EARLY EXPRESSIVE VOCABULARIES IN TENNESSEE'S GREAT APPALACHIAN VALLEY: DESCRIBING SIZE AND LEXICAL CHARACTERISTICS OF THE REGIONAL SAMPLE

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ABSTRACT

The current paper examined early expressive vocabulary development in infants and toddlers from Eastern Tennessee, a region characterized by persistent educational and socioeconomic disparities. Using parent-report data from the MacArthur–Bates Communicative Development Inventories (CDI), expressive vocabulary was analyzed in a cross-sectional sample of 1,738 monolingual, full-term children aged 9–30 months (2012–2024).

Study 1 assessed vocabulary size, demographic predictors, temporal trends, and the prevalence of late talking (LT). On average, children in this regional sample scored 13.4 percentile points below national CDI norms. Gestational age emerged as a significant positive predictor of vocabulary, whereas birthweight and socioeconomic status were not significant. Birth order showed a small negative association with vocabulary outcomes. Additionally, expressive vocabulary scores declined over time, with significantly lower performance observed following the onset of the COVID-19 pandemic. The prevalence of LT among 24–30-month-olds was 22.8%, with males at significantly greater risk than females.

Study 2 investigated whether item-level properties predict word production and whether these effects differ for LT children compared with typically developing age-matched (TD-AM) and vocabulary-matched (TD-VM) peers, using a subset of the larger sample of 148 18- to 30-month-olds. Using logistic mixed-effects models on item-level CDI data, results indicated that iconicity, imageability, concreteness, and child body–object interaction (CBOI) were strong positive predictors of word production across groups, whereas phonological neighborhood density showed no reliable main effect. Importantly, LT children exhibited greater reliance on iconicity, imageability, and concreteness than both the TD-AM and TD-VM groups, while CBOI effects were consistent across groups.

Overall, the findings suggest that children in this region may be at elevated risk of early language delays and that early lexical development is primarily supported by perceptually grounded word properties. Results further indicate that LT children rely more heavily on salient lexical features, consistent with a delayed but largely continuous developmental trajectory.

Keywords: expressive vocabulary, first-language acquisition, infancy, late-talking

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CHAPTER ONE

INTRODUCTION AND GENERAL INFORMATION

Language development is one of the most significant achievements of early childhood (Kuhl, 2010). Language abilities in infancy and childhood predict school readiness outcomes, with studies consistently reporting that language is associated with reading abilities in both early and later academic years (e.g., Chaney, 1998; Dickinson et al., 2003; Duff et al., 2015). Specifically, infant vocabulary size is associated with better comprehension (Duff et al., 2015) and literacy skills (Lee, 2011). Further, language supports social and behavioral development, as children's language skills are positively related to their ability to communicate with teachers and peers and to regulate their emotions (Cole et al., 2010; Vallotton & Ayoub, 2011). Given the importance of language development, it is essential to properly assess infants' emerging language abilities in a given geographic region to understand the unique linguistic development and considerations relevant to the study area.

The University of Tennessee, Knoxville, is located in Tennessee's Great Appalachian Valley in eastern Tennessee. This region of Tennessee has faced economic and cultural inequities that continue to negatively impact its residents (Terry et al., 2025). In relation to language development, these disparities are reflected in the state's consistent reports that reading scores for school-age children fall below the 50th percentile (TN DOE, 2024). Further, national trends of these reading scores indicate declining abilities from 2012 to 2022 (US DOE, 2022). Taken together, these academic language-related concerns highlight the critical need to assess infants' language abilities before these school-readiness consequences emerge.

Overview

The paper describes early expressive vocabulary in 9- to 30-month-old infants, using a sample collected from 2012 to 2024 at our lab in Eastern Tennessee, specifically Tennessee's Great Appalachian Valley. Participants in the sample originally took part in one of several studies conducted over the years at the collection site. Upon their participation, all subjects in the current study completed a form of the MacArthur-Bates Communicative Development Inventory (CDI). This is a parent-report checklist assessing the receptive and productive vocabulary of their infant. This measure provides data on the infant's vocabulary size, a percentile ranking for this size relative to their age & sex, and responses to the specific items (words) on the checklist. This expressive vocabulary measure can be used as an indicator of an infant's lexical development. In older infants (≥ 24 months), the CDI can be used to assess language delays (such as late-talking).

The CDI expressive vocabulary data from this regional sample are analyzed across two studies. Study 1 aims to describe expressive vocabulary size, assess predictors of vocabulary size, and examine the prevalence of late talking. In study 2, the differences in item-level responses between typically-developing and late-talking infants are assessed in older infants (24-30 months) and an ability-matched sample (18-23 months).

CHAPTER TWO

STUDY 1 BACKGROUND

Lexical Acquisition in Typically-Developing Infants

In typical development, infants rapidly acquire core communicative, lexical, and grammatical skills with minimal explicit instruction during the first 3 years of life. Early milestones include the emergence of communicative gestures and basic word comprehension around 8–9 months, followed by the production of first words at approximately 12–13 months (Marchman et al., 2023). The acquisition of spoken vocabulary following initial lexical production is rapid. At 12 months, the average number of words produced is 12.3 items (Marchman et al., 2023). Receptive and expressive vocabulary then expand considerably across the second and third years, with comprehension preceding and supporting expressive growth (Caselli et al., 2012; Fenson et al., 2007; Sansavini, Bello, et al., 2010; Sansavini, Favilla, et al., 2021). Between 20 and 24 months, many children begin combining words, and by 30–36 months, their speech typically includes complex multiword utterances incorporating bound and free morphemes (Marchman et al., 2023). By 3 years old, most infants produce 400–600 words and demonstrate command of foundational morphological and syntactic structures (Bates & Goodman, 1997; Sansavini, Favilla, et al., 2021). This spurt in expressive vocabulary size in toddlerhood is mechanistically described in the literature as lexical bootstrapping. This means that as children learn new vocabulary, their existing lexical representations facilitate the acquisition of additional words, producing a snowballing or bootstrapping effect (Pinker, 1984).

Research has consistently demonstrated that children who exhibit weaker oral language abilities from age 3 onward face disadvantages in the development of speaking, listening, and reading skills once formal schooling begins (e.g., NICHHD Early Child Care Research Network,

2005). Among the various components of oral language, vocabulary knowledge has been identified as particularly influential in supporting emergent literacy. For example, vocabulary knowledge contributes to the development of phonological awareness (Bowey, 1994; Goswami, 2001; Metsala, 1999), an ability central to recognizing and manipulating sounds in words. In addition, vocabulary can influence reading development directly (Chaney, 1998; Dickinson et al., 2003) and is an established predictor of later reading comprehension ability (Duff et al., 2015).

Early differences in emergent literacy skills also tend to widen over time. Children who demonstrate lower levels of print knowledge or related skills during the preschool years often fall further behind once formal instruction begins (Dickinson et al., 2003), a pattern that may persist into adulthood (Bruck, 1993). Vocabulary development in the preschool years also shows considerable continuity across early childhood. Early lexical knowledge has been found to predict vocabulary growth through third grade (Storch & Whitehurst, 2002), illustrating a developmental pattern in which those with larger vocabularies in infancy tend to continue expanding their lexical knowledge more rapidly than peers with smaller vocabularies. The literature on the effects of expressive vocabulary development in infancy highlights the importance of this specific lexical measure for capturing broader language and academic outcomes.

Delays in Expressive Vocabulary

For some children, however, communicative-linguistic development proceeds more slowly than expected. These children, commonly referred to as late talkers (LT), show delayed expressive language development between 18 and 35 months of age despite otherwise typical cognitive, sensory, neurological, and socio-emotional functioning (Hawa & Spanoudis, 2014; Rescorla & Dale, 2013; Rudolph & Leonard, 2016). Identification typically relies on expressive

vocabulary size, measured using parental-report instruments such as the MacArthur–Bates Communicative Development Inventories (MB-CDI; Fenson et al., 2007) or the Language Development Survey (Rescorla, 1989). Criteria often include vocabulary at or below the 10th percentile (Bello et al., 2018; Desmarais et al., 2010; Sansavini et al., 2021; Suttora et al., 2020) or fewer than 50 words with no word combinations by 24–30 months (Thal et al., 2013). Prevalence estimates range from 9% to 21% among children aged 24–36 months (Collisson et al., 2016; Horwitz et al., 2003; Reilly et al., 2007; Sansavini et al., 2021; Zubrick et al., 2007).

Although some toddlers classified as LT later receive diagnoses of developmental disorders (Dale et al., 2003), roughly half demonstrate substantial improvement in vocabulary by the preschool years and are often described as "late bloomers" (Fisher, 2017). Nevertheless, even those who catch up tend, on average, to show weaker academic outcomes compared to typically developing (TD) peers who exhibited typical vocabulary growth in toddlerhood (Bleses et al., 2016; Rescorla, 2011). As a result, it remains unresolved whether the slower language development observed in LT children reflects a variation within the typical developmental range (Jones & Brandt, 2019) or instead signals qualitatively atypical processes (e.g., Beckage et al., 2011; MacRoy-Higgins et al., 2016).

Mac-Arthur Bates Communicative Development Inventories

Expressive vocabulary size has been outlined above as an important measure in infancy of concurrent and subsequent language development. A widely used tool to quantify an infant's vocabulary size is the CDI, a set of parent-report instruments designed to measure children's receptive and expressive vocabularies between roughly 8 and 30 months of age. In these inventories, caregivers indicate which words their children understand or produce from a standardized list. The CDI has become popular in both research and clinical contexts due to its

relatively simple administration and its availability in numerous languages. Another advantage of the instrument is the availability of normative percentile tables, which allow a child's performance to be compared with that of age-matched and sex-matched peers. These norms were established using large samples of children spanning infancy through the toddler period (Marchman et al., 2023)

The CDI has served multiple purposes in developmental research. In some studies, it functions as an outcome measure used to document language development across childhood in various populations, including typically developing children, those with developmental conditions such as Down syndrome (Caselli et al., 1998), and children born prematurely (Stolt et al., 2007). In other contexts, the CDI serves as an early indicator of potential language difficulties. Clinicians and researchers frequently rely on the instrument to classify children over 24 months as "late talkers" or "early talkers," as well as to identify atypical language profiles—for instance, children who have age-appropriate vocabulary sizes but experience delays in combining words (Rielly et al., 2007).

Although the CDI is widely used as a predictive tool, its long-term predictive accuracy has been debated. Some studies suggest that early vocabulary measures may have limited ability to identify language disorders several years later (Dale et al., 2003; Rescorla, 2005). Nevertheless, other research indicates that children who display delayed expressive vocabulary at age two remain at elevated risk for persistent language difficulties, even if their vocabulary size appears to normalize by ages three or four (Rescorla, 2011). Difficulties may continue in other linguistic domains, such as syntactic development (Rescorla, 2009; Rice et al., 2008). Overall, vocabulary size measured at approximately 2 years of age has been shown to provide a moderate level of prediction of language outcomes in subsequent years among typically developing

children (Bornstein et al., 2014; Duff et al., 2015). Beyond prediction, CDI data have been used to investigate broader questions about language development, including the relationship between early speech perception abilities and later language growth (Kuhl et al., 2005; Tsao et al., 2004). The contributions of genetic and environmental influences on language development have also been investigated using this measure (Dale et al., 1998; Oliver et al., 2005).

