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The relationship between preterm birth and academic achievement among diverse early-life lingual environments

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By

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B.S., University of Arizona, 2017

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An abstract of
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Abstract

The relationship between preterm birth and academic achievement among diverse early-life lingual environments

By Emily Judson

Objective
Early cognitive development is an important predictor of children's academic success as well as their health and life accomplishments. There is evidence that preterm birth is associated with cognitive development. However, the effect of early-life lingual environment on cognitive development is mixed. To our knowledge, there has been no examination of the combined effect of preterm birth and lingual environment. In this analysis, we aim to understand the independent effects of gestational age (GA) and lingual environment on cognitive outcomes, as well as the interaction of the two.

Methods
Data from the Early Childhood Longitudinal Study, Birth Cohort (ECLS-B) were used. We examined kindergarten reading and mathematics scale scores for 3,814 children born in 2001. Linear regression was used to understand the independent and joint effects of GA and lingual environment on cognitive development, using academic achievement as a proxy.

Results
Main effects of GA were associated with cognitive outcomes in all models. After adjusting for covariates, main effects of lingual environment were not associated with cognitive outcomes. The linear regression models indicated that when adjusting for household socioeconomic status, child race/ethnicity, and maternal education and maternal age at delivery, there was no evidence of interaction between preterm birth and early-life lingual environment, except among early preterm children.

Conclusion
This analysis provides evidence of the association between preterm birth and cognitive development. Further research is needed to understand the factors that are creating the disparity in cognitive development between children born preterm compared to those that are not. These results will help inform educators and policymakers that household language is not the driving force of academic achievement.

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Introduction and Literature Review

Childhood cognitive development, which is often proxied by academic achievement, is an important public health outcome. Though cognitive ability has been shown to be influenced by children's physical health and genetics, the malleability of cognitive development can be explained by the magnitude of environmental or social differences.[1] More specifically, research suggests that factors influencing cognitive development include gestational age, maternal age, socioeconomic inequality, parental education success, and overall parenting.[2–4] Early childhood cognitive development is important for predicting educational success, which in turn predicts adolescent and adult health outcomes and accomplishments later in life.[5] Therefore, childhood cognitive development is imperative to understand because it is an early-life modifiable social determinant of health.

Public health action on children's cognitive development is necessary, but does not come without challenges. As mentioned, research suggests that development is influenced by aspects of environmental and social disparities. However, challenges arise when identifying specific risk factors for poor developmental trajectories. An additional challenge includes identifying populations with the highest prevalence of these risk factors in order that early intervention might be targeted.

Researchers have hypothesized predictors of cognitive development. One hypothesis is that children born with shortened gestation (i.e., preterm birth; < 37 weeks) are at an increased risk for neurodevelopmental consequences, compared to children born full term (i.e., 39-40 weeks).[6–9] As early childhood cognitive development is often proxied by academic achievement, evidence indicates that children born preterm have lower mathematics and reading scores at kindergarten.[4]

Another hypothesized predictor of childhood cognitive development is early-life lingual environment. Early-life lingual environment involves the language(s) children are surrounded with and speak in the home and at school, and can be described by children's bilingual status. However, there is no standard definition in the literature for the term "bilingual", irrespective of the outcome being studied. Some researchers define bilingual as speaking two languages, such as English and Spanish.[10–12] However, other researchers define bilingual more broadly, as a non-English language being the primary household language.[13–15] To our knowledge there is no research in the U.S. using the latter definition of bilingual to determine the effect of children's cognitive development.

From literature based on the first definition of bilingual, evidence of the association between early-life lingual environment and cognitive development is mixed. One hypothesized explanation is that children living in monolingual households and children living in bilingual households are equivalent in terms of academic achievement.[10,12] Although measured at different ages, researchers who came to this conclusion simply studied children's core vocabulary production. On the other hand, some researchers conclude that children with two bilingual parents are more likely to have poorer academic outcomes, compared to monolingual English children.[11] Researchers who support this conclusion suggest that more English language spoken in the home contributes to greater English language skills, which further enhance academic performance. Further, and seemingly contrary to these aforementioned conclusions, some researchers have also demonstrated that bilingual children outperform monolingual children in cognitive assessments.[16] The previous two hypotheses may be explained by the ages in which the children were measured. Researchers who discovered a deficit among bilinguals measured children who were 2-4 years old, while researchers who discovered a deficit among monolinguals measured children at eight years old. This may be explained by the early deficits that bilingual children accrue as they navigate two languages, but later accelerate. It is important to understand the relationship between early-life lingual environment and academic achievement because children's cognitive abilities are important determinants of accomplishments later in life.[5] Research has concluded that children born preterm are already at an academic disadvantage.[6–9] As most schools in the U.S. are English-based, preterm children who grow up in a non-English environment may have an increased burden of a language barrier, thus being further academically impaired.

While there is evidence supporting an association between preterm birth and cognitive development, there is a lack of evidence on the role of early-life lingual environment on development. There is also room to further our understanding on how preterm birth and lingual environment may interact to influence childhood cognitive development. Within this study, I will aim to investigate whether the association between preterm birth and academic achievement differs between various diverse lingual environments among children at kindergarten age in the United States, using an analytic observational study design.

Cognitive Development and Academic Achievement

Children's cognitive development is an important determinant of school-readiness and academic achievement as well as accomplishments later in life.[5,17] School-readiness involves the skills that children need in entering school in order to fully benefit from educational experiences.[18] Cognitive abilities and school readiness are primarily measured through academic assessments.[17] As development is not fixed, but in fact is a malleable process, it is largely influenced by social and environmental factors, including children's overall health and familial elements. Cognitive development involves children's physical, behavioral, and social development. Research has suggested that the most critical period for intellectual and language development is from 0 to 3 years of age.[19] In the 2011-2012 National Survey of Children's Health, 26% of children ages 0-5 were at risk of developmental delays.[20] In the same survey, 40% of parents reported concerns about their child's development.[20] This emphasizes that early cognitive development is vital and is a relevant concern in the United States.

Social and Environmental Disparities of Development.

There are notable social and environmental disparities that affect development, thus leading to worse academic outcomes. Disparities that may affect cognitive development include household socioeconomic status, parental educational success, and overall parenting.[19,21]

Children residing in economically disadvantaged households are at an increased risk for lack of school readiness.[18] School readiness is partially affected by early language development. Early language development plays a critical role in children's overall cognitive development. Researchers have found that more advantaged children are exposed to five times more words by age four compared to those on welfare assistance.[19] As these children from lower socioeconomic areas enter school already at risk, they also have the additional increased risk of receiving poorer education. Research shows that higher quality preschool education predicts greater English and mathematics scores later in children's academic careers.[19] A study that assessed children at age eight found that those from backgrounds of low socioeconomic status were less likely to obtain a grade of a B or higher. Researchers from this study also found that children who attended fee-paying or private schools performed better when compared to their peers at public schools.[22] In an effort to reduce this significant disparity and improve school outcomes, U.S. policies including the Elementary and Secondary Education Act and the No Child Left Behind Act were initiated in 1965 and 2001, respectively.[23] However, since the implementation of these policies, socioeconomic inequality is still a relevant disparity for educational achievement.

