A Cross-Validated Approach Towards Identifying the Unique and Cumulative Contributions of Child and Family Factors Predictive of Speech-Language Therapy Start Time

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Abstract

Language is an important milestone in early childhood and paves the way for later achievement and outcomes. Early identification and communication-focused interventions can provide additional environmental supports to foster language development for children who face challenges in acquiring language. To accurately identify and predict who may be likely to receive speech/language services, it is crucial to understand the *unique* contribution and the *cumulative* effect of factors that best predict speech-language service status and service receipt start time. Using data from the Early Childhood Longitudinal Study – Birth Cohort (ELCS-B), the current study sought to identify, within a bio-ecobehavioral framework, the unique and combined contribution of child and family factors predictive of speech-language therapy (SLT) start time. Multinomial logistic regression was used to evaluate child and family factors predictive of SLT start time. In addition, *k*-fold cross-validation was performed to assess generalizability. The final model accurately predicted SLT start time 62% of the time and only included child-related factors. The presence of an intellectual and developmental disability (IDD), prelinguistic performance, cognitive growth, and the number of words said at 24-months all provided a unique contribution in predicting SLT start time.

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Chapter 1

Introduction

The ability to communicate opens the door to countless opportunities; it allows us to convey our wants, needs, ideas, facilitates social connections, and provides access to knowledge about the world around us, to name but a few examples. To achieve this, we have a conventional system of symbols and rules shared by a group of people (i.e., language). Speech is often a primary means to transmit symbols, but it does not have to be; gestures, facial expressions, and other strategies can serve as alternatives to spoken language or augment it.

One of the first things we learn is to communicate. As children develop, their communication becomes more intentional and specific: moving from crying and babbling, verbal approximations and single words to complete sentences. Some children, however, may encounter challenges to acquiring language (rules and conventions) and/or ways in which language is transmitted (e.g., speech vs. sign). Access to speech-language therapy (SLT) can help change language development trajectories and improve outcomes.

Language delays and impairments can be secondary or primary. Secondary language delays and impairments are attributed to other conditions such as autism, Down syndrome, or a developmental delay. In contrast, primary speech delays/impairments are not associated with any underlying organic basis and are known as developmental language disorder (DLD) – formerly known as specific language impairment (SLI). This study will include children with both primary and secondary speech delays/impairments. Going forward, unless specified otherwise, the term *speech delays/impairments* refers to both primary and secondary causes for speech delays/impairments.

Between 3%-16% of children in the United States have a speech-language or communication disorder (Centers for Disease Control and Prevention, 2012). For preschoolers, prevalence estimates increase to 2%-19% (Nelson et al., 2006), and between 40%-50% of children receiving early intervention/early childhood special education (EI/ESCE) services have a speech or language impairment (Hebbeler et al., 2007; Scarborough et al., 2006). Because language and communication are a cornerstone of our society, we need to do all we can to provide environmental supports to foster language and communication development for our youngest learners.

Theoretical Foundation

This dissertation situates language development within three complementary frameworks: bioecological (e.g., Bronfenbrenner & Ceci, 1994; Shonkoff, 2010), developmental (e.g., Adamson et al., 2019), and ecobehavioral (e.g., Ford et al., 2020). These theories provide frameworks to highlight the complexities of child development and how the interplay of proximal and distal factors can affect and thus change developmental trajectories. While both ecobehavioral and bioecological models emphasize and accommodate development, ecobehavioral frameworks examine malleable variables (both proximal and distal from the outcome of interest) that can be leveraged to change developmental trajectories. By contrast, bioecological frameworks also include more stable variables that may still have relations to overall development. Both theories incorporate time and the effect of cumulative experiences on development. Because language development does not happen in a vacuum, we cannot examine it in a vacuum. By placing language acquisition at the center of a bioecological/ecobehavioral framework, it shows the interplay of a multitude of factors that influence and contribute to language development: child and family characteristics, but also system-level policies, practices, and inequalities. For example, parental leave may afford the time and space for parent-child interactions, creating language learning opportunities (Berger et al., 2005; Galtry & Callister, 2016). However, there are racial disparities in who has parental leave (Bartel et al., 2019). This example illustrates how laws, history, and social conditions (i.e., macrosystem) can impact caregiver work environments (i.e., exosystem) and, in turn, affect family environments (i.e., microsystem) and the individual child.

The Language Opportunity Gap

Due to the pivotal nature of language and communication, delays and impairments can have cascading consequences on academic achievement, behavior development, social skills, later employment, and quality of life (Fujiki et al., 1996; Justice et al., 2009; Rescorla, 2009; Tomblin et al., 2003; Yew & O'Kearney, 2015). For some of the associations (e.g., social skills), the relationship is more reciprocal: language facilitates social connections, but social interactions, particularly in the early years, also foster language development. For others, it is more linear (e.g., literacy and academic achievement). This section provides a brief overview of the relationship between language, literacy development, academic achievement, social skills, and behavior. In addition, it illustrates the opportunity gap that arises when there is a language or communication delay or impairment that only widens without mediation (e.g., Scarborough, 2001).

Language, Literacy, and Academics

As children navigate more complex language environments during their school-aged years, they require equally complex language proficiencies. Complex language proficiencies and modes used to transmit language (e.g., literacy, lexical complexity) rest on the more foundational skills (e.g., expressive vocabulary). For example, literacy becomes increasingly prevalent as children progress through their education, becoming a tool to share and receive information in their classes. The relation between early language development and later literacy skills is well established: oral language performance predicts reading abilities for children with typical development (e.g., Dickinson et al., 2010; Duff et al., 2015; Kendeou et al., 2009; Roth et al., 2010) and those with language delays/impairments (e.g., Hammer et al., 2010; Rescorla, 2009; Skibbe et al., 2008). Thus, the relation between oral language and literacy demonstrates how early language foundations (e.g., oral language) affect later more complex language skills and highlights how interventions could change developmental trajectories.

Furthermore, Barton-Hulsey et al. (2018) found that speech ability in children with developmental disabilities and complex communication needs (CCN) is not related to phonological awareness. Rather, receptive language and print knowledge skills, independent of their speech ability, supported phonological awareness development. Findings like, Barton-Hulsey et al. (2018) demonstrate how low expectations, inadequate literacy interventions, and supports may be playing a role in the language opportunity gap for children who require speech/language services. The relationship between early language skills and writing (e.g., Kent et al., 2014) and math (e.g., Chow & Jacobs, 2016) is also well documented in the literature. These findings underscore how pivotal a strong language foundation is to a child successfully navigating their academic careers.

Language and Social Skills

Language, typically speech, is integral to social interactions and social interactions are integral to developing language. Children who experience challenges in developing spoken language and are in environments where speech is the expected mode of communication, but do not have the adequate supports to join in that communication (e.g., augmentative and alternative communication) are likely to fall short. Children with language delays/impairments tend to be more withdrawn from social interactions (Fujiki et al., 1996), have fewer friends, and smaller social networks (Chen et al., 2020). This may be due to a mismatch of communication strategies needed to navigate social interactions and mitigate conflicts (Chen et al. 2020). Another contributing factor could be that children with typical language development are less likely to choose play partners with a language delay and more likely to interact with peers with similar language abilities (Fujike et al., 1996). When the communication abilities of children with language delays/impairments are centered, it highlights shortcomings in how the environment is structured (e.g., supports, accommodations) and the communication skills of the communication partners, rather than shortcomings in their inherent ability. Besides providing timely speech and language services, there is a need to focus on interventions and supports to increase language and communication in students with language delays/impairments *and* their communication partners.

Behavior

The co-occurrence of language and behavior problems is well documented. Stronger language skills - both receptive and expressive - are associated with fewer disruptive behaviors (Chow, 2018; Chow & Wehby, 2016; Curtis et al., 2018; Roberts et al., 2018). However, this relation may be stronger for receptive language (Chow et al., 2018). These associations are present as early as 18 months (Roberts et al. 2018) and are stronger for females (Roberts et al. 2018; Chow et al. 2018). Furthermore, a recent meta-analysis conducted by Curtis and colleagues (2018) examined the relations between language disorders and problem behavior across development and found a compounding effect of time – the difference in the rate of problem behavior increases over time compared to children without language disorders.

Closing the Language Opportunity Gap

It is evident that there is an opportunity gap related to academic, social, and behavioral outcomes for children with language delays/impairments (Fujiki et al., 1996; Justice et al., 2009; Rescorla, 2009; Tomblin et al., 2003; Yew & O'Kearney, 2015). It is also clear that we can reduce the language opportunity gap by providing timely services and supports (Hebbeler et al., 2007). Furthermore, more significant gains can be made if services start before school entry (Harrison et al., 2009). The first years are critical for laying down the foundations for language development (Kuhl, 2010); therefore, children who require language/communication supports must be identified as early as possible.

Predictors of Language Delay/Impairment and Service Use

Predictors

Bioecological theories (e.g., Bronfenbrenner & Ceci, 1994) and ecobehavioral models (e.g., Ford et al., 2020) provide helpful frameworks for examining risk and protective factors associated with language development. They offer a visual organization of different elements that illustrate their proximity to language acquisition and highlight the complex interplay between proximal (e.g., caregiver-child interactions, family/child characteristics) and distal factors (e.g., Community supports, policies). Chapter 2 will provide a more in-depth review of the literature concerning predictors of speech/language impairments and who receives services, but a brief overview is presented below.

Child characteristics are some of the most proximal factors. Language delays and impairments are commonly associated with intellectual and developmental disabilities (IDD: e.g., Down syndrome, autism, Fragile X; Abbeduto et al., 2016) and are likely to be identified via a primary IDD diagnosis or other medical diagnoses such as low birth weight and or premature births (McManus et al., 2013). For others, there is no organic basis for speech/language delays/impairments –developmental language disorder (DLD), formerly known as specific language impairment (SLI). Other child factors include sex – males are more likely to develop speech/language impairment (Harrison & McLeod, 2010). Moving outward, family characteristics such as an increase in maternal wellbeing and supportive home learning environments serve as protective factors for language acquisition (Harrison & McLeod 2010). Moving even further out, we can see the negative impact of social inequalities (e.g., SES) on language development (Fernald et al., 2013; Hoff, 2006).

These examples illustrate how bioecological and ecobehavioral frameworks can work in tandem. We as researchers/practitioners/educators cannot change a child's biological sex, diagnosis, or a family's SES, and as a result, these variables are not targets for intervention. However, they are associated with malleable factors that can be used to change developmental trajectories. For example, we can provide supports and resources to reduce parental stress for parents of children with disabilities or lower SES backgrounds who may be experiencing higher levels of stress (Baker et al., 2002; Jess et al., 2018; Stanton-Chapman et al., 2004). By increasing parental wellbeing, we can enhance parents' capacity to facilitate language learning opportunities (Paulson et al., 2009). Although we cannot change a family's SES, we can use our research to advocate for policies that reduce SES inequalities. The application of ecobehavioral and bioecological frameworks to guide identification and intervention efforts provides the opportunity to intervene at multiple levels. We can include both strategies to increase parental wellbeing and teach strategies that foster language acquisition and, as a result, enhance the home learning environment more than if focusing on one level.

Who receives services?

We know little about who, on a United States national scale, receives speech and language services, nor about the timing and duration of service use. In addition, most of the research on service use examines speech/language interventions in focused populations (e.g., premature birth, low-birth weight; McManus et al., 2013) or international data (e.g., Skeat et al., 2014). Therefore, results of these previous studies may not be generalizable to the U.S. population as a whole.

Parental concern is a primary indicator of who receives SLT (Skeat et al., 2010; Skeat et al., 2014). Expressive language is also another important predictor of receiving SLT (Morgan et al., 2016). Morgen and colleagues (2016) found that low birth weight and expressive language delay at 24 months were strongly predictive of receiving services by five years of age. Additionally, they found that Black children and children whose parents' native language was not English were less likely to receive speech/language services. However, some studies provide evidence of overrepresentation of students from non-dominant cultures in special education and related fields (Annamma et al., 2014). These discrepancies highlight the nuances in disproportionality and disabilities research and emphasize a need to go above and beyond simple binary framing (Artiles et al., 2012).

Limitations of Past Research

The aims of the current study sought to address some of the limitations of past research. Studies examining focused populations and the use of cross-sectional designs provide valuable insight into identifying who receives SLT and when those services begin. However, they do not capture developmental trajectories or the impact of policies and practices at a national level. Therefore, the current study used data from the Early Childhood Longitudinal Study – Birth Cohort (ECLS-B) that provided both longitudinal data and was nationally representative. Many studies only include predictors measured at 24 months (e.g., Morgen et al., 2016), preschool age (e.g., Wittke & Spaulding, 2018), and kindergarten (e.g., Zhang & Tomblin, 2000). Given that earlier start times to receiving early intervention are associated with improved outcomes (e.g., Harrison et al., 2009; McManus et al., 2019), it is essential to identify children who need additional supports as early as possible. Thus, the current study includes data assessed at 9-months to examine if SLT start time can be identified at 9-months. Lastly, the application of logistic regression to early intervention and SLT can provide helpful insights into examining and identifying risk and protective factors: it handles qualitative outcomes (e.g., received services or not, responding to intervention or not; i.e., categorical dependent variables), and results can be interpreted in odds ratios (see Tomblin et al., 1997; Zubrick et al., 2007 for a further description related to the field of speech-language pathology). However, given that the application is often used to predict what would happen for cases similar to the study data, results must be robust and generalizable, especially when used to inform policies and practices. This is particularly true when using national representative data where claims are made that generalize to the population that is being studied. Cross-validation (CV) is one method that can be incorporated into analyses to assess the model's generalizability and was used in the current study.

Purpose of Dissertation

The purpose of this dissertation was twofold: to provide a substantive contribution to identifying predictors of who receives SLT through EI/ESCE services and to highlight some methodological considerations when building logistic regression models. By examining the unique and combined contribution of factors within an ecobehavioral framework, this study built upon previous work in identifying who receives speech/language intervention services. To accurately identify and predict who may be likely to receive speech/language services, it is crucial to understand each factor's *unique* contribution and the *cumulative* effect of the clusters that best predict speech-language service status. By accurately identifying who is receiving SLT and determining the earliest window for identification, researchers can detect factors that can be used for future early screening and intervention efforts (Harrison & McLeod, 2010; Morgan et al., 2016).

A second study purpose was to examine the accuracy and generalizability of the models used to predict SLT status. As secondary data analysis becomes more common within the special education and speech-language field and the increasing number of advanced statistical methods that can be used to gain new insights from these datasets, it is important to ensure robust results. The generated models must not be overfitted, reducing their ability to generalize results. Cross-validation is one method to determine if the model generalizes from the training dataset to a validation dataset and was used in the current study. The following two research questions guided the current study.

- ***RQ1:*** For children who are receiving early intervention services, are there differences in child, family, and community characteristics associated with speech-language therapy status: never receiving speech-language services (*never*), start receiving services at 24mos (*early*), and start receiving services at 48 or 60mos (*late*)?
- ***RQ2:*** Using cross-validation techniques to assess predictiveness, what child, family, and community characteristics best predict speech-language therapy status?

Chapter 2

Literature Review

We live in a society where language affords us the opportunity to interact with our surrounding environments. Whether engaging in social interactions with peers and families, acquiring new knowledge, or expressing our needs and wants, we often rely on language to achieve these objectives. Acquiring language is a foundational milestone in a child's development and is a dynamic and ongoing process that begins long before a child's first words. Given the importance of language ability to navigate these complex interactions, it is not surprising to imagine how having difficulties acquiring the conventions of our language system can have a negative impact on social, academic, and quality of life outcomes. Children who experience language delays are more likely to experience poorer academic, social, and behavioral outcomes (Fujiki et al., 1996; Harrison et al., 2009; Walker et al., 1994; Yew & O'Kearney, 2015), often compounding over time without adequate supports and interventions.

Children follow different language developmental trajectories, shaped by biological and environmental factors that vary in proximity to the language acquisition process (Adamson et al., 2019; Hayiou-Thomas, 2008). For example, more proximal factors such as individual characteristics (e.g., biology) and family and home characteristics (e.g., family history of disability, language nutrition), as well as more distal variables (e.g., access to services or screening and identification efforts; see Figure 1), can influence individual trajectories towards communicative competency (Adamson et al., 2015; Bang et al., 2019; Haebig et al., 2017; Hirsh-Pasek et al., 2015; Saffran, 2018; Zauche et al., 2017). For many children, their individual characteristics and environmental supports, or the naturally occurring opportunities to respond and participate in language-building interactions, are enough to facilitate language acquisition (Fernald & Weisleder, 2011; Hoff, 2006; Hurtado et al., 2008; Romeo et al., 2018; Rowe, 2012; Rowe et al., 2017; Walker et al., 2019).

For some children, additional supports and modifications may be needed. Given the right timing and intensity of these supports, developmental trajectories can change course and, in turn, improve language outcomes (Koegel et al., 2014; Moeller, 2000). Practical experience and research findings suggest that various factors affect who gets these services, how early in a child's life these services begin, and the effect these services produce. In addition, families may face barriers to accessing services. These include staff shortages (ASHA, 2019; Wise et al., 2010), the timing of screening and evaluations, and long waitlists (Dimian et al., 2021; McGill et al., 2020). Furthermore, once receiving services, there is often a mismatch between service needs and services received. For example, Hustad and Miles (2010) analyzed the individualized education plans (IEPs) of 22 children with cerebral palsy (CP). They found that 95% of these children would benefit from AAC-related goals, but only 57% of children had AAC-focused IEP objectives.