Predictors of Vocabulary Size

There are several known predictors in the literature of an infant's vocabulary size, including an infant's sex, birth characteristics, and socioeconomic status (SES). There are consistently reported effects of sex differences in language development. In the first years of life, girls acquire language faster and have a larger vocabulary than boys (Eriksson et al., 2012; Fenson et al., 2007). This effect favoring girls has been reported in the acquisition of several languages (Eriksson et al., 2012), in production and comprehension, and in lexical and grammatical development (Fenson et al., 2007). Some studies have also found that boys are more likely to be classified as LT than girls (e.g., Collison et al., 2016), although this sex difference in LTs is not consistent (Marchman et al., 2023). These communicative sex differences are most noticed during language-related milestones (Huttenlocker et al., 1991; Marchman et al., 2023) and persist into adulthood (Hyde, 2014; Wallentin, 2009).

Another known predictor, SES, is positively associated with estimates of vocabulary size (e.g., Hart & Risley, 1999; Rindermann & Baumeister, 2015). While SES accounts for significant variation in vocabulary size, its effects are largely mediated by factors that correlate with SES, such as parental educational behavior (Rindermann & Baumeister, 2015), knowledge of child development (Rowe, 2008), and the diversity and quantity of linguistic input (Huttenlocher et al.,

2010). Still, even after accounting for these mediating effects, measures of SES significantly predict language outcomes.

A substantial body of research has also identified birth characteristics as important predictors of early developmental outcomes. Preterm birth (< 37 weeks' completed gestation) has consistently been associated with an increased risk of developmental delays, including cognitive, language, and motor delays during infancy and beyond (Allotey et al., 2018; Boonzaaijer et al., 2021; Zambrana et al., 2021). More recent work suggests that gestational age may be relevant for developmental outcomes even among infants born within the full-term range (37–41 weeks completed gestation). Studies examining variation in gestational duration across both preterm and term births have reported that shorter gestational periods are associated with a greater likelihood of developmental delay, indicating that the impact of gestational age on early development extends beyond cases of premature birth (Dueker et al., 2016; Gleason et al., 2022; Hochstedler et al., 2021). A recent 2024 study provided further support for the relationship between gestational age and early development in full-term infants, finding that longer gestation was significantly positively correlated with cognitive, language, and motor development in their sample of German-learning infants (Kappelt et al., 2024). While the impact of these birth characteristics reportedly decreases with age (Zambrana et al., 2021; Kappelt et al., 2024), the positive effects of longer pregnancy continue into adulthood (Yang et al., 2010).

Birth weight has also been widely examined as a factor associated with developmental risk. Low birth weight (< 2500g) frequently co-occurs with preterm birth but is also observed among infants born at term (Tucker & McGuire, 2004). Numerous studies have reported associations between low birth weight and developmental delays in toddlers, including both children born prematurely and those born at term (Drozd-Dąbrowska et al., 2018; Flensborg-

Madsen et al., 2019; Hilaire et al., 2021; Sacchi et al., 2020; Scharf et al., 2018). However, interpretation of these findings should be approached with caution, as some investigations have not accounted for gestational age as a potential confounding variable (Drozd-Dąbrowska et al., 2018; Hilaire et al., 2021). Consequently, disentangling the independent contributions of gestational age and birth weight remains an important consideration in research on early developmental risk.

Birth order is also linked to variation in early language development. A growing body of research suggests that children with older siblings may exhibit somewhat slower growth in expressive vocabulary during the early stages of language acquisition. Evidence from studies of infants and toddlers indicates that the number of older siblings is negatively associated with expressive vocabulary size. For instance, research with French-speaking 2-year-olds and English-learning 18-month-olds has found that children with more older siblings tend to produce fewer words than firstborn children (Laing & Bergelson, 2024). Similar patterns have been observed in broader cross-linguistic datasets. A large multinational sample of children aged 8-36 months observed that later-born children generally had smaller expressive vocabularies than their earlier-born peers (Frank et al., 2021). Overall, findings in the literature indicate a negative impact of birth order on language outcomes in infancy.

Additional Factors Impacting Language Development in the Current Study

The population of interest for the current study is located in Eastern Tennessee, specifically a region known as Tennessee's Great Appalachian Valley. Structural inequalities relating to economic, educational, and health outcomes have long plagued this region (Terry et al., 2025). Counties in Eastern Tennessee with higher child poverty have lower reading scores and poorer economic mobility, with only 23% of low-income 3rd graders meeting or exceeding

expectations on state reading tests from 2017-2019 (The Sycamore Institute, 2023). However, in terms of SES, the county of interest for the current study has a 12.8% poverty rate and a median annual income of $74,222 (US Census Bureau, 2024), which is proportionally better than many Eastern TN counties (Terry et al., 2025). Still, average reading scores for 3rd-grade students statewide consistently fall below the 50th percentile (TN DOE, 2024). Given this data in school-age children, we predict that infants in our sample will, on average, underperform relative to national averages. We also predict higher LT rates in our sample based on these reading data.

Over recent years, we have seen a decline in national reading ability (US DOE, 2022). Additionally, our society has endured the COVID-19 pandemic in recent years. An event who's cognitive and socioemotional impacts cannot be understated. Recent studies have indicated that many domains of early language development were adversely affected by the pandemic (Giesbrecht et al., 2024). The current study will use a cross-sectional sample collected over the years surrounding the pandemic and predicts that average performance will decrease over time.

Study 1 Overview

Study 1 analyzed the productive vocabulary reported from CDI measures collected from 9- to 30-month-old infants in East Tennessee. Data were collected from 2012 to 2024. The effect of an infant's sex, SES, birthweight, gestational age, birth order, and collection year on expressive vocabulary size was assessed. The interaction of these predictors with age and sex was also reviewed. SES, birthweight, gestational age, and being female were predicted to positively correlate with expressive vocabulary, whereas birth order, collection year, and being male were predicted to have negative associations. Using a subset of this sample, the prevalence of late talking among 24-30-month-olds is also assessed. The prevalence was expected to exceed national averages, with more males being classified as LT than females.

CHAPTER THREE

STUDY 1 MATERIALS AND METHODS

Participants

From 2012-2024, our lab, located at the University of Tennessee, Knoxville, has collected CDI measures across several experimental and descriptive studies, resulting in a total sample of 1,899 9- to 30-month-olds. From this sample, subjects were excluded if they were born 4 or more weeks premature (n = 61), reported second-language exposure greater than 10 hours per week (n=94), or reported a history of hearing issues (n=6). The resulting sample comprised 1,738 subjects (50.2%, females) who met our inclusion criteria: English-learning, monolingual, full-term infants aged 9 to 30 months at the time of data collection.

Measures

Mac-Arthur Bates Communicative Development Inventory

The CDI is a parent-report questionnaire in which caregivers respond to items on their child's lexical development (Marchman et al., 2023). The CDI items of interest for the current study ask parents to indicate whether their child *understands and says* each listed word as a measure of expressive vocabulary. CDI measures were administered using a paper-and-pen form, an online Qualtrics form, or webCDI (DeMayo et al., 2022), depending on the original study in which the participant was involved. There are several CDI forms designed to assess abilities in infants aged 8 to 30 months. Data collected using four different forms are used in the study. These forms are outlined below:

CDI Words & Gestures consists of 396 vocab items and is used for 8- to 18- month-olds

CDI Words & Sentences consists of 680 vocab items and is used for 16-to 30-month-olds

CDI Level 1 Short Form consists of 89 vocab items and is used for 8-to 18-month-olds

CDI Level 2 Short Form consists of 100 vocab items and is used for 16-to 30-months

CDI provides a raw score for how many items were selected and a percentile ranking, which allows for standardized comparison of vocabulary size based on a subject's raw score compared to normative values for their age and sex. As these scores are standardized, rankings at the 50th percentile represent average performance based on the most recently updated normative sample from the Third edition of the CDI (Marchman et al., 2023). The raw scores can only be directly compared with raw scores collected using the same CDI form. To create visualizations that model these unstandardized raw scores, the proportion of words produced was calculated as the number of vocabulary items selected divided by the total number of items on the form. To summarize, CDI data of expressive vocabulary used in the current study include *raw vocabulary size* (unstandardized), age- and sex-based *percentile rankings* (standardized), and a calculated *proportion of words produced* (standardized).

The most recent update of the CDI normative sample was used for assigning percentile rankings based on raw scores (Marchman et al., 2023). This updated norming sample was collected from 2017-2021 and includes over 4,000 CDI reports, in addition to those reported in Fenson et al. (2007). Data were collected by a consortium of researchers across the U.S., including sites in New Haven, Connecticut; San Diego, California; Seattle, Washington; Dallas, Texas; Madison, Wisconsin; New Orleans, Louisiana; Providence, Rhode Island; and Storrs, Connecticut. All subjects were typically developing, English-learning, monolingual infants.

The CDI can be administered to infants as young as 8 months. However, in this young age group, there is concern for floor effects, as performance is typically at 0. As a result, in our sample, the distribution at 8 months lacks sufficient variability (SD = 13.2) to meaningfully estimate percentile-based differences. By 9 months of age, these variability concerns are

decreased as 9-month-olds report comparable variation (SD = 23.9) to older ages (10 to 30 months; mean SD = 28.6, SD range = 22.9 - 34.7). Considering this variation, only 9 to 30-month-olds will be analyzed in the current study.

Late-Talking

Based on these CDI percentile rankings, subjects older than 24 months can be identified as late talkers. Late-talkers are identified as infants 24 months old or older who fall at or below the 10th percentile in expressive vocabulary for their age and sex (Reilly et al., 2007). Infants between 24 and 30 months in our sample (n = 171) will be classified as typically developing or late talking based on their CDI percentile ranking to assess the prevalence of late talking. See Table 1 for characteristics of our 24-30-month-old sample.

Table 1. Demographic characteristics of the 24-30-month-old sample

	N	Collection Years-Range
Female	114	2013-2022
Male	118	2015-2023
Total	232	2012-2023

Demographic Measures

Several demographic measures were collected for each subject, although the specific measures collected depend on the original study in which the subject participated. The measures assessed as predictors of expressive vocabulary size in the current study include SES, sex, gestational age, birthweight, birth order, and test year. SES was indexed using two measures. One measure is the highest degree earned by either parent and is available for 1,872 subjects (of 1,899 total). The other measure asks caregivers to indicate which rung of a 10-step ladder they

should be placed on in terms of money, education, and occupation, with the top and bottom rungs representing the best- and worst-off, respectively. This ladder rung measure is available for 821 subjects (of 1,899 total). Gestational age was measured in weeks. Birthweight was measured in pounds. Birth order refers to when an infant is born in relation to their siblings (e.g., first-born, second-born, etc.). All measures were assessed via parent report when caregivers completed the CDI. See Table 2 for a comparison of the demographic characteristics of our sample, those of Knox County, Tennessee, and those of the US.

Table 2. Demographics of the sample in the current study compared to Knox County and the US

	Study Sample	Knox County	United States
Bachelor's Degree or higher	76.9%	40.2%	35%
Race/Ethnicity			
Asian	3%	2.6%	6.4%
Black	1.6%	8.7%	13.7%
Hispanic	3.7%	6.4%	19.5%
Native American	0.34%	0.5%	1.6%
White	91%	80%	58.4%
2 or more races	2.9%	2.9%	3.1%

CHAPTER FOUR

STUDY 1 RESULTS

Participant Characteristics

The sample consisted of 910 girls (50.6%) and 888 boys (49.4%), ranging in age from 9 to 30 months (mean = 17.7, SD = 4.8). Mean birthweight and gestational age were 7.6 pounds (SD = 1.4) and 39.4 (SD = 1.2) weeks, respectively. For our SES measures, the most common response for the highest parental degree was a bachelor's degree (36.9%, n = 660), followed by a master's degree (30.1%, n = 550). The most common response to the ladder rung SES question was "7" (mean = 6.4, SD = 1.5), with no responses for "1". We had birth orders ranging from 1 to 9 (mean = 1.6, SD = 0.7). See Table 3 for more of the descriptive information for each measure.