In addition to household socioeconomic level, disparities in parent's educational attainment and success also affect children's cognitive outcomes. It is likely that on average, more children residing in an economically disadvantaged home also have parents with lower attained education.[18] Sylva et al. report that maternal education has the greatest effect on their offspring during early years of development.[19] Parental educational success is a strong predictor of their children's academic success and achievement. Maternal education of high school or less has been associated with lower cognitive abilities in offspring.[24,25] A study conducted in the UK measuring children's academic abilities at high school age found that students with parents who had a college degree scored higher on the UK standardized test for further education or employment.[19]

Studies are relatively consistent in their finding that parenting is a strong predictor of children's cognitive development and educational success. Overall parenting includes providing academic enrichment opportunities to their children, including activities such as theater or science museum outings.[19] Additionally, parents actively reading to children and using complex language is associated with improved development.[26] Parenting is influenced by poverty and parents in poverty are less able to provide intellectually stimulating environments. Research suggests that parents with more intellectually stimulating jobs provide more support and cognitive stimulating materials to their children. As a result, these stimulating materials are shown to improve children's verbal skills and thus their overall cognitive development.[23]

As there are many factors that may determine children's development, socioeconomic status, parental educational attainment, and overall parenting are among the social disparities taking the biggest toll.

Early Development Predicts Educational Success.

Overall early development is an important predictor of school readiness, and school readiness is an important predictor of academic achievement. Lower academic achievement is influenced by preschool cognitive abilities.[27] Recent reports indicate that only about half of eligible children in the U.S. are enrolled in preschool.[28] Those children who miss the opportunity to attend preschool are already at a disadvantage for school readiness, thus placing them at an increased risk for a gap in academic achievement. Children who begin school later are unlikely to ever be able to achieve the same academically as their peers.[28] Preschool cognitive ability is not the only predictor of later academic achievement. A recent study in the UK determined a relationship between cognitive abilities at age eight and educational achievement at age sixteen.[22] This provides evidence that steps taken to enhance early cognitive development could make a difference in academic attainment and success.

Research suggests that early cognitive development is an important determinant in the educational choices an individual makes.[5] Conti and Heckman demonstrate that academic abilities that develop by age ten are important determinants of health outcomes by age 30.[5] For instance, children who attain lower academic achievement were more likely to smoke, become obese, and have poor overall health in subsequent years.[5] Cognitive ability which is measured by academic achievement largely develops in early life years. This is a modifiable factor that can be altered in order to reduce future negative health and academic outcomes.

Predictors of Cognitive Development

There are many factors that may influence cognitive development, including children's physical health and genetics as well as social and environmental differences. This study will explore the interacting roles of two distinct hypotheses. The first premise is well studied by researchers and posits that gestational age largely influences cognitive development, especially in children's early years. The second hypothesis is not as well established and has varying conclusions. This theory mentions that children's early-life lingual environment plays a role in influencing development.

Preterm Birth.

The World Health Organization (WHO) defines preterm birth as birth before 37 completed weeks of gestation. More specifically, births that take place between 24-27 weeks are typically classified as early preterm, 28-33 weeks as preterm, and 34-36 weeks as late preterm.[29] Worldwide, preterm birth is the most common cause of neonatal mortality.[3] In the United States, preterm birth is a persistent concern with about 10% of children born preterm.[30] Children who are born preterm are at an increased risk for short and long term complications, including delayed cognitive development and lower academic achievement.[9,31] About one-third of all infants born preterm have some sort of cognitive impairment.[3]

There are certain risk factors for preterm birth that have been previously established by researchers, including maternal education, maternal age, socioeconomic status, and race and ethnicity. Maternal education is often a proxy for socioeconomic status. Researchers studying the effect of maternal education on preterm birth found that mothers with higher education had lower rates of preterm birth.[32,33] One study in particular determined a preterm birth rate of 7.9% for mothers with no high school diploma versus 4.9% for mothers with a post-graduate education.[32]

A similar study in Europe found the relative risk of preterm birth to be 48% higher for low maternal education compared to higher maternal education.[33] It is also important to note that child cognitive development is partially related to genetics, which is proxied by maternal education. Therefore, it is unclear whether maternal education is a confounder, mediator, or exposure in the relationship between preterm birth and cognitive development.

Maternal age is also a significant predictor of preterm birth, with women at the tail ends of the curve being at the greatest risk.[34,35] A study looking at the risk of preterm delivery concluded that mothers less than 16 years had a two-fold increased risk of delivering preterm when compared to women aged 18-29.[36] Similar findings were found in a study conducted in Brazil. Researchers found a 70% increased risk of preterm birth for women less than 18 years when compared to women aged 25-29.[37] Researchers determined that this increased risk is likely due to the biological immaturity among younger mothers.[36] Women who give birth at older ages are also at an increased risk for having a child born preterm. A retrospective study in Washington State concluded that women aged 40 or older had an 80% increased risk for preterm birth when compared to those aged 20-24.[38]

Women classified as being of lower socioeconomic status are at higher risks for having children born preterm. Socioeconomic status is typically determined in epidemiologic research studies through a combination of education, income, and occupation. Individuals classified as being of low socioeconomic status reside in areas of high unemployment and poverty, have low education, and poor housing. A study measuring area-based socioeconomic status and using U.S census data reported that cities in which 25% or more of the population lives below the poverty line have the highest rates of preterm birth.[39] A study conducted in the UK used the Child Poverty Index to measure socioeconomic status. This was based off of the percentage of children under age 16 residing in low-income families. Researchers discovered that the incidence of very preterm births increased with increasing deprivation. More specifically, mothers giving birth in the most deprived area were at a 94% higher risk for giving birth to a very preterm infant, compared to those in the least deprived area.[40]

Another large predictor of preterm birth is maternal race and ethnicity. Non-Hispanic Black mothers have the highest rates of preterm birth.[30] Researchers in a study adjusted for education and came to a comparable conclusion. Specifically, Black college graduates had 67% higher risk for preterm birth compared to white college graduates.[41] This highlights that the racial disparity is not solely from racial differences in socioeconomic status, which is proxied by maternal education, because even for college graduates, the disparity persists. Similarly, another study found that mothers of African-American background had an increased risk for preterm birth, while women of Asian descent had a protective effect.[42] As there are many risk factors affecting preterm birth risk, maternal education level and age, socioeconomic status, and race or ethnicity stand out as predominant influences.