Conceptual Framework

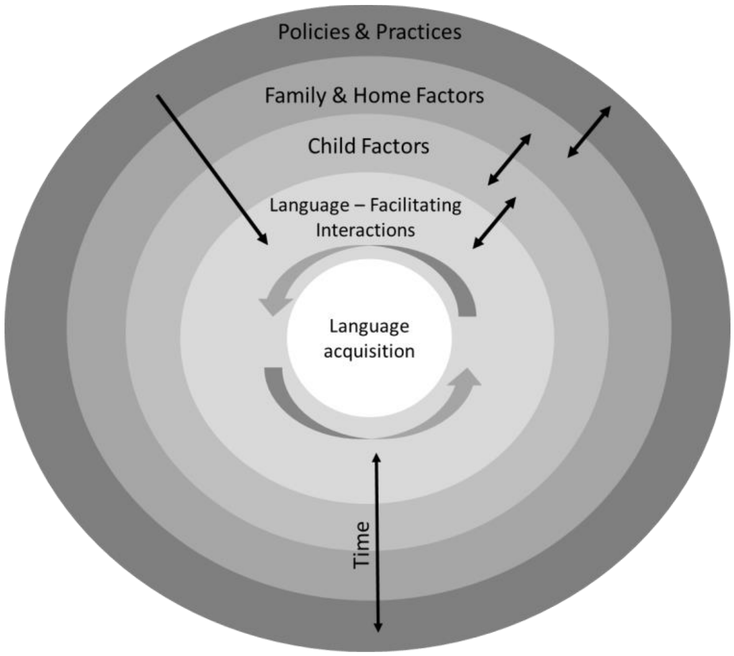
The purpose of the current chapter is to provide an overview of the conceptual framework that guided my dissertation, highlighting how proximal and distal variables interact to influence who may require additional support to achieve communicative competency and how these variables impact access to services. This current framework (see Figure 1) places language acquisition at the center of the model and argues that children acquire language through dyadic exchanges with communication partners facilitated by supports and stimuli in their environment (i.e., language facilitating interactions). As one moves out from the center of the model, other variables, in turn, affect the quantity and quality of these child-communication partner interactions, which in turn drive language acquisition. Three layers vary in their proximity to language acquisition and the interactions that drive it; child characteristics, home and family factors, and policy and practices. Each layer contains factors that influence the trajectory of language acquisition through language-facilitating interactions. Time is the last component of the model, and its contribution will be discussed within each section. I will provide a brief overview of the theoretical frameworks in which the current dissertation and the current conceptual framework are situated and then go on to describe how factors in each layer influence language development

Guiding Theoretical Frameworks

The current conceptual framework is situated within three complementary conceptual frameworks: bioecological (e.g., Bronfenbrenner & Ceci, 1994), developmental (e.g., Adamson et al., 2019), and ecobehavioral (e.g., Ford et al., 2020). These frameworks illustrate the complexities of child development and how biological and environmental factors can influence developmental trajectories. When designing and evaluating screening, evaluations, and interventions efforts to foster language development, it is essential to have a holistic picture of language development and understand the complexities surrounding one of the most important components of our society.

Figure 1

Conceptual Framework for the Current Study



Note. A bio-ecobehavioral model of language development, which views language facilitating interactions as the mechanisms for language acquisition, seeks to conceptualize the influences that individual child characteristics, family and home factors, and policies and practices have on the quality and quantity of these interactions. The arrows represent the bidirectional influences and the impact of developmental change over time.

Developmental Perspective

Developmental perspectives are present in both ecobehavioral and bioecological frameworks, as both are concerned with understanding and/or changing developmental trajectories to improve later outcomes. Both theories underscore the importance of understanding child development, in this case, language acquisition, in designing and implementing resources and supports to foster language development.

Adamson and colleagues (2019) proposed eight developmental premises for early language acquisitions with direct implications for language interventions and, in their case, parent-focused language interventions (e.g., different pathways to language development lead to important outcomes; parents play a crucial role in establishing the contexts that introduce a child to language; language-facilitating interactions are collaborative, transactional processes composed of more than just the child's and parent actions). These premises, also heavily influenced by Bronfenbrenner's ecological systems theory and the transactional model of development (Sameroff, 2010), help illustrate how factors varying in proximity to language acquisition shape developmental trajectories (Adamson et al., 2019). Many of Adamson and colleagues' (2019) premises are captured in the application of ecobehavioral (e.g., the importance of language facilitating interactions) and bioecological (e.g., the influence of multilayer system surrounding the child) frameworks to guide language development research and practice.

There are, however, three premises worth noting individually that highlight the importance of infusing a developmental perspective into language research. These are: (a) the pathway to language begins well before the first word; (b) pathways contain a variety of challenges to language learning; and (c) different pathways lead to important differences in outcome (Adamson et al. 2019). The first premise highlights the importance of foundational language skills such as prelinguistic skills, statistical learning, and joint attention in building the foundations for language acquisition (Bakeman & Adamson, 1984; Mundy et al., 2007; Oller et al., 1999; Saffran et al., 1996). The second premise illustrates that language is a complex task to acquire, that it does not happen overnight, and that there are various challenges that all children face. The timing and intensity of these challenges differ for children and, as a result, influence their pathway to communicative competency. For example, children with a developmental language disorder (DLD) may only start to display challenges when combining words (Hadley, 2006). The third premise highlights the variability in how a child acquires language and notes that these differences can have cascading effects. For example, slower vocabulary growth is related to literacy and academic outcomes (Duff et al., 2015; Hammer et al., 2010; Hammer et al., 2017; Shanahan & Lonigan, 2010; Walker et al., 1994).

Ecobehavioral Theory

Ford and colleagues (2020) proposed an ecobehavioral model of language development. Adult-child interactions are at the center of the model and serve as the mechanism for language acquisition. These interactions provide opportunities for the child to develop both receptive and expressive language skills in back-and-forth transactions. Influenced both by ecological (Bronfenbrenner 1975) and behavioral perspectives (Skinner, 1953; 1986), the model illustrates how more proximal (e.g., caregiver knowledge and beliefs) and distal factors (e.g., childcare quality standards) to adult-child interactions can influence the quantity and quality of interactions. As these language-facilitating interactions are the driving force in language acquisition, any change in their structure or frequency can impact language trajectories. A key tenant of ecobehavioral models is the inclusion of malleable factors that can be leveraged to foster language acquisition. This, in turn, can be used to improve language outcomes by tailoring these interactions to contain specific supports needed to address an individual child's challenges.

Within an ecobehavioral framework, language-facilitating interactions are viewed through a behavior-analytic paradigm and can be broken down into three components: (a) antecedents (i.e., the initiation of the interaction by a communication partner); (b) behavior of the other communicative partner (i.e., response to the initial communicative bid); and (c) consequence to the behavior (i.e., initial communicative partner responds). This paradigm assumes that language-facilitating interactions provide the causal features of language learning. Antecedents provide developmentally appropriate opportunities to evoke child communicative behaviors and responses from the adult reinforce the child's behavior. Ideally, the response is both a functional reinforcer *and* serves as the next antecedent to keep the interaction going. These interactions provide the necessary language input and opportunities to practice and perfect our language system. When applied to language acquisition, the utility of ecobehavioral frameworks helps identify malleable factors that can be leveraged to improve language outcomes. For example, some children face challenges in acquiring spoken language. In this case, interventions and supports that incorporate augmentative and alternative communication (AAC) strategies can be used to augment or supplement speech, providing an alternative mode of communication that allows the child to interact with those around them (e.g., (Dimian et al., 2018; Romski et al., 2010). Incorporating AAC into language-facilitating interactions can also provide another mode of language-input for children that can support language development (Chazin et al., 2021).

Bioecological Theory

Bronfenbrenner's (1975) ecological systems theory and his updated bioecological theory (Bronfenbrenner & Ceci,1994) illustrate the different levels surrounding the child and how factors within each level are interconnected with the most proximal aspects of a child's environment and their biological characteristics (i.e., proximal processes also known as engines of development). Five layers surround the child in Bronfenbrenner's bioecological systems theory; these are the microsystem (e.g., factors related to family, school, and health services), mesosystem (the interaction between a child's microsystem), exosystem (factors related to a parent's employment, policies and practices), macrosystem (relates to attitudes and ideologies of the child's culture) and chronosystem (relates to environmental changes that occur over time). Factors within each layer are intertwined, and their effects can compound over time. For example, there are differences in how the brain processes language (i.e., statistical learning) between children with typical language development and those with language disorders (e.g., Haebig et al., 2017; Saffran, 2018). For example, compared to children with autism and children with typical language development, those with DLD performed lower on word segmentation and fast-mapping tasks (there was no difference in performance between children with typical language development and those with autism; Haebig et al., 2017). These differences illustrate how child characteristics, in this case, word-segmentation abilities in children with DLD, can impact the power of language-facilitating interactions in driving language acquisition.

Conceptual Framework for the Current Study

Child Factors

The child plays a critical and active role within language-facilitating interactions. However, some child characteristics can influence these interactions, impacting both their communicative behaviors and their communication partner's actions and thus language trajectory. The following section will describe how individual child characteristics can influence language-facilitating interactions and, as a result, shape a child's pathway to language acquisition.

Perinatal Factors. There is evidence to suggest that some perinatal factors are associated with later speech and language impairments. For example, extreme maternal stress, maternal infections, and late or no prenatal care are significant predictors of DLD at six years of age (Fox et al., 2002; Stanton-Chapman et al., 2002). Preterm births and low birth weight may also influence language trajectories. Several studies have shown that low birth weight is a predictor of receiving SLT (Harrison & McLeod, 2010; Morgan et al., 2016), language delays (Zubrick et al., 2007), or a diagnosis of DLD (Stanton-Chapman et al., 2002). However, contrasting studies show that low birth weight and preterm are not associated with later language delays (Reilly et al., 2006; Reilly et al., 2007; Tomblin et al., 1997). Consideration of these discrepancies within the current study's conceptual framework, may suggest that perinatal factors are examples of potential challenges that children may experience along the pathway to language acquisition and may be associated with other distal variables that, in turn, affect language outcomes. However, other more protective factors (e.g., early intervention, supportive home environments) may ameliorate the negative impact of perinatal factors on language acquisition.

Primary and Secondary Language Disorders. Many children face language delays and challenges to language acquisition due to primary or secondary language disorders. Secondary language disorders refer to language acquisition challenges attributed to another disability (e.g., autism, Down syndrome (DS), or cerebral palsy). In contrast, a primary language disorder is not accompanied by any other underlying biological basis for a language delay (e.g., DLD). These differences in underlying etiology influence the developmental pathway to language acquisition and when children are identified for early intervention services (Hebbeler et al., 2007). For example, children with a secondary language disorder are likely to receive early intervention (EI) services due to their primary disability or diagnosis, and communication-focused goals are likely to be part of their EI services. In contrast, children with primary language disorders (e.g., DLD) may only be identified as requiring SLT as they start to combine words. However, recent advances in how the brain processes language (Haebig et al., 2017) might be a potential avenue for early identification. In addition, males are more likely to receive SLT and experience language delays (Harrison & McLeod, 2010; Zubrick et al., 2007).

Understanding the differences in underlying etiologies for language challenges has important implications both for identification and intervention efforts. The specific challenges (e.g., difficulties with acquiring spoken language, syntax, pragmatics) that children are experiencing can be used to identify children and then provide interventions tailored to specific challenges. For example, children with autism are likely to experience challenges with joint attention skills (Adamson et al., 2017; Bruinsma et al., 2004). Because joint attention is a foundational skill for language acquisition (Adamson et al., 2017; Toth et al., 2006), this challenge can create cascading consequences and alter the pathway to language acquisition. Embedding episodes that teach joint attention into interventions for children with autism can, in turn, provide a stronger foundation for acquiring language (Ingersoll & Schreibman, 2006; Kasari et al., 2014). For children with DS, challenges to acquiring language can also come from multiple avenues. For example, children with DS are likely to experience recurring bouts of otitis media and, as a result, face intermittent hearing loss, which can have negative impacts on language learning

(Chapman et al., 2000). Oral motor problems are also associated with speech intelligibility issues (Barnes et al., 2006). Being aware that children with DS may be exposed to fewer language-facilitating interactions can inform intervention efforts to ensure a higher quantity of learning opportunities are embedded into intervention. In addition, the use of AAC could be used to supplement spoken language.

Motor Development. Motor milestones, such as crawling or walking, are important developmental markers for later motor skill acquisition and other developmental domains such as language (Bedford et al., 2016; Houwen et al., 2016; Iverson, 2021). Being able to move around and explore one's environment enables the child to be exposed to more language-facilitating interactions, by being present with others, providing the opportunity to initiate interactions, and not having to wait for communicative partners to come to them. For example, the transition from crawling to walking is associated with different forms of object behaviors: children who are walking are more likely to access objects distant to them, carry objects, or share objects with communication patterners (Adolph & Tamis-Lemonda, 2014; Karasik et al., 2011). These behaviors are likely to increase the frequency of language-facilitating interactions, even if a child is not sharing an object. The child sets the stage for a communicative partner to initiate an interaction about the object by just holding an object (i.e., setting event or antecedent). The development of more fine motor skills, like object manipulation, is also associated with language acquisition (West & Iverson, 2017; Yu & Smith, 2012). Again, it provides opportunities for communication partners to comment on the child's actions or label the object they are manipulating. It has also been found to facilitate joint attention (Yu & Smith, 2012).

Medical Conditions. Lastly, other medical conditions may also present potential challenges along the pathway to language acquisition. For example, persistent otitis media and more permanent hearing loss are associated with later language delays (Paradise et al., 2000; Shirberg et al., 2000), although the association may be influenced by other factors predisposing children to otitis media (Paradise et al., 2000; Roberts et al., 2004). Loss of hearing, temporary or permanent, illustrates how not being able to access language-facilitating interactions has a negative impact on developing language. However, it also illustrates that when interventions are tailored to address specific challenges (e.g., sign language or amplification strategies), they can change developmental trajectories and improve language outcomes (e.g., Tomblin et al., 2014).

Home and Family Factors

Moving outwards from language-facilitating interactions and child characteristics, are factors related to the home and family. Factors within this level can impact the quality and frequency of language-facilitating interactions, thus, in turn, influence language development.

Language-Input. A key contributing factor to the quality and quantity of language-facilitating interactions is language input, and in this case, from family members (e.g., parents, siblings, extended family members, etc.). There is a wealth of evidence demonstrating the positive impact between language input and language acquisition (Chazin et al., 2021; Dunst et al., 1990; Fernald & Weisleder, 2011; Hart &

Risley, 1995; Romeo et al., 2021). Caregivers play a critical role as a child's communicative partner, and their input plays an essential role in these language-building interactions. Their communicative actions foster language acquisition through responding to a child's communicative cues and behaviors, commenting on shared activities, asking questions, recasting, and expanding on the child's previous communicative act (Bottema-Beutel et al., 2018; Brady et al., 2014; Hirsh-Pasek et al., 2015; Rowe, 2012; Rowe et al., 2017; Soto et al., 2019; Sterling et al., 2013; Tamis-LaMonda & Bornstein, 2002). All these examples of language input can serve as functional consequences to a child's communicative behavior and further reinforce their abilities as communicators, which over time accumulate and propel a child's language learning.

Parental Knowledge and Beliefs. Differences in parental knowledge regarding child development are associated with differences in parenting and how language-facilitating interactions are structured (Benasich & Brooks-Gunn, 1996; Rowe, 2008). Understanding and knowing the timing of developmental milestones allows caregivers to embed developmentally appropriate language-learning opportunities into caregiver-child interactions (Huang et al., 2005; Rowe, 2008). Furthermore, being aware of developmental milestones and when they occur provides caregivers with a gauge of when to be concerned about developmental delays. Skeat et al. (2010; 2014) found that parents concerned about their child's communication development were more likely to seek advice or help about their child's communication status.

A caregiver's culture can greatly influence their beliefs and behavior and, in turn, influence their language-input during communicative exchanges with their child (Bornstein et al., 1996; Perry et al., 2008; Weber et al., 2017). In addition, culture can shape the family structure and roles biological parents, extended family members, and community members have in child-rearing (e.g., Allison-Burbank & Collins, 2020; Hossain et al., 1999). While this may not necessarily directly influence the quality and quantity of language-facilitating interactions, it has important implications in designing and implementing communication-focused interventions to improve child language outcomes.

Parental Wellbeing and Family History of Disabilities. Evidence suggests that a family history of disabilities increases the likelihood of a child within that family also being diagnosed with a disability. Research suggests this relation exists for intellectual and developmental disabilities such as autism (Hansen et al., 2019; Xie et al., 2019) and also language-specific disabilities like DLD (Fox et al., 2002; Tomblin et al., 1997; Zubrick et al., 2007) and dyslexia (Snowling et al., 2007). These findings highlight the importance of considering family history within screening and evaluation efforts.

Parental wellbeing is associated with child outcomes (e.g., (Paulson et al., 2009; Sarche et al., 2009). For example, maternal depression has a negative impact on children’s language acquisition (Quevedo et al., 2012; Stein et al., 2008). However, research suggests that this relation is not direct. Rather maternal depression seems to influence the quality of maternal care and sensitivity, which in turn impacts child language acquisition (Stein et al., 2008). Specifically, recent research suggests that mothers who are depressed use less infant-directed speech and less exaggerated pitch while engaging in interactions with their infant (Lam-Cassettari & Kohlhoff, 2020). These are important components of high-quality adult language input that are associated with English language acquisition (Golinkoff et al., 2015; Singh et al., 2009; Thiessen et al., 2005). Regarding parental wellbeing, it is also important to consider how trauma and social inequalities may impact wellbeing and consequently impact language-facilitating interactions and thus child language learning (e.g., effects of historical trauma among Native American people; Allison-Burbank & Collins, 2020; Evans-Campbell, 2008: or the effects of poverty; Shonkoff et al., 2012).

Location. Lastly, where families reside may impact language-facilitating interactions and access to early intervention services, including SLT. Factors such as feeling safe in one's home and neighborhood can influence parental wellbeing and, in turn, impacts child language acquisition (Meyer et al., 2014). In addition, states vary in their eligibility criteria for receiving EI services, impacting who can receive services (Barger et al., 2019). There are also differences in available services between rural and urban areas (Decker et al., 2020; Hallam et al., 2009; Haring & Lovett, 2001). Not having access to services and supports when needed can have cascading consequences on the structure of language-facilitating interactions and, in turn, language acquisition. For example, an appropriate intervention for children with autism might initially focus on building joint attention skills before moving onto more complex language skills. However, suppose children do not receive interventions specific to their needs. In that case, they will likely continue to experience language delays and challenges that will likely only compound as they progress through their academic years.

Policies and Practices

At the most distal layer in this study's conceptual model are policies and practices. Although they do not directly impact language-facilitating interactions, they have trickle-down effects that ultimately influence the nature of these interactions.

Increasing Exposure to Language-Facilitating Interactions. Parental leave policies afford caregivers focused time to spend with their newborn, thus increasing the frequency of caregiver-child interactions and opportunities for child language learning. Although parental policies vary, research evaluating its impact on child development is positive (Berger et al., 2005; Galtry & Callister, 2016). As research continues to affirm that the importance of the home language environment in fostering language acquisition (Barton-Hulsey et al., 2020; Beecher & Van Pay, 2020; Romeo et al., 2021; Swanson et al., 2019), it will be important to continue to advocate for parental leave policies. Furthermore, recent work from Larson and colleagues (2020) suggests that young children are exposed to more language-facilitating interactions at home compared to childcare settings.

Educational program quality standards are another example of how policy influences practice and can impact the quality and frequency of language-facilitating interactions a child is exposed to in childcare settings. For example, professional development can help ensure childcare educators are embedding high-quality language-input in their interactions with children. In addition, policies targeting lower adult-to-child ratios can also increase the frequency of language-facilitating interactions children are exposed to (NICHD Early Child Care Research Network, 2002, 2005).

