

DESCRIBING, PREDICTING & IMPACTING SPEECH AND LANGUAGE
DEVELOPMENT IN YOUNG CHILDREN WITH HEARING LOSS

by

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A thesis submitted to the
Faculty of the Graduate School of the
University of Colorado in partial fulfillment
of the requirement for the degree of
Doctor of Philosophy
Department of Speech, Language, and Hearing Sciences
2015

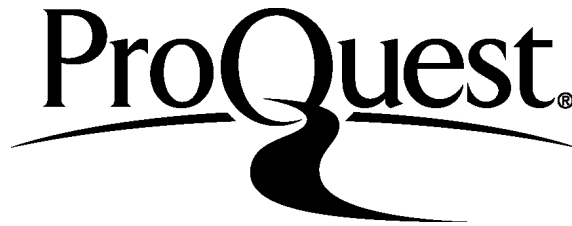
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Describing, Predicting & Impacting Speech and Language Development in Young Children with Hearing Loss

Thesis directed by Professor Christine Yoshinaga-Itano

Children with hearing loss may demonstrate speech and language delays as a result of reduced auditory access. Though this population historically has exhibited delayed or deviant speech and language, there have been decreases in the average age of identification as a result of Universal Newborn Hearing Screening and advancements in cochlear implants and hearing aids over the last 20 years to improve these outcomes. Three studies are presented addressing different areas of speech and language development where progress has been noted as compared to historical outcomes. Phoneme development is described for children with hearing loss ages 4 years to 7 years and compared to normal hearing typically developing peers. Specific demographic factors impacting phoneme development are considered and evaluated using Hierarchical Linear Modeling (HLM). The school and home language environment is described using LENA (Language Environment Analysis). Additionally, LENA is used to assess the impact of parent education. Implications for clinical practice are discussed as they pertain to developing speech and language in young children with hearing loss.

DEDICATION

This work is dedicated to my husband, Jameson,
and our daughter, Juliette.

You have given me the gift of time.

Time is our most precious commodity.

Thank you with all my heart.

ACKNOWLEDGEMENTS

“I expect to pass through this world but once. Any good, therefore, that I can do or any kindness I can show to any fellow creature, let me not defer or neglect it for I shall not pass this way again.” – Stephen Grellet

The completion of my dissertation marks a significant milestone in my life, and this work would not have been possible without you who showed me kindness as I passed this way.

Quite simply, thank you. As I search for the words for each of you that truly capture my gratitude, I come up short.

First and foremost, I would like to thank my mentor, Dr. Christine Yoshinaga- Itano. You have been with me from the beginning until the end. You are truly extraordinary. It has been an enormous privilege to be your student. Your career has forever changed the world for children with hearing loss, and I am humbled to have received such a generous gift of your time. May I have a career that makes you proud and lives out the knowledge and values you have generously instilled in me.

Dr. Allison Sedey, your mentorship started when I entered the program and has extended far beyond the bounds of my dissertation. Through example you have taught me more than you realize. I admire you, and I am grateful to you.

Dr. Eliana Colunga, you taught the most fun and interesting course I took during my graduate program. You made reading research a dynamic collegial dialogue.

Dr. Pui Fong Kan, you taught me a new analysis tool on the eve of your sabbatical. You provided ongoing encouragement and support on the ordinary days around the SLHS building.

Dr. Jill Gilkerson, through the LENA Foundation my final article was possible. Thank you for the generosity of the Foundation resources and your generosity of time from outside the University.

Ms. Simalee Smith-Stubblefield and Dr. Mary Carpenter, I appreciate your early encouragement of my academic pursuits.

Janet DesGeorges, you are the picture of a servant heart. Sharing an office with you has kept me grounded in the purpose for our work: to continually strive to improve the future in big and small ways for children with hearing loss.

My family...Uncle Cameron, Chris, Mom, Dad, Cousin Thomas, Scott Jones, & Mary Lou Reece, you each contributed in your own special and important way.

To all the families with children who have hearing loss that I have worked with over the years. Thank you for allowing me to join your family and your journey.

An African proverb says that it takes a village to raise a child. Amy Barnes, Gammy, Rew, and the Boyd Family, thank you for being Juliette's village.

