither gestational age nor growth rate were significant predictors of subtest performance [gestational age as continuous variable: $F(1,33) = .13$, *ns;* gestational age as binary variable: $F(1,33) = .04$, *ns*]. Sex was significantly related to variance in subtest performance, with girls performing significantly better than boys [R^2 change = .15, $F(1,33) = 6.70$, $p < .05$]. There was also a significant effect of multiple gestation status on subtest performance, with singletons performing significantly better than multiples [R^2 change = .10, $F(1,33) = 4.33$, $p < .05$].

Forty-three cases were included in the analysis of Oromotor Sequences performances, as 4 cases had missing data (2 due to lack of comprehension of the task, 1 due to lack of cooperation, and 1 due to lack of socioeconomic status data). Again, neither gestational age nor growth rate were significantly related to subtest performance [gestational age as continuous variable: $F(1,36) = 00$, *ns*; gestational age as binary variable: $F(1,36) = .03$, *ns*; growth rate: $F(1,35) = .94$, *ns*]. Sex, however, was significantly related to variance in performance on Oromotor Sequences, with girls performing significantly better than boys [R^2 change = .12, $F(1,36) = 5.35$, $p < .05$].

For analysis of performance on Speeded Naming, data from 40 participants was included, as 5 cases had missing data (2 due to lack of cooperation with examiner, 1 due to inability to attend second session, 2 due to missing socioeconomic status data), and 2 multivariate outliers were identified by SYSTAT. Gestational age was not a significant predictor of subtest performance [gestational age as continuous variable: $F(1,33) = .01$, *ns;* gestational age as binary variable: $F(1,33) = 1.04$, *ns*]. There also was a non-significant relationship between growth rate and subtest performance [*F*(1,33) = .68, *ns*]. Additionally, there was not a significant relationship between sex and subtest performance [*F*(1,33) = .09, *ns*].

Forty-one participants were included in the analysis of Word Generation performance, as 6 cases had missing data (2 due to lack of comprehension of the task, 1 due to lack of cooperation, 1 due to inability to attend second session, 2 due to missing socioeconomic status data). Gestational age was not a significant predictor of subtest performance [gestational age as continuous variable: *F*(1,34) = .17, *ns;* gestational age as binary variable: *F*(1,34) = .14, *ns*]. Additionally, growth rate and sex were not significantly related to variance in subtest performance [*F*(1,34) = 2.01, *ns; F*(1,34) = 1.87, *ns*].

CHAPTER 4: DISCUSSION

The initial hypotheses that intrauterine growth rate (Hypothesis 1) and gestational age (Hypothesis 2) would be associated with cognitive and language outcomes were not supported in the current study. The hypothesis that immaturity would be associated with impairments in specific language domains (Hypothesis 3) also was not supported. Although nonsignificant trends were detected, significant relationships between these factors and outcome measures were not observed, even though language skills, in particular, were thoroughly assessed in this middle class sample. The hypothesis that boys would exhibit significantly poorer performance on outcome measures (Hypothesis 4) partially supported, with significant effects obtained for three measures, and nonsignificant trends also obtained for three measures. It is possible that a larger sample would have allowed us to demonstrate a greater number of significant associations between sex and language outcome.

Hypothesis 1, that intrauterine growth rate would be associated with outcome measures, was not supported. A nonsignificant trend for a relationship between growth rate and pragmatic skills was present, although there were no significant relationships between intrauterine growth rate and any outcome measures. Hypotheses 2, 3a, and 3b, that gestational age would be significantly associated with cognitive and specific language outcome measures, was not supported. While no significant relationships between gestational age and outcome measures were present, there was a single nonsignificant trend for a relationship between gestational age and Sound Blending. Additionally, it should be noted that whether gestational age was treated as a binary or continuous variable in the analyses did not affect the results.

The hypothesis that boys would exhibit poorer performance than girls on outcome measures (Hypothesis 4) was partially supported. In regard to cognitive outcome measures, there was a nonsignificant trend for a relationship between sex and performance on the verbal component, with boys obtaining somewhat lower scores than girls; perhaps a larger sample would have allowed us to conclusively demonstrate this effect. Analysis of language performance resulted in a nonsignificant trend for a relationship between sex and performance on the Expressive Language Index, with boys exhibiting poorer performance than girls (Hypothesis 4b). In addition, the analyses revealed that boys obtained significantly poorer scores on measures of language memory (Recalling Sentences in Context), pragmatic skills (Affect Recognition), and articulation (Oromotor Sequences). There was also a nonsignificant trend for a relationship between sex and language structure skills, with boys again obtaining somewhat lower scores than girls. Because gender-biased items were eliminated during the standardization process for the CELF-P2 (Wiig, Secord, & Semel, 2004, p. 106), the sex differences on CELF-P2 indices that were discovered in this study probably reflect differential language outcome that is associated with preterm-birth.

One potential explanation for null findings is that intrauterine growth rate and gestational age do not account for variance in cognitive and language skills during the preschool years in this sample; however, numerous studies have found these factors to be significantly related to cognitive and language development (e.g., Mikkola et al., 2005; Foster-Cohen et al., 2007, etc.). Previous studies have typically assessed older children, and from lower socioeconomic strata, thus it is possible that these relationships are not present until a child is at least in preschool, or in middle class strata.

Methodological issues may have contributed to the null findings for Hypotheses 1 and 2. The medium sample size may have rendered detection of differences between groups more difficult. Prior to the study, it was estimated that a sample size of 68 was necessary in order to detect a medium effect size with only 2 predictors, so it is probable that the current study was under-powered. The gestational age of the sample was also skewed, and included more children born at the higher gestational ages (although this reflects the natural distribution of surviving children born prematurely). Even though the gestational age variable was transformed statistically, this uneven distribution may have contributed to the null findings. Because of the young age of the children, floor effects may also be involved in regard to the measures used. The measures may not have accurately captured the variability in skill between the children. There were also a proportion of children (ranging from 1 to 10 children, depending on the measures used) who were unable to cooperate either due to behavioral issues or due to not understanding the task during test administration, which could have led to the development of an inaccurate picture of this sample's abilities.