Screening and Identification. During the first few years of life, there are a variety of early childhood screenings and identification tools (e.g., developmental screenings, newborn hearing test) that evaluate and identify children who may not be achieving developmental milestones on time and providing opportunities for additional supports and resources to help foster development (Mackrides & Ryherd, 2011; Pool &

Hourcade, 2011). However, despite the importance of early language development for later outcomes, in 2015, the US Preventive Services Task Forces (USPSTF) restated their position that there is insufficient evidence in routine screening in primary care settings to detect speech and language delays in children aged five years or younger (Siu, 2015). This position is unlikely to affect children with more significant language delays or those attributed to other disabilities (e.g., autism, DS) or children whose parents are concerned about their child's language. However, it is more likely to affect children with DLD (e.g., Hebbeler et al., 2007). They are more likely to achieve the early language development milestones, but face challenges as language becomes more complex. More research is required to establish reliable language screenings and demonstrate the effectiveness of early identification and intervention. Early identification and interventions are generally associated with improved language outcomes (Koegel et al., 2014; Moeller, 2000).

Health Insurance Coverage. Some research suggests that even though all children who require early intervention services should receive such services through IDEA Part C, uninsured children have disparities in access (Grant, 2005; Hallam et al., 2009; Shapiro & Derrington, 2004). Furthermore, insurance coverage may not just be related to whether a child receives EI services or not, but also the type of services they receive and the dosage (i.e., the total number of sessions and length of session; Hallman et al., 2009). These findings have important implications for improving child find efforts. Particularly in outreach efforts, for example, ensuring caregivers know that insurance coverage is not an eligibility criterion for receiving EI services. In addition, there is also a need to advocate for increased Medicaid funding, as states vary in the services Medicaid may provide (e.g., Medicaid does not cover physical therapy, occupational therapy, or

SLT in 35% of states; Grant, 2005). Although insurance coverage may not impact the quality and quantity of language-facilitating interactions for every child, it is more likely to impact the interactions of children who are experiencing delays and challenges in acquiring language.

Conclusion

This chapter provided a broad overview of how proximal and distal variables influence the frequency and quality of language-facilitating interactions and, in turn, language acquisition. Situating child language learning in this framework allows researchers, practitioners, and policymakers to understand better the malleable and stable factors that influence language acquisition. In addition, it provides a framework to leverage the more malleable factors to improve language outcomes through screening and identification efforts as well as the design and implementation of communication-focused interventions.

Given this conceptual model for understanding factors affecting language development, it is necessary to extend available empirical evidence to begin describing the importance, both uniquely and in combination, of factors that vary in their proximity to language-facilitating interactions and thus in their contribution to language acquisition and how they relate to the age of starting SLT. For instance, we need to know if differences in when children start SLT are related to underlying differences in etiologies or differences in the supports and resources available to families or to both. Gaining a better understanding of when children start SLT and who these children are can be used to inform future screening and evaluation efforts.

The purpose of the current study was to examine the unique and cumulative contribution of child, family, and community factors associated with speech-language-therapy start time. To address this aim, the following research questions were examined.

- ***RQ1:*** For children who are receiving early intervention services, are there differences in child, family, and community characteristics associated with speech-language therapy status: never receiving speech-language services (*never*), start receiving services at 24mos (*early*), and start receiving services at 48 or 60mos (*late*)?
- ***RQ2:*** Using cross-validation techniques to assess predictiveness, what child, family, and community characteristics best predict speech-language therapy status?

Chapter 3
Method

Data Source

Analyses for the current study were conducted using restricted data from the Early Childhood Longitudinal Studies – Birth Cohort of 2001-02 (ECLS-B), a restricted-access database collected and maintained by the National Center for Education Statistics (NCES). The ECLS-B recruited a nationally representative sample of 14,000 U.S. children born in 2001-2002 and followed them longitudinally through kindergarten entry. The study collected information on children's social-emotional, cognitive, physical, academic performance, and home environments. Data were collected when children were aged 9-months (Wave 1), 24-months (Wave 2), 48-months (Wave 3), and at kindergarten entry (60-months; Waves 4 & 5). Various methods were used to collect data: birth certificate records, direct assessments, and surveys from caregivers, childcare providers, and teachers. There were two data collection rounds at kindergarten to capture around 25% of the sample who did not enter kindergarten in the previous round or were repeating kindergarten. When reported here, unweighted sample sizes were rounded to the nearest 50 per ECLS-B confidentiality requirements. The university's institutional review board approved this study.

Although the ECLS-B is an older dataset, it was chosen because it has several specific advantages for this study, compared to other similar extant databases. Primarily, the ECLS-B followed infants through kindergarten. In comparison, the Pre-Elementary Education Longitudinal Study (PEELS) followed cohorts of 3, 4, 5-year old children, all of whom had identified disabilities. The Special Education Elementary Longitudinal

Study (SEELS) only included elementary school-aged children. Lastly, the Baby FACES study only included families attending Early Head Start programs. Because the first few years in life are a critical period for language development and because SLT often does not begin until a child is 24 months, the ECLS-B dataset provided the optimal developmental assessment period.

Analytic Sample

The analytic sample of the current study included 800 children whose parents indicated in at least one data collection wave that their child received early intervention (EI) services. Specifically, children were included in this study (a) if they had complete information regarding SLT status at 24, 48, and 60 months, (b) had complete information for all analytic measures, and (c) had a Kindergarten entry sampling weight corresponding to the caregiver survey.

Information regarding EI services came from two questions administered as part of the caregiver Computer Assisted Personal Interview (CAPI). Children were included if their parents responded *yes* to either question. These questions were only asked if parents indicated that their child has one or more special needs/condition(s). The first question was asked at all data collection waves: “Is (child’s name) currently participating in an early intervention program or regularly receiving any services for his/her condition(s) from: (a) *your local school district*, (b) *a state or local health or social service agency,* (c) *A doctor, clinic, or other health care provider, or* (d) *some other source*.” The 9-month options included: (a) *your local school district*, (b) *a state or local health agency,* (c) *a social service agency,* (d) *a private doctor’s office*, (e) *clinic, and* (f) *some other source*. If parents responded *yes* to any of the options, the child was included in the analytic sample. The second question was asked at the 48- and 60-months data collection waves. Parents were asked, “Is (child’s name) receiving special education services related to either an IEP or IFSP?” If parents responded *yes*, the child was included. All measures with data from Waves 4 and 5 were combined and treated as one timepoint (i.e., kindergarten) to create the sample. If a child was present in Waves 4 and 5, only Wave 4 data was included. Tables A1 and A2 (in Appendix A) provide descriptive information for the analytic sample and full sample of children receiving EI services, but had missing values for analytic variables. The analytic sample closely approximated the full sample.

Data Collection Procedures

Birth Certificate

NCES used birth certificate records to identify potential ECLS-B participants and gather child demographics (e.g., sex, mother/father race/ethnicity) and perinatal information (e.g., birth conditions, prematurity, birth weight, mother’s age at birth). Children were identified via registered births from the National Center for Health Statistics (NCHS) vital statistics system and sampled within a set of primary sampling units (PSUs). Individual counties or groups of contiguous counties were the PSUs in the ECLS-B. This process resulted in approximately 14,000 sampled births and yielded 10,700 9-month completed cases.

Computer-Assisted Personal Interview

NCES completed interviews with each child's primary caregiver, usually the child's mother, during each data collection wave (>90% per wave). In addition, starting at Wave 2, childcare and early education providers were interviewed. These interviews were conducted using the computer assistive personal interview (CAPI). The questionnaire protocol was installed on a computer, recorded the participants' responses, and presented questions based on their responses.

Bayley-Short Form – Research Edition

NCES field staff administered the Bayley-Short Form-Research edition (BSF-R) to capture children's mental and motor abilities at Waves 1 and 2. The BSF-R contains a subset of items from the full Bayley Scales of Infant Development – 2nd Edition (BSID-II) using item response theory. The correlation between the BSID-II scores and BSF-R scores was 0.74 (Barry et al. 2004). The cognitive portion assessed early problem solving, expressive language, and receptive language skills. The motor portion contained items related to fine and gross motor.

Nursing Child Assessment Teaching Scale

During Wave 1, the Nursing Child Assessment Teaching Scale (NCATS) was administered. This assessment is a semi-structured caregiver-child interaction observation that provides both child and caregiver scores for engagement and responsiveness. During the 9-month data collection rounds, parents were asked to select an NCATS task that their child did not yet know and then teach them the task. The observation provided caregiver, child, and total interaction scores.

Measures

This section will describe measures included in the current study, including data collection wave and source. Some measures will be used for both descriptive and analytic purposes, others only for descriptive purposes. The measures are presented in relation to their placement within an ecobehavioral model.

Child Variables

Sex. Child sex was treated as a dichotomous variable. Female was the reference category (0 = female; 1 = male), and information came from birth certificate records.

Race/Ethnicity. The ECLS-B dataset contains multiple child race/ethnicity variables (e.g., birth certificate records based on maternal race/ethnicity, parent report, and composite variables). For the current study, race/ethnicity came from the Wave 1 caregiver CAPI and was treated as a categorical variable. The CAPI source was chosen because it represents the child's race/ethnicity identified by the primary caregiver and allows for multi-race classification. The following race categories were provided: (a) White (b) Black or African American, (c) American Indian or Alaska Native, (d) Asian Indian, (e) Chinese, (f) Filipino, (g) Japanese, (h) Korean, (i) Vietnamese, (j) other Asian, (k) Native Hawaiian, (l) Guamanian or Chamorro, (m) Samoan, and (n) other Pacific Islander. In addition, caregivers were asked if the child was Hispanic or Latino. A composite race/ethnicity variable was created from the Hispanic ethnicity variable and race categories to create the following composite variable: Asian, non-Hispanic; Black or African American, non-Hispanic; Hispanic, race specified; Hispanic, no race specified; Native American, or Alaska Native, non-Hispanic; Native Hawaiian or other Pacific

Island, non-Hispanic; White, non-Hispanic; and more than once race specified, non-Hispanic. Categories were further collapsed for the current study, consistent with other ECLS-B studies evaluating special education and related services (e.g., Morgan et al., 2016; Sullivan & Field, 2013). These were: Black, Hispanic, Other (Native American, Asian, Native Hawaiian, Pacific Islander, and more than one race), and White (reference group). Categories were collapsed to adhere to IES confidentiality requirements.

Type of Services Received. Responses from two questions from the caregiver CAPI were used to describe the types of services and supports families received and to determine speech-language service status. The first question: “I’m going to read a list of services. For each service, please tell me if your (insert child name) or your family received this service to help with (insert child name) special needs". Wave 1 data collection options included: (a) physical therapy, (b) vision services, (c) hearing services, (d) social work services, (e) psychological services, (f) home visits, and (g) parent support or training. At Wave 2, two additional services were listed (a) speech or language therapy and (b) special classes with other children, some or all of whom also had special needs. During Waves 3 and 4, the CAPI included a few more additional options: (a) private tutoring or schooling for learning problems, (b) instruction in Braille, and (c) instruction in sign language, cued speech, ASL, and TOCO.

The second question was asked during Waves 3 and 4. Caregivers were asked, "Is (child's name) receiving special education services related to either an IEP or IFSP?".

The first question was used to determine speech-language therapy (SLT) status, and the second question was used for descriptive purposes only. Speech-language therapy status was treated as a categorical variable with three mutually exclusive categories: (a)

Never – included children whose caregivers reported that they never received SLT, (b) Early – included children whose caregivers reported that they received SLT at Wave 2 (24-months), and c) Late – included children whose caregivers reported that they received SLT at Waves 3, 4, or 5 (48 -months to 60-months) but not Wave 2 (24-months).

Identified Disability/Delay. Information about disability came from the caregiver CAPI. Data from all collection waves was used because some disability categories (e.g., autism) were only asked at later time points. Diagnoses were collapsed into the following, not mutually exclusive, categories: *intellectual and developmental disabilities* (IDD; autism, Down syndrome, intellectual disability, developmental delay, Turner's syndrome, Fetal alcohol syndrome), *health impairment* (allergies, blood diseases, diabetes, epilepsy, vision and hearing impairments), *mobility impairment* (cerebral palsy, health condition related to the mobility of limbs, and spina bifida.), *other diagnosis* (attention deficit hyperactive disorder, obsessive-compulsive disorder, and diagnoses related to "attention" and "activity level"), *other disability* (no information provided on this category within ECLS-B), *more than diagnosis*, and *communication impairment* (if the diagnosis obtained by a professional regarding the child's ability to communicate). The presence/absence of an IDD diagnosis was used analytically, and all other categories were used for descriptive purposes.

Birth weight. Information on birth weight was collected from birth certificate records. Three categorical variables were created and used for descriptive purposes only: very low birth weight (≤ 1449 grams), moderately low birth weight (≥ 1500 and ≤ 2249 grams), and normal birth weight (≥ 2250). These categories are consistent with other

ECLS-B studies (e.g., Morgan et al., 2016) and medical classifications (Infant Health and Development Program, 1990).

Motor Development. During Waves 1 and 2, children's motor development was assessed using the BSF-R. The 9-month scale score was used in analyses.

Jabbers Expressively. The BSF-R provided proficiency probabilities for both mental and motor scales. Proficiency probabilities (PP) estimate ability within a developmental domain and provide information on whether certain milestones have been achieved. Children can have values between 0.0 and 1.0, based on overall performance. Jabbers Expressively refers to a child's early communication skills, including gestures, vowel and vowel-consonant sounds, and babbling with inflection and change in tone of voice. Only the 9-month score was used in analyses to capture emerging communication abilities.

Purposeful Exploration. The purposeful exploration proficiency probability from the BSF-R mental scale was included to characterize children's ability to manipulate objects and explore their environment. Data from the 9-month data collection wave was used for analyses.

Cognitive Development. A gain score (Wave 2-Wave 1) using the scale score from the BSF-R cognitive scale was calculated for each child to characterize children's early cognitive growth. This variable was treated as continuous.

Number of Words Said. This was treated as a continuous variable, indicating the number of words, per parent report, that the child used expressively at 24-months. During the Wave 2 CAPI, caregivers were given a modified MacArthur-Communicative

Development Inventory (MCDI; Fenson et al., 2007; see Andreassen et al., 2007 for additional information regarding modifications). The modified MCDI included a list of 50 common words and phrases, and caregivers were asked whether their child was able to say each word/phrase. The total number of *yes'* were summed to create each child's expressive vocabulary score.

Family and Home Variables

Home Language. The child's home language was used descriptively and indicated if the child's home language was English or not. In the ECLS-B data set, home language other than English included Arabic, Chinese, Filipino, French, Polish, Portuguese, Spanish, Vietnamese, African, Indian Subcontinent, Southeast Asia, Pacific Islander, and other language specified (data not provided in ECLS-B dataset). Because of low base rates, it was not possible to provide more detailed results for individual home languages other than English due to IES confidentiality requirements. Data came from the Wave 1 caregiver CAPI.

Family History of Disability. A dichotomous variable was created, indicating if parents reported any family history of a learning disability or special needs (for blood relatives). During the 9-month CAPI, caregivers were asked: "if they or any other household member had a special need, delay or disability"? At the 24-month CAPI, caregivers were asked: "Have you or any of your blood relatives ever had a learning disability?" Answers of *yes* were coded as 1 and *no* as 0.

Parent Responsiveness. The NCATS parent total score was used as a measure of parent responsiveness from Wave 1. The total score is the sum of *yes* responses from a possible 50 items from the NCATS teaching-task observation. These 50 items sampled the following domains: sensitivity to cues (e.g., caregiver pauses when the child initiations behaviors during the teaching episode), response to child's distress (e.g., caregiver changes volume to a softer or higher pitch, does not yell), socio-emotional growth fostering (e.g., caregiver laughs or smiles at child during teaching interaction) and cognitive growth fostering (caregiver uses the teaching loop at least once). This variable was treated as continuous.

Urbanicity. This was treated as a dichotomous variable (1 = urban; 0 = rural), indicating if the child lived in an urban area or not. Data came from the Wave 1 CAPI.

Socioeconomic Status. Information regarding household SES came from a composite score based on both parents' highest education level, income, and occupation. The ECLS-B dataset provided a continuous variable and a quintile indicator based on the continuous variable (lowest quintile, second-lowest quintile, middle quintile, second-highest quintile, and highest quintile). The continuous variable was used for regression analyses. For descriptive purposes, the quintile indicators were collapsed into three groups: low (lowest and second-lowest quintiles), medium (medium quintile), and high (second highest and highest quintiles). This was to adhere to IES confidentiality requirements. Data used to create this variable came from the Wave 1 caregiver CAPI.

Mother Education. Given the correlated relation between maternal education and vocabulary development, a categorical variable indicating the mother's education level at child's birth was used for descriptive purposes. During the Wave 1 9-month data collection wave, the following options were provided to assess the highest maternal education level: No formal schooling, 1st grade, 2nd grade, 3rd grade, 4th grade, 5th grade,

6^{th} grade, 7^{th} grade, 8^{th} grade, 9^{th} grade, 10^{th} grade, 11^{th} grade, 12^{th} grade but no diploma, high school diploma/equivalent, vocational/technical program after high school but no diploma, vocational/technical diploma after high school, some college but no degree, associate's degree, bachelor's degree, graduate or professional school but no degree, master's degree, doctorate degree, professional degree after bachelor's degree. For descriptive purposes, categories were collapsed into (a) less than high school (HS), (b) HS or equivalent, (c) vocational/technical degree or some college, (d) 4-year college degree, and (e) graduate degree.

Community and Societal Variables

Access to Health Insurance. This was treated as a dichotomous variable, indicating if the child had health insurance coverage or not. Data was collected during the Wave 1 caregiver CAPI.

Daycare with Screening/Evaluation Resources. I created a dichotomous variable indicating if the child attended a childcare setting that offered screening/evaluations at 24 months (*yes* = 1). The information came from the Child Care Provider (CCP) Wave 2 interview. The CCP was asked, "Does your center provide any of the following services to children or their families? a) physical screenings or examinations b) dental screenings or examinations, c) hearing screenings or evaluations, d) vision screenings or examinations, e) speech/language screenings or evaluations, f) developmental assessments, g) assessments of social or behavior problems, and h) sick child care on an as-needed basis." If the CCP answered *yes* to options e, f, or g, this was coded as 1, and all other responses were coded as 0.

Data Analysis Procedures

All data cleaning, preparation, and statistical analyses were performed in R (version 4.0.3) using a remote secure-access server provided and managed by Administrative Data Research Facility (ADRF) for NCES. Restricted data was accessed via an approved license for Dr. Mark Davison (license number: 940817147). All results presented here have gone through both ADRF and IES disclosure reviews to ensure they are compliant with reporting and confidentiality requirements. Data analysis plans are presented in relation to the research question being addressed.