Delayed cognitive development is an important consequence of preterm birth. Since children born prematurely are born less than 37 weeks' gestation, gray and white brain matter does not fully develop, ultimately placing children born preterm at a risk for neurodevelopmental delays.[43] Throughout preterm born children's lives, neurodevelopmental delays can impact cognitive abilities and behavior (e.g., attention and activity disorders), thus creating a greater likelihood of learning difficulties.[3,7] Delayed cognitive abilities may also persist throughout preterm children's lives. Children who are born preterm tend to have a smaller brain size and less overall brain matter, potentially affecting their IQ scores, language development, memory, motor skills, and executive functioning.[8,43]

Many studies have assessed cognitive development through educational achievement among children born preterm and compared that to those born full term. In a study using the Early Childhood Longitudinal Study, Birth Cohort (ECLS-B), it was found that kindergarten children born preterm are approximately 0.1 to 0.6 and 0.1 to 0.4 standard deviations lower than full-term born children in the areas of mathematics and reading, respectively.[4] Developmental issues are even more apparent for children born early preterm (i.e. <28 weeks). In a cohort study conducted in Ohio, researchers measured academic achievement in early preterm born children and compared them to full term born children. They found that early preterm children scored lower overall on spelling and applied problems. Additionally, this group of children had lower ratings of writing and mathematics learning progress, as indicated by their teachers.[44]

As children born early preterm have the most developmental issues, there is also concern for children born preterm and late preterm. A systematic review that evaluated the child development from ages 1 through 7 found that when compared to full term born children, those born late preterm (i.e., 34-36 weeks) were still at an increased risk for neurodevelopmental delays and poorer academic achievement. However, when late preterm children were compared to preterm and early preterm, those born late preterm performed better overall.[45]

Not only can preterm birth take a toll on children's health and development, but it also brings about economic concerns for families as well as society. In 2005, the economic burden associated with preterm birth care in the U.S. was over $26 billion, and has presumably grown with the rising preterm birth rate.[46] Many children born preterm undergo early intervention strategies. The annual estimated cost of this is $857 per infant across all gestational ages. However, children born 24 to 31 weeks' gestation produced the highest intervention costs at $5,393 per infant.[47] The economic burden as well as the health and cognitive development implications of preterm birth provide reason for developing strategies to reduce the incidence of preterm birth.

Early-life lingual environment.

Approximately 22% of children in the United States speak a language other than English at home.[48] The lingual environment that a child is born into and resides in may influence their cognitive development and overall academic achievement. The effect of language environment on academic achievement has largely been studied through children's bilingual status. As previously mentioned, there has not been an established standard definition of bilingual used in literature. Though research to-date that examines the association between language environment and cognitive development define bilingual as children speaking two languages, this study will apply the broader definition of children's primary household language (i.e., English versus non-English).

Most bilingual children in the U.S. are sequential bilinguals, meaning they learn their first language at home and their second language at school.[49] Many children who speak a language other than English in the U.S. are immigrant children or children of immigrant parents. As most schools in the U.S. are English-speaking, many non-English speaking children are forced to assimilate into this linguistic culture. Some researchers suggest that this forced assimilation predicts the lower academic achievement and higher dropout rates observed among this population.[50] However, other researchers propose that an early bilingual environment sets children up for developmental delays since they are overloaded by learning two languages.[49]

Though research may not coincide, the U.S. federal government has recognized the needs of children with limited English-speaking abilities. In an attempt to relieve issues of language differences, federal acts have been implemented. For instance, the Bilingual Education Act of

1967 encouraged school districts to fund new programs that targeted low-income and non-English speaking children. This act implemented what is called, "transitional bilingual education" in which part of the classroom instruction was in the children's native language, with the goal of easing children into the conventional schooling system.[50] Although this act exists, research varies, with some suggesting that assimilating children into an English-only environment is not beneficial for cognitive development.[16]

As evidence is mixed, some researchers suggest that bilinguals have cognitive benefits over monolinguals.[16] A prospective cohort study was conducted that aimed to assess whether bilingual proficiency growth, measured through translation equivalents (TE's), improves executive function over a seven-month period beginning at 24 months. Researchers found that an increase in TE's within the bilingual group of children predicted greater executive function, including better performance on conflict tasks.[51] Another study that concluded similar findings assessed bilingual children at seven months and matched them with monolingual children. Researchers found that when words were played aloud, the bilingual infants had better overall cognitive control abilities, even in this preverbal stage.[52] As these studies assessed children's cognitive abilities at different ages, a review of U.S. studies notes that benefits of bilingual environment are largely seen from two to six years old, with some reporting benefits at seven months. This review presents conflicting study results, but mentions some studies that state that children who speak two languages have potential for cognitive benefits, while those only exposed to and not speaking both languages are at risk for cognitive consequences.[53]

On the other hand, some researchers conclude that children who are exposed to and speak English in the home have better cognitive outcomes. A longitudinal study identified the change in vocabulary from two to four years and vocabulary achievement at four years among children with one Spanish-speaking parent, two Spanish-speaking parents, or English-speaking parents (i.e., monolingual). Researchers concluded that although bilingual children with two Spanish-speaking parents had a faster rate of acquiring vocabulary in both languages, these children had a smaller English vocabulary than monolingual children or those with one native Spanish-speaking parent. The greater amount of English in the home predicted greater English vocabulary scores. From these results, authors recommended that school readiness can be optimized by providing children access to English speakers early in life.[11]

Alternatively, other researchers conclude that the early lingual environment does not affect cognitive development. A study conducted in Pennsylvania assessed bilingual mothers and children beginning at four years old who attended an English immersion program. Vocabulary and emergent literacy development assessments were conducted for two years at Head Start and at kindergarten. While the authors found that children's vocabulary and literacy abilities increased during Head Start, there were no significant changes in kindergarten when analyzing within-child differences. Authors also found that changes in children's household lingual environment from their mothers attending the English immersion program did not have an effect on cognitive development.[54] Another study conducted in Canada assessed children with a mean age of 5.5 years who spoke just French, French as a primary language and English as secondary, or vice versa. When measuring the children's vocabulary, it was found that all groups of children use the same core words in French, meaning there was no important difference.[12] A third study looked at the comprehension and vocabulary production in monolingual Dutch and bilingual Dutch and French children at 13 and 20 months. Researchers found that both monolingual and bilingual children understood and produced the same amount of word meanings.[10]

Though there are varying findings on the effect of early-lingual environment on children's cognitive development, there are possible explanations to this difference. Based on the studies mentioned, one possible explanation is the particular languages and the quantity of languages that were assessed. It is assumed that some languages are inherently more difficult, and thus produce different measures. For instance, Kovacs et al. looked at monolingual Italians and a variety of bilingual combinations with Italian, while Hoff et al. only studied children English and Spanish.[11,52] Another explanation to these differences may point to the age at which the cognitive outcomes were measured. In particular, the studies mentioned ranged from assessing children at 7 months to 5.5 years. This age difference also yields another possible explanation- understanding how cognitive abilities were assessed. While Kovacs and Mehler measured preverbal children, they identified infants anticipatory looks to auditory cues.[52] Alternatively, studies that assessed children at older ages measured their vocabulary production.[10–12,54] Lastly, all studies noted included a sample size of less than 100. With a small sample size, the power is smaller and it is more difficult to detect a difference and draw conclusions on the associations.

As evidence regarding the effect of early-life lingual environment of cognitive development varies, there is room for further research. With greater research in this subject area, interventions targeted towards the specified lingual environment group can be created to optimize children's school readiness, and ultimately their academic achievement.

Purpose

Early-life lingual environment, preterm birth, and early childhood development outcomes are important and relevant public health concerns. From previous research, it has been well established that being born preterm leads to negative cognitive outcomes. However, research has not provided any set conclusion on the impact of early-life lingual environment on the association between preterm birth and cognitive development.