Although gestational age and intrauterine growth rate were not found to be significantly related to neuropsychological outcomes, we did find significant relationships between sex and specific outcomes. Additional results of this study suggest that multiple gestation status may be an important contributor to language development. Twin gestation was associated with lower scores on a measure of pragmatic skills. This supports previous findings that twins typically obtain lower scores than singletons on measures of cognitive and language skills.

The number of total complications was also significantly associated with expressive language skills. There was also a nonsignificant trend for a relationship between total complications and the verbal component of the cognitive outcome measure. These findings suggest that perinatal medical status accounts for a unique proportion of the variance in verbal-linguistic skills, above and beyond the contributions of associated factors, such as gestational age, growth rate, and multiplicity.

In sum, the main finding in the current study was a sex effect on select measures of language performance, which is likely attributable to differential effects of perinatal adversity on the two genders, with boys performing more poorly than girls. A larger sample size will likely be needed to demonstrate the effects of gestational maturity and intrauterine growth rate on language outcome.

APPENDIX A

Table 1
Methodological Characteristics and Findings of Prior Research on Language and Cognitive Performance

Authors & Year	GA cut-off (weeks)	BW (g)	EPT, VPT, or MPT	N per Group(PT:C)	Age at Testing	Comparison Group	Exclusions	Outcome Measures	Covariance or Matching	Results
Briscoe, Gathercole, & Marlow, 1998	<32 (M= 28.8)	815-1985 (M= 1209)	E & V	26:26	3:3-4:2 years (M=43.6 mos.)	FT	Minor or major physical impairment (UC)	Lang: BPVS, MSCA-Oral Vocab, Bus Story Test Cog: Griffiths Mental Development Scales (PT only at 12 and 24 mos) Nonverbal ability: Raven's Progressive Colured Matrices	For Nonverbal analyses between at-risk and no-risk PT, age and Raven's scores were covariates	**Between Groups** Lang: PT sig lower scores on BPVS raw & Bus Story Information. No other differences present. More PT at-risk for language impairment. Cog: No sig. differences Nonverbal: At-risk PT sig. lower than FT. No sig differences between PT & FT overall **Within PT Group** Lang: PT with at-risk language development scored sig. lower on all measures than other PTs and FTs at 3-4 years old Cog: PT with at-risk language development scored sig. lower on all measures than other PTs and FTs at 3-4 years old; At-risk and no-risk PTs comparable Griffiths at 12 and 24 mos.
Bühler, Limongi & Diniz, 2009	24-33 (M= 29.4)	≤1500 (M= 1073)	V	12:20	Monthly from 1 mo. to 18 mos.	FT	Major malformations, genetic syndromes, severe neonatal asphyxia, hearing or visual impairments	Lang & Cog: PELDCO (US)	None	**Between Groups** Lang: Expressive language sig. better in FT at 9, 11-14, 16 & 18 mos. Cog: FT sig. higher scores from 6 months on
Caldú et al., 2006	<33 (M= 29.48)	<33 (M= 29.48)	E & V	25:25	M=13.44	FT	Complications other than hypoxic-ischemic damage or PVH; mental or physical disabilities (no subject had parenchymal lesions)	Lang: phonetic & semantic verbal fluency tests Cog: WISC-R or WAIS-III	Matched on age, gender, and SES	**Between Groups** Lang: semantic verbal fluency lower for PT than FT, but phonetic fluency performance did not differ Cog: PT lower VIQ, PIQ & FSIQ than controls

Table 1 (continued)

Authors & Year	GA cut-off (weeks)	BW (g)	EPT, VPT, or MPT	N Per Group (PT:C)	Age at Testing	Comparison Group	Exclusions	Outcome Measures	Covariance or Matching	Results
Casiro et al., 1990	25-34 (M= 29)	585-1500 (M= 1174)	V	28:32	1 year	FT	Severe neurological handicaps, developmental quotients <70, & abnormal audiometry responses	Lang: Reynell Developmental Language Scales, REEL Neurodevelopment: Gesell Developmental Scales	Developmental quotient and sex	**Between Groups** Lang: PT sig. lower language scores; PT had a greater prevalence of language delays. Neurodevelopment: PT group had sig. more children with suboptimal developmental quotients **Within PT Group** Lang: language quotient associated with GA and 5 min apgar scores & inversely related to IVH and length of hospital stay. SGA had higher quotients than AGA & those with BPD had lower quotients than those without.
Foster-Cohen, Friesen, Champion & Woodward., 2010	≤33 (M=28, 23-33)	≤1500 (M= 1050, 440-1790) *Met either the GA or BW cutoff	V	110: 113	4 years	FT	Congenital abnormalities & non-English speaking parents	Lang: CELF-P Cog: abbreviated WPPSI-R	Neurosensory impairments & social risk factors; matched on gender (didn't differ on BW or SES)	**Between Groups** Lang: PT had sig. worse receptive & expressive skills & were twice as likely to have a clinically significant mild to severe language delay **Within PT Group** Lang: increased social risk, moderate to severe white matter abnormalities, neonatal MRI, parental instability, intrusive and less warm parenting behavior sig. related to risk of later language delay. No sig. differences in regard to GA, BW, medical risk (composite of chronic lung disease, postnatal steroid exposure, ROP, patent ductus arteriosis, necrotizing entercolitis, & septicaemia), maternal mental health, family size, or family stressful events.