Data Cleaning and Preparation

The analytic dataset was created by selecting all children whose parents reported their child received EI services and then selecting the relevant measures included in the analyses. Next, some variables needed to be recoded (e.g., creating dummy codes for race/ethnicity, SES, and gain scores for cognitive growth). All initial data preparations were completed using Tidyverse 1.3.0 (Wickham et al., 2019).

Weighting. Several sampling weights are provided in the ECLS-B datasets corresponding to each data collection wave and different data sources. Per NCES guidelines, weights were chosen that a) reflected the last round of data collection used in analyses and b) adjusted for nonresponse to the greatest number of components providing data for the analysis. The current study included data from the Kindergarten entry timepoint, and most data came from the parent CAPI. Therefore, the survey design was set using kindergarten caregiver CAPI weights.

The ECLS-B datasets provide researchers with three approaches (one replication method, one linearized estimate, and manual estimation) to appropriately estimate the standard error (i.e., sampling variance estimation). Paired-Jackknife (JK2) is the replication method, and the Taylor linearization method is the linearized estimate method. For descriptive statistics of participant characteristics, the Taylor's linearization method was used in conjunction with survey 4.0. package (Lumley, 2020). However, for analyses conducted to address Research Questions 1 and 2, the weighting and design effect was accounted for manually through the estimation method. This was necessary because the R package used for the cross-validation component (caret 6.0-86; Kuhn, 2020) did not support the survey package. The two methods, Taylor's linearization and manual estimation, produce the same results within rounding errors. Equation (1) shows the manual estimation conducted to create a variable that was used as a weight in analyses to account for nonresponse rates and the design effect (*n* = unweighted sample size). This allowed the analytic sample (*n* = 800) to be representative of children born in 2001-2002 and entered kindergarten in 2004/2005.

$$Analysis\ Weight = \frac{sampling\ weight \times n}{sum(sampling\ weight) \times Design\ Effect} \quad (1)$$

Model Assumptions and Diagnostics. Multinomial logistic regression was used for both Research Questions 1 and 2. Logistic regression assumes three characteristics: a) low multicollinearity between predictors, b) linear relationships between predictors and the logit of the outcome variable, and c) independence of the sample (i.e., independence of errors). The current study included no repeated measures, and the clustered sampling approach was accounted for within the analysis weight. As a result, the independence of errors assumption was met. However, there are not many diagnostics and model fit statistics for multinomial logistic regression. Therefore, to assess the remaining assumptions and model diagnostics, the final multinomial model was broken down into its binomial components (i.e., never-late, never-early, and late-early). Binomial logistic regressions were completed using base R.

The variance inflation factor (VIF) was evaluated for all three binomial logistic regressions to assess multicollinearity using the Companion to Applied Regression (car) package (Fox & Weisberg, 2019). The maximum VIF value was 2.3 (see table B1 in Appendix B), indicating no multicollinearity issues. Linearity was evaluated for all continuous predictors in the final model by graphing the logit transformation of the outcome (SLT group status) on fitted predictors. Graphs were visually inspected to determine that the relationship between each predictor was linear versus a quadratic or exponential relation. Graphs were created with ggplot (tidyverse; Wickham, 2019). Graphs indicated that there were linear relationships between all continuous predictors and the logit transformation of the outcome (see Appendix B, figures B1-B3).

In addition, the final model (broken down into separate binomial models) was inspected for outliers and potential influential observations. Data were examined by visualizing the Cook's distance to identify outliers. However, it is important to note that not all outliers are influential observations. Standardized residuals were graphed to check for influential observations, and any observations with a standardized residual greater than 3 were identified and examined. Results indicated there were two observations with standardized residuals greater than 3 in the early-never comparison (Figure B7); given the size of the sample size, these were not removed from analyses.

Research Question 1

To answer the first research question, are there differences associated with speech-language therapy status? Analyses were conducted to assess potential group differences in child, family, and community characteristics. The purpose of Research Question 1 was to inform variable selection for Research Question 2 and was guided by the purposeful selection method (Hosmer et al., 2013). Purposeful selection begins with a univariable analysis of each predictor and the outcome. Contingency tables were created for each categorical variable to identify any zero-frequency cells, as this would result in the model failing to converge. Two variables (health insurance coverage and daycare with screening/evaluations) were excluded at this point due to a lack of variance in participant responses.

Separate multinomial logistic regressions (i.e., univariable multinomial logistic regression) were conducted for each renaming predictor (see Table 1). The late group served as the referent group for each model. Predictors were retained for analyses to answer Research Question 2 if they had a *p*-value less than 0.25 (Hosmer et al., 2013). Multinomial logistic regression analyses were performed using the nnet package (Venables & Ripley, 2002). The nnet package fits multinomial logistic regression models using a neural network fitted with maximum conditional likelihood.

Table 1

Predictors to Assess Group Differences in Speech-Language Therapy Status

Child	Family
Child sex	Parent responsiveness
Jabbers expressively	Urbanicity
Purposeful exploration	SES
Motor	Family history of disability
Cognitive growth	
Number of words said	
Race/ethnicity	
Black	
Hispanic	
Other	
White (referent)	

Note. SES = Socioeconomic status

Research Question 2

To answer the second research question, cross-validated hierarchical multinomial logistic regression was conducted to identify the unique and combined contribution of child and family factors on the likelihood of belonging to the never, early, or late SLT group. In hierarchical regression, predictors are added manually into the model one at a time or in clusters. Thus, providing the opportunity to evaluate the unique contribution of predictors on the outcome (group membership) when accounting for the other included variables. Both the parameter estimates (e.g., logit coefficients and odds ratios) and the change in residual deviance provide information regarding the relative contribution of individual predictors. Understanding both the unique and cumulative impact of factors associated with SLT start time is essential for accurately identifying children who would benefit from SLT and providing timely services.

The following sections will first describe cross-validation procedures and then analysis details for the hierarchical multinomial logistic regression. However, these two methods were conducted at the same time. Weighted main effects were used for all models. All analyses were conducted with the caret 6.0-86 package (Kuhn, 2020) and the nnet package (Venables & Ripley, 2002).

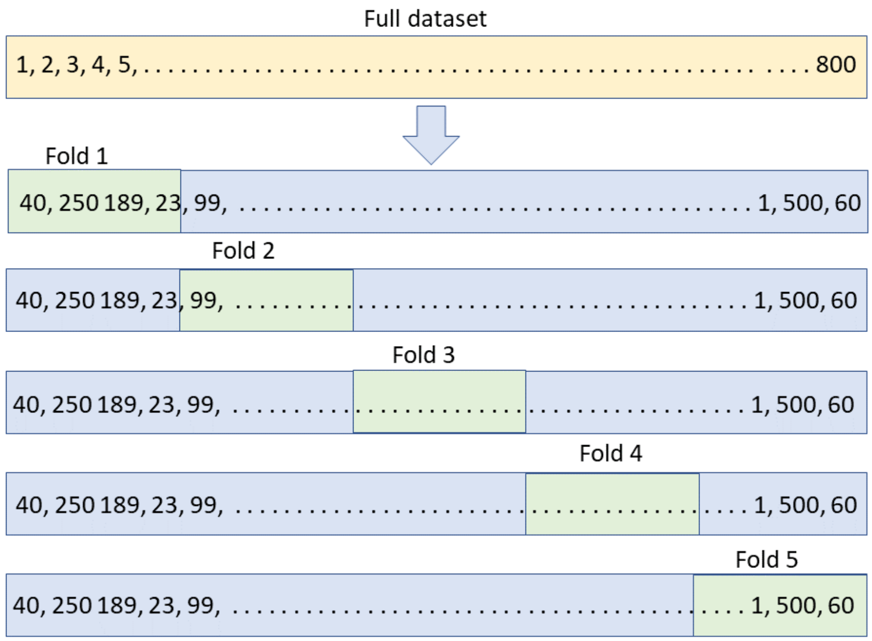
Cross-Validation. Cross-validation is a form of model validation that measures how well results will generalize to an independent dataset. It provides an estimation of how well the model will fit unseen data and flag any potential issues (e.g., overfitting or selection bias) that could reduce model fit and predictive ability. For example, does a model predicting SLT start time have the same accuracy in correctly classifying individuals when used with new data as opposed to the initial dataset?

There are several different CV methods, but all follow the general principle of having a *training set* and a *validation set*. The training set refers to data that the model is initially run on (i.e., trained), and then the model is rerun on new unseen data (i.e., validation set). The validation set could be an entirely new sample or partition(s) of the original sample. The test error rate obtained from the validation set provides an estimate of how well the results will generalize to independent data from the training set. The test error rate can be interpreted as a goodness of fit measure. In classification problems (e.g., logistic regression), the test error rate can be quantified as the number of misclassified observations. This is determined by looking at the predicted probability of an observation being classified as falling into one of the outcome groups versus the actual observation group membership. This is often displayed in a confusion matrix, also known as an error matrix.

The current study used *k*-fold CV due to its computational advantages and bias-variance trade-off (James et al., 2013). When implementing *k*-fold CV, the data is randomly divided into a set of non-overlapping *k folds* (groups). Typically, $k = 5$ or 10, as simulation studies have shown, these values result in test error rate estimates that do not suffer from excessive high bias or high variance (James et al., 2013). Figure 2 provides a visualization for $k = 5$. The first fold is used as a validation set, and the model is fitted to the remaining folds (i.e., the training set). The test error rate is then computed on the observations in the validation set. This process is repeated so that each fold is treated as the validation set, and then the k-fold CV test error estimate is computed by averaging the results from each fold.

Figure 2

5-fold CV Diagram



Note. The full sample is randomly divided into five non-overlapping subgroups. Each fold (highlighted in green) serves as a validation set, the remaining as a training set (highlighted in blue). The CV test error rate is estimated by averaging the test error rates for each fold.

The current study used *k* = 10. There were approximately 80 observations in each fold. So, the data was trained on approximately 720 observations for each iteration, and results were validated on 80 observations.

Hierarchical Multinominal Logistic Regression. Multinomial logistic regression (MLR) is an extension of binomial regression, but allows for the classification of two or more outcomes, given a set of dependent variables. The hierarchical component refers to adding predictors one at a time (not to be confused with hierarchical linear regression (HLM) for modeling multilevel data). Unlike stepwise regression, when the inclusion of predictors is based on partial F-tests and is an automated process, in hierarchical regression the order of predictor introduction is guided by theory (Pedhazur, 1997). Variables were added into the model one at a time, and placement of the predictors was based on proximity to language acquisition within an ecobehavioral framework. Child characteristics were entered in first and then family characteristics. Timing of events was also considered; for example, a variable assessed at 24-months was not entered before a variable measured at 9-months.

Regardless of significance, child sex, SES, and race/ethnicity served as control variables and were entered as an initial set for all models. First, child sex was added, given the higher occurrence of speech-language disorders in males (Harrison & McLeod, 2010). Second, SES was added as a control due to its association with expressive vocabulary and caregiver responsivity (e.g., Hoff, 2003). Finally, race/ethnicity was added given the differences in access to services due to systematic racism penetrating early intervention and special education services (Annamma et al., 2014; Morgan et al., 2017; Morgan et al., 2016). However, it is important to note that the current study is severely limited in speaking to the impact of racial disparities in SLT service delivery due to the collapsed nature of the race/ethnicity variable.

Participants identified for SLT at or after the 48-month wave (i.e., late) served as the referent group for all models. The order of variable placement is presented below. However, if a variable was nonsignificant ($p > 0.25$) based on results from Research Question 1, it was not included (with control variables being the exception). Each time a variable was added a new model was created.

Base model: $\ln\left(\frac{\hat{\pi}_i}{1-\hat{\pi}_i}\right) = \beta_0 + \beta_{Female} + \beta_{SES} + \beta_{Black} + \beta_{Hispanic} + \beta_{Other}$

Order of variable placement: 1) Jabber's expressively; 2) purposeful exploration; 3) motor; 4) cognitive growth; 5) number of words said; 6) parent responsiveness; 7) family history of disability; and 8) urbanicity

Assessing Predictor Contribution and Model Fit. Various indicators were used to assess the unique contribution of individual factors and the best clustering of variables to predict the likelihood of children belonging to each group. Relative risk ratios (RRR) and confidence intervals (CI) were reported, along with logit coefficients and standard errors. RRR assesses the risk of belonging to a certain group (i.e., early or never) relative to the referent (i.e., late) group. Values greater than 1.0 correspond to an increased likelihood of being assigned to the comparison group, and less than 1.0 corresponding to a decreased likelihood of belonging in the comparison group, in other words, more likely to belong in the referent group. Values equaling 1.0 indicate equal likelihoods of belonging either in the comparison or referent group, providing evidence that the corresponding predictor does not explain group membership.

Because results were cross-validated, *p*-values were not reported for models in Research Question 2. This is because the model is fitted to the data several times, which is unaccounted for when reporting *p*-values, thus making them misleading. The residual deviance (goodness of fit statistic) was used to understand the unique contribution of individual variables as they were stepped into the model above and beyond other predictors. The deviance statistic represents the difference between the current model and a model that perfectly predicts the outcome, and smaller values indicate a better model fit. As the residual deviance decreases with the addition of another variable, this suggests that the newly added predictor contributes to the outcome relative to the other included predictors.

Two different indices were used to identify the best cluster of predictors and evaluate model fit. These were McFadden's Pseudo R^2 and Akaike Information Criterion (AIC). Values for McFadden's Pseudo R^2, like all pseudo R^2 statistics, are typically much lower than R^2 statistics in linear regression. However, they still allow for the interpretation of the model's predictive capability. McFadden's Pseudo R^2 is a transformation of the likelihood ratio statistic, and values from 0.20-0.40 represent a good model fit (McFadden, 1997). AIC provides information for comparing model fit among the regression models, but not at the individual model level. Lower AIC values suggest a good fit. Decisions regarding model selection and inclusion of predictors were based on residual deviance, AIC, and R^2 values.

Assessing CV- Model Performance. To examine model performance, model accuracy (1-minus the misclassification rate) was reported for each model. This provided an indicator of how well each model performed on unseen data and as the models got larger if they were overfitted. In addition, to examine if the model was better at predicting one group versus another, confusion matrices were created for each model. Confusion matrices were also used to describe the contribution of individual variables on the overall model performance broken down by groups.

Chapter 4
Results

Reported results adhere to the Institute of Education Science (IES) confidentiality requirements for the ECLS-B dataset: unweighted sample sizes were rounded to the nearest 50, and cell sizes with less than 24 observations were suppressed. In addition, it was always my intent to report results for variables with the greatest level of detail. However, this was not always possible (e.g., race/ethnicity and home language). In these cases, categories were either collapsed or were reported only for the full analytic sample.

Descriptive Statistics

Tables 2 and 3 provide (weighted) descriptive statistics for the analytic sample broken down across the three outcome groups (i.e., never, early, late). Table 2 provides results for child variables and Table 3 reports family and community variables. Overall, descriptives for children in the never and late groups were similar, with a few exceptions (e.g., Child Sex, Cognitive Gain Score, and the Number of Words Said). They tended to have higher scores on measures corresponding to developmental domains (e.g., language) than children in the early group. Except for cognitive gains made between 9 and 24 months; here, children in the late group made the smallest gains (never: M = 45.69, SD = 0.93; early: M = 44.78. SD = 1.73; late: M = 41.61, SD = 1.48).

Table 2

Child Participant Characteristics for the Analytic Sample (n = 800)*

Variable	Never (*n* = 400*)	Early (*n* =150*)	Late (*n* = 250*)	Full (*n* = 800*)	Missing Full
	M (SD) or %	M (SD) or %	M (SD) or %	M (SD) or %	%
Sex (male)	62%	73%	72%	67%	0
Race/Ethnicity					0
Black	16%	-	15%	14%	
Hispanic	19%	24%	15%	19%	
Other	4%	-	9%	6%	
White	61%	61%	64%	62%	
BSF-R: Jabbers Expressively-9mos	0.38 (0.02)	0.26 (0.03)	0.36 (0.03)	0.35 (0.02)	0
BSF-R: Purposeful Exploration -9mos	0.84 (0.01)	0.77 (0.03)	0.85 (0.02)	0.84 (0.01)	0
BSF-R: Motor scale score - 9mos	55.09 (0.64)	50.53 (1.62)	54.99 (0.97)	54.25 (0.63)	0
BSF-R: Cognitive scale score 9mos	75.35 (0.81)	71.38 (1.12)	75.03 (0.91)	74.56 (0.63)	0
BSF-R: Cognitive scale score 24mos	121.93 (0.75)	116.16 (1.74)	116.65 1.43)	119.30 (0.85)	0
BSF-R: Cognitive gain score 9-24mos	45.69 (0.93)	44.78 (1.73)	41.61 (1.48)	44.74 (0.90)	0
Number of words said – 24-mos	23 (0.79)	13 (1.30)	17 (1.41)	19 (0.75)	0
Low Birthweight					4
Very Low <1449g	3%	9%	4%	4%	
Mod. Low 1550-2249g	7%	10%	7%	8%	
Normal >2500g	89%	81%	88%	88%	
Identified Disability					0
IDD	19%	92%	77%	50%	
Health Impairment	71%	72%	74%	72%	
Mobility Disability	13%	41%	34%	24%	
Other Diagnosis	37%	48%	70%	49%	
Other Disability	14%	22%	13%	15%	
More than one diagnosis	69%	86%	94%	79%	
Communication Impairment	58%	68%	81%	67%	
IEP 48 - months	29%	59%	52%	43%	
IEP 60 - months	37%	61%	47%	47%	

Note. * Rounded to the nearest 50 per IES confidentiality requirements. Percentages may not add up to 100, as they are rounded up or may exceed 100% for categories that are not mutually exclusive (i.e., disability). - = unable to report for cells with less than 24 unweighted observations, per IES confidentiality requirements. BSF-R = Bayley Short Form – Research Edition. Mos = months. IDD = intellectual and developmental disability. Other includes: Native American, Asian, Native Hawaiian, Pacific Islander and more than one race specified. IEP = Individualized Education Plan.

Source: U.S. Department of Education, National Center for Education Statistics, Early Childhood Longitudinal Study – Birth Cohort (ECLS-B) 2001-2008.

As expected, there was a higher proportion of males in the early (73%) and late (72%) groups compared to never (62%). The two child-related variables that had the greatest difference across the three groups were number of words said at 24-months and presence/absence of IDD. Children who received SLT early spoke around 13 (SD = 1.30) words, compared to 17 (SD = 1.41) in the late group and 23 (SD = 0.79) in the never group. Only 19% of children in the never group had an IDD, compared with 92% in the early group and 77% in the late group. At 9-months children in the late and never groups had comparable scores in overall cognitive ability (never: M = 75.35, SD = 0.81; late: M = 75.03, SD = 0.91) and these were higher compared to children who started SLT early (M = 71.38, SD = 1.12). However, at 24-months, children in the early group had comparable overall cognitive scores to children in the late group (early = 116.16, SD = 1.71; late: M = 116.65, SD = 1.43) and these were lower compared to children in the never group (M = 121.93, SD = 0.75).