While there is substantial evidence linking gestational age and cognitive outcomes, there are no current studies, to our knowledge, that assess the interaction of gestational age and early-life lingual environment on cognitive outcomes. As researchers, we do not fully understand the mechanisms for the association between preterm birth and cognitive development, and certainly not for diverse early-life lingual environments and development. Assessing gestational age and early-life lingual environment together can inform about possible etiologic pathways of one or the other. This analysis aims to address the following questions:

1. What are the independent effects of preterm birth and early-life lingual environment on cognitive development among kindergarten children born in the United States?
2. To what degree, if at all, does early-life lingual environment (i.e. English versus non-English as primary household language) modify the relationship between preterm birth and cognitive outcomes among kindergarten children born in the United States?

In answering this research question, we anticipate to leverage findings to improve public health outcomes and provide new insight and implications for research. Understanding the interaction between early-life lingual environment and preterm birth will assist in developing and implementing public health interventions, such as tailoring preschool to optimize development, aimed towards the population at risk for worse cognitive outcomes. Through this knowledge, we hope to decrease the prevalence of low cognitive outcomes and provide a basis for future research.

Methods

Study Sample

This study analyzed data from the Early Childhood Longitudinal Study, Birth Cohort (ECLS-B).[55] This is a nationally representative study of approximately 10,700 children born in the United States in 2001. This population-based longitudinal study collected information on children's health, development, care, and education from nine months to kindergarten. Oversampling of Chinese, Asian and Pacific Islanders, American Indian and Alaska Native children, twins, and children with low and very low birth weights took place. Data were collected based on stratified, clustered sampling of 2001 birth certificates and followed longitudinally. Data were collected in 5 waves: when children were nine months (2001-2002), two years (2003-2004), four years (2005-2006), and kindergarten (2006-2008). Collection at kindergarten accounted for waves four and five. Due to a wide range of the children's birthdays, 75% began kindergarten in the fall of 2006. The other 25% included children in the cohort who began kindergarten in the fall of 2007 due to later birthdates or who were repeating kindergarten.

Figure 1 outlines the children included in our final sample. For this analysis, we only included children in the ECLS-B dataset that were followed to kindergarten (n = 6,856) and had reported reading and mathematics scores at kindergarten (n = 6,683). We also excluded children who were a part of a multiple birth (n = 1,277), were born with a congenital anomaly (n = 255), had a missing birthweight or gestational age (GA) value on their birth certificate (n = 946), fell outside of 24-40 weeks' GA range, or if the birth weight on the birth certificate was improbable for GA based on national reference cutoffs (n = 379).[56] Considering language as a potential modifier of the association between GA and cognitive development, we also excluded children who did not have a primary language at home recorded at two years old (n =12). The final sample size included for analyses after exclusions, was 3,814.

Figure 2 shows the hypothesized relationships among GA at delivery, primary household language, and cognitive development at kindergarten. Primary household language acts as a potential effect modifier of the relationship between GA at delivery and cognitive development. Hypothesized potential confounders of both the exposure-outcome and modifier-outcome relationship included household socioeconomic status (SES), maternal education, maternal age at delivery, and child's race or ethnicity. Child's age at assessment was used as a control variable due to quick changes in development and associated increases in academic scores.

Exposure: Gestational Age

Gestational age at delivery was collected from birth certificates at the start of the study and measured using the clinical estimate reported on the birth certificate. Gestational age categorizations in this analysis included, early preterm (i.e., 24-27 weeks), preterm (i.e., 28-33 weeks), late preterm (i.e., 34-36 weeks)**,** early term (i.e., 37-38 weeks), and term (i.e. 39-40 weeks).

Outcome: Cognitive Development

Children's cognitive development was measured through their academic achievement. Academic achievement was measured based on children's mathematics and reading skills from ECLS-B evaluations at waves four and five. In this analysis, mathematics and reading scores were assessed from children's first entry into kindergarten. Scale scores were used, which accounted for the number of questions each child would have answered correctly had they been asked all of the scored questions.[55] Academic achievement scale scores ranged from 12.39 to 82.48 for reading, and 11.23 to 69.69 for mathematics.

Covariates

Household SES was measured at wave 1 (i.e., 9 months) using a combined index created by ECLS-B which includes maternal and paternal education, occupation, and household income, and categorized into quintiles.[55] Maternal educational attainment and child's race or ethnicity were also reported from wave 1. The ECLS-B dataset merges data found on the birth certificate to each child. Maternal age as reported on the birth certificate was used in this analysis.

A child's primary household language may have an independent effect on development, or may modify the anticipated effect of GA in this study. The primary language at home was recorded when the child was 2 years old (i.e., second wave) in this study. Primary household language was recorded at 2 years old because research has shown that early language exposure predicts future academic outcomes.[19] The categorization includes 1) English as the primary household language and 2) a language other than English as the primary household language.

Statistical Analyses

In order for the results to be representative of children born in the United States in 2001, ECLS-B data uses sample weights. These weights sum to the population of children born in the United States in 2001 and account for nonresponse and loss to follow-up. At each round of data collection, multiple weights are provided. The appropriate sample weight, WKRO, was applied in this analysis and adjusted for nonresponse at kindergarten. This weight corrects the kindergartener's selective loss as well as non-response.

Frequencies and percentages of GA categories and covariates were calculated by the primary household language categorization for our sample (Table 1). To understand the joint distributions of GA and primary household language, mean reading and mathematics scale scores were computed (Table 2). Linear regression was used to estimate the differences in scores.

In addition to the crude, three adjusted models were fit. The first estimated the association between GA (full term = referent) and primary household language with cognitive development while controlling for children's age at assessment. The second model controlled for children's age at assessment as well as household SES, maternal education, maternal age at delivery, and child race/ethnicity. The third model controlled for the same covariates while allowing for interaction between GA and primary household language (Table 3).

This study was approved by the Emory Institutional Review Board. All analyses used SAS, version 9.3 statistical software (SAS Institute, Inc., Cary, North Carolina). As per the National Center for Educational Statistics guidelines, all unweighted counts were rounded to the nearest 50.

Results

Of the 6,856 children who were followed to kindergarten, 3,814 were eligible for this analysis after further exclusions. The composition of the analytic sample included 85% of children who spoke English as their primary language at home and about 15% who spoke a language other than English as their primary language at home (Table 1). Approximately 8% of the sample was born preterm (i.e., early preterm, moderate preterm and late preterm) and another 29% was born at early term. Fewer than 0.4% of children were missing any information for covariates, including child race and ethnicity and maternal education.

The distributions of gestational age (GA) and maternal age were similar among both language categories. In the total sample, the highest proportion of mothers gave birth between ages 25 and 29 (26.4%), 20 and 24 (25.4%), and 30 and 34 (23.7%). A larger proportion of individuals in the non-English category fell in the lowest socioeconomic index (33.3%), compared to the English category (14.3%). The highest proportion of mothers in the non-English sample received less than a high school education (35%) or reached high school graduation (30.2%). In comparison, in the English sample, highest proportion of mothers had some college (30.3%) and were high school graduates (28.8%). A majority of the children who spoke a primary language other than English at home were majority Hispanic (76%).

Weighted average mean reading and mathematics scale scores of the total sample were 44.3 (range: 12.39-82.48) for reading, and 44.3 (range: 11.23-69.69) for mathematics (Table 2). Distribution of reading and mathematics scale scores were similar across GA categories. Lower GA was associated with lower academic scores at kindergarten for both English and non-English primary household languages. Children who spoke a primary language other than English at home had lower average academic scores for both reading and mathematics.