CDI Expressive Vocabulary Raw and Percentile Scores

Size and Percentile Ranking by Age and Sex

As predicted, based on population-normed percentile rankings, the average for our sample fell 13.4 points below the national average for expressive vocabulary (mean = 36.6, SD = 28.7). Of the ages included, 24-month-olds had the highest average percentile ranking (mean = 46.9, SD = 29.4), followed by 29-month-olds (mean = 45.2, SD = 31.8). 9-month-olds had the lowest rankings (mean = 19.4, SD = 23.9), followed by 10-month-olds (mean = 24.5, SD = 26.9). . A one-way ANOVA treating age as a categorical variable revealed significant differences in percentile ranking by age, $F(21, 1815) = 3.88$, $p < .001$, $\eta^2 = .043$. See Figure 1 for percentile ranking by age. Age was not assessed as a linear predictor of percentile ranking because these percentiles are standardized and thus should not increase or decrease linearly with age, as raw scores should.

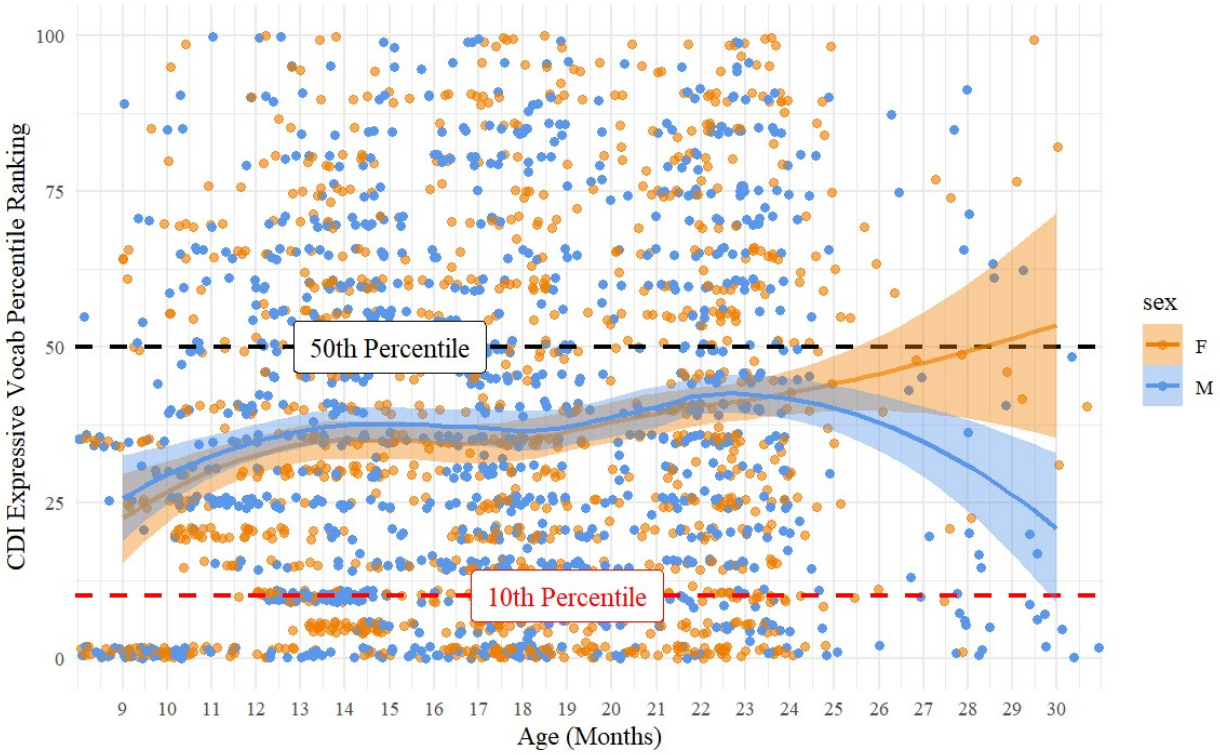


Figure 1. CDI Words Produced percentile ranking by age at test (months) with separate lines by sex

The effect of sex on expressive vocabulary size was assessed using a linear regression model that controlled for age (in months). In this model, the expressive vocabulary outcome variable was the proportion of CDI items checked. As subjects in the sample completed different forms of the CDI with varying numbers of vocabulary items, using the proportion of items checked allows for direct comparisons of raw scores across forms. In this linear model comparing the effect of sex on expressive vocabulary size, controlling for age, there was a significant effect of sex ($p < .001$), such that being male was associated with a 0.05 decrease in vocabulary size. When comparing group averages by sex, males had higher percentile ranks than females (males: 37.5, SD=27.4; females: 36.4, SD=29). See Figures 2 and 3 for the raw scores of Females and Males, respectively, across age.

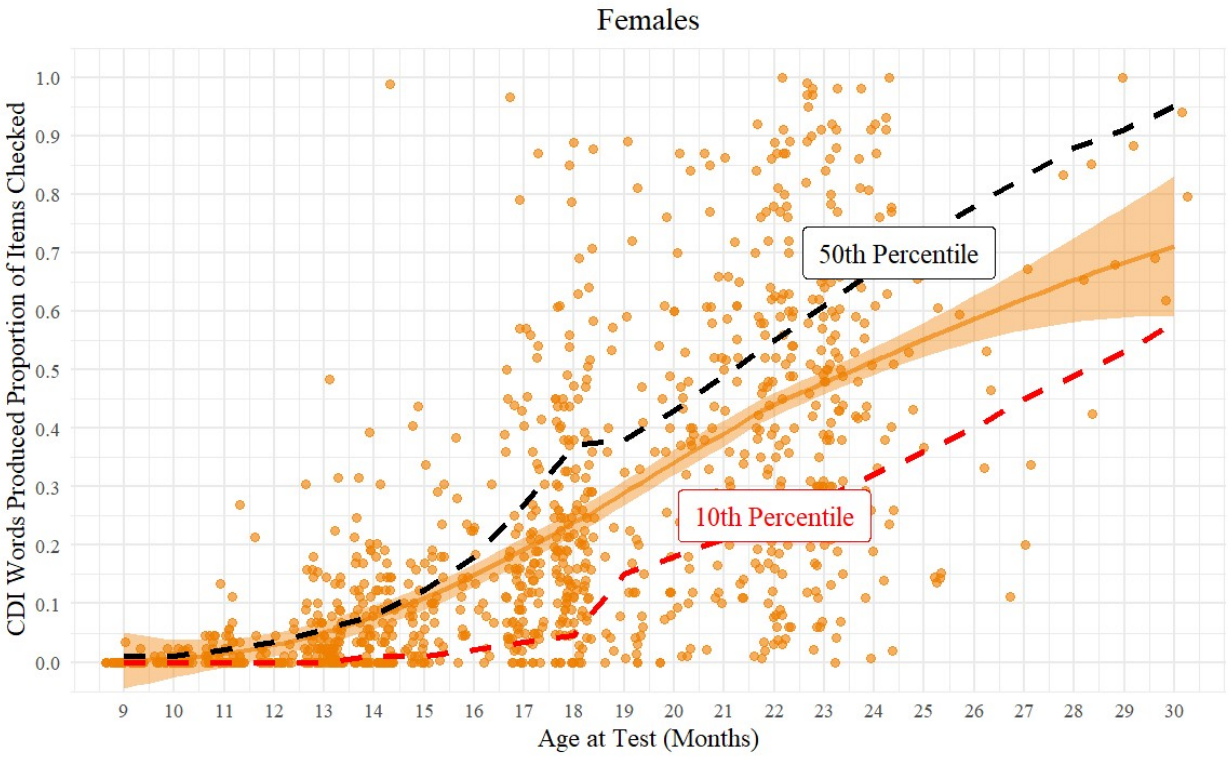


Figure 2. Proportion of words produced by age at test (in months) for females compared to 50th and 10th percentile trajectories

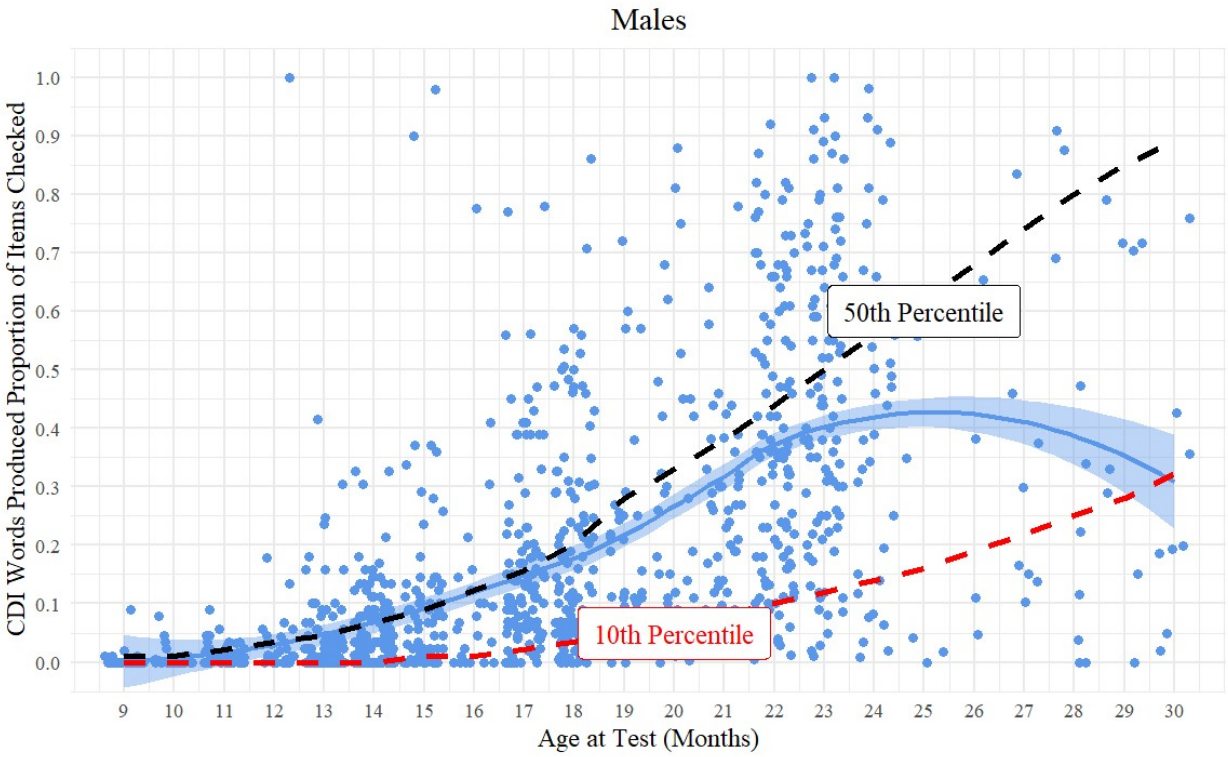


Figure 3. Proportion of words produced by age at test (in months) for males compared to 50th and 10th percentile trajectories

Predictors of Percentile Ranking

Both SES measures (highest degree and ladder rung) were assessed as predictors of CDI percentile score. A one-way ANOVA assessing differences in percentile ranking by highest parent degree found no significant differences, $F(6, 1835) = 1.12$, $p = .37$. A similar ANOVA on the other SES measure, the ladder rung question, also found no significant differences between groups, $F(8, 803) = 1.09$, $p = .35$.