Table 1 (continued)

Authors & Year	GA cut-off (weeks)	BW (g)	EPT, VPT, or MPT	N Per Group (PT:C)	Age at Testing	Comparison Group	Exclusions	Outcome Measures	Covariance or Matching	Results
Foster-Cohen, Edgin, Champion & Woodward, 2007	≤33 (23-33), M=28	<1500 (440-1790), M=1050	E&V	100:105	2 years	FT	Congenital abnormalities & non-English speaking parents. Included IVH 3 or 4, and CP.	Lang: MCDI-WS Cog: BSID - II	Gender, twin status, ethnicity, change of parents, income, SES, maternal education, maternal age at birth, family size No sig. changes when SGA and multiples were excluded' Matched on gender and DOB	**Between Groups** Cog: PT sig. lower MDI and PDI than FT **Within PT Group** Lang: **linear relationship between GA and vocabulary size**; GA sig. related to use of decontextualized words, use of morphological endings, irregular forms, , and word combining (EPT<VPT<FT); sentence length in morphemes, over-regularized word use, total vocabulary production non-sig. after factors controlled for.
Gayraud & Kern, 2007	<28, 28-32, & 33-36	Not reported	E,V,M	323:166	24-26 mos	FT	Bilingual or multilingual children, multiple-birth children	Lang: French MCDI-WS	None	**Between and Within Groups** No main effects of gender or maternal education Lang: Main effect of GA (EPT<VPT, MTP & FT; VPT <FT) and birth order (first-borns had larger vocabularies than later-born); FT produced sig. more nouns than VPT & EPT; sig. relationships between GA, birth order, and predicate use (EPT<VPT,MPT,FT & FT>VPT); GA sig. related to CCI (EPT<other groups); GA and birth order sig. related to others' (EPT>VPT, MPT, FT; VPT>FT); main effect of birth order and an effect of GA for MaxLU (EPT<MPT,FT; VPT<MPT)

Table 1 (continued)

Authors & Year	GA cut-off (weeks)	BW (g)	EPT, VPT, or MPT	N Per Group (PT:C)	Age at Testing	Comparison Group	Exclusions	Outcome Measures	Covariance or Matching	Results
Gonzalez & Robison, 2001	25-37 (30-37)	1000-2500 (3 lbs. – 6 lbs. 13 oz.)	E,V,M	10:10	6:10-8:11 years	FT	Severe developmental disabilities (CP, MR, IVH), uncorrected vision problems, failed audiometric screening, ongoing medical problems after NICU discharge, abnormal progression through school	Lang.: EVT, GFTA, OSMSE-R, PPVT-III, TPS-R, TOLD-P:2 Cog.: TONI-3	Matched on gender & ethnicity	**Between Groups** Lang: Only difference was PT had sig. lower scores on TOLD Test of Oral Vocabulary Cog: No differences on any cognitive scores
Guarini et al, 2010	25-33 (M=30.44)	600-1840 (M=1243)	E,V,M	68:26	7:5-8:10 years	FT	CP, laukomalacia, IVH >II, hydrocephalus, motor & sensory impairments; Allowed respiratory distress, BPD, apnoea, ivh I & ii, IUGR, ROP I or II, visual problems, hyperechogenicity, hyperbilirubinemia	Lang: Italian language measures Cog: Italian K-BIT	None Listed	**Between Groups** Lang: No sig. differences on any language measure Cog: No sig. differences on any measure

Table 1 (continued)

Authors & Year	GA cut-off (weeks)	BW (g)	EPT, VPT, or MPT	N Per Group (PT:C)	Age at Testing	Comparison Group	Exclusions	Outcome Measures	Covariance or Matching	Results
Guarini et al., 2009	24-33 (M= 29.7)	600-1980 (M= 1137)	E,V,M	70:34	M=72.6 mos.	FT	CP, leukomalacia, IVH>II, hydrocephalus, significant motor or sensory impairments	Lang: Italian language measures Cog: K-BIT	IQ	**Between Groups** Lang: PT made sig. more vocabulary and grammar errors, gave sig. fewer correct responses for phonological awareness at syllabic level; no differences between PT & FT on phonological awareness at phonemic level. ((Conclusion:PT without frank damage affects linguistic abilities)) Cog: No differences on any K-BIT scores **Within PT group** No effect of medical complications on vocabulary, phonological awareness of syllable or phoneme, or full IQ; IVH I or II sig. related to grammar
Hack et al., 1991	M=29.7	≤1500 (M=1176.5)	V	249: none	8-9 years	None (norms)	None of the participants had major congenital malformations or births complicated by intrauterine infections	Lang: Token Test for Children part V, Rapid Automatized Naming Test--objects, CELF model sentence subtest, Cog: WISC-R (verbal & performance)	Demographic & perinatal risk factors and gross neurological impairments.	**Within PT Group** Cog:: Small head size at 8 mos. related to significantly lower VIQ & PIQ at 8 years old Lang: Small head size at 8 mos. related to significantly lower receptive language at 8 years old

Table 1 (continued)

Authors & Year	GA cut-off (weeks)	BW (g)	EPT, VPT, or MPT	N Per Group (PT:C)	Age at Testing	Comparison Group	Exclusions	Outcome Measures	Covariance or Matching	Results
Lee, Yeatman, Luna & Feldman, 2011	<36 (M= 28.8)	<2500 (M= 1215)	E,V,M	65:35	9-16 yrs	FT	Active seizure disorder/anticonvulsant mediation use, history of infection, revisions or complications of ventriculoperiotneal shunt for hydrocephalus, presence of neurological lesions (eg. Congenital malformation, meningitis, encephalitis), estimated receptive vocabulary score <70, sensorineural hearing loss & non-English speakers; Also for controls—PT birth, language, learning or attention disorder, other Axis I disorder, and retention in grade after 7 years	Lang: RLI, ELI, & LMI—CELF-4; PPVT-III, TROG-2, Basic Reading Skills Cluster & Passage Comprehension subtest--WJ-III Cog: WASI	Matched on age, gender, race, and maternal education (SES measure); 2 subsamples matched for SES & PIQ or VIQ	**Between Groups** Language: PT sig. lower receptive & expressive language, syntactic comprehension, linguistic processing speed, verbal memory, decoding, and reading comprehension than FT; No differences on receptive vocabulary; **Degree of prematurity was a significant predictor of linguistic processing speed** after controlling for SES & PIQ; ELGA sig. worse on all measures than FT & VLGA sig. worse than FT on PIQ, VIQ, verbal memory and reading comprehension. Cog: PT lower on PIQ & VIQ **Within PT Group** Language: ELGA sig. lower scores than VLGA on syntactic comprehension and linguistic processing speed
Le Normand & Cohen, 1999	28-35	780-2210 (E= 780-1200, V= 1201-1500, L= 1501-2210)	E, V, L	51:51	42 & 60 mos.	FT	Postnatal medical disorders (e.g., hyaline membrane disease, toxemia, cardiovascular disorders, epilepsy, visual & auditory impairment, broncho-pulmonary disease)	Lang: Transcribed verbal interactions using the CHILDES	Matched for age, sex, birth order, family SES, & family sociocultural level	**Between Groups** Lang: PTs produced sig. fewer verbs of all 3 types than the FT. High SES performed better than low SES on the verb type measure, regardless of group of birth weight. **Within PT Group** Lang: similar performance between 3 PT groups on production and use of verbs (no effect of PT severity)