When only adjusting for age at kindergarten assessment, preterm birth and non-English primary household language were each independently associated with lower academic achievement at kindergarten. There was no association found between primary household language and academic achievement when controlling for additional covariates (i.e., SES, child race/ethnicity, maternal education and age). When controlling for primary household language and age at assessment, there was an association found between preterm birth and achievement. Children born preterm scored 2-7 points lower in reading and 1-8 points lower in mathematics than children born full term (Table 3). In fully adjusted models, there was an association found between children born early preterm and lower reading scale scores. There was also an association between children born early preterm and moderate preterm and lower mathematics scale scores.

Children from English-speaking families perform slightly better than non-English speaking children at every gestational age, except for early preterm. For instance, English-speaking children born moderately preterm performed 0.67 (95% CI: -8.9, 7.5) points higher in reading than non-English speaking children in the same gestational age category (Table 4). The additive interaction between GA and primary household language did not show a significant change in academic outcomes (Figure 3). The differences of mean reading scale scores among English versus non-English speaking children were not significant within each GA category. The difference in the mean mathematics scale score between English and non-English speaking children within early preterm children was significant (95% CI: -14.4, -1.4). Differences in the mean mathematics scale score were not significant for all other GA categories, including moderate preterm, late preterm, early term, and full term. Though insignificant, larger differences were seen for reading scale scores compared to mathematics scale scores among all GA categories, with the exception of children born late preterm.

Discussion

After adjusting for household socioeconomic status, child race/ethnicity, and maternal education and maternal age at delivery, lower gestational age was associated with deficits in children's reading and mathematics academic achievement at kindergarten. However, the main effect of primary household language was not significantly associated with academic outcomes in adjusted models. Our results suggest that primary household language does not modify the association between preterm birth and achievement outcomes when the two factors are considered together. One explanation of this result may be that there are additional unmeasured factors that confound the relationship. Another possible explanation is that children born preterm who reside in households in which the primary language is not English may receive extra assistance in school to aid in their development. Additionally, it is possible that there is simply no association.

To our knowledge, this analysis is the first to evaluate the interaction between preterm birth and early-life lingual environment, in their associations with cognitive development, proxied by academic achievement. Prior studies on the association between preterm birth and cognitive outcomes indicate that children born preterm have lower overall performance compared to children born full term.[7,9,31,57] Research suggests that age at assessment may alter conclusions on cognitive outcomes. Three studies concluded that preterm birth is associated with lower cognitive abilities when children were assessed at kindergarten, just as we have in the current analysis.[7,31,57] When only adjusting for age at assessment, our analysis showed an association for children born in any preterm category. After further adjustment, being born early preterm was associated with lower reading scores and early preterm and moderate preterm was associated with lower mathematics scores.

Very little research in the U.S. uses the definition of bilingual as a non-English language being the primary household language, to determine the effect of children's cognitive development. One study in which primary language was used to determine achievement, evaluated primary language differences among English-language proficient and English-language learner (ELL) children using the Early Childhood Longitudinal Survey, Kindergarten. Similar to our results, researchers involved in this analysis found that primary language was not a significant predictor of mathematics achievement.[58] Prior studies in which bilingual is defined as speaking two languages, the association between early-life lingual environment and cognitive development are not consistent. This is due to how and what age cognitive abilities are assessed. Studies that assessed the vocabulary outcomes at various ages (i.e., 1-6 years) concluded that mean vocabulary levels were comparable for both monolingual and bilingual children.[10–12] One study that measured executive function at 24 and 31 months concluded that bilinguals had better performance on conflict tasks but not on delay tasks, and monolinguals had higher vocabulary.[51] On the other hand, another study that measured children at 7 months concluded that children raised with two or more languages have greater cognitive abilities.[52] These varying results suggest that additional research is needed in order to understand the relationship between early-life lingual environment and cognitive outcomes.

In our analysis, preterm birth and residing in household in which the primary language is not English were each associated with deficits in academic achievement scores at kindergarten before adjustment. Though the only evidence of additive interaction between the two exposures was seen among early preterm children in mathematics scale scores, each factor had important impacts on achievement.

Strengths and Limitations

As there is a lack of research assessing the interaction between preterm birth and primary household language, this analysis enhances this area of focus. The present study utilized a large, nationally representative sample of U.S. children with rigorous, prospective measurements of cognitive development. Weights were used in this analysis to ensure results are representative of children born in the U.S. in 2001. This sample follows children from 9-months to kindergarten. This population-based sample included an oversample of children born with low birth weight, and diverse socioeconomic and racial/ethnic backgrounds.

It is also important to acknowledge the limitations in this study. We assessed the primary household language from the parent survey at wave 2 (i.e., when the child was 2 years old) since research has shown that early language exposure predicts future academic outcomes.[19] If this variable were assessed at later time periods, our conclusions may have been altered, possibly due to longer emersion in the primary language. We included any language other than English in the Non-English primary household language category. Considering Non-English primary household languages independently may have shifted results. Additionally, measurements for maternal age and gestational age were taken from the birth certificate. By using birth certificates, we are assuming that numbers entered are valid. This assumption may have induced misclassification bias, potentially altering any observed associations. Since the outcome was based off of kindergarten reading and mathematics scores, representation of the children may be disproportional due to lost to follow-up. Though low birth weight infants were oversampled, our sample population only included about 8% preterm children. Additionally, the interaction between gestational age and language may have proved to be significant for early preterm mathematics scale scores due to sparse data.

Future Directions

Since our results suggest that primary household language is not a significant predictor, and children who have non-English speaking parents can still perform well in school. Alongside this, it is vital to inform policymakers and educators that household language is not the driving force of academic achievement.

As this analysis examined the primary household language, it would be beneficial to further explore if and how the primary classroom language is affecting children's academic outcomes alone and in combination with household language. Additionally, future research should explore the effect of primary household language on cognitive outcomes when measured at a later age, such as kindergarten. Future research should also involve studying and understanding the environmental factors that are creating the academic disparity for preterm children. Findings from these future studies would help to understand groups of children, especially preterm children, with the greatest needs and create and implement targeted interventions.