A linear regression analysis examined whether birthweight and gestational age predicted percentile score. The model including both predictors provided a better fit to the data than a model including birthweight alone, as indicated by a lower Akaike Information Criterion (AIC). The overall model was statistically significant [$F(2, 1625) = 9.47$, $p < .001$] though it explained a

small proportion of variance ($R^2 = .012$). Gestational age was a significant positive predictor [$b = 2.64$, $SE = 0.63$, $t(1625) = 4.17$, $p < .001$] whereas birthweight was not significant [$\beta = -0.10$, $SE = 0.54$, $t(1625) = -0.19$, $p = .847$]. See Figure 4 for the regression line modeling this relationship between gestational age and CDI percentile ranking while controlling for birthweight.

An additional linear regression was conducted to assess the association between birth order and CDI percentile ranking. This regression found that birth order significantly and negatively predicts, $t(1846) = -2.99$, $p = .003$. This reported beta indicates that a one-unit increase in birth order decreases percentile scores by about 3 units ($\beta = -2.99$). However, despite the significance of this predictor, birth order accounts for less than 1% of the overall variation ($R^2 = .0048$).

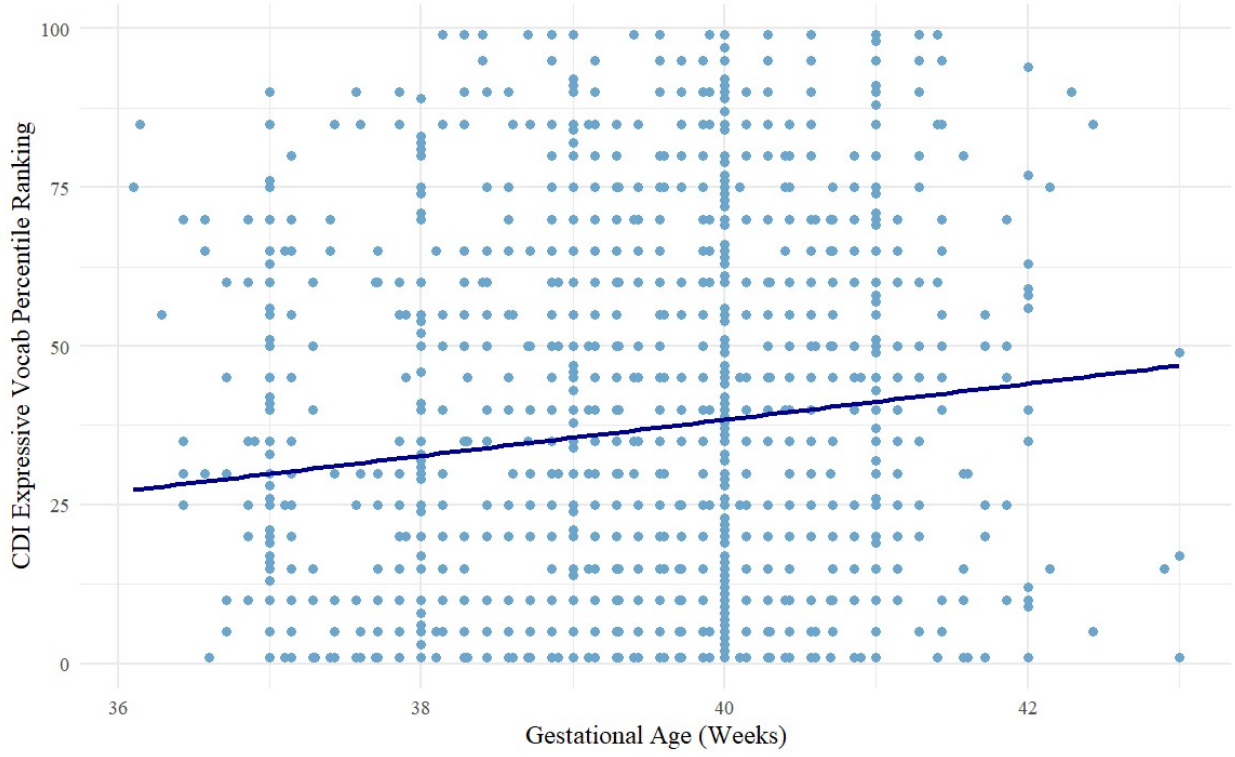


Figure 4. Regression line of gestational age (weeks) on CDI Words Produced percentile ranking when controlling for birthweight

Test Year and COVID-19

Over the years of data collection, percentile rankings have decreased, with 2022 reporting the lowest average (mean = 19.2, SD = 28.1). A Pearson correlation was conducted to examine the relationship between test year and CDI percentile scores and found a small but significant negative correlation between the variables, $r(1835) = -.13$, $p < .001$, 95% CI [−.17, −.08], indicating that CDI percentile scores tended to be slightly lower in more recent test years.

A subset of the sample in which data was collected from 2018-2024 was used to assess the impact of the COVID-19 pandemic on percentile rankings. This subset, which includes only more recent years, was used for pre-vs-post pandemic-onset analyses to create more equally sized pre-vs-post samples than would be obtained by including all pre-COVID collection years. Data were split into pre-COVID-19 test years (2018-3/13/2020) and post-COVID-19 test years (3/14/2020-2024). This subset includes 851 subjects (pre-COVID: n = 482; post-COVID: n = 369). A t-test was conducted to compare pre- and post-COVID scores and found significant differences between groups, $t(546.9) = 4.45$, $p < .001$. Lower scores are reported in post-COVID years (mean = 30.6, SD = 29.5) than in the pre-COVID period (mean = 38.2, SD = 28.6). See Figure 5 for a plot of percentiles over time.

Late-Talking Prevalence

Only 24 to 30-month-olds were assessed for LT status because LT cannot be determined using CDI scores until 24 months. Of this sample of 159 subjects, 38 subjects are indicated as LT (20.8%). As the prevalence of LT is around 10% in the normative sample, rates in our sample are twice that. A larger proportion of males (29.1%) met the LT criteria than females (12.5%). Sex significantly predicted the odds of meeting the criteria for LT ($\beta = 1.04$, $p < .01$), such that males had higher log-odds of scoring below the 10th percentile than females (see figure X.). Those who

were classified as late talkers had a mean vocabulary of 48.1 items (SD = 45.4). In this sample of 24-30-month-olds, 25-month-olds had the largest proportion of subjects classified as LT (37.5%; n = 6). See Figure 6 for LT status by sex.



Figure 5. CDI Words Produced percentile ranking by sex from test years 2012-2024, with a red solid line marking the onset of the COVID-19 pandemic

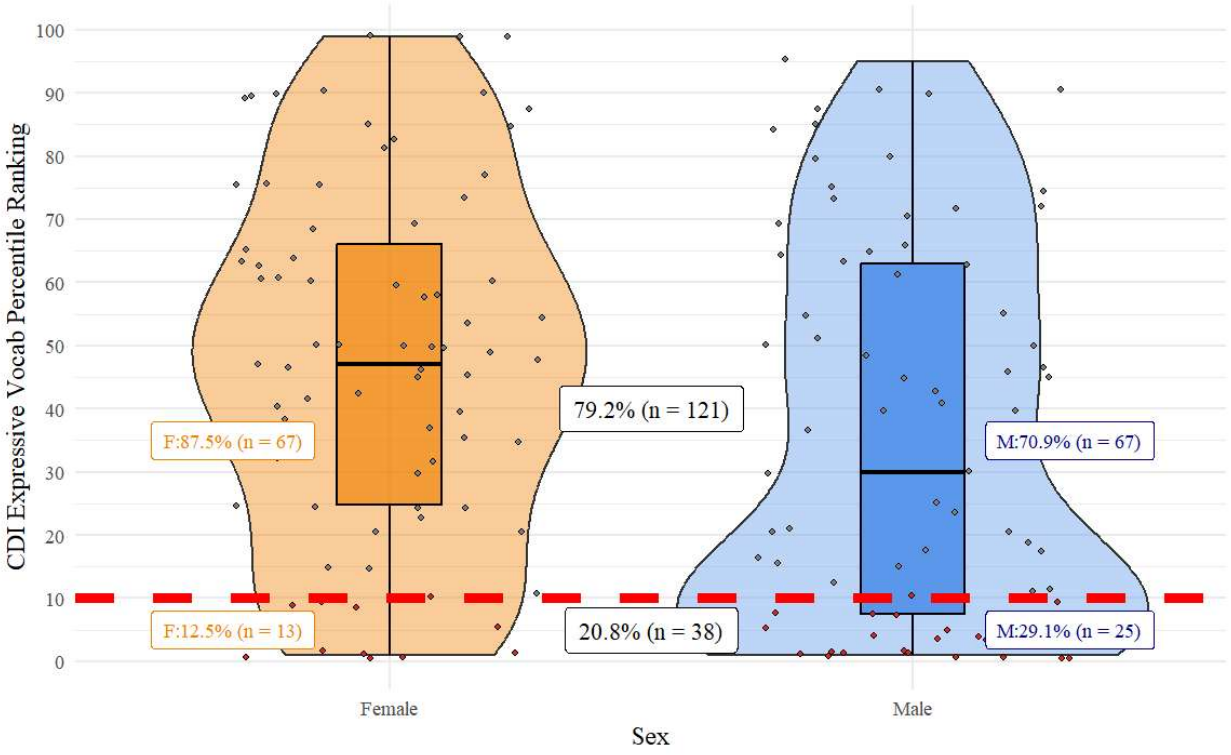


Figure 6. CDI Words Produced percentile ranking by sex for 24-30-month-olds that fall above and below the 10th percentile (late-talkers)

CHAPTER FIVE

STUDY 1 DISCUSSION

The present study examined expressive vocabulary development in a large sample of infants and toddlers from East Tennessee, with the goal of identifying demographic and developmental predictors of variation in language outcomes and assessing regional performance relative to national norms. Several key findings emerged. First, children in this sample, on average, demonstrated lower expressive vocabulary percentile scores than national norms. Second, gestational age—but not birthweight—was a significant predictor of vocabulary outcomes. Third, birth order and test year were associated with poorer language outcomes, whereas socioeconomic status (SES) was not a significant predictor in this sample. Finally, the prevalence of late talking was elevated relative to national estimates, particularly among males.

Regional Differences in Expressive Vocabulary

Consistent with predictions, the average expressive vocabulary percentile in this sample fell substantially below the national norm. This finding aligns with broader educational trends in Tennessee, where reading and language-related outcomes often lag behind national averages (TN DOE, 2024). Because early vocabulary development is closely tied to later literacy and academic success, these findings raise concerns about potential downstream effects on school readiness in this region. Although the present study does not directly assess causal mechanisms, the observed pattern may reflect broader structural and environmental factors that characterize the region, including variability in access to educational resources and differences in early language environments.

Effects of an Infant's Sex

As predicted, there was an effect of an infant's sex on expressive vocabulary size, such that males had lower vocabulary sizes on average than females when controlling for the effect of age. These results, showing that females acquire vocabulary at a faster rate and have a larger overall vocabulary size than males, are consistently reported in the literature. These effects are observed in first-language acquisition and in second-language learning (Payne & Lynn, 2011). Previous literature has reported that these effects might be attributed to differences in socialization between the genders (Simpson et al., 2016), histological sexual dimorphism in brain regions associated with language (Jacobs et al., 1993), and differences in brain activation patterns while completing language-related tasks (Burman et al., 2008).