I also now believe it takes a village to raise a scholar. All of you mentioned above are my village. And I could not have done this without every single one of you!

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CHAPTER I

Introduction

Hearing loss is the most common birth defect, and approximately 3 per 1,000 newborns are affected (White, 2004). One in 1,000 are born with severe to profound hearing loss (NIH, 1993; Northern & Downs, 2002). The historic lack of timely and appropriate treatment in this population has led to significant adverse effects during development. The negative consequences of hearing loss extend to language, speech, emotional, social, and academic development in children. Despite this historically poor outlook for children with hearing loss, recent changes to policy and technology have greatly shifted the landscape. Policy changes to develop newborn hearing screening programs and advancements in hearing aid and cochlear implant technology have set the stage for a new era of development. Now is an exciting and optimistic time for the study of young children with hearing loss.

Early Hearing Detection and Intervention (EHDI) is a recent policy change that when effectively implemented includes the basic components of newborn hearing screening, audiological diagnosis, and early intervention. The “1-3-6 EHDI Plan” calls for all infants to be screened using a physiologic measure at no later than 1 month of age. This means that many infants are screened before they leave the birthing hospital. If an infant does not pass the initial screening, the child should have appropriate medical and audiological follow up to confirm the presence of hearing loss by the age of 3 months. If the infant does not pass the follow up

assessment, intervention services should start immediately and certainly no later than 6 months of age.

Part C of Public Law PL 108-446 is the Individuals with Disabilities Education Act (IDEA), which provides public early intervention services for infants, toddlers, and their families. These services are intended to be provided in a “natural environment.” For many children, this means that they receive therapy in their home environment. Intervention may also include daycare- or center-based services.

In addition to these policy changes, technology has improved for young children with hearing loss both in terms of age of access to and quality of amplification. Infants are being fit with hearing aids as young as a few weeks of age. Digital hearing aids provide access to spoken language and environmental sounds in ways that are unlike previous technology. This digital technology converts an incoming signal from the microphone into a digital format to provide more sophisticated sound processing. However, even the best hearing aids currently available have difficulty making the details of spoken language clear when distance or background noise competes with the primary signal. Clear and complete speech signals are necessary to facilitate the development of speech and oral language (Anderson, 2004; Estabrooks, 2006).

Infants with more significant hearing loss requiring cochlear implants can receive this technology at around 12 months of age. Cochlear implants are surgically inserted biomedical devices that provide sound access by bypassing the damaged parts of the inner ear (typically the hair cells) (Niparko, 2004). The brain receives the information through coded electrical signals that stimulate hearing nerve fibers (Niparko, 2004). Sound signals presented by the cochlear implant differ from acoustical hearing, but the brain learns to interpret the information as sound.

Research on this new generation of children with hearing loss shows that children who receive early and appropriate amplification and intervention are more likely to mirror typical speech sound development (Eriks-Brophy, Gibson, & Tucker, 2013; Ertmer, 2011; Ertmer & Inniger, 2009; Warner-Czyz, Davis & Morrison, 2005). Children with hearing loss may also demonstrate positive language and social-emotional outcomes (Calderon & Naidu, 2000; Dornan et al., 2010; Yoshinaga-Itano, 2003). As a result of these improved outcomes, therapists are able to follow a developmental model rather than a remedial model in intervention. Many children with hearing loss are now able to enter a mainstream kindergarten classroom.

Though many children with hearing loss have the opportunity to develop speech and language commensurate with their same-age peers, this is not true for all children with hearing loss. Up to 40% of infants may be lost to follow up in the early hearing detection and intervention (EHDI) process (JCIH, 2013). A child who does not receive timely access to amplification and intervention may experience outcomes that parallel historic outcomes for children with hearing loss.

Because children with hearing loss remain at risk for delayed or deviant development, intervention is key to monitoring and furthering growth of speech, language, and listening skills. New technology developed by the Language Environment Analysis (LENA) Research Foundation provides a way for parents and therapists to examine the language environments of young children. The LENA Digital Language Processor (DLP) is a small digital recording device that is worn by the child in specialized clothing. Information from the DLP is downloaded and analyzed in a software program that uses algorithms to characterize the language environment. LENA calculates conversational turns (CTs), child vocalizations (CVs), adult word count (AWC), the percentage of meaningful language, the percentage of

television/automated speech, and the percentage of silence. This new technology provides a cost-effective and detailed examination of the components of the language environment. LENA can be used to determine whether the child's language environment has the quantity of meaningful speech necessary for immersion in spoken language.