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Tables

Table 1. Characteristics of Singleton Children by Primary Language Spoken at Home, Enrolled in the Early Childhood Longitudinal Study, Birth Cohort (ECLS-B), United States, 2001-2008

Characteristic	Total			English at home		Non-English at home	
	No.[d]	%	SE of %	%	SE of %	%	SE of %
Total	3,800	100.0		85.3	1.1	14.7	1.1
Gestational age [a]							
Early preterm	100	0.3	0.0	0.4	0.0	0.2	0.1
Moderate preterm	250	1.5	0.2	1.6	0.2	1.3	0.3
Late preterm	300	5.7	0.5	5.6	0.5	6.4	1.2
Early Term	1,000	29.1	1.1	29.0	1.1	29.4	2.4
Full term	2,100	63.3	1.1	63.5	1.2	62.7	2.4
Socioeconomic index [b]							
Quintile 1 (lowest)	700	17.1	0.9	14.3	0.8	33.3	3.1
Quintile 2	750	21.1	1.0	19.8	1.1	28.5	2.5
Quintile 3	750	20.8	0.9	21.5	1.0	16.6	1.9
Quintile 4	750	21.0	0.9	22.9	1.0	10.0	1.6
Quintile 5 (highest)	850	20.0	1.4	21.4	1.3	11.6	2.2
Child's race/ethnicity [c]							
White, non-Hispanic	1,550	57.7	2.1	65.9	2.2	10.1	2.3
Black, non-Hispanic	700	15.9	1.4	18.0	1.6	3.6	1.1
Hispanic	650	19.9	1.5	10.2	1.4	76.0	3.3
Asian, non-Hispanic	400	2.0	0.2	0.6	0.1	9.8	1.3
Native Hawaiian or other Pacific Islander	50	0.1	0.1	0.1	0.1	0.2	0.1
American Indian or Alaska Native	100	0.4	0.0	0.4	0.0	0.1	0.0
More than 1 race, non-Hispanic	350	4.0	0.4	4.7	0.5	0.2	0.1
Maternal age group at birth, years							
15-17	150	3.6	0.4	3.4	0.4	4.9	1.1
18-19	300	7.7	0.6	7.7	0.7	7.3	1.3
20-24	1,000	25.4	0.9	26.1	0.9	21.4	2.4
25-29	950	26.4	0.8	26.1	1.0	28.0	2.3
30-34	900	23.7	1.0	23.5	1.0	24.7	2.2
35-39	450	10.9	0.8	10.7	0.8	12.0	1.7
≥40	100	2.3	0.3	2.5	0.3	1.5	0.6
Maternal Education Attainment [c]							
< High School	650	16.7	1.0	13.6	1.0	35.0	3.3

High School Graduate	1,050	29.0	1.0	28.8	1.2	30.2	2.3
Some College	1,050	28.4	1.0	30.3	1.1	17.7	2.3
Bachelors or higher	1,050	25.8	1.4	27.3	1.4	17.1	2.4

Abbreviations: SE, Standard Error

[a] Gestational age at delivery was reported on the birth certificate and categorized as early preterm (24-27 weeks), moderate preterm (28-33 weeks), late preterm (34-36 weeks), early term (37-38 weeks), or full term (39-40 weeks).

[b] The SES Index was created by ECLS-B and includes maternal and paternal education, occupation, and household income

[c] 11 subjects missing information for child race/ethnicity (0.3% total sample), and 3 subjects missing maternal education attainment information (0.08% total sample)

[d] Unweighted sample sized are rounded to the nearest 50 per National Center for Education Statistics guidelines.

Table 2. Mean Academic Achievement Scores by Gestational Age Stratified by Primary Language Spoken at Home, Among Singleton Children Enrolled in the Early Childhood Longitudinal Study, Birth Cohort, United States, 2001-2008

Assessment by Gestational Age	Total		English at home	non-English at home
	No.[a]	Mean (SD)	Mean (SD)	Mean (SD)
Reading scale score				
Total	3,800	44.3 (0.5)	44.8 (0.5)	41.5 (1.0)
Early preterm	100	38.3 (1.3)	38.8 (1.3)	33.5 (0)
Moderate preterm	250	42.3 (1.2)	42.8 (1.3)	38.7 (3.1)
Late preterm	300	43.0 (0.9)	43.9 (0.9)	38.2 (0.9)
Early Term	1,000	43.6 (0.8)	44.1 (0.8)	40.6 (1.3)
Full term	2,100	44.9 (0.5)	45.3 (0.5)	42.4 (1.1)
Mathematics scale score				
Total	3,800	44.3 (0.3)	44.8 (0.3)	41.7 (0.6)
Early preterm	100	36.9 (0.9)	36.5 (0.8)	40.7 (0)
Moderate preterm	250	41.2 (0.9)	41.8 (1.0)	37.6 (1.0)
Late preterm	300	43.5 (0.8)	44.3 (0.8)	39.0 (0.8)
Early Term	1,000	44.1 (0.5)	44.5 (0.5)	41.9 (0.8)
Full term	2,100	44.6 (0.3)	45.0 (0.3)	42.0 (0.7)

Abbreviations: SD, Standard Deviation

[a] Unweighted sample sized are rounded to the nearest 50 per National Center for Education Statistics guidelines.

Table 3. Association between Gestational Age at Delivery and Academic Achievement at Kindergarten, Among Singleton Children Enrolled in the Early Childhood Longitudinal Study, Birth Cohort (ECLS-B), United States, 2001-2008

Exposure	Reading Scale Score				Mathematics Scale Score			
	Model 1[a]		Model 2[b]		Model 1[a]		Model 2[b]	
	β[c]	95% CI	β[c]	95% CI	β[c]	95% CI	β[c]	95% CI
Gestational age								
Early preterm	-6.9	-9.8, -4.0	-5.5	-8.2, -2.8	-8.0	-10.1, -5.8	-6.5	-8.6, -4.3
Moderate preterm	-3.1	-5.5, -0.7	-1.3	-3.6, 0.9	-3.8	-5.5, -2.0	-2.1	-3.7, -0.5
Late preterm	-2.2	-3.7, -0.7	-0.7	-2.3, 0.9	-1.4	-2.7, -0.1	0.0	-1.3, 1.2
Early Term	-1.0	-2.4, 0.4	-0.5	-1.8, 0.8	-0.3	-1.1, 0.5	0.1	-0.6, 0.9
Full term	0.0	Referent	0.0	Referent	0.0	Referent	0.0	Referent

Abbreviations: CI, confidence interval

[a] Adjusted for language and child's age at kindergarten assessment

[b] Adjusted for language, household socioeconomic status (quintile 1-5), child's race/ethnicity (non-Hispanic black, Hispanic, Asian, Native Hawaiian or other Pacific Islander, American Indian or Alaska Native, more than one race, non-Hispanic white), maternal education (<high school, high school graduate, some college, college graduate, > college), and maternal age at delivery (15-17 years, 18-19 years, 20-24 years, 25-29 years, 30-34 years, 35-39 years, 40 years and older)

[c] Estimated β represents estimated difference in mean academic achievement scores

Table 4. Difference in Mean Academic Achievement at Kindergarten Between non-English-speaking and English-speaking Children Within Gestational Age Categories, Among Singleton Children Enrolled in the Early Childhood Longitudinal Study, Birth Cohort (ECLS-B), United States, 2001-2008

Exposure	Reading Scale Score			Math Scale Score		
	Non-Eng : Eng[a]	95% CI	p-value	Non-Eng : Eng[a]	95% CI	p-value
Gestational age						
Early preterm	0.10	-11.7, 11.9	0.9870	7.89	1.4, 14.4	0.0183
Moderate preterm	-0.67	-8.9, 7.5	0.8719	-1.43	-4.2, 1.3	0.3019
Late preterm	-2.13	-7.7, 3.4	0.4495	-2.51	-7.0, 2.0	0.2714
Early Term	-0.91	-3.8, 2.0	0.5346	-0.28	-2.3, 1.7	0.7775
Full term	-0.38	-2.7, 1.9	0.7436	-0.63	-2.1, 0.8	0.3785

[a] Represents the estimated difference in mean academic achievement scores between primary household language of non-English compared to English; positive values represent higher average scores for non-English-speaking children and negative numbers represent higher average scores for English-speaking children.