Table 1 (continued)

Authors & Year	GA cut-off (weeks)	BW (g)	EPT, VPT, or MPT	N Per Group (PT:C)	Age at Testing	Comparison Group	Exclusions	Outcome Measures	Covariance or Matching	Results
Mikkola et al., 2005	M=27.3	<1000 (M= 806)	E	172: none	Perinatal, infancy, 1.5 yrs., 5 yrs.	Norms	Moderate-severe cognitive impairments & kids who were uncooperative	Lang: selected NEPSY subtests Cog: WPPSI-R [Finnish version]	Na	**Between Groups** Lang: PT sig. lower language scores than norms **Within PT Group** Language: SGA language scores sig. lower than AGA; GA >27 and SGA had sig. worse language scores than PT AGA Cog: Each BW increase of 100g sig. related to 2pt IQ increase. Sig. lower IQ for those with IVH 3 or 4, males, multiparity, multiple pregnancy, vaginal delivery & lack of antenatal steroids.
Pritchard et al., 2009	≤33 wks (23-33, M=28)	Not Reported	V	102: 108	6 yrs	FT	PT: Congenital abnormalities & non-English speaking families; FT: also FAS & birth complications	Lang. Achievement: Selected WJ-III Subtests—Understanding Directions & Passage Comprehension Cog: WPPSI-R short form (Comprehension, Arithmetic, Picture Completion, & Block Design)	Severe impairments & SES; Matched on gender	**Between Groups** Lang Achievement: VPT sig. lower on Understanding Directions; also sig. lower on 2 of the 5 indicators of early literacy skills; no differences on Passage Comprehension. Cog: VPT sig. higher rates of severe cog delay & moderate to severe CP
Sansavini et al, 2006	25-33 (M= 30.4)	600-1600 (M= 1211.8)	E,V,M	73:22	2.5 yrs	FT	CP, leukomalacia, IVH>II, hydrocephalus, genetic malformations, motor handicaps, significant sensory impairments, parents not native Italian speakers, or single parent families	Language: Il primo vocabolario del bambino (Italian MCDI), Test di Ripetizione di Frasi (Italian TRF)	Matched on socio-demographic variables	**Between Groups** Lang: No sig. group differences on number of total words, vocabulary composition, grammatical development, MLU **Within PT Group** Lang: BW, GA & gender for PTs related to linguistic abilities (PT <1000g, <31 wks & male had worse lexical and grammatical development); sig. interaction between GA and gender on MLU (males with GA <31 had sig. lower MLU than males with GA ≥31)

Table 1 (continued)

Authors & Year	GA cut-=off (weeks)	BW (g)	EPT, VPT< or MPT	N Per Group (PT:C)	Age at Testing	Comparison Group	Exclusions	Outcome Measures	Covariance or Matching	Results
Sansavini et al., 2010	24.5-33 (M= 30.4)	600-1600 (M= 1192.5)	E & V	64:62	2:6 & 3:6 years	FT	Major cerebral damage (PVL, IVH>II, hydrocephalus, ROP>III), congenital malformations, visual or hearing impairments	Lang: PVB & PRF Cog: Stanford-Binet IQ	Matched on gender; controlled for maternal education	**Between Groups** Lang: No sig. differences on any language measures at 2:6; At 3:6 PT sig. shorter PRF MLUs & sig. higher risk for language impairment Cog: No sig. differences on any cognition measures at 2:6; at 3:6 PT sig. worse scores **Within PT Group** Lang: males with BW ≤1,000g produced less words than all females; males with GA <31 wks had lower MLU scores than males ≥31; male controls had lower MLU than females
Schirmer, Portuguez & Nunes, 2006	<37	<2500	L (39) & V (30)	69: none	12 mos., 2 yrs., 3 yrs.	none	Hearing impairment & malformation of CNS	Lang: Nicolosi Sequence of Language Development Cog: BSID-II	None	**Within PT Group (compared normal, NLA, to delayed, DLA, language acquisition groups)** Language: GA<32 3 times the risk for language delay Cog: NLA sig. higher mental development than DLA; DLA with BW of 1500-2500g had sig. worse BSD-I mental scores than all others;
Seidman, Allen & Wasserman, 1986	<36	1021-2000	UC	15 PT, 15 FT, 15 handicapped	23-25 mos.	1) FT & 2)handicapped (orthopedic anomalies)	CNS damage, MR Based on BSID at 12 mos., moderate to profound hearing loss	Language: Transcription of ½ hour speech samples (upper bound, MLU, number of words, functional categories coded)	None	**Between Groups** *PT group didn't differ sig. from handicapped group on any measure Lang: PT/handicapped had sig. smaller vocabularies, produced sig. less verbs, produced more utterances with no identifiable lexical content, and lower means on upper bound and MLUs than the FT; No difference in functional/pragmatic skills or mean number of utterances.

Table 1 (continued)