Regardless of the timeline of initial diagnosis or additional compounding disabilities, the reduction in the amount and quality of acoustic information makes the acquisition of spoken language challenging for all children with hearing loss. Depending on the loss severity, the acoustic signal may be absent, distorted, or reduced even with appropriate fitting of hearing aids or cochlear implants. Due to this unique auditory challenge, further work is necessary to determine how to improve outcomes for all children with hearing loss, especially those who fall behind their same-age hearing peers.

Additional information would help parents, therapists, and audiologists monitor progress and determine when additional intervention or amplification adjustments are needed to help children with hearing loss reach their full potential. Spoken language, speech development, and auditory development are very complex and interrelated processes. This paper will address three distinct questions related to speech and language development.

Chapter 1 describes speech sound development in young children with hearing loss ages 4 to 7 years. Though we understand the course of typical speech development, we do not know how speech development varies within each individual phoneme and degree of hearing loss category. Graphically representing this enables providers to gauge how a child with hearing loss compares with typically developing peers as children with a similar degree of hearing loss.

Chapter 2 discusses predictors of speech development for young children with hearing loss. Implications for practice are discussed.

Chapter 3 analyzes the language environment and intervention using LENA. The benefits of summer educational programming and the impact of parent intervention are discussed. Taken together, these three studies elucidate and predict speech development and discuss methods for impacting language development in young children with hearing loss.

CHAPTER II

Describing Phoneme Development in Young Children with Hearing Loss

Introduction

Even if treated appropriately, hearing loss can present a significant barrier to the development of speech sounds in children. Historically, children with hearing loss have been expected to have a speech disorder as a result of their hearing loss (Calvert & Silverman, 1975). Decreased auditory access in children with hearing loss complicates accessing speech sound information through audition (Ambrose, Berry, Walker, Harrison, Oleson, & Moeller, 2014; Geers & Moog, 1987; Tomblin, Oleson, Ambrose, Walker, & Moeller, 2014; von Hapsburg & Davis, 2006). In addition to the degree of hearing loss, several factors related to a child's treatment course can impact speech sound development. Such variables include the age at which the hearing loss is identified, the timing of amplification, and the appropriateness of amplification fit.

Over the last 20 years, practitioners and policymakers have made significant strides in increasing early detection, providing appropriate amplification and increasing the availability of early intervention (JCIH, 2013). With these developments, the barrier of hearing loss is being reduced for many so that young children with hearing loss who use cochlear implants or hearing aids are able to develop effective spoken communication skills (Dettman, Pinder, Briggs,

Dowell, & Leigh, 2007; Stacey, Fortnum, Barton, & Summerfield, 2006; Uchanski & Geers, 2003; Yoshinaga-Itano, 2003).

Universal newborn hearing screening (UNHS) programs are now well established (Fitzpatrick, Durieux-Smith, Ericks-Brophy, Olds, & Gaines, 2007). The development and maturity of such screening programs means that another look is warranted into how close children with hearing loss are to achieving the established norms for children with typical hearing. This paper provides one such deeper examination into the speech sound development of children with hearing loss. In this paper, we examined speech sound development data from children with hearing loss and compared the data graphically to similar charts created by Sander (1972) for typically developing children. Such information can serve as a measurement tool to evaluate the effectiveness of the hearing technology and therapy interventions provided to children identified with hearing loss.

Mastery Standards in Children with Typical Hearing

Typical patterns of speech development have been well established. Eric Sander published a seminal article in 1972 asking the question, “When do children acquire the various speech sounds of our language?” (p. 55). His article presented a new graphical method for summarizing an age range of development for each phoneme. Though this work was completed decades ago, it continues to be the “gold standard” used today by clinicians as they determine whether a child should be enrolled in therapy or if the child exhibits an age-appropriate speech sound error.