Figures

Figure 1. Exclusion cascade representing the number of children included and excluded based on specified criteria, using data from the Early Childhood Longitudinal Study, Birth Cohort, United States, 2001-2008.

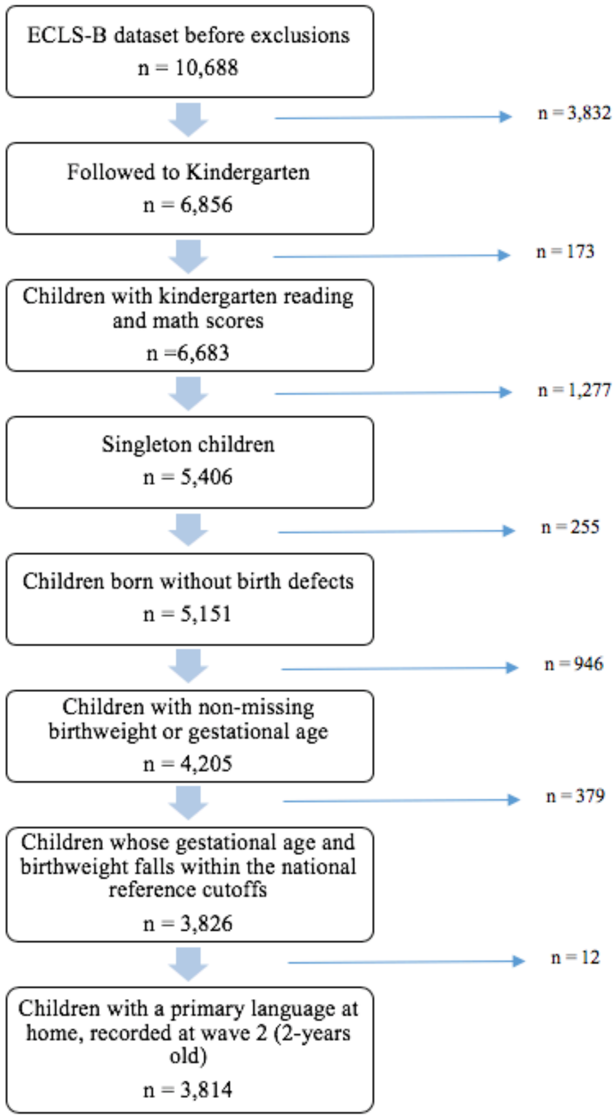


Figure 2. Directed Acyclic graph representing the potential modification of the relationship between preterm birth and children's cognitive development by primary household language, among singleton children enrolled in the Early Childhood Longitudinal Study, Birth Cohort, United States, 2001-2008.