English was the home language for most children (90-93%) across the three groups. There were differences in the highest level of maternal education between groups. Around 29% of mothers whose children received SLT early had a 4-year college degree compared to 14% in the never group and 13% in the late group. Proportions for SES across groups are similar to maternal education given that it was included along with paternal education, occupation, and household income in creating the composite SES score. Around 93% of children in the early group lived in urban areas compared to 77% in the never group and 84% in the late group.

Table 3

Home, Family, and Community Characteristics for the Analytic Sample (n = 800)*

Variable	Never (*n* = 400*) M (SD) or %	Early (*n* =150*) M (SD) or %	Late (*n* = 250*) M (SD) or %	Full (*n* = 800*) M (SD) or %	Missing Full %
Home language – English	91%	90%	93%	92%	0
Caregiver Responsivity – 9mos	34.07 (0.29)	35.24 (0.56)	34.5 (0.49)	34.39 (0.25)	0
Family history of disability	29%	34%	27%	29%	0
Maternal Education					-
Less than HH	16%	-	17%	17%	
HH or equivalent	34%	26%	28%	31%	
Voc. Tech/some college	29%	15%	33%	28%	
4-year college	14%	29%	13%	16%	
Graduate degree	8%	-	-	9%	
SES					0
Low	46%	36%	37%	42%	
Medium	23%	13%	24%	22%	
High	31%	51%	39%	37%	
Urban	77%	93%	84%	82%	
Attend childcare with screening/eval	-	-	-	31%	64

Note. * Rounded to the nearest 50 per IES confidentiality requirements. Percentages may not add up to 100, as they are rounded up. - = unable to report for cells with less than 24 unweighted observations, per IES confidentiality requirements. HH = High School. SES = socioeconomic status.

Source: U.S. Department of Education, National Center for Education Statistics, Early Childhood Longitudinal Study – Birth Cohort (ECLS-B) 2001-2008.

Research Question 1

Univariable analyses using logistic regression were conducted to evaluate differences in child and family factors associated with SLT status. In addition, results from Research Question 1 were used to inform variable selection for Research Question 2. Following recommendations from Hosmer et al. (2013) for purposeful selection of covariates for logistic regression, variables with a *p*-value less than 0.25 were included in analyses conducted for Research Question 2. The referent group for all analyses was the late group: this allowed for relative comparisons between late-never and late-early.

Table 4 displays results relative to children who started SLT late (the referent group). The logit coefficients, standard errors, relative risk ratios (RRR), confidence intervals (CI), and *p*-values are provided for each univariable analysis. A RRR of less than 1 indicates that the individual is more likely to be a member of the referent group (i.e., late). In contrast, a RRR value greater than 1 indicates that the individual is more likely to be a comparison group member (i.e., early or never, depending on the comparison). A RRR of 1 indicates equal likelihood, and values close to one suggest little difference. The 95% confidence interval (CI) provides a range for where we are 95% confident that the 'true' parameter may lie for a given predictor. For CIs, if the interval contains 1, it indicates that the direction of the effect is not certain.

Table 4

Results from the Univariable Multinomial Logistic Regression (n = 800[a])

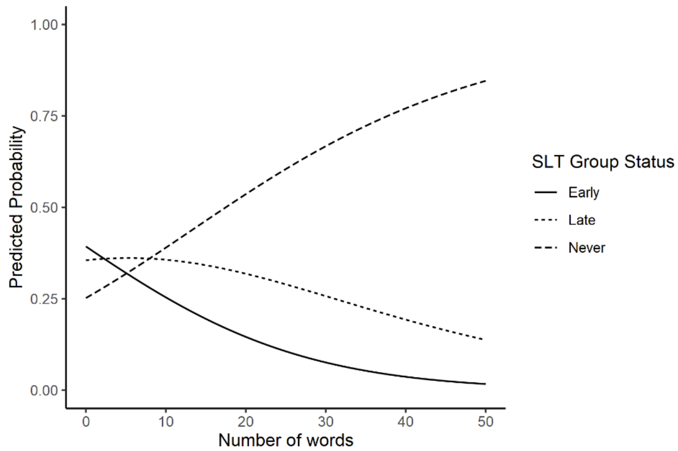
Variable	RRR 95% CI	*B* (*SE*)	*p*	RRR 95% *CI*	*B* (*SE*)	*p*
	Late – Never Comparison			Late – Early Comparison		
Male	0.62 [0.38, 1.01]	-0.48 (0.25)	0.055	1.01 [0.52, 1.97]	0.01 (0.34)	0.971
SES	0.80 [0.60, 1.06]	-0.23 (0.14)	0.115	1.17 [0.81, 1.69]	0.16 (0.19)	0.393
Race/Ethnicity						
Black	1.14 [0.60, 2.19]	0.13 (0.33)	0.690	0.49 [0.16, 1.44]	-0.74 (0.56)	0.188
Hispanic	1.40 [0.75, 2.64]	0.34 (0.32)	0.292	1.73 [0.80, 3.74]	0.55 (0.39)	0.163
Other	0.75 [0.27, 2.06]	-0.29 (0.52)	0.572	1.48 [0.47, 4.64]	0.39 (0.58)	0.506
IDD	0.07 [0.04, 0.12]	-2.69 (0.28)	0.000	3.58 [1.33, 9.67]	1.28 (0.51)	0.012
Jabbers Expressively	1.16 [0.49, 2.75]	0.15 (0.44)	0.729	0.14 [0.03, 0.56]	-1.98 (0.71)	0.005
Purposeful Exploration	0.99 [0.29, 3.46]	-0.01 (0.64)	0.992	0.17 [0.04, 0.70]	-1.78 (0.72)	0.014
Motor	1.00 [0.98, 1.02]	0.00 (0.01)	0.925	0.95 [0.92, 0.98]	-0.05 (0.02)	0.002
Cognitive growth	1.03 [1.01, 1.05]	0.03 (0.01)	0.000	1.02 [1.00, 1.04]	0.02 (0.01)	0.105
No. Words Said	1.04 [1.02, 1.07]	0.04 (0.01)	0.000	0.96 [0.93, 0.99]	-0.04 (0.02)	0.005
Caregiver Responsivity	0.98 [0.93, 1.03]	-0.02 (0.03)	0.453	1.04 [0.97, 1.12]	0.04 (0.04)	0.228
Family history of disability	1.15 [0.69, 1.90]	0.14 (0.26)	0.594	1.43 [0.75, 2.73]	0.36 (0.33)	0.274
Urban	0.63 [0.34, 1.13]	0.90 (0.30)	0.122	2.40 [0.85, 6.75]	-1.34 (0.53)	0.098

Note. [a]Sample size rounded to the nearest 50 per ECLS-B confidentiality requirements. RRR = Relative risk ratio. CI = Confidence interval. SE = standard error for logit coefficient. SES = Socioeconomic status. The reference group for race/ethnicity is White. IDD = intellectual developmental disability. Source: U.S. Department of Education, National Center for Education Statistics, Early Childhood Longitudinal Study – Birth Cohort (ECLS-B) 2001-2008.

All but one variable (family history of disability) met the criterion of $p < 0.25$, suggesting that, although a family history of disability is associated with differences in the likelihood of receiving SLT regardless of the start time (late-never: RRR = 1.15, p = 0.594; late-early: RRR = 1.43, p = 0.274), these differences are not statistically significant. The number of words said and IDD were the only two measures with significant differences across all group comparisons. The presence of an IDD decreased the likelihood of never receiving SLT relative to starting late (RRR = 0.07, $p < 0.001$) and increased the likelihood of starting SLT early relative to a late start (RRR 3.58, p = 0.012). As the number of words spoken increased, the likelihood of that child never receiving SLT increased relative to starting late (RRR = 1.04, $p < 0.001$). In contrast, but as expected, as the number of words spoken increased, the likelihood of starting SLT early decreased relative to starting late (RRR = 0.96, p = 0.005). Figure 3 shows the relationship between the predicted probability of being classified as early, late, or never with observed scores for the number of words said. As expected, overall, the likelihood of receiving SLT decreased as the number of words spoken increased.

Figure 3

Univariable Multinomial Logistic Regression for Number of Words Said

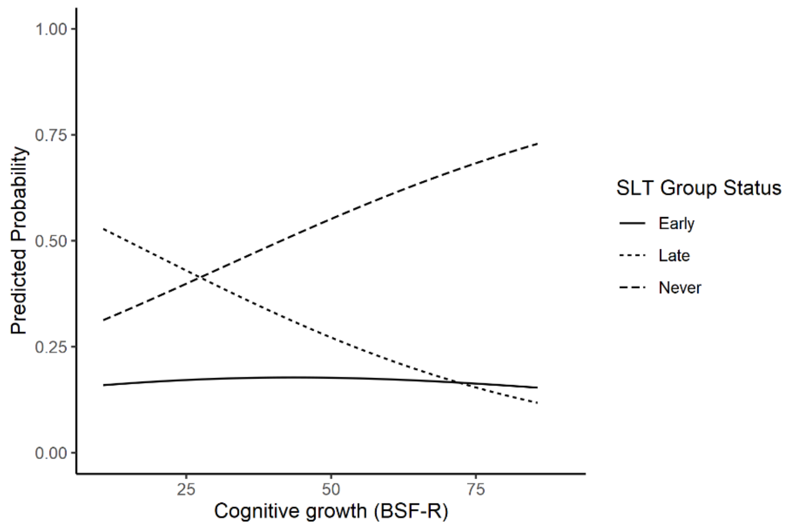


Note. Univariable multinomial logistic regression for the number of words said at 24 months. This figure shows how the predicted probability (y-axis) of being identified as early, late, or never changes with observed scores of the number of words said (x-axis). The relative risk ratios for both never-late and early-late were significant. Source: U.S. Department of Education, National Center for Education Statistics, Early Childhood Longitudinal Study – Birth Cohort (ECLS-B) 2001-2008.

In addition, there were four variables (i.e., male, SES, cognitive growth, and urban), based on $p < 0.25$, that were associated with changing the likelihood of never receiving SLT relative to a late start. Children who never received SLT were more likely to be female and live in rural areas (male: RRR = 0.62, $p = 0.055$; urban: 0.63, $p = 0.122$). As SES increased, the likelihood of never receiving SLT decreased (RRR = 0.80, $p = 0.115$). The likelihood of never receiving SLT increased as cognitive gain sores increased (RRR = 1.03, $p < 0.01$). This relationship can be seen in Figure 4. Figure 4 also illustrates that the probability of receiving SLT early did not change as cognitive gain scores increased.

Figure 4

Univariable Multinomial Logistic Regression for Cognitive growth

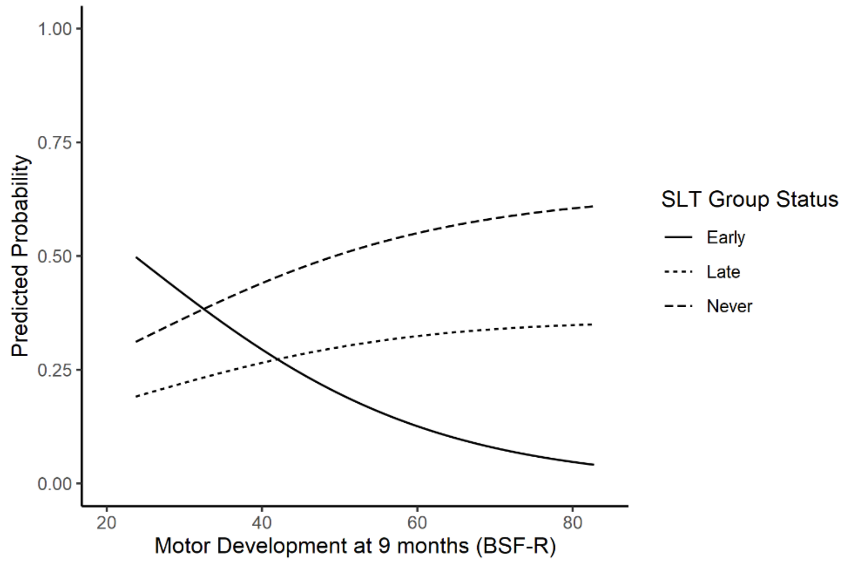


Note. This figure shows how the predicted probability (y-axis) of being identified as early, late, or never changes with observed scores of the cognitive gain scores between 9 and 24 months measured with the BSF-R cognitive scale (x-axis). The relative risk ratio for never receiving SL relative to late is significant. Source: U.S. Department of Education, National Center for Education Statistics, Early Childhood Longitudinal Study – Birth Cohort (ECLS-B) 2001-2008.

Based on the criterion of $p < 0.25$, eight variables were associated with either a decrease or increase in the likelihood of starting SLT early relative to a late start. Children who were Black were less likely to start SLT early compared to White children (RRR = 0.49, $p = 0.188$). In addition, children with higher jabbers expressively, Purposeful Exploration, and Motor Scores (see Figure 5 for motor) were less likely to start SLT at 24 months but rather at 48 or 60 months (jabbers expressively: RRR = 0.14, $p = 0.005$; purposeful exploration: RRR = 0.17, p = 0.014; motor: RRR = 0.95, $p = 0.002$). In contrast, Hispanic children were more likely to start SLT early than White children (RRR = 1.73, $p = 0.163$), as were children living in urban areas (RRR = 2.40, $p = 0.098$). Lastly, the likelihood of starting SLT early increased with each unit increase in cognitive growth (RRR = 1.02, p = 0.105) and caregiver responsivity scores (RRR = 1.04, p = 0.228).

Figure 5

Univariable Multinomial Logistic Regression for Motor Development



Note. This figure shows how the predicted probability (y-axis) of being identified as early, late, or never changes with observed scores of the BSF-R Motor scale (x-axis). The relative risk ratio for starting SL services early relative to late is significant. Source: U.S. Department of Education, National Center for Education Statistics, Early Childhood Longitudinal Study – Birth Cohort (ECLS-B) 2001-2008.

Variable Selection and Order

All variables, except for family history of a disability, had a group comparison with a p-value less than 0.25 and were therefore retained for Research Question 2. Sociodemographic variables were always entered first for each model (i.e., sex, SES, and child race/ethnicity). Additional predictor variables were then added into the model one at a time, with the order of entry based on proximity to language acquisition within an ecobehavioral framework. Thus, child characteristics were entered in first followed by family variables.

Research Question 2

Hierarchical multinomial logistic regression was conducted to examine the unique and cumulative contribution of child and family characteristics predictive of SLT group status. Tables 5 and 6 displays results (logit coefficients, standard errors, RRR, and 95% CI) relative to children who started SLT late. Each model was cross-validated (CV) using *k*-fold-10. Values for residual deviance, AIC, and R^2 were examined to identify if the addition of a variable resulted in changes.

Table 5

Cross-validated Multinomial Logistic Regression Results for Child and Family Predictors of Receiving Speech-Language Therapy Relative to the Late Group (n = 800[a]): Models 1-5

	Model 1		Model 2		Model 3		Model 4		Model 5	
Variable	B (SE)	RRR [CI]	B (SE)	RRR [CI]	B (SE)	RRR [CI]	B (SE)	RRR [CI]	B (SE)	RRR [CI]
Late – Never Comparison										
Male	-0.49	0.61	-0.08	0.93	-0.08	0.92	-0.08	0.92	-0.06	0.95
	(0.25)	[0.37, 1.00]	(0.31)	[0.51, 1.69]	(0.31)	[0.50, 1.69]	(031)	[0.50, 1.69]	(0.31)	[0.52, 1.72]
SES	-0.22	0.80	-0.24	0.78	-0.25	0.78	-0.23	0.80	-0.24	0.79
	(0.16)	[0.59, 1.09]	(0.19)	[0.54, 1.13]	(0.19)	[0.54, 1.13]	(0.19)	[0.55, 1.15]	(0.19)	[0.55, 1.13]
Race/Ethnicity										
Black	-0.02	0.98	-0.18	0.84	-0.17	0.85	-0.14	0.87	-0.13	0.88
	(0.35)	[0.49, 1.96]	(0.43)	[0.36, 1.93]	(0.43)	[0.36, 1.97]	(0.43)	[0.37, 2.01]	(0.43)	[0.38, 2.03]
Hispanic	0.26	1.29	0.41	1.51	0.41	1.50	0.40	1.49	0.40	1.49
	(0.33)	[0.68, 2.47]	(0.40)	[0.69, 3.27]	(0.40)	[0.69, 3.26]	(0.40)	[0.69, 3.22]	(0.39)	[0.69, 3.21]
Other	-0.42	0.65	-0.84	0.43	-0.86	0.42	-0.80	0.45	-0.79	0.46
	(0.53)	[0.23, 1.84]	(0.62)	[0.13, 1.43]	(0.62)	[0.12, 1.43]	(0.62)	[0.13, 1.51]	(0.62)	[0.14, 1.53]
IDD			-2.74	0.06	-2.73	0.06	-2.70	0.07	-2.69	0.07
			(0.29)	[0.04, 0.12]	(0.29)	[0.04, 0.11]	(0.29)	[0.04, 0.13]	(0.29)	[0.04, 0.12]
Jabbers exp.					0.15	1.17	0.57	1.77	0.35	1.41
					(0.54)	[0.40, 3.39]	(0.78)	[0.39, 8.09]	(0.74)	[0.33, 6.04]
Purp. Expl.							-0.75	0.47	-	-
							(1.01)	[0.06, 3.84]		
Motor									0.00	0.99
									(0.02)	[0.96, 1.03]
Late – Early Comparison										
Male	0.00	1.00	-0.15	0.86	0.03	1.03	0.01	1.01	0.08	1.08
	(0.34)	[0.51, 1.95]	(0.35)	[0.43, 1.72]	(0.36)	[0.51, 2.09]	(0.36)	[0.50, 2.04]	(0.36)	[0.53, 2.20]
SES	0.17	1.18	0.15	1.16	0.13	1.14	0.14	1.15	0.12	1.12
	(0.20)	[0.80, 1.75]	(0.20)	[0.79, 1.71]	(0.20)	[0.78, 1.68]	(0.20)	[0.78, 1.70]	(0.20)	[0.76, 1.66]
Race/Ethnicity										
Black	-0.59	0.55	-0.57	0.56	-0.74	0.47	-0.71	0.49	-0.70	0.49
	(0.58)	[0.18, 1.72]	(0.59)	[0.18, 1.79]	(0.60)	[0.15, 1.54]	(0.60)	[0.15, 1.58]	(0.60)	[0.15, 1.59]

	Model 1		Model 2		Model 3		Model 4		Model 5	
Variable	B (SE)	RRR [CI]	B (SE)	RRR [CI]	B (SE)	RRR [CI]	B (SE)	RRR [CI]	B (SE)	RRR [CI]
Hispanic	0.60	1.82	0.60	1.81	0.60	1.81	0.57	1.76	0.55	1.73
	(0.40)	[0.83, 4.03]	(0.41)	[0.81, 4.05]	(0.42)	[0.80, 4.10]	(0.42)	[0.78 ,3.99]	(0.42)	[0.76, 3.92]
Other	0.44	1.55	0.60	1.8	0.70	2.00	0.63	3.99	0.67	1.95
	(0.59)	[0.48, 4.97]	(0.61)	[0.55, 6.02]	(0.63)	[0.58, 6.91]	(0.63)	[0.54, 6.45]	(0.64)	[0.56 6.78]
IDD			1.29	3.65	1.25	3.49	1.18	3.26	1.20	3.33
			(0.52)	[1.33, 10.0]	(0.52)	[1.26, 9.64]	(0.50)	[1.21, 8.74]	(0.51)	[1.22, 9.03]
Jabbers exp					-2.00	0.13	-1.49	0.23	-1.16	0.31
					(0.71)	[0.03, 0.55]	(1.01)	[0.03, 1.64]	(0.87)	[0.06, 1.72]
Purp. Expl.							-0.62	0.54	-	
							(1.14)	[0.06, 5.01]		
Motor									-0.03	0.97
									(0.02)	[0.93, 1.01]
Model Fit and Accuracy Measures										
Resid. Dev.	768.46		593.55		583.27		586.15		584.74	
McFadden’s R^2	0.02		0.24		0.26		0.25		0.26	
AIC	792.46		621.55		615.27		622.15		620.74	
CV-accuracy	47%		60%		61%		61%		62%	
W/in accuracy	48%		60%		61%		62%		63%	

Note. [a]Sample size rounded to the nearest 50 per ECLS-B confidentiality requirements. SES = Socioeconomic status. Reference group for race/ethnicity is White. Exp. = Expressively. Purp. Expl = purposeful exploration. W/in accuracy = within sample accuracy – when the model was run on the full dataset. Source: U.S. Department of Education, National Center for Education Statistics, Early Childhood Longitudinal Study – Birth Cohort (ECLS-B) 2001-2008.