Sander (1972) re-worked data from Wellman, Case, Mengert, and Bradbury (1931) and Templin (1957) to create a chart that presented the average age estimates and upper age limit of customary consonant production. Wellman et al. presented norms that were set by the age at

which 75% or more of the children produced a sound correctly. Templin updated these standards with new data that she presented based on testing the articulation skills of 480 children.

Templin's standard for mastery was that 75% of children produce a sound correctly in all three positions of a word. Sander observed that these standards only indicated the upper age limits. He noted that this can lead to misunderstandings in discussions of articulatory development.

To improve the understanding of articulation development, Sander proposed a new method for summarizing the variability in the emergence of phonemes both in terms of differences in acquisition across children and between phonemes. He looked at the percentage of children that produced a sound correctly at each testing age. Within the articulation test, some sounds occurred in the initial, medial, and final position of words, whereas others only occurred in one or two positions. To account for this, Sander averaged the percentage of children who could produce the sound across all available word positions. Using this average, phonemes that were produced accurately by more than 50% the group were considered to be "emerging" and were represented graphically as the beginning of the bar.

Sander also presented the upper age limit at which 90% of the children produced each speech sound. This was calculated in the same way that the 50% criterion was determined. He did not use fractional ages in presenting his data. Whole ages were used for convenience and to ensure that he was not conveying a false sense of accuracy. The bar representation was selected to graphically depict the broad normal range of articulation development with the bar ending at the 90% criterion. Consonants whose averages exceeded 70% across all available word positions at the first point of testing were indicated to have emerged prior to that age.

Sander did not settle the debate about the best method to present speech sound development data. Shriberg, Gruber, and Kwiatkowski (1994) more recently suggested that an intermediate mastery percentage of 75% should be used, and they cited historical studies that followed the same standard such as Arlt and Goodban (1976) and Prather, Hedrick and Kern (1975). Shriberg et al. determined his 75% criteria using the earliest age at which 75% of the responses were phonetically correct.

Speech Sound Development in Children with Typical Hearing

Regardless of which definition of mastery is used, researchers have found children follow similar patterns as they develop phonemes. Shriberg (1993) described phoneme development as falling into three sound classes: “early-8” (/m/, /b/, /j/, /n/, /w/, /d/, /p/, /h/), “middle-8” (/t/, /ŋ/, /k/, /g/, /f/, /v/, /tʃ/, /dʒ/), and “late-8” (/ʃ/, /θ/, /s/, /z/, /ð/, /l/, /r/, /ʒ/). The “early-8” sounds emerge between ages one to three years with consistent production by age three. The “middle-8” sounds emerge between ages three to six and a half years of age. Consistent production is shown around the age of five and a half. The “late-8” sounds emerge between the ages of five years to seven and a half years, with consistent production at seven and a half years. Sander (1972) presented his data in a graphic form that followed a generally similar pattern to Shriberg’s sound classes. When considering sounds by manner, stops and nasals are typically established prior to affricates, fricatives, and liquids (Goldman & Fristoe, 2000; Prather et al., 1975; Sander, 1972; Smit, Hand, Freilinger, Bernthal, & Bird, 1990; Templin, 1957). Researchers have found this sequence of development to be influenced by a variety of factors such as cognitive, perceptual, linguistic, and motor demands (Stoel-Gammon, 1998).

Factors Impacting Development and Speech Sound Production in Children with Hearing Loss

Historically, children with hearing loss were expected to have speech disorders (Calvert & Silverman, 1975; Hudgins & Numbers, 1942). Today, children are not necessarily considered to have speech disorders simply because they have a hearing loss diagnosis. Rather, it is the difficulty accessing auditory information as a result of the hearing loss that may complicate typical speech sound development (Tomblin et al., 2014).

Research has thoroughly documented the general speech characteristics of young children with hearing loss. These speech characteristics can be influenced by a variety of factors. Yoshinaga-Itano and Sedey (2000) found expressive language skill, age, and degree of hearing loss to be the strongest intrinsic predictors of speech production outcomes for children with all degrees of hearing loss, including those with cochlear implants. Two consistent results have emerged in the literature with regard to speech production development in children with all degrees of hearing loss. First, many children with hearing loss are able to attain intelligible speech (Flipsen, 2008; Yoshinaga-Itano & Sedey, 2000). Second, though intelligible speech may be obtained, children with hearing loss often have delayed or immature speech patterns compared with their typically hearing peers (Elfenbein, Hardin-Jones, & Davis, 1994; Flipsen 2008; Moeller, Hoover, Putman, Arbataitis, Bohnenkamp, Peterson, Wood, Lewis, Pittman, & Stelmachowicz, 2007; Moeller et al., 2010; Wiggin, Sedey, Awad, Bogle & Yoshinaga-Itano, 2013).