Gestational Age and Birthweight

One of the more robust findings was the positive association between gestational age and expressive vocabulary. Infants born after longer gestational periods demonstrated higher percentile scores, even within a sample restricted to full-term births. This result is consistent with recent literature suggesting that variation in gestational age within the full-term range continues to have meaningful developmental implications (Yang et al., 2010). Importantly, gestational age remained a significant predictor even when controlling for birthweight, and model comparison using AIC indicated that including gestational age improved model fit beyond birthweight alone.

In contrast, birthweight was not a significant predictor when gestational age was included in the model. This pattern suggests that previously reported associations between birthweight and developmental outcomes may, in part, reflect confounding with gestational duration. In other words, gestational age may capture underlying developmental processes more directly related to early language outcomes than birthweight alone.

Lack of SES Effects

Contrary to a large body of prior research, SES was not significantly associated with expressive vocabulary in this sample. Moreover, the observed (non-significant) trend suggested a negative relationship, which is inconsistent with many previous findings (e.g., Hart & Risley, 1999; Rindermann & Baumeister, 2015). Several explanations may account for this pattern. First, the SES measures available in the current dataset may not have captured the most relevant dimensions of socioeconomic variation, particularly those directly tied to linguistic input (e.g., caregiver speech quantity or quality). Second, the sample may have been relatively limited in SES variability, especially given the overrepresentation of caregivers with higher educational attainment (see table 4). A restricted range can attenuate statistical associations and obscure true effects.

Birth Order Effects

Birth order emerged as a statistically significant, albeit small, predictor of expressive vocabulary, with later-born children demonstrating lower percentile scores. This finding is consistent with prior research suggesting that children with older siblings may receive less one-on-one linguistic input or may experience more distributed caregiver attention (Hoff, 2003). However, the effect size was small, accounting for less than 1% of the variance, indicating that while statistically reliable, birth order is not a major determinant of vocabulary outcomes in this sample.

Temporal Trends and COVID-19

A notable finding was the decline in expressive vocabulary scores over time, with more recent test years associated with lower percentile rankings. This trend was further supported by analyses comparing pre- and post-COVID-19 cohorts, which revealed significantly lower scores

among children assessed after the onset of the pandemic. These results are consistent with emerging evidence that the COVID-19 pandemic negatively affected early language development (Giesbrecht et al., 2024), potentially due to reduced social interaction, increased caregiver stress, and disruptions to typical learning environments. Specifically, during the pandemic, factors that support cognitive, social, and language development were affected, such as a lack of educational child care services (Davies et al., 2021), a lack of face-to-face social interactions due to mask wearing (Bourke et al., 2023), and an increase in early life stressors (Pechtel & Pizzagalli, 2011; Pierce et al., 2021)

Late-Talking Prevalence

The prevalence of late talking in this sample (22.8%) was more than double the commonly reported population estimate of approximately 10%. This elevated rate further supports the broader finding of reduced language performance in this region. Consistent with prior literature (Collisson et al., 2016), males were significantly more likely than females to meet criteria for late talking, reinforcing well-established sex differences in early language development. These findings underscore the importance of early identification and intervention, particularly for at-risk groups within this population.

CHAPTER SIX

STUDY 2 BACKGROUND

Study 1 highlighted predictors of and described the size of this early lexicon in our sample. As revealed in study 1, our sample has around twice the prevalence of LTs as the national average. While this increased prevalence is disheartening for our population of interest, the greater number of LTs in our sample than in the general population allows for further investigation into the factors contributing to their early lexical development. While study 1 examined the size of early expressive lexicons, study 2 aims to describe their composition and differences between LTs, age-matched typically developing infants (TD-AM), and a younger, vocabulary-matched group (TD-VM).

Lexical and Semantic Characteristics of Early Expressive Vocabulary

The lexicon of TD infants grows rapidly during the second year of life (Frank et al., 2021). In addition to the lexicon size examined in study 1, considerable research has sought to characterize the early lexicon (e.g., Braginsky et al., 2019), examining how grammatical category, phonological properties, semantic features, and form–meaning correspondences shape patterns of acquisition. Studies on the characteristics of this lexicon ask why some words are learned early and some much later. For example, words that children hear more frequently in speech are more likely to be learned earlier (Goodman et al., 2008). Many lexical characteristics have been examined in previous studies in relation to acquisition, including phonological and semantic structure (e.g., Gendler-Shalev & Novodrovsky, 2024; Stokes, 2010; Storkel, 2006; Storkel & Hoover, 2009; Swingley & Humphrey, 2018).

The phonological form of words influences acquisition trajectories. Early words often resemble infants' prelinguistic vocalizations, reflecting the continuity between babbling and first-

word production (Stoel-Gammon, 2011). Across languages, children first produce phonologically simpler words before more complex ones (Braginsky et al., 2019; Gendler-Shalev et al., 2021; Hansen, 2017; Vihman, 2017). Additionally, studies have found that words with many similar-sounding words (i.e., many phonological neighbors) are learned at younger ages than those with few neighbors (Stokes, 2010; Stokes et al., 2012; Storkel, 2009). This measure of phonological neighborhood size is typically referred to as phonological neighborhood density (PND). However, the effects of PND are not consistent, with Stokes (2015) and Swingley & Humphrey (2018) finding null effects of PND on acquisition.

Another lexical characteristic relating to phonological structure is iconicity. Iconicity is a measure of the correspondence between aspects of a word's form and aspects of its meaning (Winter et al., 2024). The meaning of a word can correspond to its form in terms of sound, such as the English word "crash," which imitates the sound it makes. The English word "zigzag" is also iconic, as the word mimics the motion of the action. Words with high iconicity tend to be learned earlier, suggesting a facilitative effect (Masaro & Perlman, 2017; Gendler-Shalev & Novodrovsky, 2024).

In addition to these phonological networks, infants are thought to integrate broader semantic-perceptual or experiential information to support lexical acquisition. Before infants produce their first words, sensorimotor experience, including sensory/perceptual and motor/physical information about objects, provides substantial knowledge about their environment (e.g., Lakoff, 2008; Lakoff & Johnson, 1999; Bloom, 2000; Langer, 2001). This prelinguistic information impacts lexical acquisition as infants begin acquiring their first words (Howell et al., 2005) and also impacts later language processing (Barsalou, 1999; Glenberg & Kaschak, 2002). This prelinguistic information helps learners map the words they hear to objects

and events in their environment. The first words they learn scaffold later learning and help constrain associations between labels and referents in their environment (Howell et al., 2005).

The lexical characteristics of concreteness and imageability are similar constructs that reflect this sensorimotor knowledge. Concreteness refers to the degree to which a word can be directly experienced through the senses. The English word "apple" is highly concrete, as you can directly see, touch, taste, feel, and smell it. In contrast, the English word "justice" is not concrete or abstract. Imageability is related to concreteness but refers to the effort required to generate a mental image of something. Many highly concrete words are also imageable (see "apple" example), but imageable words are not necessarily concrete (for example, "justice" can generate a mental image, but is not concrete). So, although these constructs are highly correlated, they are considered to capture distinct aspects of a word (Kousta et al., 2011; Richardson, 1976). In general, words are more likely to be present in early vocabularies if they are highly concrete (Braginsky et al., 2019; Smith & Yu, 2008; Swingley & Humphrey, 2018) and highly imageable (Smith & Yu, 2008).

Another construct related to this sensorimotor knowledge is body-object interaction (BOI), which refers to the ease with which a human body can interact with the word's referent (Siakaluk et al., 2008). Words with high BOI are learned earlier than those with lower BOI, even when controlling for word frequency and imageability (Thill & Twomey, 2016). Recently, Muraki and colleagues (2022) derived a measure of child body-object interaction (CBOI) that better reflects how easily children's bodies can interact with the word's referent, using parent-report ratings. This study also found that the CBOI variable is a better predictor of the age of acquisition for a word than the BOI variable.

Taken together, there is substantial evidence that the characteristics of words in early productive vocabularies are predictive of which words comprise this lexicon. Specifically, greater PND, iconicity, concreteness, imageability, and CBOI are thought to facilitate acquisition. However, much of this work has been done in typically developing infant populations. The impact of these predictors on the early lexicons of infants with delayed language remains unclear.

Expressive Vocabulary in Late-Talking Infants

The findings outlined above all used samples of TD infants, or infants not identified as LT or with any other developmental delays. The impact of PND, iconicity, concreteness, imageability, and CBOI in the early lexicons of LTs has received much less attention in the literature. Examining the lexical characteristics important for LTs' vocabularies can provide insight into whether their word-learning processes reflect delayed versions of typical developmental pathways or qualitatively atypical trajectories.

A 2024 study comparing Hebrew-learning LTs to TD-AM and TD-VM peers found that LTs had stronger positive effects of iconicity than TD-AM and TD-VM groups. However, the TD-VM group had a stronger effect of phonological complexity (negative) and concreteness (positive) than LTs (Gendler-Shalev & Novodrovsky, 2024). While the strength of these effects varied across groups, the direction was consistent, which supports the authors' argument that these results reflect a delay in LT's lexical organization rather than a qualitative difference.

Evidence for atypical lexical organization in LT children comes from MacRoy-Higgins et al. (2016), who compared the vocabularies of LT, TD-AM, and TD-VM toddlers. Semantic category distributions in the LT group resembled those of TD-VM peers but differed from TD-AM peers. Although nouns were the dominant word class across all groups, LT toddlers had

fewer nouns relative to TD-AM and TD-VM peers and produced more animal sounds, sound effects, and games and routines. The authors interpreted these patterns as evidence that LT vocabularies may be atypical rather than merely delayed. Consistent with this interpretation, LT toddlers' lexicons are less semantically interconnected than those of TD toddlers with equivalent vocabulary sizes, suggesting that LT children may not rely on typical semantic association processes when acquiring new words (Beckage et al., 2011).

Taken together, findings on LT children are mixed: some studies support late but typical lexical development (Gendler-Shalev & Novodrovsky, 2024), whereas others point toward atypical acquisition patterns (Beckage et al., 2011; MacRoy-Higgins et al., 2016). For this reason, analyses of LT vocabulary must include both TD-AM and TD-VM comparison groups. The LT to TD-AM comparison isolates age and general developmental experience, while the LT to TD-VM comparison isolates productive language experience.

Study 2 Overview

Study 2 aims to identify word-level characteristics as predictors for lexical acquisition. These characteristics include PND, iconicity, concreteness, imageability, and CBOI. The differential effects of these predictors in LTs, compared with both TD-AM and TD-VM subjects, are assessed. Study 2 used a subset of the sample used in study 1. The sample included an LT group (24-30 months), a TD-AM group (24-30 months), and a younger TD-VM group (18-23 months). A main effect of all predictors was expected to emerge across all groups. LTs were expected to rely more on iconicity and less on concreteness than TD-AMs and TD-VMs. LTs were expected to rely less on PND than TD-AMs, but in a similar manner to TD-VMs. This study is the first to report the effects of imageability and CBOI on LTs.