Table 6

Cross-validated Multinomial Logistic Regression Results for Child and Family Predictors of Receiving Speech-Language Therapy Relative to the Late Group (n = 800[a]): Models 6-7

	Model 6		Model 7		Model 8		Model 9	
Variable	B (SE)	RRR [CI]	B (SE)	RRR [CI]	B (SE)	RRR [CI]	B (SE)	RRR [CI]
				Late – Never Comparison				
Male	0.08 (0.32)	1.08 [0.58, 2.02]	0.08 (0.32)	1.09 [0.58, 2.02]	0.05 (0.32)	1.05 [0.57, 1.96]	0.08 (0.32)	1.09 [0.58, 2.02]
SES	-0.35 (0.19)	0.71 [0.48, 1.03]	-0.35 (0.19)	0.71 [0.48, 1.03]	-0.30 (0.20)	0.74 [0.50, 1.09]	-0.29 (0.20)	0.75 [0.51, 1.01]
Race/Ethnicity								
Black	-0.09 (0.44)	0.92 [0.39, 2.18]	-0.07 (0.44)	0.93 [0.39, 2.23]	-0.07 (0.44)	0.93 [0.39, 2.21]	-0.02 (0.45)	0.98 [0.41, 2.37]
Hispanic	0.47 (0.40)	1.60 [0.73, 3.49]	0.47 (0.40)	1.59 [0.73, 3.47]	0.44 (0.40)	2.21 [0.71, 3.38]	0.55 (0.41)	1.74 [0.79, 3.86]
Other	-0.72 (0.64)	0.48 [0.14, 1.70]	-0.72 (0.64)	0.49 [0.14, 1.71]	-0.63 (0.64)	0.53 [0.15, 1.86]	-0.68 (0.63)	0.51 [0.15, 1.76]
IDD	-2.65 (0.30)	0.07 [0.04, 0.13]	-2.69 (0.31)	0.07 [0.04, 0.12]	-2.66 (0.31)	0.07 [0.04, 0.13]	-2.68 (0.31)	0.07 [0.04, 0.13]
Jabbers exp	1.15 (0.66)	3.16 [0.87, 11.45]	1.31 (0.73)	3.69 [0.88, 15.47]	1.21 (0.73)	3.35 [0.80, 14.02]	1.12 (0.73)	3.03 [0.72, 12.74]
Purp. Expl.	-	-	-	-	-	-	-	-
Motor	-	-	-	-	-	-	-	-
Cog. Growth	0.04 (0.01)	1.04 [1.01, 1.07]	0.04 (0.02)	1.04 [1.01,1.08]	0.04 (0.02)	1.04 [1.01, 1.08]	0.04 (0.02)	1.04 [1.01 1.07]
Words said			-0.01 (0.02)	0.99 [0.96, 1.02]	-0.01 (0.12)	0.99 [0.96, 1.02]	-0.01 (0.02)	0.99 [0.96, 1.02]
CG Resp					-0.02 (0.34)	0.98 [0.91, 1.05]	-	-
Urban							-0.53 (0.39)	0.59 [0.28, 1.27]
				Late – Early Comparison				
Male	0.07 (0.37)	1.07 [0.52, 2.20]	0.05 (0.37)	1.05 [0.51, 2.19]	0.01 (0.37)	1.01 [0.49, 2.08]	-0.06 (0.37)	0.95 [0.45, 1.97]

Variable	Model 6 B (SE)	Model 6 RRR [CI]	Model 7 B (SE)	Model 7 RRR [CI]	Model 8 B (SE)	Model 8 RRR [CI]	Model 9 B (SE)	Model 9 RRR [CI]
SES	0.12 (0.20)	1.12 [0.75, 1.67]	0.13 (0.21)	1.13 [0.76, 1.70]	0.09 (0.22)	1.09 [0.71, 1.68]	0.06 (0.21)	1.06 [0.70, 1.62]
Race/Ethnicity								
Black	-0.73 (0.60)	0.48 [0.15, 1.57]	-0.61 (0.61)	0.54 [0.16, 1.81]	-0.62 (0.60)	0.54 [0.17, 1.76]	-0.73 (0.61)	0.48 [0.15, 1.61]
Hispanic	0.61 (0.42)	1.83 [0.81, 4.15]	0.68 (0.42)	0.42 [0.86, 4.52]	0.63 (0.42)	1.88 [0.82, 4.29]	0.50 (0.43)	1.64 [0.70, 3.83]
Other	0.73 (0.64)	2.07 [0.60, 7.22]	0.80 (0.65)	2.23 [0.63, 7.94]	0.68 (0.64)	1.98 [0.56, 6.96]	0.81 (0.65)	2.26 [0.63, 8.13]
IDD	1.27 (0.52)	3.56 [1.28, 9.87]	1.02 (0.53)	2.77 [0.98, 7.85]	0.88 (0.51)	2.41 [0.89, 6.55]	0.93 (0.52)	2.53 [0.92, 6.94]
Jabbers exp	-1.80 (0.79)	0.17 [0.04, 0.78]	-0.82 (0.87)	0.44 [0.08, 2.41]	-0.99 (0.87)	0.37 [0.07, 2.03]	-1.02 (0.87)	0.36 [0.07, 1.98]
Purp. Expl.	-	-	-	-	-	-	-	-
Motor	-	-	-	-	-	-	-	-
Cog. Growth	0.00 (0.01)	1.01 [0.98, 1.04]	0.04 (0.02)	1.04 [1.00, 1.08]	0.03 (0.02)	1.03 [0.99, 1.07]	0.03 (0.02)	1.03 [0.99, 1.07]
Words said			-0.05 (0.02)	0.95 [0.91, 0.99]	-0.05 (0.02)	0.95 [0.92, 0.99]	-0.05 (0.02)	0.95 [0.92, 0.99]
CG Resp					0.02 (0.04)	1.02 [0.95, 1.10]	-	-
Urban							0.80 (0.56)	2.23 [0.74, 6.70]
Model Fit and Accuracy Measures								
Resid. Deviance	575.35		568.48		570.34		565.63	
McFadden's R^2	0.27		0.28		0.27		0.28	
AIC	611.35		608.48		614.34		609.63	
CV-accuracy	60%		62%		61%		62%	
W/in accuracy	62%		63%		62%		63%	

Note. *Note*. [a]Sample size rounded to the nearest 50 per ECLS-B confidentiality requirements. SES = Socioeconomic status. Reference group for race/ethnicity is White. Exp. = Expressively. Purp. Expl = purposeful exploration. W/in accuracy = within sample accuracy – when the model was run on the full dataset. Source: U.S. Department of Education, National Center for Education Statistics, Early Childhood Longitudinal Study – Birth Cohort (ECLS-B) 2001-2008.

The initial model examined all control models (sex, SES, race/ethnicity). As expected, this cluster of variables had low predictive ability in classifying SLT status (*R^2* = 0.02; CV-accuracy = 47%). Relative to starting SLT late, females were more likely never to receive SLT (B = -0.49, SE = 0.25). Black and Other (Native American, Asian, Native Hawaiian, Pacific Islander, more than one race) children were more likely to never receive SLT compared to White children (Black: B = -0.02, SE = 0.35; Other: B = -0.42 SE = 0.53), whereas Hispanic children were more likely to start SLT late compared to White children (B = 0.26, SE = 0.33). Child sex did not change likelihood of starting SLT early relative to late (B = 0.00, SE = 0.34). Black children are more likely to start SLT late than White children (B = - 0.59, SE = 0.58). In contrast, Hispanic and Other (Native American, Asian, Native Hawaiian, Pacific Islander, more than one race) children were more likely to start early compared to White children (Hispanic: B = 0.60, SE = (0.40); Other: B=0.44, SE = 0.59). Table 7 shows cv-model accuracy for each group and shows the model bias for classifying children as never receiving SLT.

Table 7

Cross-Validated Confusion Matrix: Predicted and Observed Speech-Language-Therapy Status for Model 1 (n = 800[a])

	Observed Group		
Predicted Group	Never	Early	Late
Never	44.9	18.1	27.3
Early	1.5	0.1	0.6
Late	3.8	2.0	1.6

Note. Sample size rounded to nearest 50 per IES confidentiality requirements. Values are percental average across folds (*k* = 10). Source: U.S. Department of Education, National Center for Education Statistics, Early Childhood Longitudinal Study – Birth Cohort (ECLS-B) 2001-2008.

Model 2 added the presence/absence of an IDD as a predictor (see Table 5). The addition of IDD greatly improved the model (R^2 = 0.24, CV-accuracy = 60%, AIC = 621.55). Table 8 shows the impact of improving model accuracy for correctly predicting early and late. Correct classification of late increased from 1.6% to 17.3%, and correct classification for Early increased from 0.1% to 4.4%. Children with an IDD were more likely to start SLT late than never (B = -2.74, SE = 0.29) and were more likely to start services early relative to late (B =1.29, SE = 0.52).

Table 8

Cross-Validated Confusion Matrix: Predicted and Observed Speech-Language-Therapy Status for Model 2 (n = 800[a])

	Observed Group		
Predicted Group	Never	Early	Late
Never	38.5	2.1	6.6
Early	2.4	4.4	5.6
Late	9.3	13.8	17.3

Note. Sample size rounded to nearest 50 per IES confidentiality requirements. Values are percental average across folds (*k* = 10). Source: U.S. Department of Education, National Center for Education Statistics, Early Childhood Longitudinal Study – Birth Cohort (ECLS-B) 2001-2008.

Jabbers expressively was stepped into Model 3 and improved the model (R^2 = 0.26, CV accuracy = 61%, AIC = 615.27; see Table 5). There was a slight reduction (-1.7%) for accurately classifying late starts, but a 4.4% improvement in identifying early (see Table 9). Children with higher jabbers expressively scores at 9-months were more likely never to receive SLT (B = 0.15, SE = 0.54) than starting late and were less likely to start services early relative to late (B = -2.00, SE = 0.71).

Table 9

Cross-Validated Confusion Matrix: Predicted and Observed Speech-Language-Therapy Status for Model 3 (n = 800[a])

	Observed Group		
Predicted Group	Never	Early	Late
Never	38.5	2.1	6.6
Early	3.3	7.3	7.3
Late	8.4	10.9	15.6

Note. Sample size rounded to nearest 50 per IES confidentiality requirements. Values are percental average across folds (*k* = 10). Source: U.S. Department of Education, National Center for Education Statistics, Early Childhood Longitudinal Study – Birth Cohort (ECLS-B) 2001-2008.

Model 4 included Purposeful Exploration at 9-months in the model (Table 5). The addition of Purposeful Exploration had a negative impact on the model: reducing predictive power ($R^2 = 0.25$) and increasing AIC and residual deviance values (AIC = 622.15, residual deviance = 586.15). Table 10 provides the confusion matrix for predicted and observed classification for Model 4. There was no difference in the never predictions, but purposeful exploration did have a small impact on early and late predictions. Higher scores were associated with decrease in never receiving SLT relative to starting late and less likely to start early (late-never: B = -0.75, SE = 1.01; late-early: B = -0.62, SE = 1.12). Due to the negative impact of purposeful exploration on the model, it was removed from future models.

Table 10

Cross-Validated Confusion Matrix: Predicted and Observed Speech-Language-Therapy Status for Model 4 (n = 800[a])

	Observed Group		
Predicted Group	Never	Early	Late
Never	38.5	2.1	6.6
Early	4.0	7.0	7.8
Late	7.6	11.1	15.1

Note. Sample size rounded to nearest 50 per IES confidentiality requirements. Values are percental average across folds (*k* = 10). Source: U.S. Department of Education, National Center for Education Statistics, Early Childhood Longitudinal Study – Birth Cohort (ECLS-B) 2001-2008.

Motor ability at 9-months was added into Model 5 (table 5). The addition of motor did not provide an improvement to the model compared to Model 3. Values for AIC and residual deviance were still higher than Model 3 (AIC = 620.74, residual deviance 584.75). However, it did improve model accuracy (CV-accuracy = 62%; see Table 11 for confusion matrix). There was no difference in log-odds for motor ability between the Never-Late comparison (B= 0.00, SE = 0.02). In comparison, higher motor scores were associated with a decrease in starting SLT early relative to a late start (B = -0.03, SE = 0.02). Despite the improvements in model cv-accuracy, it was removed from subsequent models because of its negative effect on model fit, based on AIC and residual deviance.

Table 11

Cross-Validated Confusion Matrix: Predicted and Observed Speech-Language-Therapy Status for Model 5 (n = 800[a])

Predicted Group	Observed Group		
	Never	Early	Late
Never	38.5	2.1	6.6
Early	3.9	8.1	8.0
Late	7.8	10.0	14.9

Note. Sample size rounded to nearest 50 per IES confidentiality requirements. Values are percental average across folds (k = 10). Source: U.S. Department of Education, National Center for Education Statistics, Early Childhood Longitudinal Study – Birth Cohort (ECLS-B) 2001-2008.

Model 6 included adding cognitive growth as a predictor, which improved the model (R^2 = 0.27, AIC = 611.35; see Table 6). Greater cognitive gains were associated with a slight increase in the likelihood of never receiving SLT relative to a late start (B = 0.04, SE = 0.01). However, there was no difference between an early and late start (B = 0.00, SE = 0.01). Even though cognitive growth explained differences in group membership above and beyond the other variables in the model, model accuracy decreased to 60% (see Table 12 for group breakdowns).

Table 12

Cross-Validated Confusion Matrix: Predicted and Observed Speech-Language-Therapy Status for Model 6 (n = 800[a])

	Observed Group		
Predicted Group	Never	Early	Late
Never	38.4	2.9	7.0
Early	4.0	6.8	7.4
Late	7.8	10.6	15.1

Note. Sample size rounded to nearest 50 per IES confidentiality requirements. Values are percental average across folds (k = 10). Source: U.S. Department of Education, National Center for Education Statistics, Early Childhood Longitudinal Study – Birth Cohort (ECLS-B) 2001-2008.

Model 7 examined if adding the number of words said at 24-months provides any additional contribution to the model, with results suggesting it does (see Table 6). Decreases were observed for the residual deviance and AIC (AIC = 608.45, residual deviance = 568.48) and increases in R^2 (0.28) and model accuracy (62%; see Table 13 for group breakdown). Children with a larger vocabulary size were less likely to never receive SLT relative to starting late (B = -0.01, SE = 0.02) and less likely to start early relative to a late start (B = -0.5, SE = 0.2).

Table 13

Cross-Validated Confusion Matrix: Predicted and Observed Speech-Language-Therapy Status for Model 7 (n = 800[a])

	Observed Group		
Predicted Group	Never	Early	Late
Never	38.9	2.9	6.9
Early	3.3	7.5	7.0
Late	8.0	9.9	15.6

Note. Sample size rounded to nearest 50 per IES confidentiality requirements. Values are percental average across folds (*k* = 10). Source: U.S. Department of Education, National Center for Education Statistics, Early Childhood Longitudinal Study – Birth Cohort (ECLS-B) 2001-2008.

Caregiver responsivity was stepped into Model 8 (Table 6). The addition of caregiver responsivity had an overall negative impact on the model, increasing AIC and residual deviance values (AIC = 614.34, residual deviance 570.34) and resulted in a decrease in R^2 (0.27) and model accuracy (61%; see Table 14). As a result, it was not included in Model 9. Higher responsivity scores were associated with a decrease in the likelihood of never receiving SLT (B = -0.02, SE 0.34). In addition, children with parents who were more responsive were more likely to start SLT early relative to a late start (B = 0.02, SE = 0.04).

Table 14

Cross-Validated Confusion Matrix: Predicted and Observed Speech-Language-Therapy Status for Model 8 (n = 800[a])

Predicted Group	Observed Group		
	Never	Early	Late
Never	38.9	2.4	6.8
Early	2.6	7.4	7.7
Late	8.6	10.4	15.1

Note. Sample size rounded to nearest 50 per IES confidentiality requirements. Values are percental average across folds (*k* = 10). Source: U.S. Department of Education, National Center for Education Statistics, Early Childhood Longitudinal Study – Birth Cohort (ECLS-B) 2001-2008.

The last model (Model 9) assessed whether living in urban or rural areas provided a unique contribution to predicting SLT status. The addition of urban did not improve R^2 (0.28) or AIC (609.63) values compared to Model 7, but reductions in residual deviance were observed (565.63). Children living in rural areas were more likely never to receive SLT relative to a late start (B = -0.53, SE = 0.39; see Table 6), and children living in urban areas were more likely to start SLT early relative to late (B = 0.80, SE = 0.56).