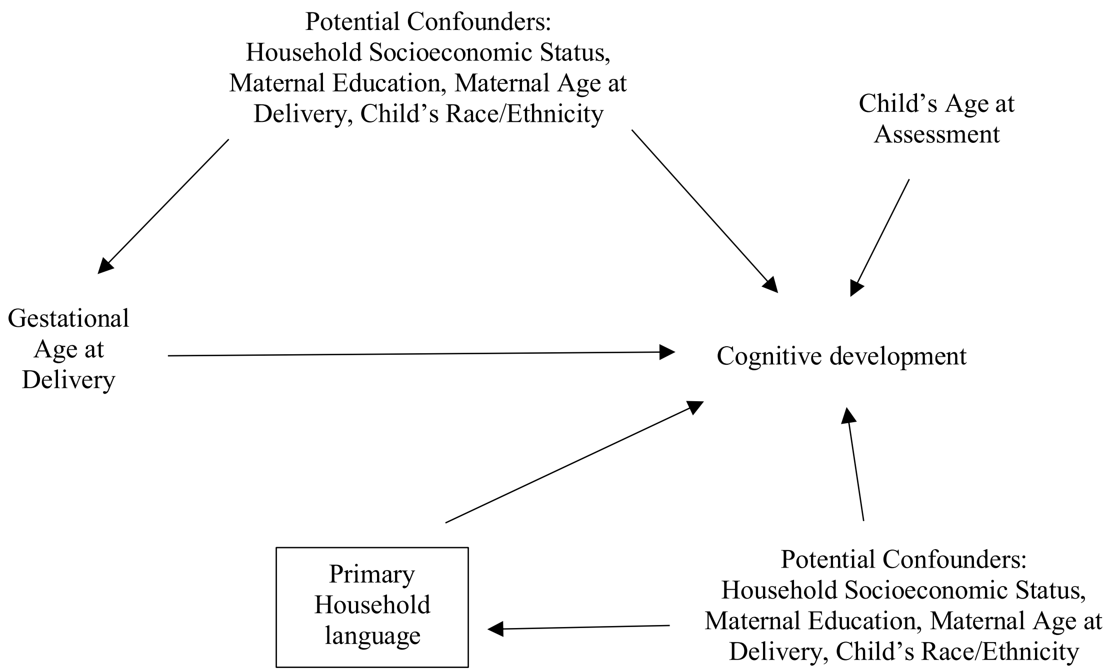
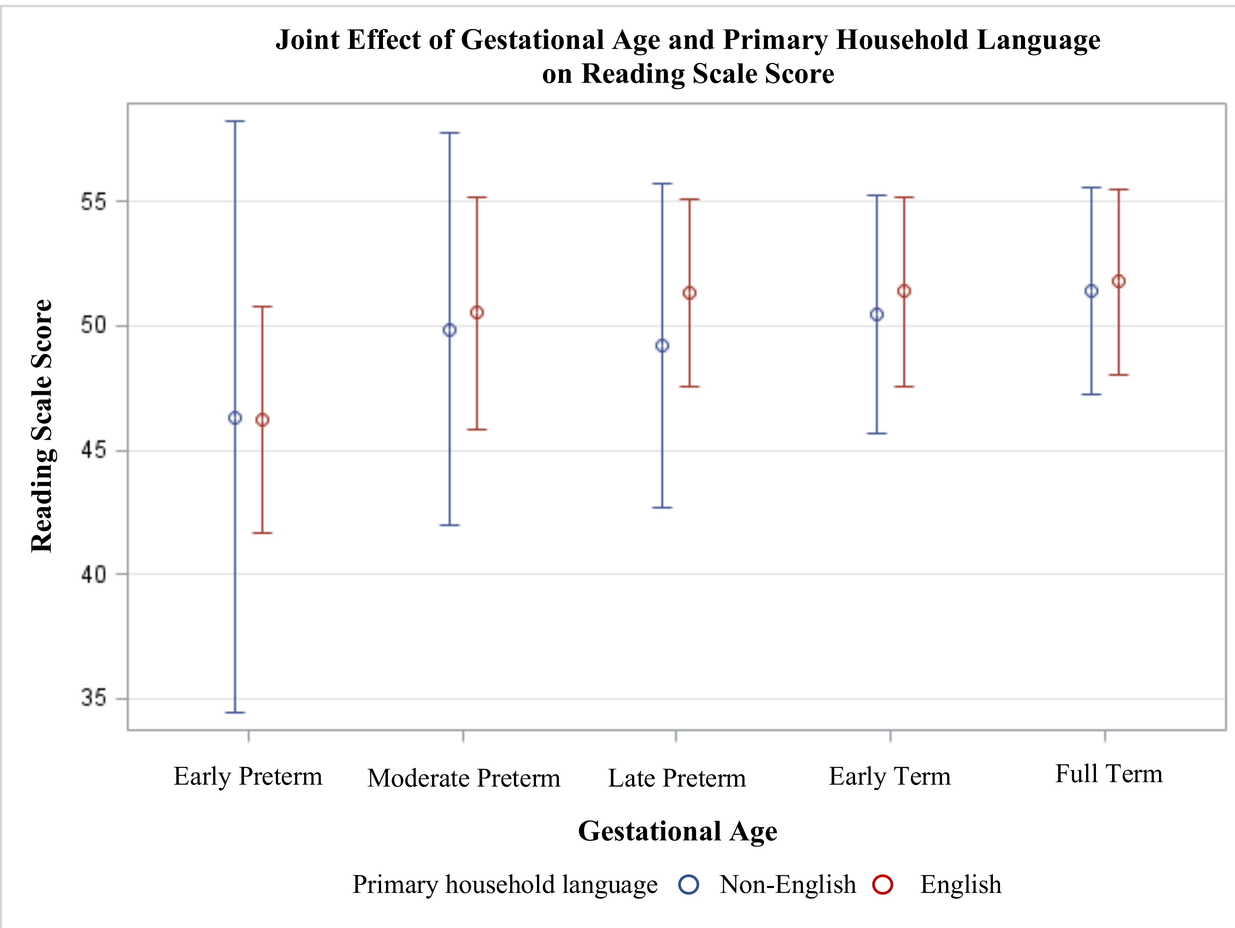
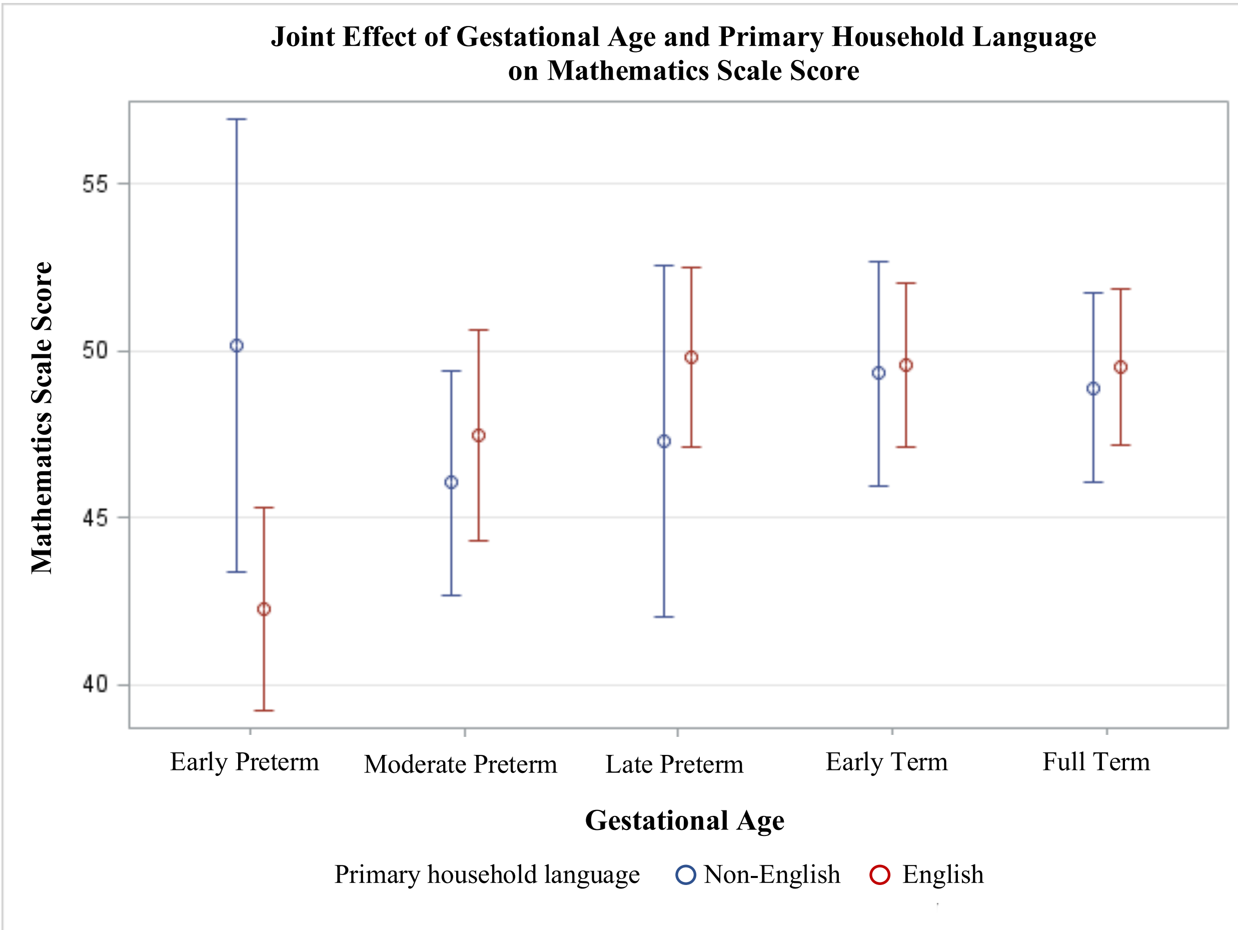


Figure 3. Academic achievement scores and 95% confidence intervals derived from models estimating interaction between gestational age and primary household language for A) reading scale scores at kindergarten, and B) mathematics scale scores at kindergarten, among singleton children enrolled in the Early Childhood Longitudinal Study, Birth Cohort, United States, 2001-2008. Both models were controlled for household socioeconomic status, maternal education and age, and child race/ethnicity.

A)



B)


Joint Effect of Gestational Age and Primary Household Language
on Mathematics Scale Score
Mathematics Scale Score
55
50
45
40
Early Preterm
Moderate Preterm
Late Preterm
Early Term
Full Term
Gestational Age
Primary household language
Non-English
English

Appendix

IRB Approval

EMORY UNIVERSITY | Institutional Review Board

July 20, 2018

Emily Judson
School of Public Health
Emory University

RE: Determination: No IRB Review Required
Title: ***Relationship of Cognitive Development in Preterm Children Among Mono- and Multilingual Households***
PI: Emily Judson

Dear Ms. Judson:

Thank you for requesting a determination from our office about the above-referenced project. Based on our review of the materials you provided, we have determined that it does not require IRB review because it does not meet the definition of "research" with "human subjects" as set forth in Emory policies and procedures and federal rules, 45 CFR 46.102(f)

Specifically, in this project, there will be no interaction from anyone at Emory with human subjects. Analysis will be conducted on secondary de-identified data received from the National Center for Education Statistics.

Please note that this determination does not mean that you cannot publish the results. This determination could be affected by substantive changes in the study design, subject populations, or identifiability of data.

If the project changes in any substantive way, please contact our office for clarification.

Thank you for consulting the IRB.

Sincerely,

Ashton Hughes
Research Protocol Analyst
Emory University Institutional Review Board