CHAPTER SEVEN

STUDY 2 MATERIALS AND METHODS

Subset Sample

Only subjects who completed the CDI: Words & Sentences are included in study 2 because this form of the CDI is appropriate for the age range of interest for LT comparisons, and it has more items for lexical analyses than the short-form CDI for the same age range. As such, subjects from the larger sample were excluded if they were not between 18 and 30 months or if they completed a different CDI form (not CDI: Words & Sentences). Three groups were delineated from this smaller sample. First, subjects aged 24 to 30 months were denoted as LT (≤10th percentile for expressive vocabulary), resulting in 29 subjects (6 females, 23 males) between 24 and 30 months (mean = 26.7, SD = 2). Based on this LT group, two matched comparison groups were created. The TD age-matched (TD-AM) group comprises 29 subjects (6 females, 23 males) who were age- and sex-matched to each LT subject. Accordingly, TD-AM subjects were also between 24 and 30 months (mean = 26.7, SD = 2). The final matched group consisted of TD vocabulary-matched (TD-VM) subjects aged 18-23 months (mean = 20, SD = 1.7); this group was matched for raw expressive vocabulary size and sex to each LT subject, resulting in 29 subjects (6 females, 23 males) in the TD-VM group. The total sample for study 2, including all 3 groups, comprised 87 subjects (20.1% female) aged 18 to 30 months. As in study 1, all subjects were English-learning, monolingual infants born full-term (>36 weeks' gestation). See Table 3 for the ages and raw and percentile ranking expressive vocabulary scores for the sample by group.

Table 3. Group Descriptives for Study 2 Sample

	N (% female)	Age (months)		Raw Vocab Size		Vocab Percentile Ranking	
		Range	*Mean (SD)*	*Range*	*Mean (SD)*	*Range*	*Mean (SD)*
LT	29 (20.1%)	24-30	26.7 (2)	5-171	66.8 (45.6)	1-10	5.6 (3.3)
TD-AM	29 (20.1%)	24-30	26.7 (2)	56-516	286.4 (133.2)	12-74	39.5 (19.8)
TD-VM	29 (20.1%)	18-23	20 (1.7)	6-161	65.8 (42.1)	7-75	29.6 (16.6)
Total	87 (20.1%)	18-30	24.4 (3.7)	5-516	139.7 (134.1)	1-75	24.9 (20.7)

Item-Level Characteristics

The MacArthur-Bates Communicative Development Inventory: Words and Sentences (CDI) is a 717-item parent-report questionnaire (Fenson et al., 2007). This questionnaire is for use in 16-30-month-old infants. Of the total items, 680 are words that parents must indicate whether their infant has produced yet. Finally, words not produced by any of the children in the LT or VM groups were removed from the analysis to avoid potential bias in coefficient estimation due to floor effects, resulting in the removal of 89 words. Note that all words were produced by children from the TD group. Thus, the analysis included 591 words out of the 680 words.

Item-level characteristics were obtained for each of the 591 CDI items. PND values were obtained from the English Lexicon Project (Balota et al., 2007). These PND values were calculated using corpus data. Iconicity, concreteness, imageability, and CBOI ratings were given on a 7-point scale, with each value representing the average of adult ratings for that item from the original norming studies. Iconicity ratings were provided by Winter et al. (2024). Ratings for imageability and concreteness were attained from the Glasgow Norms (Scott et al., 2018). CBOI

information was collected from Muraki et al. (2022). See Table 4 for correlations among these item-level variables.

Table 4. Correlations among item-level variables

Measure	1	2	3	4
1. PND				
2. Iconicity	-0.23			
3. Concreteness	-0.19	0.83		
4. Imageability	-0.17	0.91	0.81	
5. CBOI	-0.19	0.65	0.71	0.63

Logistic Mixed-effects Models

To examine how lexical-semantic properties relate to word production, a series of logistic mixed-effects regression models was fit. For each lexical-semantic predictor, a separate model was estimated with word production (produced vs. not produced) as the binary outcome. Fixed effects included age (in months), the lexical-semantic predictor (z-scored), group (LT, TD-AM, or TD-VM), and the interaction between the lexical-semantic predictor and group. Separate models were run to compare LT subjects with TD-AM subjects and LT subjects with TD-VM subjects. Random intercepts for both subject and word were included to account for repeated observations across children and items. Models were fit using a logit link and Laplace approximation. Logistic regressions were computed in R (R Core Team, 2015, version 4.4.1) using the *glmer* function of the *lme4* package (Bates et al., 2015).

All lexical predictors were standardized prior to analysis, allowing coefficients to be interpreted as the change in log-odds of production associated with a 1-standard-deviation increase in the predictor. Age was also standardized. Standardizing these variables aids in model convergence and allows for easier interpretation of coefficients. As only two groups were included in each model, the group variable was dummy coded, with 0 indicating membership in the control group (TD-AM or TD-VM) and 1 indicating membership in the LT group. The estimates of coefficients yielded by these models represent the log-odds of word production with respect to each predictor. Analyses focused on (a) overall effects of each lexical-semantic property and (b) whether these effects differed between LT and comparison groups (TD-AM and TD-VM), as indexed by interaction terms.

CHAPTER EIGHT

STUDY 2 RESULTS

Predictors of Producing a Specific Word

A series of logistic mixed-effects regression models were fit to examine how lexical–semantic properties relate to word production. Each model predicted whether a given word was reported as produced (1) or not produced (0). For each lexical–semantic predictor, a separate model was estimated, including fixed effects of the predictor (z-scored), group (LT vs. comparison group), their interaction, and age (z-scored) as a covariate. Random intercepts for subject and word were included to account for repeated observations across children and lexical items. Because group comparisons were conducted separately (TD-AM vs. LT; TD-VM vs. LT), the main effect of each predictor reflects its effect in the reference group (TD-AM or TD-VM), while interaction terms indicate differences in that effect for LT.

Across models, variance associated with both subjects and words was substantial (random intercept variances typically ranging from 1.7 to 3.8), indicating meaningful heterogeneity in overall production rates across children and across lexical items. These results underscore the importance of accounting for clustering at both the item and participant levels to avoid inflated Type I error rates and to reflect meaningful item- and subject-level differences in production likelihood.

Fixed-effects

Age was a robust positive predictor of production across all models (all ps < .05), indicating that older children were more likely to produce words.

PND was not a significant predictor of word production in either comparison group (TD-AM: $\beta = 0.05$, $p = .48$; TD-VM: $\beta = 0.10$, $p = .29$). However, small but reliable interaction

effects indicated that the influence of PND differed by group. Specifically, the effect of PND was weaker in LT relative to both TD-AM (β = −0.08, p = .044; OR ≈ 0.93) and TD-VM (β = −0.15, p < .001; OR ≈ 0.86). These results suggest reduced sensitivity to phonological neighborhood structure in LT, although the overall effect of PND was small.

In contrast, iconicity had strong positive effects on production (TD-AM: β = 0.68; TD-VM: β = 0.73; both ps < .001; ORs ≈ 1.97–2.08). The effect was significantly stronger in LT relative to both TD-AM (β = 0.16, p = .003) and TD-VM (β = 0.37, p < .001), indicating heightened sensitivity to form–meaning resemblance in LT.

Imageability was also a robust positive predictor of production in both comparison groups (TD-AM: β = 0.68; TD-VM: β = 0.74; both ps < .001), corresponding to approximately twofold increases in the odds of production (ORs ≈ 1.98–2.09). Importantly, the effect of imageability was significantly stronger in LT than in both TD-AM (β = 0.16, p = .003) and TD-VM (β = 0.37, p < .001), indicating that LT are particularly sensitive to how easily a word can be visualized.

Similarly, concreteness was a strong positive predictor of production (TD-AM: β = 0.57; TD-VM: β = 0.60; both ps < .001; ORs ≈ 1.77–1.82). This effect was significantly stronger in LT relative to both TD-AM (β = 0.15, p = .001) and TD-VM (β = 0.34, p < .001). Together, these results suggest that late talkers show a particularly strong bias toward producing highly concrete words.

Finally, CBOI was a strong positive predictor of word production in both comparison groups (TD-AM: β = 0.79; TD-VM: β = 0.85; both ps < .001), corresponding to substantial increases in the odds of production (ORs ≈ 2.19–2.34). There was no clear evidence that this

effect differed by group (TD-AM comparison: p = .092; TD-VM comparison: p = .38), indicating that CBOI facilitates production similarly across LT and comparison groups.

To summarize these results, production in all groups was positively predicted by iconicity, imageability, concreteness, and CBOI. PND did not predict production in any groups. Interactions revealed that LTs rely more heavily on iconicity, imageability, and concreteness than TD-AM and TD-VM. The effect of CBOI was consistent across all groups.

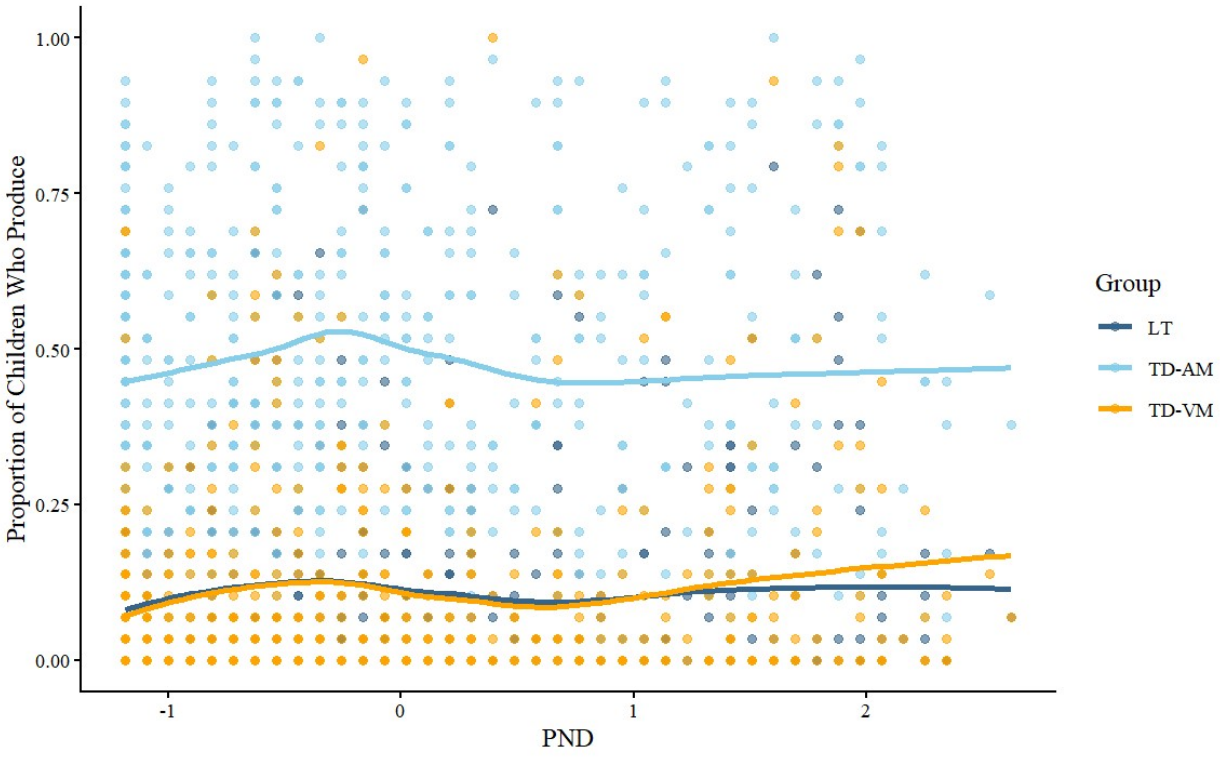


Figure 7. PND by the proportion of children who produce the word with separate lines for LT, TD-AM, and TD-VM groups