Table 15

Cross-Validated Confusion Matrix: Predicted and Observed Speech-Language-Therapy Status for Model 9 (n = 800[a])

	Observed Group		
Predicted Group	Never	Early	Late
Never	38.9	2.5	7.3
Early	3.3	8.1	6.9
Late	8.0	9.6	15.4

Note. Sample size rounded to nearest 50 per IES confidentiality requirements. Values are percental average across folds (k = 10). Source: U.S. Department of Education, National Center for Education Statistics, Early Childhood Longitudinal Study – Birth Cohort (ECLS-B) 2001-2008.

Determining Predictor Contribution, Model Fit, and Accuracy

The residual deviance and reduction between models provide information regarding the relative importance of a given variable in relation to other predictors. The presence/absence of IDD provided the greatest unique contribution for classifying SLT status, with a reduction in residual deviance of 174.9. Jabbers expressively and cognitive growth also contributed above and beyond other included predictors with reductions in residual deviance of around 10.

The model with the best clusters of predictors was Model 7. This was chosen based on AIC. However, it is important to note that the final model can only accurately predict SL group status 62% of the time. In the final model, relative to a late start, male children were more likely never to receive SLT (RRR = 1.09, CI = 0.58, 2.02); higher SES scores were associated with an increase in the likelihood of receiving SLT late (RRR = 0.71, CI = 0.48. 1.03). Compared to White children, being Black (RRR = 0.93, CI = 0.39, 2.23) or Native American, Asian, Native Hawaiian, Pacific Islander, more than one race (Other; RRR = 0.49, CI = 0.14, 1.71) were more likely to start SLT late. The absence of an IDD increased the likelihood of never receiving SLT (RRR = 0.07, CI = 0.04, 0.12). Higher jabbers expressively (RRR = 3.69, CI = 0.88, 15.47) and cognitive gain scores (RRR = 1.04, CI = 1.01, 1.08) also increased the likelihood of never receiving SLT services. There was almost no difference in the number of words said in the likelihood of never receiving SLT relative to a late start. However, a slight increase in receiving SLT late was associated with a larger spoken vocabulary repertoire (RRR =0.99, CI = 0.96, 1.02).

Results show that relative to a late start, children who started SLT early were more likely to be male (RRR = 1.05, CI = 0.51, 2.19), come from families with higher SES (RRR = 1.13, CI = 0.76, 1.70). In addition, higher language scores decreased the likelihood of starting SLT early relative to late (jabbers expressively: RRR = 0.44, CI = 0.08, 2.41; number of words said: RRR = 0.95, CI = 0.91, 0.99). In contrast, higher cognitive gain scores were associated with a higher likelihood of starting SLT early relative to late (RRR = 1.04, CI = 1.00, 1.08).

Chapter 5

Discussion

Given the importance of early identification and timely access to speech-language therapy (SLT), the aim of the current study was to identify characteristics of children in the United States who were more likely never to receive SLT, those who started early (i.e., 24-months), and those who started late (i.e., 48 or 60 months). Examining both the unique and combined contribution of factors influencing the likelihood of different start times can help us further understand factors related to SLT start times. In addition, including factors that vary in proximity to language development allows for a more nuanced understanding of the factors at play, resulting in more targeted mechanisms to increase early start times for children who would benefit from SLT. In the following section, I will summarize findings from the current study and their implications, identify and describe current limitations, and provide suggestions for future research.

The Unique and Cumulative Contribution of Child and Family Factors

First, this study explored differences in individual child and family characteristics associated with the timing in receipt of SLT. Results from the univariable analyses conducted showed that there were several child variables (i.e., presence/absence of IDD, jabbers expressively, purposeful exploration, motor, cognitive growth, and the number of words said at 24-months) but no family factors that significantly ($p < 0.05$) predicted the likelihood of receiving SLT and when.

The presence of an IDD was significantly associated with both the likelihood of receiving SLT and the age at which services start (i.e., children with an IDD were more likely to start SLT at 24-months relative to 48 or 60-months. As expected, higher language scores were associated with a decrease in the likelihood of receiving SLT or an increase in the likelihood that services would start at a later date (i.e., at 48 or 60-months). At 9-months, higher prelinguistic scores (i.e., jabbers expressively) significantly increased the likelihood of starting SLT late rather than early. Although there were no differences in prelinguistic abilities between those who never received SLT and those who started late, by 24-months of age, there were significant differences in the number of words said between children who never received SLT and those that started late.

These results suggest that there may be some additional factors interacting with prelinguistic abilities in children who are more likely to start SLT late that impacts their expressive vocabulary development. Although children across all groups demonstrated relatively high proficiency probability scores for purposeful exploration, children with higher mastery of this developmental measure were significantly more likely to start SLT late rather than early. Lastly, albeit a small effect, greater cognitive gain scores were associated with an increase in the likelihood of never receiving SLT.

The second research question examined the relative contribution of an individual variable above and beyond other variables in the model after considering the contribution of the child-level control variables (i.e., child sex, SES, and race/ethnicity). Variables were stepped into the model given their proximity to language facilitating interactions in my conceptual model of language acquisition, guided by bioecological and ecobehavioral frameworks. The presence/absence of IDD, jabbers expressively, cognitive growth, and the number of words said at 24-months all contributed above and beyond already included variables in the model. Although on their own, both higher purposeful exploration and motor development scores at 9-months significantly increased the likelihood of starting SLT late compared to early, they did not contribute to predicting SLT status above and beyond other variables. In addition, both caregiver responsivity and whether the child lived in an urban area reduced model fit. All four of these variables – purposeful exploration, motor development, caregiver responsiveness, and urban home – were removed from successive comparisons. The final model correctly predicted SLT status 62% of the time. Given that the model was cross-validated, it provides a more realistic estimate of how the model would perform in practice and the relative contribution of predictors for classifying SLT status. Although the model's generalizability is good, it would not be adequate to use the model in practice to guide identification efforts due to the low classification accuracy.

Contributions and Implications

The current study extends findings from Morgen et al. (2016) that vocabulary delays at 24-months predicted receiving SLT at 5-years of age by looking at *when* parents reported that their children *first* started receiving SLT. The final model from the current study suggests that expressive vocabulary at 24-months can also be used to predict who starts receiving SLT at 24-months compared to 48 or 60-months. However, it may not be able to predict who never receives SLT relative to a late start. In the final model, increases in the number of words said were associated with a decreased likelihood of never receiving SLT. However, the RRR was close to 1. In other words, the number of words said may not help differentiate between children who do not need SLT and those that do but are only identified at a later age (e.g., 48 or 60 months).

Results from Morgen et al. (2016) support the use of a brief parent-reported measure of expressive vocabulary like the MacArthur-Communicative Development

Inventory (M-CDI) in early screening efforts. Although this study showed a small difference in the number of words said being associated with changing the likelihood of never receiving SLT versus starting those services late, results suggest a meaningful difference (i.e., we observed significant changes in model fit and accuracy when the number of words said was added to the model). These results indicate that expressive vocabulary at 24-months could be used to identify children who need SLT and for whom services should start sooner than 48 or 60 months. Because parent concern is a strong predictor of SLT use (Skeat et al., 2014) and parents of children with less overt communication difficulties might be less likely to have a concern (Hendricks et al., 2019) or seek support (Skeat et al. 2010), the use of a brief expressive vocabulary screener (e.g., M-CDI or oral language measure from the Age-3 Individual Growth Development Indicators (IGDI) suite; McConnell et al., 2019) could be used in universal screening efforts to identify children who would benefit from SLT. Not only do we need to identify children who might benefit from SLT, but we also identify them as early as possible to ensure they have access to services in a timely fashion.

The current study suggests that there may be differences in factors associated with whether a child receives SLT and in the age at which those services start. For example, there is some evidence to suggest that a family history of a disability is associated with both a diagnosis of developmental language disorder (DLD) and whether children receive SLT (Flax et al., 2003; Morgan et al., 2016; Tallal et al., 2001). However, in the current study, family history of disability was not associated with the starting age for SLT services. Similarly, past research indicates that boys are more likely to receive SLT than girls (Harrison et al., 2010; Morgen et al., 2016) and are also more likely to receive special education services (Woods, 2018). In this study, however, child gender was not a significant predictor in the univariable analyses, nor was it reliably associated with an increase or decrease in receiving SLT. Furthermore, in the final model, being male was associated with an increase in the likelihood of never receiving SLT relative to starting late, but males, compared to females, were more likely to start services early, relative to a late start. These differences might be due to the current study's sample size not having enough power to detect real differences, suggesting that these effects are small. However, small effects can still be theoretically meaningful and practically relevant.

The final model suggests the best cluster of variables to accurately identify SLT status and age at start, in addition to the sociodemographic control variables, were IDD, jabbers expressively, cognitive gain score, and the number of words said. However, it is important to note that most of the prediction accuracy resulted from the model identifying those children who never received SLT. Although from a cost-benefit perspective, it is essential to know who does not need SLT, to ensure timely service delivery, we need to identify those needing services as soon as possible. Mean performance in developmental domains assessed (e.g., language, motor), particularly at 9-months, were similar for children who never received SLT and those that started late. Given the similarities in means, it indicates that the measures used in the current study and/or the age at which these assessments were completed may not accurately distinguish between the two groups. Findings from the current study would also suggest that it is not likely to identify SLT status at 9-months or 24-months accurately with the measures used here. This could be due to various reasons, including the precision of the measures assessing language and cognitive ability. Or that children in the never group would have still benefited from receiving SLT but were not receiving services. In addition, children who never received SLT or started those services late may have received communication-related services through their EI services, but parents did not indicate that they specifically received SLT services. It is quite likely that many children in the never group would also benefit from early communication interventions due to the overall low expressive vocabulary in that group: children with typical language development tend to say 50 or more words by 24-months (e.g., Identify the Signs; ASHA, n.d.).

Limitations

This study has several limitations worth noting here. Most of these stem from limitations associated with the use of extant databases and secondary data analyses. The strength of the ECLS-B is that it provides great breadth related to factors that impact early childhood development. However, one weakness is that its breadth does not allow researchers to investigate mechanisms that may influence developmental trajectories with any depth. My analyses relied on the survey questions being able to accurately capture early interventions services received and assumed that caregivers responded to those questions correctly. For example, some children may have received communication-related interventions through other types of services (e.g., EI), not direct SLT, but this may not have been reflected in at least some parent reports. It was not possible to verify caregiver responses, as ECLS-B did not collect any information from speech-language pathologists or other EI providers. There are also considerable differences in eligibility criteria for EI services between states in this national sample, and evidence suggests that many children who would be eligible for EI services do not receive them (e.g., Feinberg et al., 2011; Rosenberg et al., 2013; Rosenberg et al., 2008). As a result, the current study cannot fully capture all the factors associated with SLT start time.

Data used in the current study is also somewhat dated (i.e., children born in the U.S in 2000-2001, with analyses completed in 2021), which may affect its overall validity. The early intervention landscape has changed considerably since 2001. For example, in 2007, the American Academy of Pediatrics recommended that all toddlers be screened for autism by 24-months (Johnson et al., 2007). Since that recommendation, there has been considerable focus on improving screening and identification efforts for autism at 24-months or earlier (e.g., Boyd et al., 2010; Daniels et al., 2014; Levy et al., 2020). In addition, the reauthorization of IDEA part C in 2004 placed an increasing amount of focus and importance on child find initiatives to identify children who would benefit from EI services (for example, expansion of Help Me Grow to statewide implementation in Minnesota). Shifts in policies and practices like these would likely improve identification efforts and also when those services start.

In addition, the majority of predictors examined were child characteristics. Although in this study, family variables did not improve prediction accuracy, there may be additional family factors (e.g., level of concern, beliefs about disability) as well as societal factors (e.g., access to screening, health insurance) associated with differences in SLT start times. In addition, receptive language would be an important child characteristic to examine due to its importance in early language acquisition and was not included in the current study.

Finally, the performance of logistic regression adds another possible limitation to the study. The algorithm used for logistic regression tends to favor the group with the highest base rates, as inherently, it is associated with higher reinforcement rates (Galar et al., 2012; Sun et al., 2011). There are ways to address this (for example, reduce base rates of the majority group, increase base rates of smaller groups, or add in weighting to penalize the algorithm for misclassification as in cost-sensitive logistic regression); however, they were not used in the current study.

Future Directions

Results from the current study have implications for future research. First, it will be important to continue to further identify child characteristics (e.g., receptive language) and the timing of assessments related to SLT start times. One possible avenue would be to include a broader range of variables at the family and societal level and examine possible interaction effects between proximal and distal factors. These efforts should focus both on multiple levels of causal influence, including variables that can be targeted directly to change language trajectories (e.g., expressive vocabulary) *and* variables that produce change at the policy level (e.g., parental leave policies) and, in turn, help increase the frequency of language-learning opportunities.

Next, more work is needed to examine how SLT start time and duration of interventions are related to later outcomes and not just language-related outcomes. Are outcomes for those who start early and persistently receive SLT through their school years different to children who have a delayed start or only receive SLT for a short time? Gaining a better understanding of the longitudinal patterns of SLT receipt can help inform our understanding of which children are receiving SLT and the consequences of these patterns while also identifying underlying patterns of characteristics associated with different service trajectories. However, it will be important to consider different underlying etiologies of language and communication delay when looking at differences in outcomes related to the start and duration of SLT.

Conclusion

Children may experience several challenges while acquiring language, and access to early communication interventions can help address many of these challenges. Given that language provides the building blocks for many later skills and outcomes (e.g., literacy, social skills, academic achievement), it is vital that children who require additional supports receive them. However, well-designed interventions do little if those who require them are not identified and receive them. The current study provides further evidence that prelinguistic and expressive vocabulary measures can be used to identify children who may require SLT. However, there is a need to develop more sensitive measures to increase identification accuracy. Understanding the characteristics of when children receive SLT can help improve future identification efforts and ensure timely access services and supports for those that need it.

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Appendix A
Analytic vs. Full Sample Weighted Descriptives

Table A1

Child Participant Characteristics for Analytic (*n* = 800[a]) vs. Full Sample (*n* = 1000[a])

Variable	Analytic		Full	
	M (SD) or %	% Missing	M (SD) or %	% Missing
Sex (male)	67%	0	67%	0
Race/Ethnicity		0		-
Black	14%		13%	
Hispanic	19%		20%	
Other	6%		6%	
White	62%		61%	
BSF-R: Jabbers Expressively-9mos	0.35 (0.02)	0	0.35 (0.02)	5
BSF-R: Purposeful Exploration -9mos	0.84 (0.01)	0	0.83 (0.01)	5
BSF-R: Motor scale score - 9mos	54.25 (0.63)	0	53.88 (0.57)	5
BSF-R: Cognitive scale score - 9mos	74.56 (0.63)	0	74.53 (0.60)	5
BSF-R: Cognitive gain score 9-24mos	44.74 (0.90)	0	44.58 (0.90)	11
Number of words – 24 mos	19 (0.75)	0	19 (0.70)	0
Low Birthweight		4		5
Very Low <1449g	4%		5%	
Mod. Low 1550-2249g	8%		8%	
Normal >2500g	88%		87%	
Identified Disability		0		0
IDD	50%		52%	
Health Impairment	72%		71%	
Mobility Disability	24%		27%	
Other Diagnosis	49%		49%	
Other Disability	15%		16%	
More than one diagnosis	79%		80%	
Communication Impairment	67%		80%	
IEP – 48 months	43%	-	44%	-
IEP – 60-months	47%	0	47%	-

Note. [a]Rounded to the nearest 50 per IES confidentiality requirements. Percentages may not add up to 100, as they are rounded up or may exceed 100% for categories that are not mutually exclusive (i.e., disability). - = unable to report and meet IES confidentiality requirements. IDD = intellectual and developmental disability. Other includes: Native American, Asian, Native Hawaiian, Pacific Islander and more than one race specified. BSF-R = Bayley Short Form – Research Edition. IEP =

Individualized Education Plan. Source: U.S. Department of Education, National Center for Education Statistics, Early Childhood Longitudinal Study – Birth Cohort (ECLS-B) 2001-2008.

Table A2

Home, Family, and Community Characteristics for Analytic (*n* = 800[a]) vs. Full Sample (*n* = 1000[a])

	Analytic		Full	
Variable	M (SD) or %	% Missing	M (SD) or %	% Missing
Home language – English	92%	0	89%	0
Caregiver Responsivity	34.39 (0.25)	0	34.37 (0.27)	16
Family history of disability	29%	0	30%	0
Maternal Education		-		-
Less than HH	17%		18%	
HH or equivalent	31%		31%	
Voc. Tech/some college	28%		26%	
4-year college	16%		15%	
Graduate degree	9%		9%	
SES		0		0
Low	42%		41%	
Medium	22%		29%	
High	37%		36%	
Urban	82%		83%	0
Attend childcare with screening/eval	31%	64	31%	66

Note. [a]Rounded to the nearest 50 per IES confidentiality requirements. Percentages may not add up to 100, as they are rounded up or may exceed 100% for categories that are not mutually exclusive (i.e., disability). - = unable to report and meet IES confidentiality requirements. SES = socioeconomic status. Source: U.S. Department of Education, National Center for Education Statistics, Early Childhood Longitudinal Study – Birth Cohort (ECLS-B) 2001-2008.

Appendix B
Model Assumptions and Diagnostics

Model assumptions and diagnostics were performed on the final model (Model 7). For some tests (e.g., multicollinearity), the multinomial model was broken down into its binomial components.