Authors & Year	GA cut-off (weeks)	BW (g)	EPT, VPT, or MPT	N Per Group (PT:C)	Age at Testing	Comparison Group	Exclusions	Outcome Measures	Covariance or Matching	Results
Stolt et al., 2007	24-35 (M=28)	<1501 (400-1500, M= 1067)	E & V	66:87	2 yrs.	FT	None	Language: Finnish CDI Cog: BSID - II	Cognitive Development	**Between Groups** Language: no differences in vocabulary size; With vocabularies >425 words, PT used sig. more common nouns and less grammatical function words than FT; No differences between groups on acquisition of lexical categories Cog: PT's with MDIs >85 (group with higher MDIs) had sig. lower MDIs than FT **Within PT Group** Lang: Sig. correlation between BW and vocabulary size (not seen in FT group);maternal education associated with vocabulary size in PT group; growth retardation was not related to lexicon size; no sex differences
Van Lierde, Roeyers, Boerjan & De Groote, 2009	23-26 (M=25.1)	605-1000 (M=792.9)	E	15:19	M=3.3	FT	Major physical, sensorial or neurological impairments, or a mental development index (Bayley) <55	Lang: Dutch Reynell Developmental Language Scales Cog: Dutch BSID - II	SES comparable	**Between Groups** Lang: PT had sig. lower scores on all receptive and expressive measures Cog: PT had sig. lower MDIs
Wolke, Samara, Bracewell & Marlow, 2008	≤25	360-1040	E	241: 160	Median= 6:4	FT	None Reported	Language: PLS-3 UK, PAT, quality of speech scales (US), DSM-IV criteria for language disorders Cog: K-ABC (or Griffiths or NEPSY for kids with impairments)	Severe physical disability; Overall cognitive score (caused language discrepancies to disappear, but rate of speech impairment & educational problems remained). Matched on age & sex.	**Between Groups** Language: All of PLS-3 scores sig. lower for PT; PT had sig. lower PAT scales; Sig. more PT met criteria for phonological disorders; PT used sig. less developmentally appropriate speech sounds and had sig. more difficulties in speech sound production; PT had sig. more disturbances in speech fluency and patterning Cog: PT sig. lower cognitive scores **Within PT Group** Cog: Boys had sig. lower cognitive scores than girls Language: Boys had sig. higher rates of language impairment than girls

Table 1 (continued)

Authors & Year	GA cut-off (weeks)	BW (g)	EPT, VPT< or MPT	N Per Group (PT:C)	Age at Testing	Comparison Group	Exclusions	Outcome Measures	Covariance or Matching	Results
Wolke & Meyer, 1999	29.3-29.7 (M= 29.5)	1247-1330 (M= 1288)	V	264: 264	6:3	FT & norms	Language differences interfering with language testing	Language: Heidelberger Sprachentwicklungstest, articulation test (US), quality of speech coding (consensus ratings), adapted measure of phonological awareness (US) Cog: German K-ABC	Matched on gender, SES, marital status of parents, and maternal age. For language analyses, controlled for IQ and excluded those with major impairment.	**Between Groups** Language: PT sig. lower total articulation scores, quality of speech scores, and naming of numbers score Cog: PT sig. lower scores on all K-ABC composites; PT sig. higher rates of serious cognitive impairment; PT specific deficiencies with complex information processing requiring reasoning and spatial orientation; Sig. more PT had cognitive deficiencies in >1 cognitive areas assessed than FTs

Note: GA=Gestational Age, BW=Birth weight, PT=Preterm, C=Control, EPT=Extremely Preterm, VPT=Very Preterm, MPT=Moderately Preterm, FT=Full Term, UC=unclear, BPVS = British Picture Vocabulary Scales, MSCA = McCarthy Scales of Children's Abilities, Lang.=Language, Cog.=Cognitive, PELDCO = Protocol for Expressive Language and Cognition Development Observation, PVH=Periventricular Hemorrhage, WISC/R = Wechsler Intelligence Scale for Children, WAIS-III=Wechsler Adult Intelligence Scale, 3rd Edition, SES=socioeconomic status, VIQ=Verbal IQ, PIQ=Perceptual IQ, FSIQ=Full Scale IQ, REEL=Receptive-Expressive Emergent Language Scales, IVH=intraventricular hemorrhage, SGA=small for gestational age, AGA=appropriate for gestational age, CELF (4/P) = Clinical Evaluation of Language Fundamentals (4th edition/Preschool), WPPSI-R= Wechsler Preschool and Primary Scale of Intelligence, MRI=magnetic resonance imaging, ROP=retinopathy of prematurity, BSID-II = Bayley Scales of Infant Development, Second Edition, MCDI (WS) = MacArthur-Bates Communicative Development Inventories (Words and Sentences), DOB=date of birth, MDI = Mental Development Index (BSID-II), PDI = Psychomotor Development Index (BSID-II), CCI=closed-class items (MCDI-WS), MaxLU=maximum length of utterance, CP=cerebral palsy, MR=mental retardation, NICU=neonatal intensive care unit, EVT = Expressive Vocabulary Test, GFTA = Goldman-Fristoe Test of Articulation, OSMSE –R = Oral Speech Mechanism Screening Examination – Revised; PAT = Phonological Abilities Test, PPVT-III = Peabody Picture Vocabulary Test (3rd edition), TPS-R = Test of Pragmatic Skills-Revised, TOLD/P:2 = Test of Language Development, TONI-3 = Test of Nonverbal Intelligence (3rd edition), BPD= bronchopulmonary dysplasia, IUGR=intrauterine growth restriction, K-BIT = Kaufman Brief Intelligence Test, CBCL = Achenbach Child Behavior Checklist, WJ = Woodcock-Johnson Psychoeducational Battery, WRAT/R = Wide Range Achievement Test, RLI= Receptive Language Index (CELF-4), ELI=Expressive Language Index (CELF-4), LMI = Language Memory Index (CELF-4), TROG-2 = Test for Reception of Grammar-Version Two, WASI = Wechsler Abbreviated Scale of Intelligence, ELGA=extremely low gestational age, VLGA=very low gestational age, CHILDES = child language data exchange system, NEPSY = Developmental Neuropsychological Assessment, TRF = Test of repetition of noun-phrases and sentences, MLU=mean length of utterance, PVL= periventricular leukomalacia, PVB= Il Primo Vocabolario del Bambino (parent report of lexical and grammatical skills), PRF=Prova di Ripetizione di Frasi (measure of direct language ability), NLA=normal

Table 1 (continued)

language development, DLA=delayed language development, UC=unclear, CNS=central nervous system, MDI=Mental Developmental Index (BSID II), K-ABC = Kauffman Assessment Battery for Children, PLS-3 = Preschool Language Scale-3 (UK version), PAT = Phonological Abilities Test, DSM=Diagnostic and Statistical Manual of Mental Disorders