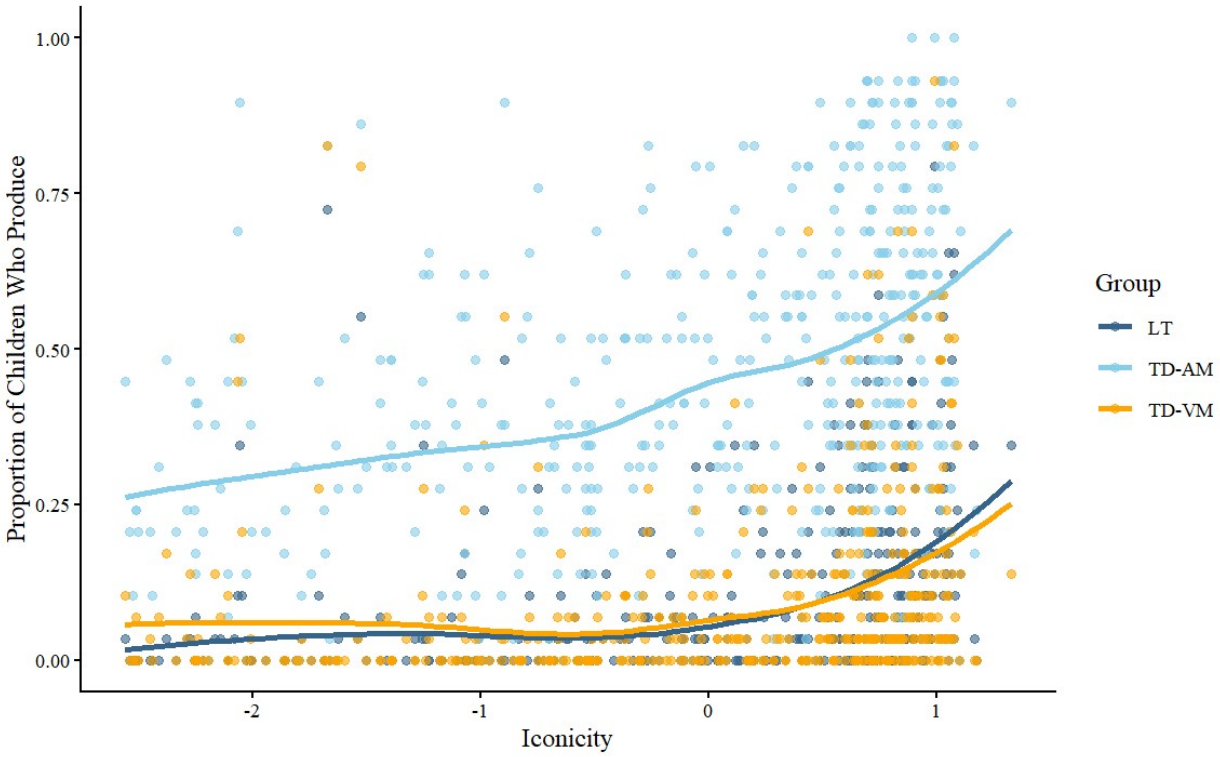


Figure 8. Iconicity by the proportion of children who produce the word with separate lines for LT, TD-AM, and TD-VM groups

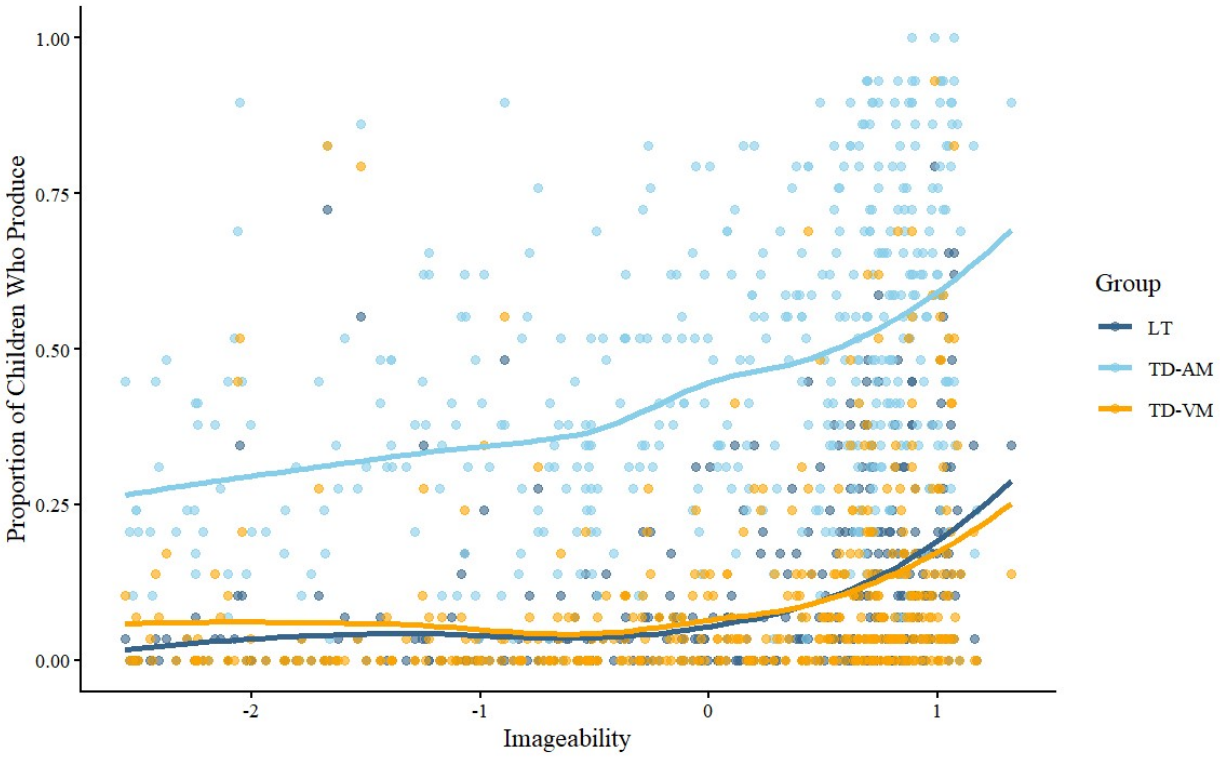


Figure 9. Imageability by the proportion of children who produce the word with separate lines for LT, TD-AM, and TD-VM groups

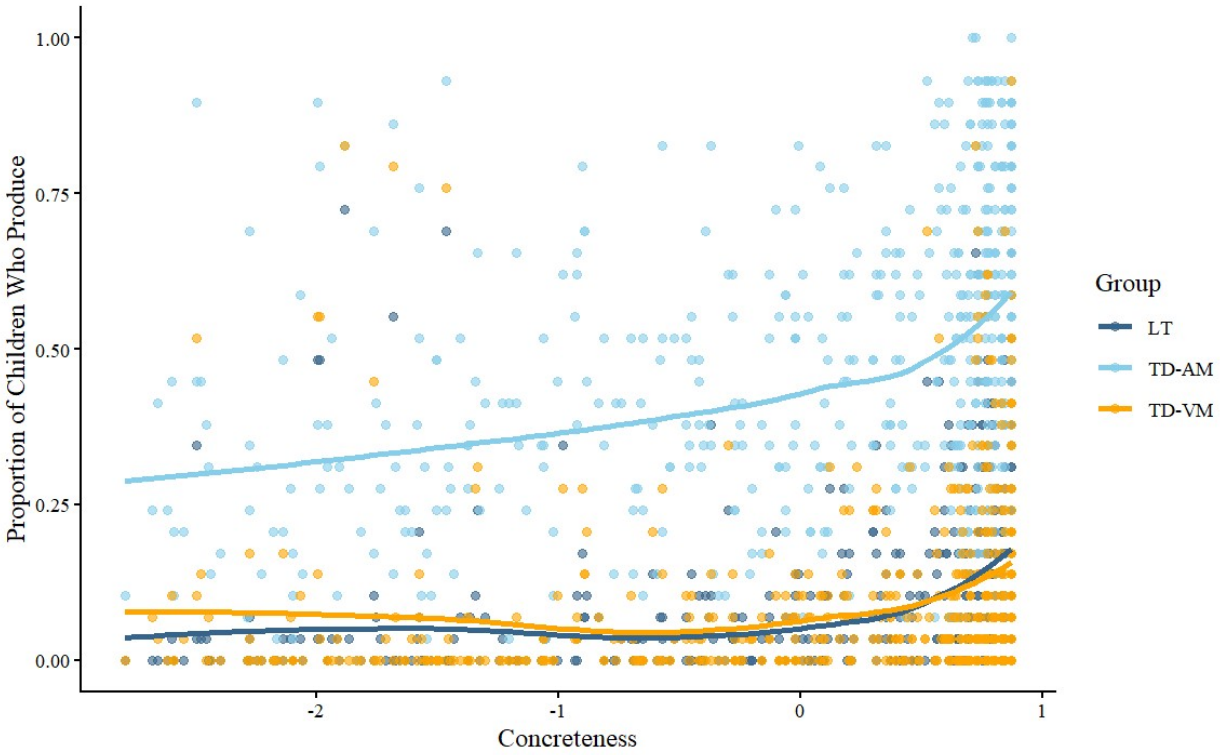


Figure 10. Concreteness by the proportion of children who produce the word with separate lines for LT, TD-AM, and TD-VM groups

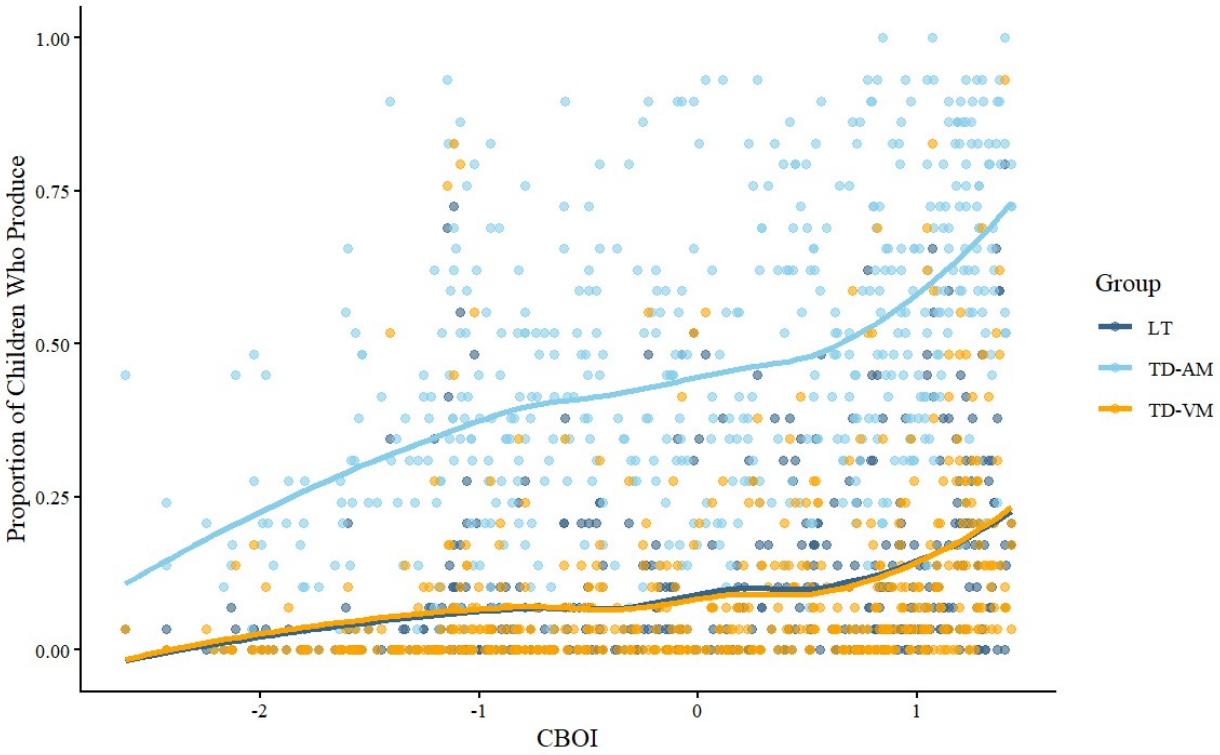


Figure 11. CBOI by the proportion of children who produce the word with separate lines for LT, TD-AM, and TD-VM groups

CHAPTER NINE

STUDY 2 DISCUSSION

The present study investigated how word-level properties relate to early productive vocabulary and whether these relations differ in LTs compared to TD-AM and TD-VM peers. By modeling word production as a function of item-level features while controlling for age, the current findings provide a fine-grained view of the properties that support early word production across different developmental profiles. A central finding across analyses was that age robustly predicted word production in all models, confirming expected developmental increases in expressive vocabulary. Importantly, the consistency of this effect across models indicates that item-level lexical properties explain variation in production above and beyond broad developmental differences.