Table B1

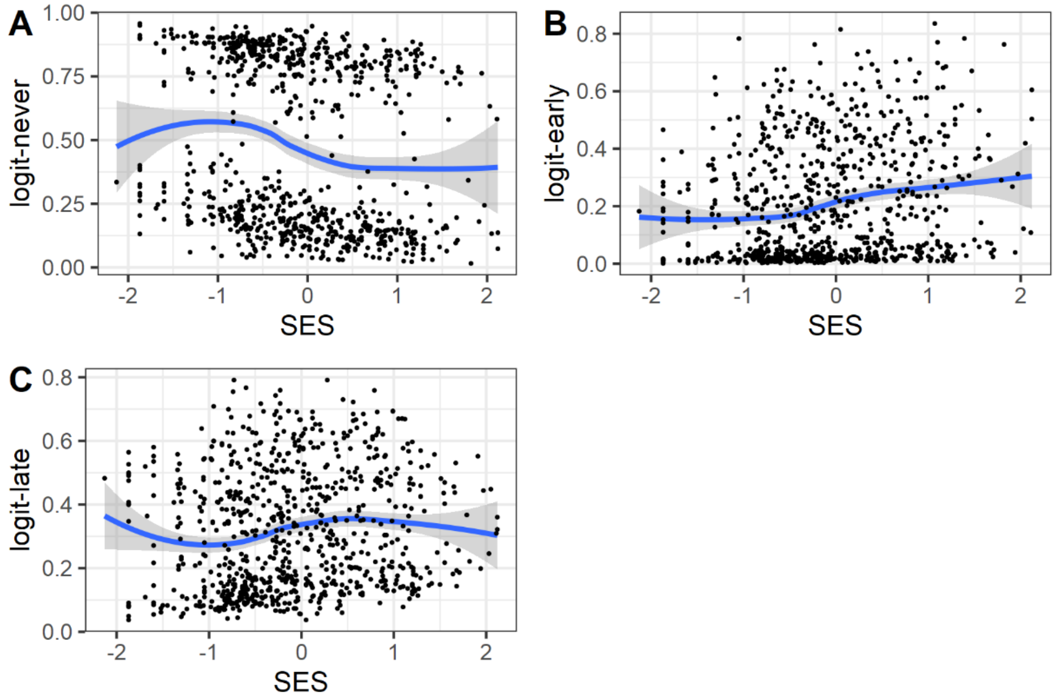
Variance Inflation Factor for Binomial Components to Assess Multicollinearity

Variable	Never-Late	Never-Early	Early-Late
Male	1.070679	1.077336	1.084020
SES	1.169339	1.145985	1.264407
Black	1.201411	1.088355	1.197419
Hispanic	1.105571	1.239213	1.147650
Other	1.051716	1.129120	1.104008
Jabbers Expressively	1.766757	1.579556	1.502103
Cognitive Gain Score	2.049216	2.129930	2.332191
Number of Words Said	1.310344	1.581862	1.784505

Source: U.S. Department of Education, National Center for Education Statistics, Early Childhood Longitudinal Study – Birth Cohort (ECLS-B) 2001-2008.

Figure B1

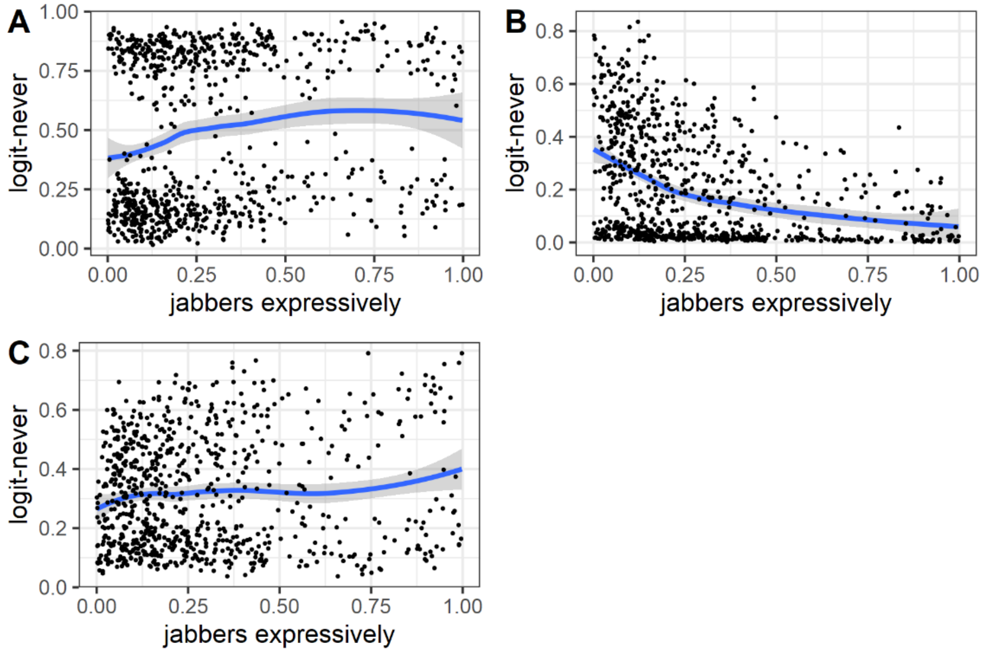
Linearity Assumption Graphs for SES



Note. Relationship between logit transformation of the outcome and socioeconomic status (SES). (A) displays the relationship between never and SES. (B) displays relationship between early and SES. (C) displays relationship between late and SES. Source: U.S. Department of Education, National Center for Education Statistics, Early Childhood Longitudinal Study – Birth Cohort (ECLS-B) 2001-2008.

Figure B2

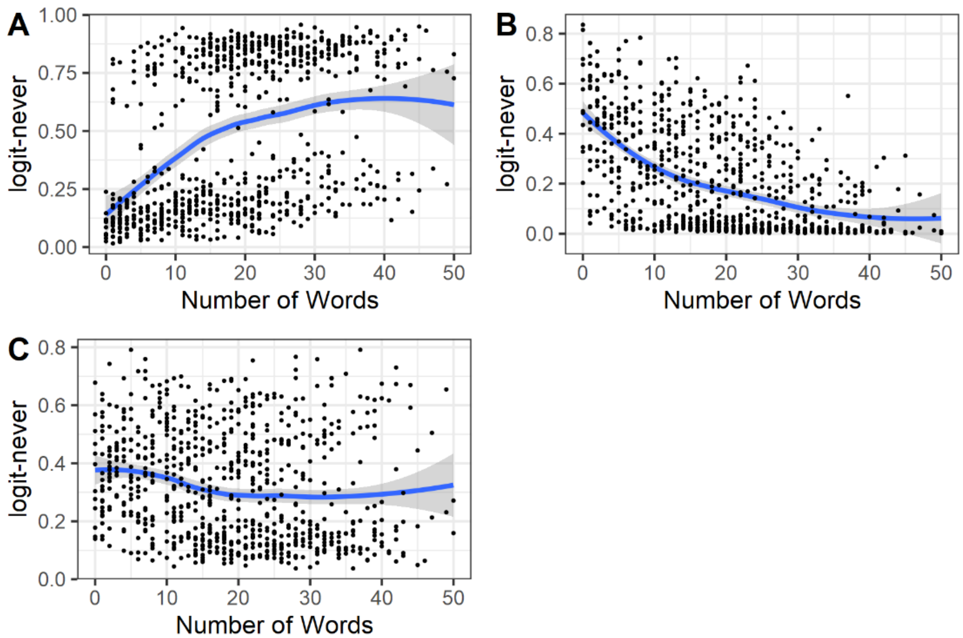
Linearity Assumption Graphs for Jabbers Expressively



Note. Relationship between logit transformation of the outcome and jabbers expressively. (A) displays the relationship between never and jabbers expressively. (B) displays relationship between early and jabbers expressively. (C) displays relationship between late and jabbers expressively. Source: U.S. Department of Education, National Center for Education Statistics, Early Childhood Longitudinal Study – Birth Cohort (ECLS-B) 2001-2008.

Figure B3

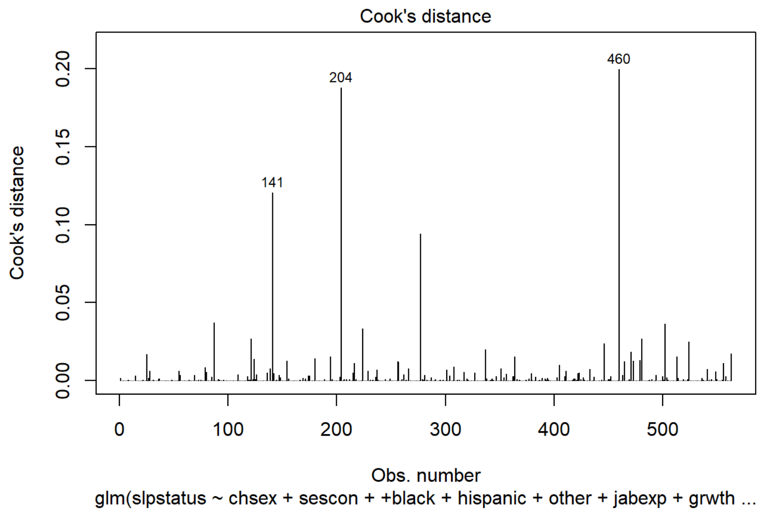
Linearity Assumption Graphs for Number of Words Said



Note. Relationship between logit transformation of the outcome and number of words said. (A) displays the relationship between never and number of words said. (B) displays relationship between early and number of words said. (C) displays relationship between late and number of words said. Source: U.S. Department of Education, National Center for Education Statistics, Early Childhood Longitudinal Study – Birth Cohort (ECLS-B) 2001-2008.

Figure B4

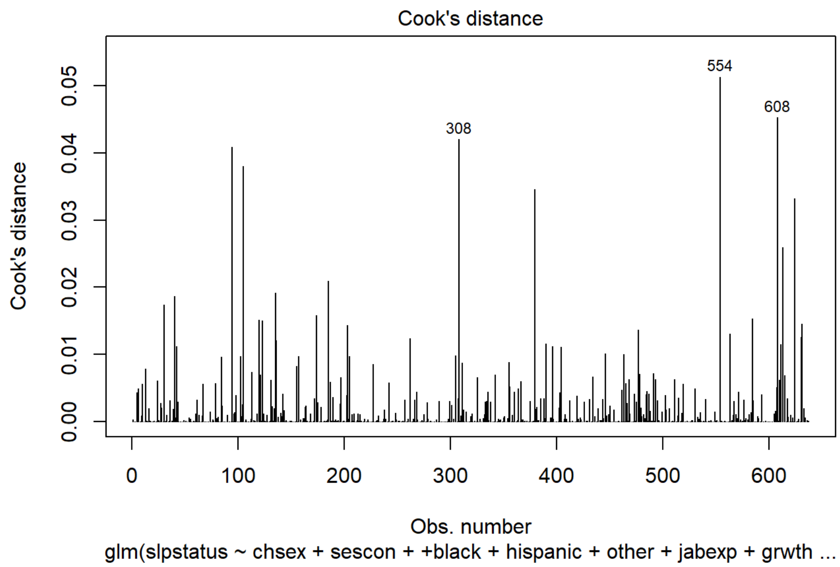
Assessing Potential Outliers for Never-Early Comparison



Note. Graph displaying Cook's distance to detect potential outlier observations. This graph is for the never-early binomial comparison. Source: U.S. Department of Education, National Center for Education Statistics, Early Childhood Longitudinal Study – Birth Cohort (ECLS-B) 2001-2008.

Figure B5

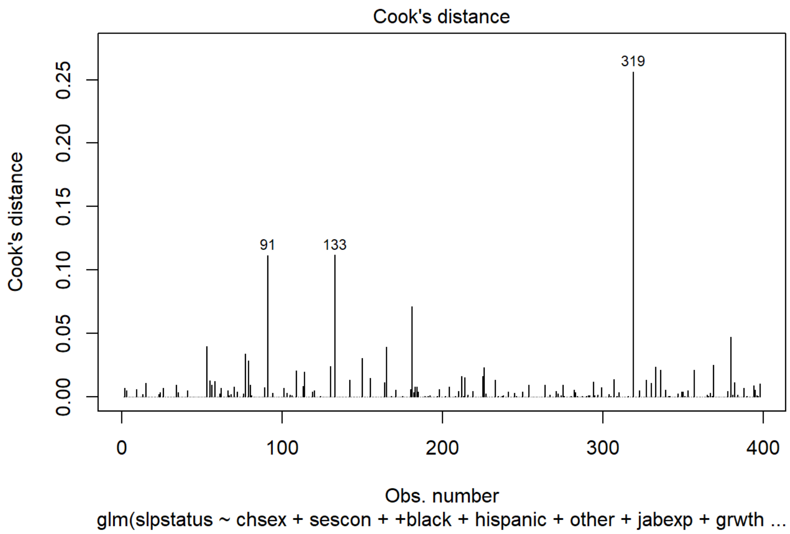
Assessing Potential Outliers for Never-Late Comparison



Note. Graph displaying Cook's distance to detect potential outlier observations. This graph is for the never-late binomial comparison. Source: U.S. Department of Education, National Center for Education Statistics, Early Childhood Longitudinal Study – Birth Cohort (ECLS-B) 2001-2008.

Figure B6

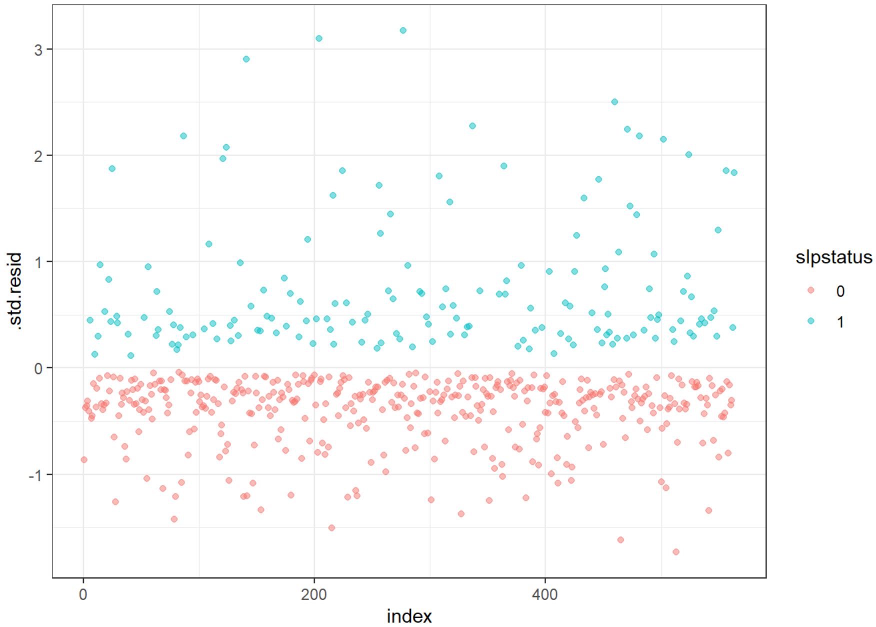
Assessing Potential Outliers for Early-Late Comparison



Note. Graph displaying Cook's distance to detect potential outlier observations. This graph is for the early-late binomial comparison. Source: U.S. Department of Education, National Center for Education Statistics, Early Childhood Longitudinal Study – Birth Cohort (ECLS-B) 2001-2008.

Figure B7

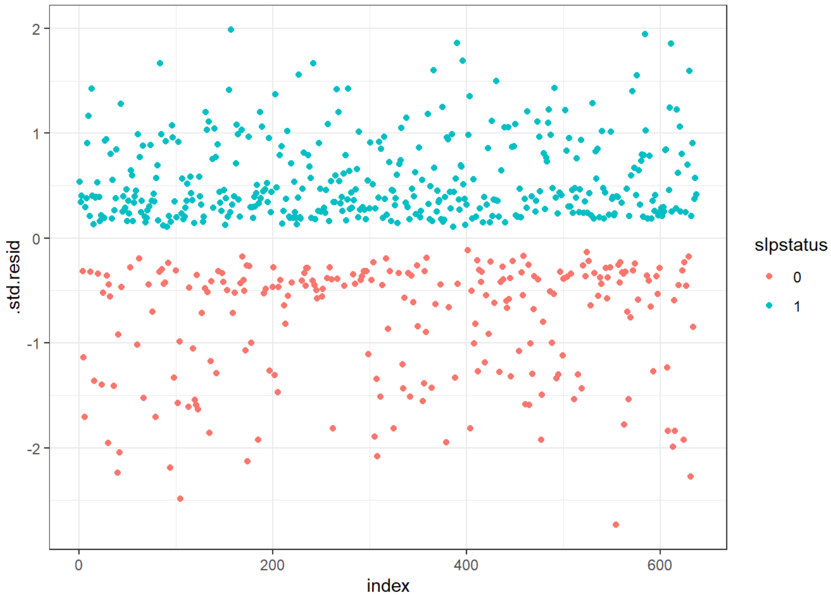
Assessing Potential Influential Observations for the Never-Early Comparison



Note. Graph displaying standardized residuals (y-axis) for each observation (x-axis). This graph is for the never-early binomial comparison. 0 = never 1 = early. Source: U.S. Department of Education, National Center for Education Statistics, Early Childhood Longitudinal Study – Birth Cohort (ECLS-B) 2001-2008.

Figure B8

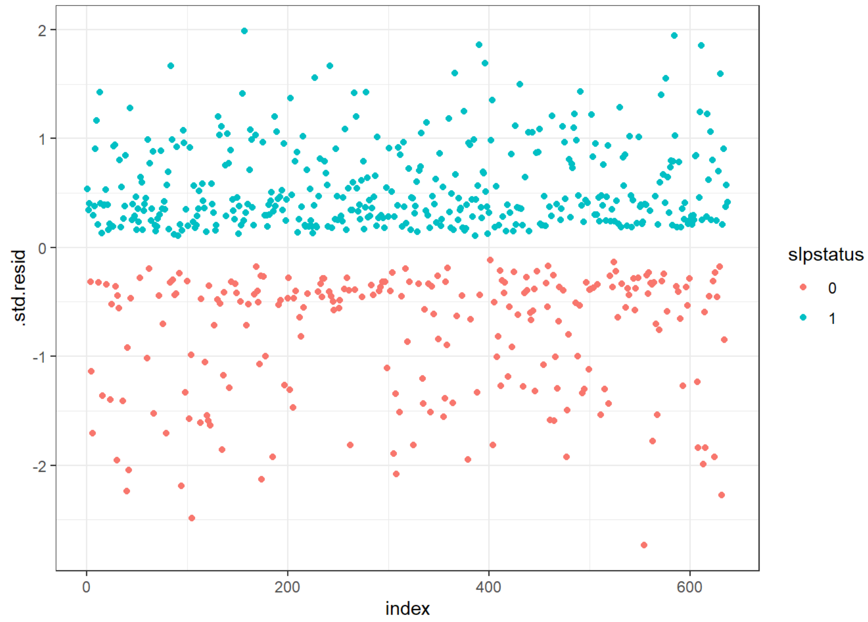
Assessing Potential Influential Observations for the Never-Late Comparison



Note. Graph displaying standardized residuals (y-axis) for each observation (x-axis). This graph is for the never-late binomial comparison. 0 = late 1 = never. Source: U.S. Department of Education, National Center for Education Statistics, Early Childhood Longitudinal Study – Birth Cohort (ECLS-B) 2001-2008.

Figure B9

Assessing Potential Influential Observations for the Early-Late Comparison



Note. Graph displaying standardized residuals (y-axis) for each observation (x-axis). This graph is for the early-late binomial comparison. 0 = late 1 = early. Source: U.S. Department of Education, National Center for Education Statistics, Early Childhood Longitudinal Study – Birth Cohort (ECLS-B) 2001-2008.