Given optimal amplification and early intervention, researchers may have expected that children born after UNHS would have full access to the speech frequencies. However, McCreery, Bentler and Roush (2013) found that children who use hearing aids, especially those with greater degrees of loss, do not always meet this goal. Even with access to hearing aids,

factors such as distance to speech, reverberation, and noise can distort the quality of auditory input. Additionally, Strauss and van Dijk (2008) found that hearing aid fit was not optimal for many preschool children. The limitations of hearing aid technology make an additional factor (amplification fit) important to providing children with the best opportunity to develop speech.

Speech Sound Development in Children with Mild to Moderate Hearing Loss

Eisenberg (2007) reported that children with mild to moderately-severe hearing loss have generally intelligible speech. However, Von Hapsburg and Davis (2006) found that even children with mild hearing loss who were identified early were still at risk for early speech sound production delays. Articulation errors in children with less severe degrees of hearing loss are often described as resembling typically hearing children who are younger (Elfenbein et al., 1994; Oller & Kelly, 1974; Wiggin et al., 2013). Specifically, Moeller and colleagues (2007) found affricate and fricative development to be persistently difficult. Ambrose and colleagues (2014) found that children with hearing loss who were at risk for speech delay could be identified as early as two and three years of age through assessment and considering a combination of demographic, linguistic and audiologic characteristics. At age 2, the children with hearing loss had vowel production abilities commensurate with their same-age peers; however, consonant production was delayed. The delay in consonant production paralleled the growth pattern shown by children with typical development.

Speech Sound Development in Children with Severe to Profound Hearing Loss

Children with more severe degrees of hearing loss have typically been described in the literature as developing less intelligible speech. This is particularly true for children who receive access to appropriate technology at a later age. These children may have difficulty with a number of characteristics impacting speech intelligibility including voice quality, resonance, respiration, phonation, rate of speech, and consonant production (Culbertson, 2007; Dunn &

Newton, 1994; Ling, 2002; Okalidou & Harris, 1999). Specific phoneme categories that are difficult include affricates, fricatives, plosives, semivowels, and liquids (Abraham, 1989; Elfenbein et al., 1994).

However, the degree of hearing loss is no longer the predictor of outcome that it once was (Flipsen, 2011). Children who receive cochlear implants at a young age to treat severe to profound hearing loss often demonstrate intelligible speech (Chin & Pisoni, 2000; Connor, Craig, Raudenbush, Heavener, & Zwolan, 2006) and can be assessed using speech measures developed for children with typical hearing (Flipsen, 2011). This new population of children receiving cochlear implants at young ages warrants research to further define how closely speech sound development approximates typical development and to determine whether this can inform intervention and amplification fitting procedures.

Purpose

Prior to universal newborn hearing screening (UNHS), there were many uncontrolled variables regarding identification, age of amplification and intervention, and quality of amplification and intervention. As a result, the vast proportion of children with hearing loss had a significant delay or difficulty with speech sound acquisition. UNHS has set timelines for screening, diagnosis, and amplification. Children with hearing loss are now a more clearly defined population. This has enabled recent research to investigate hearing loss as an isolated facet rather than assessing groups of children who have received vastly different treatments for hearing loss.

Children with any degree of hearing loss are at risk for delayed speech sound development and may have persistent errors that do not resolve without intervention. Although previous research has provided information describing typical errors in children with hearing

loss, there is less information illustrating the development of individual phonemes and setting expected performance levels. The purpose of this paper is to present a graphical representation of speech sound development for children with hearing loss based on an assessment tool that is commonly used in clinical practice. This is intended to be used as a resource for speech-language pathologists or other qualified professionals who evaluate children with hearing loss to determine the differential diagnosis of hearing loss and other speech disorders. This information may also be helpful for school administrators and therapy providers when determining which children are eligible for particular services.