Table 2
Psychometric Properties of Measures Used

	Internal Consistency 3 years Old	Internal Consistency 4 years old	Test-Retest Reliability 3 years old	Test-Retest Reliability 4 years old
WPPSI-III				
Block Design	.84 (all ages)		2:6-3:11: .9	4:0-5:5: .5
Information	.88 (all ages)		2:6-3:11: .3	4:0-5:5: .9
FSIQ (prorated)	.713	NA	.919	NA
CELF-P2				
Core Language	3:0-3:5: .91 3:6-3:11: .91	4:0-4:5: .93 4:6-4:11: .93	.92	.89
Receptive Language	3:0-3:5: .91 3:6-3:11: .92	4:0-4:5: .94 4:6-4:11: .91	.92	.95
Expressive Language	3:0-3:5: .93 3:6-3:11: .92	4:0-4:5: .94 4:6-4:11: .94	.95	.92
WJ-III				
Sound Blending	NA	NA	.93	.90
NEPSY				
Word Generation (Semantic total score)	.59	.59	NA	NA
Oromotor Sequences	NA	NA	NA	NA
Affect Recognition	.80	.68	.58	.58
Speeded Naming (Combined scaled score)	.93	.93	NA	NA

Note: NA = Not Available

Table 3
Group Comparison of Demographic and Sociofamilial Characteristics

Characteristics	Gestational Age ≤ 30 weeks n = 25	Gestational Age >30 weeks n = 22
Adjusted age (mos.)[a]	44.660 ± 3.478	45.423 ± 3.640
Gender (M:F)[b]	8:17	10:12
Multiples	8[c]	6
Race (W : O)[d]	16:9	15:7
SES[e]	47.580 ± 10.149	49.075 ± 9.154 (20)
Maternal VIQ[f]	100.174 ± 8.892 (23)	103.211 ± 9.449 (19)
Mother's education (yrs.)	16.400 ± 1.732	16.214 ± 1.488 (21)
Father's education (yrs.)	14.960 ± 2.010	15.545 ± 2.262

Note. All differences n.s.
Frequencies are reported for discrete data, means and standard deviations for continuous data. Group differences examined via *t* test (continuous data) or 2 X 2 χ^2 with Yates correction (discrete data). In the case of missing data, number of subjects used in calculating group means and SD's is provided in parentheses.
[a] Adjusted age at first testing session
[b] M=male, F=female
[c] Two participants were twin gestation, with the co-twin passing away around time of birth
[d] W=White, O = Other
[e] Hollingshead's (1975) Four Factor Index of Social Status.
[f] Prorated parental IQ based on three subtests (Vocabulary, Similarities, and Information) of the Wechsler Adult Intelligence Scale-IV (Wechsler, 2008); Testing was completed on the biological mothers in 41 out of the 42 cases.

Table 4
Antenatal Perinatal and Neonatal Factors by Group[a]

Characteristics	Gestational Age ≤30 Weeks n = 25	Gestational Age > 30 Weeks n = 22
Antenatal Factors		
Abruption of the placenta	3 (21)	1
Chorioamnionitis (histological)	8 (24)	4
Diabetes[b]	3	3
HELLP syndrome[c]	2 (22)	0 (20)
Hypertension in pregnancy	9	7
Intrauterine growth (*z*-score)[d]	-0.185 ± 0.566	-0.162 ± 0.657
IUGR diagnosis	5	3
Membranes ruptured >12 hrs[e]	6	5
Mother's age at delivery (years)	33.000 ± 4.072	32.636 ± 3.749
Mother's height (inch)	65.680 ± 2.561	65.409 ± 3.217
Oligohydramnios	1 (14)	1 (15)
Parity	0.360 ± 0.860	0.773 ± 0.813
Smoking during pregnancy[f]	0 (21)	1 (19)
Vaginal bleeding (abnormal)	0 (14)	3 (11)
Total antenatal complications[g]	1.440 ± 0.870	1.091 ± 0.811
Perinatal Factors		
Abnormal presentation[h]	10	9 (19)
Birth weight (g)***	1138.800 ± 321.398	1693.318 ± 226.880
Birth length (cm) ***	37.132 ± 3.616 (24)	42.024 ± 3.000
Birth head circumference (cm) ***	26.039 ± 2.571 (23)	29.548 ± 1.215
Cesarean section	16	19
Forceps	0 (19)	0 (20)
General anesthesia	3 (21)	5 (19)
Gestational age (weeks)[i] ***	28.508 ± 1.893	31.964 ± 0.540
Nuchal Cord	3 (22)	4 (20)
Fetal Tachycardia	0	1
1 minute Apgar*	6.120 ± 1.453	7.182 ± 1.868

5 minute Apgar[*]	8.080 ± 0.812	8.591 ± 0.666
Total perinatal complications[j]	1.280 ± 1.021	1.727 ± 0.985
Neonatal Factors		
Anemia at birth[k]	4	3
Apnea[*]	21	11
Bronchopulmonary dysplasia[*]	6	0
Days in Neonatal Intensive Care[***]	56.560 ± 23.454	23.318 ± 6.282
Hyaline membrane disease[l*]	23	13
Hyperbilirubinemia[m*]	1 (24)	6
Hypermagnesemia	4	2
Hypotension[n]	0	0
Intracranial hemorrhage[o]	5	2
Meconium aspiration	1 (17)	0 (20)
Necrotizing enterocolitis[p]	0	0
Patent ductus arteriosus[q *]	10	2
Peak bilirubin (mg/dl)[***]	8.392 ± 1.689	11.032 ± 1.651
Persistent pulmonary stenosis	1	0
Pneumothorax	0	0
Retinopathy of prematurity[r]	4	1
Sepsis (initial or acquired)[s]	1	0
Thrombocytopenia	2	0
Total neonatal complications[t ***]	3.320 ± 1.574	1.818 ± 1.053
Total complications [*]	6.040 ± 2.590	4.636 ± 1.649

$^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$
Note. Frequencies are reported for discrete data, means and standard deviations for continuous data. Group differences examined via *t* test (continuous data), 2 X 2 χ^2 with Yates correction (discrete data), or Fisher exact probability test (less than five cases per cell). In the case of missing data, number of subjects used in calculating group means and SD's is provided in parentheses.

[a]All comparisons between ≤30 weeks and >30 weeks Gestational Age groups.
[b] Includes both gestational diabetes and diabetes mellitus.
[c] Hemolysis, elevated liver enzymes and low platelets.
[d] A *z*-score expressing the deviation of an infant's birth weight from the mean weight of his/her gestational age group, at delivery, according to norms published by Kramer et al. (2001).