Contrary to accounts emphasizing phonological neighborhood structure as a constraint on early lexical access (Stokes, 2010; Stokes et al., 2012; Storkel, 2006). PND did not show a reliable main effect on word production in either comparison group. These results do mirror those of Gendler-Shalev & Novodrosky (2024), who also found no main effect of PND. This finding suggests that, at least within the present age range and vocabulary distributions, the density of phonological neighbors does not strongly facilitate or inhibit whether a word is produced. However, small but consistent interaction effects indicated that PND was even less predictive of production in the LT group than in the TD-AM and TD-VM groups. While these effects were statistically reliable in some comparisons, their magnitude was small, suggesting that phonological neighborhood structure is not a primary organizing factor in early productive vocabularies. One interpretation is that phonological competition effects may become more relevant later in development, once lexical density increases and phonological representations

become more finely tuned. Alternatively, early vocabularies may simply not be large enough for neighborhood structure to exert strong competition-based influences. Overall, these findings align with a growing view that phonological constraints play a secondary role relative to semantic and perceptual factors in early word learning (Howell et al., 2005).

In contrast, iconicity, imageability, and concreteness showed significantly stronger effects in LT relative to both comparison groups. This group interaction for iconicity follows our hypothesis and is similar to findings that Hebrew-learning LTs rely more heavily on iconicity than TD-AMs or TD-VMs. However, the findings for concreteness conflict with those from the same study (Gendler-Shalev & Novodrosky, 2024), which found that TD-AMs infants relied on concreteness more than LTs and TD-VMs. Our findings suggest that LT children may rely more heavily on perceptual and form-based cues when producing words. One possible interpretation is that these properties provide additional scaffolding when lexical representations are weaker or less robustly encoded. Rather than indicating a qualitatively different learning system, this pattern may reflect a compensatory reliance on more salient or easily representable word features.

CBOI showed remarkably stable effects across LT, TD-AM, and TD-VM groups, suggesting that this property reflects highly general constraints on early lexical acquisition. Words more closely tied to children's bodily interactions appear to be universally privileged in early production, consistent with embodied accounts of language learning.

Taken together, the findings suggest a coherent pattern: early word production is most strongly supported by semantic and perceptually grounded properties of words, whereas phonological structure plays a comparatively limited role. These findings contribute to theories of early lexical development by highlighting the central role of semantic and embodied structure

in shaping production. In particular, they support accounts in which early vocabulary acquisition is grounded in perceptual and action-based experience, rather than being primarily driven by phonological similarity or abstract lexical structure. This interpretation is supported by theories of grounded cognition (Barsalou, 1999) and word learning, which posit that perceptually salient, and thus embodied, concepts direct word learning (Howell et al., 2005; gu et al., 2005).

The results of the current study also add to the theoretical debate on whether LTs' use of lexical cues represents a developmental delay or, instead, a qualitative difference when compared to TDs. On the one hand, LTs used the same cues as the TD comparisons, with positive effects for iconicity, concreteness, imageability, and CBOI reported across groups. The effects of iconicity, concreteness, and imageability were stronger in LTs. So, while LTs show a similar overall profile of lexical sensitivity, they also show stronger weighting toward certain representational features. Thus, an argument can be made that this pattern is more consistent with a graded difference than with a qualitatively distinct developmental pathway, as LT children appear to draw on the same types of cues and leverage them in the same direction as TD children. In this way, LT development may reflect a shift in the relative weighting of cues over time, rather than a fundamentally different learning system.

However, LTs showed greater reliance on these properties when isolating age (TD-AM comparisons) and vocabulary knowledge (TD-VM comparisons). These differences in effect strength, when accounting for the impact of age and ability in the study design, better support the notion that the composition of LTs' lexicons is qualitatively different from that of TD-AM and TD-VM. Under this interpretation, LTs rely more on perceptual and embodied cues for word learning than TDs. This has implications for the development of interventions to support lexical

development in LTs, as treatments could aim to leverage LTs' preference for these embodied cues or to develop LTs' use of lexical cues to better match that of TDs.

Study 2 Conclusions

The present findings demonstrate that early word production is systematically shaped by perceptual and embodied properties of words, with relatively limited influence of phonological neighborhood structure. While LTs show reduced overall production, the organization of their vocabularies is broadly consistent with that of comparison groups. Differences between groups primarily reflect variation in the strength of sensitivity to specific lexical properties but still suggest qualitatively distinct patterns of lexical organization. These results support a view of early vocabulary development as grounded in experience-based learning for all infants, but LTs show stronger dependence on the perceptually relevant cues that support word production.

CHAPTER TEN

GENERAL DISCUSSION AND CONCLUSIONS

The present work examined early expressive vocabulary development in a large regional sample of infants and toddlers from Eastern Tennessee, with the goal of characterizing both vocabulary size (Study 1) and lexical composition (Study 2). Across these two studies, several converging findings emerged. First, children in this sample demonstrated lower-than-average expressive vocabulary scores and elevated rates of late talking relative to national norms. Second, while demographic and developmental factors (e.g., gestational age, birth order, and cohort effects) accounted for some variation in vocabulary size, much of the variability remained unexplained. Third, analyses of lexical composition revealed that word production is strongly shaped by perceptual and experiential properties, and that LTs show heightened sensitivity to these properties relative to TD-AM and TD-VM peers. Taken together, these findings provide a more comprehensive account of early lexical development in this population and offer insight into the mechanisms underlying both typical and delayed language acquisition.

Integration of Vocabulary Size and Lexical Composition

A central contribution of the present work is the integration of macro-level outcomes (vocabulary size) with micro-level structure (word-level characteristics). Study 1 demonstrated that, on average, children in this regional sample produced fewer words relative to national norms and exhibited a substantially higher prevalence of late talking. Study 2 extends this finding by showing that, despite these quantitative differences, the qualitative structure of the lexicon remains largely intact.

Specifically, across all groups, word production was strongly predicted by imageability, concreteness, iconicity, and CBOI. These findings are consistent with a large body of literature

suggesting that early lexical acquisition is grounded in sensorimotor and perceptual experience (Howell et al., 2005). Importantly, these effects were not only present in TD children but also in LT children.

However, LT children exhibited systematically stronger effects of imageability, concreteness, and iconicity. When considered alongside the reduced overall vocabulary size observed in Study 1, this pattern suggests that LT children may rely more heavily on highly salient or easily representable words during early lexical development. Thus, differences in vocabulary size appear to be accompanied by differences in the weighting of lexical cues, rather than differences in the presence or directional effects of those cues.

Implications for Late Talkers

These findings bear directly on the ongoing debate regarding whether late talking reflects a delay within typical development or a qualitatively distinct developmental pathway. The results of the present studies provide stronger support for a qualitative difference. On one hand, the overall similarity in the direction of lexical effects across LT and TD groups suggests reliance on the same underlying learning mechanisms. This aligns with accounts proposing that early lexical acquisition is driven by general-purpose learning processes grounded in perceptual and experiential input (Howel et al., 2005). However, the amplified sensitivity to perceptual and semantic features observed in LT children indicates that these mechanisms may be differentially engaged depending on the state of the developing lexicon.

At a broader theoretical level, these findings support embodied and usage-based accounts of language development, which emphasize the role of perceptual experience and interaction with the environment in shaping early lexical representations (Juhasz et al., 2011). The robust and consistent effects of CBOI across all groups further suggest that action-based experience

may serve as a foundational constraint on early word learning, independent of developmental status.

Regional and Environmental Considerations

The present findings also highlight the importance of contextual and regional factors in early language development. The lower average vocabulary scores and elevated rates of late talking observed in Study 1 are consistent with broader educational trends in the region, including below-average reading performance (TN DOE, 2024). While the current data do not allow for causal inference, these patterns suggest that environmental factors may influence early language outcomes at the population level.

Additionally, the observed decline in vocabulary scores over time, particularly in the post-COVID cohort, aligns with emerging evidence that the pandemic may have disrupted early language development (Giesbrecht et al., 2024). Reduced social interaction, changes in caregiver stress and availability, and altered learning environments may all have contributed to these effects. Importantly, Study 2 suggests that even with a reduced vocabulary size, the lexicon's structure remains governed by similar principles, indicating a degree of resilience in underlying learning mechanisms.

Limitations

Several limitations should be considered when interpreting these findings. First, the cross-sectional nature of the data limits conclusions about developmental change. Longitudinal analyses would be particularly informative for determining whether the observed group differences reflect delays, developmental shifts, or stable differences in lexical organization. Second, vocabulary was assessed using the CDI, which, while widely validated, relies on parent report and may not capture all aspects of language use or comprehension. Additionally, infants

may produce words not included in the CDI vocabulary checklist. Incorporating experimental or naturalistic measures of word use could help refine interpretations of these effects. Third, the lack of SES effects in Study 1 may reflect limitations in how SES was operationalized and limited variability in the sample. Finally, in Study 2, several lexical variables (e.g., imageability and concreteness) are highly correlated, which may complicate the interpretation of individual effects.

Conclusions

The present work provides a comprehensive examination of early lexical development by integrating population-level patterns of vocabulary size with item-level analyses of lexical structure. Across both studies, the findings suggest that: Early vocabulary development in this regional sample is delayed relative to national norms, with elevated rates of late talking. Word learning is strongly shaped by perceptually salient and embodied properties across all developmental groups. Late talkers exhibit greater reliance on these properties, consistent with a developmental delay rather than a qualitatively different system. These results underscore the importance of examining both how much children know and what kinds of words they know when studying early language development. Future research should extend this work by incorporating longitudinal designs, more fine-grained measures of language input, and experimental approaches to better understand how lexical representations evolve over time More broadly, the findings suggest that early language development is robustly grounded in experience, with variability arising not from differences in the underlying system, but from differences in how learners engage with and weight the information available to them.

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