[e] Time from spontaneous or artificial rupture of membranes to delivery.
[f] Smoking behavior: >30 Weeks Group: 1 case < 5 cigarettes per day, 3 cases no information. ≤30 Weeks Group: 21 cases no smoking reported, 4 cases no information.
[g] Total antepartum complications includes placental abruption, chorioamnionitis, maternal diabetes, HELLP syndrome, maternal hypertension, IUGR, membranes ruptured >12 hours, smoking during pregnancy.
[h] Includes various atypical presentations such as breech or transverse lie.
[i] As determined by obstetrician; > 95% of cases were corroborated by antenatal ultrasound.
[j] Total perinatal complications include abnormal presentation, C- section, forceps, general anesthesia, nuchal cord, and fetal tachycardia.
[k] Hematocrit < 40 %.
[l] Based on a chest roentgenogram and clinical evaluation.
[m] Peak bilirubin ≥ 12 mg/dl
[n] Requiring treatment
[o] Documented on the basis of cranial ultrasound
[p] Documented by radiographic changes, positive stool guiacs and abdominal distention.
[q] Diagnosed by clinical manifestations and echocardiographic information.
[r] ≤30 weeks group had 2 with Stage 1, 1 with Stage 2, 1 with Stage 3; >30 weeks group had 1 of unknown stage
[s] Established by positive blood culture.
[t] Total neonatal complications includes anemia, apnea, hyaline membrane disease, bronchopulmonary dysplasia, hyperbilirubinemia, hypermagnesemia, hypotension, intracranial hemorrhage, meconium aspiration, necrotizing enterocolitis, patent ductus arteriosus, persistent pulmonary stenosis, pneumothorax, retinopathy of prematurity, sepsis, and thrombocytopenia.

Table 5
Antenatal and Neonatal Diagnostic and Intervention Procedures by Group[a]

	Gestational Age	
Diagnostic and intervention procedures	≤ 30 Weeks n = 25	> 30 Weeks n = 22
Antenatal magnesium sulfate[b]	16	9
Antenatal steroids [c]	22	22
Antenatal steroid doses	1.640 ± 0.700	1.864 ± 0.351
Hypertension medications (m)	6 (21)	7 (20)
Neonatal cranial ultrasound	25	19
Neonatal steroids	0	0
Surfactant administration	11	3
Days respiratory support [d] ***	37.240 ± 39.462	1.909 ± 2.408
Days ventilation	7.280 ± 16.960	0.318 ± 0.646
Highest percentage O_2 *	50 ± 26.428 (10)	30.000 ± 12.751 (11)
Home on O_2 *	7	0

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

Note. Frequencies are reported for discrete data, means and standard deviations for continuous data. t-tests were used to test continuous data; 2x2 chi-square with Yates correction were used for discrete data, and Fisher's exact probability test were used for discrete data with less than five cases per cell.
In the case of missing data, number of subjects used in calculating group means and SD's is provided in parentheses.
[a] All comparisons between the ≤30 weeks and >30 weeks Gestational Age groups.
[b] Magnesium sulfate, administered to inhibit preterm labor and/or control seizures in preeclampsia
[c] Betamethasone, to promote fetal lung maturation
[d] Including mechanical ventilation, continuous positive airway pressure (CPAP), nasal cannulae and oxyhood

Table 6
Summary of Simultaneous Multiple Regression Analyses

Index	Source	F	*df*	*p*	R^2 Change[f]
WPPSI-III					
FSIQ[c]	Gestational Age	.00	1,37	.953	
	Growth rate (*z*-score)	.05	1,37	.824	
	Sex	.95	1,37	.336	
	Multiple Gestation	.02	1,37	.898	
	Total Complications	.15	1,37	.706	
	Socioeconomic Status	.84	1,37	.365	
Block Design[c]	Gestational Age	.02	1,37	.899	
	Growth rate (*z*-score)	.65	1,37	.425	
	Sex	.00	1,37	.981	
	Multiple Gestation	.31	1,37	.582	
	Total Complications	.79	1,37	.379	
	Socioeconomic Status	.09	1,37	.763	
Information	Gestational Age	.03	1,38	.869	
	Growth rate (*z*-score)	1.24	1,38	.273	.03
	Sex	3.34	1,38	.075	.07
	Multiple Gestation	.20	1,38	.656	
	Total Complications	2.75	1,38	.106	.06
	Socioeconomic Status	1.25	1,38	.271	.03
CELF-P2					
Core	Gestational Age	.00	1,38	.951	
	Growth rate (*z*-score)	.87	1,38	.356	
	Sex	.44	1,38	.512	
	Multiple Gestation	.42	1,38	.521	
	Total Complications	.82	1,38	.370	
	Socioeconomic Status	3.75	1,38	.060	.09
Receptive[d]	Gestational Age	.18	1,36	.672	

Table 6 cont.

Index	Source	F	df	*p*	R^2 Change
	Growth rate (*z*-score)	.13	1,36	.723	
	Sex	.93	1,36	.341	
	Multiple Gestation	1.91	1,36	.176	.04
	Total Complications	.04	1,36	.852	
	Socioeconomic Status	.25	1,36	.620	
	SES*Mult interaction term	1.76	1,36	.193	.04
Expressive	Gestational Age	.00	1,35	.969	
	Growth rate (*z*-score)	.75	1,35	.394	
	Sex	2.26	1,35	.142	.04
	Multiple Gestation	.23	1,35	.637	
	Total Complications	5.32	1,35	.027[b]	.10
	Socioeconomic Status	2.98	1,35	.093	.08
	Adjusted Age	3.74	1,35	.061	.07
Structure	Gestational Age	.00	1,37	.972	
	Growth rate (*z*-score)	.16	1,37	.695	
	Sex	2.20	1,37	.146	.05
	Multiple Gestation	.23	1,37	.634	
	Total Complications	.289	1,37	.596	
	Socioeconomic Status	3.83	1,37	.058	.10
Content	Gestational Age	.09	1,37	.767	
	Growth rate (*z*-score)	.91	1,37	.348	
	Sex	.72	1,37	.402	
	Multiple Gestation	.15	1,37	.699	
	Total Complications	.31	1,37	.579	
	Socioeconomic Status	3.65	1,37	.064	.09
Recalling Sentences in Context	Gestational Age	.40	1,29	.533	
	Growth rate (*z*-score)	.16	1,29	.690	
	Sex	7.67	1,29	.010[A]	.20

Table 6 cont.

Index	Source	F	df	*p*	R^2 Change
	Multiple Gestation	.35	1,29	.556	
	Total Complications	.16	1,29	.695	
	Socioeconomic Status	1.86	1,29	.183	.08
Pre-Literacy Rating Scale	Gestational Age	.03	1,35	.871	
	Growth rate (*z*-score)	.04	1,35	.840	
	Sex	.01	1,35	.942	
	Multiple Gestation	.62	1,35	.437	
	Total Complications	.30	1,35	.587	
	Socioeconomic Status	11.42	1,35	.002[B]	.18
	Adjusted Age	4.61	1,35	.039[b]	.11
Descriptive Pragmatics Profile	Gestational Age	.54	1,36	.466	
	Growth rate (*z*-score)	1.29	1,36	.264	.03
	Sex	.80	1,36	.376	
	Multiple Gestation	2.50	1,36	.123	.06
	Total Complications	.07	1,36	.794	
	Socioeconomic Status	1.08	1,36	.307	
	Adjusted Age	4.50	1,36	.041[b]	.10
WJ-III					
Sound Blending	Gestational Age	2.98	1,28	.095	.09
	Growth rate (*z*-score)	1.61	1,28	.215	.05
	Sex	.18	1,28	.672	
	Multiple Gestation	.06	1,28	.815	
	Total Complications	.28	1,28	.598	
	Socioeconomic Status	3.72	1,28	.064	.12

Table 6 cont.

Index	Source	F	df	*p*	R^2 Change
NEPSY-2					
Affect Recognition	Gestational Age	.13	1,33	.725	
	Growth rate (*z*-score)	.01	1,33	.922	
	Sex	6.70	1,33	.014[a]	.15
	Multiple Gestation	4.33	1,33	.045[a]	.10
	Total Complications	.75	1,33	.393	
	Socioeconomic Status	1.25	1,33	.272	.05
Oromotor Sequences	Gestational Age	.00	1,36	.974	
	Growth rate (*z*-score)	1.38	1,36	.248	.03
	Sex	5.35	1,36	.027[a]	.12
	Multiple Gestation	.43	1,36	.516	
	Total Complications	.12	1,36	.736	
	Socioeconomic Status	.15	1,36	.697	
Speeded Naming[e]	Gestational Age	.01	1,33	.921	
	Growth rate (*z*-score)	.68	1,33	.415	
	Sex	.09	1,33	.769	
	Multiple Gestation	1.63	1,33	.210	.04
	Total Complications	1.13	1,33	.295	.03
	Socioeconomic Status	6.25	1,33	.018[a]	.16
Word Generation	Gestational Age	.17	1,34	.686	
	Growth rate (*z*-score)	2.01	1,34	.165	.05
	Sex	1.87	1,34	.180	.05
	Multiple Gestation	2.04	1,34	.163	.05
	Total Complications	.18	1,34	.672	
	Socioeconomic Status	.00	1,34	.964	

[a] significant at the .05 level or [A] significant at the .01 level, when sex, multiple gestation, total complications, and SES are used as covariates in a multiple regression analysis.
[b] Significant at the .05 level or [B] significant at the .01 level, when adjusted age at testing (in addition to sex, multiple gestation, total complications, and SES) used as a covariate in a multiple regression analysis.

[c]A single multivariate outlier with a studentized residual of >3 was identified by SYSTAT and removed prior to statistical analyses.
[d]Significant interaction between SES and multiple gestation entered into a multiple regression analysis (along with sex, multiple gestation, total complications, and SES).
[e]Two multivariate outliers with studentized residuals of < -3 were identified by SYSTAT and removed prior to statistical analyses
[f] R^2 Change reflects the increase in R^2 of the GLM model when that specific predictor was added to the analysis

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ABSTRACT

LANGUAGE DEVELOPMENT AMONG PRESCHOOL AGE CHILDREN BORN PREMATURELY

by

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August 2013

Advisor: Dr. Sarah Raz

Major: Psychology (Clinical)

Degree: Master of Arts

Premature birth has been shown to be associated with various deficits in neuropsychological functioning during early childhood; however, few studies have attempted to understand the variables that contribute to variability in performance among children born prematurely. The purpose of the current study was to investigate the relationships between specific perinatal factors and language and cognitive outcome measures in a group of preschool-aged children born prematurely (N=47). As predicted, there were significant relationships between sex and specific outcome measures, with boys performing more poorly than girls; however, contrary to hypotheses, significant relationships failed to be found between outcome measures and both gestational age and intrauterine growth rate. The overall implications of these findings for the development of preschool-aged children born prematurely are discussed.

AUTOBIOGRAPHICAL STATEMENT

Brittany Peters was raised in Fenton, Michigan. She moved to Chicago following high school to attend college at Loyola University Chicago. She initially intended to major in biology, but ended up developing an interest in psychology, and in particular, brain-behavior relationships (neuropsychology). She was involved with various faculty-led research projects while at LUC, and also conducted an independent project on the visual processing of words with Dr. Anne Sutter. She graduated from Loyola in May 2010, with a Bachelor of Science in Psychology.

Brittany returned to Michigan in August of 2010 and enrolled at Wayne State University, where she is a clinical psychology graduate student with an emphasis on child neuropsychology. She works with Dr. Sarah Raz. In this lab, she has been conducting research aimed at gaining a better understanding of the effects of premature birth on early development. In regard to clinical work, she has conducted assessments as well as both individual and group psychotherapy at the Wayne State Psychology Clinic. Brittany is a practicum student at the Children's Hospital of Michigan, under the supervision of Dr. Robert Rothermel, where she conducts neuropsychological assessments with children who suffer from a variety of neurological conditions. She plans to graduate with her Master of Arts in Clinical Psychology from Wayne State University in August of 2013.