Method

The data for this study were collected as part of a longitudinal investigation of a sample of children, ages 48 months through 84 months, who were previously enrolled in the Colorado Home Intervention Program. The Colorado Home Intervention Program is a statewide early intervention program that serves children with hearing loss from birth to age three. The larger research project measured the speech, language, and cognitive abilities of children with permanent, bilateral hearing loss. This article reports on the speech sound development testing portion of the project. These data were obtained using the Sounds in Words subtest of the Goldman Fristoe Test of Articulation – 2nd Edition (GFTA-2, Goldman & Fristoe, 2000).

Participants

Children were recruited according to a set of inclusion criteria. The following criteria were used to determine eligibility: (1) resident of the state of Colorado, (2) prior participation in the early intervention assessment program within the state, (3) no significant additional

disabilities impacting speech/language development, (4) hearing parents, (5) primary home language of English, (6) permanent bilateral hearing loss, and (7) cognitive ability at or above average range. Children with auditory neuropathy, unilateral hearing loss, or other disabilities impacting speech/language development were excluded from participation. Despite screening via interview prior to participating in the study, ten children were found to have cognitive abilities outside the average range when testing was completed. These children were excluded from all analyses.

This study included 144 children with permanent bilateral hearing loss between the ages of four to seven years ($M = 66.3$ months; $SD = 13.2$ months). Longitudinal data were available for 111 of these children, resulting in 355 GFTA-2 assessments. The children were tested at the ages of four, five, six, and seven years, yielding a range of one to four assessments depending on their age when they entered the study and their age when the study ended. Thirty-three children completed one assessment, 42 children completed two assessments, 38 children completed three assessments, and 31 children completed all four assessments. Summary characteristics of the children within each degree of hearing loss group are presented in Table 1.1.

Table 1.1. Demographic characteristics within each degree of hearing loss

<i>Characteristic</i>	<i>Hearing loss group</i>			
	Mild (n=26)	Moderate (n=57)	Severe (n=15)	CI (n=38)
<i>Gender</i>				
Boy	65.4%	49.1%	33.3%	55.3%
Girl	34.6%	50.9%	66.7%	44.7%
<i>Ethnicity</i>				
Minority	34.6%	26.3%	33.3%	28.9%
Not a minority	65.4%	73.7%	66.7%	71.1%
<i>Age of identification</i>				
By 6 months	88.0%	69.6%	17.5%	63.2%
After 6 months	12.0%	30.4%	82.5%	36.8%
<i>Mother's education</i>				
Below high school	3.8%	1.8%	13.3%	2.7%
High school	19.2%	35.1%	40.0%	35.1%
Associates or Vocational	18.2%	19.0%	12.5%	19.2%
Bachelor's degree	30.8%	31.6%	26.7%	35.1%
Graduate degree	28.0%	12.5%	7.5%	7.9%

Maternal level of education. Socioeconomic status was indicated using maternal level of education. Data were available for all but one of the participants. The total group had a range of 8 to 20 years of education with a mean education level of 14.4 years. Specifically, 14.6% ($n=21$) had a graduate degree, 32.6% ($n=47$) had a Bachelor's degree, 16.7% ($n=24$) had a Vocational or Associate's degree, 30.6% ($n=44$) had high school diplomas, and 4.9% ($n=7$) had less than a high school education.

Degree of hearing loss. To determine each participant's degree of hearing loss, this study used unaided pure tone average (PTA: average of hearing thresholds at 500, 1,000, and 2,000 Hz) in the better hearing ear. The study divided participants into the following five hearing loss groups: mild (better ear PTA: 26-40 dB HL), moderate (better ear PTA: 41-70 dB HL), severe (better ear PTA: 71-90 dB HL), profound (better ear PTA: > 90 dB HL), and cochlear implant. In total, 26 participants were categorized as having mild hearing loss, 57 had moderate hearing loss, 15 had severe hearing loss, and 8 had profound hearing loss. All of these children used

hearing aids. A fifth group was created that was comprised of 38 children who used a cochlear implant. All of the children that had received cochlear implants were implanted by the age of 48 months, meaning that no children with implants needed to be categorized according to their pre-implant hearing ability.

Age of identification. All of the participants had data available for the age at which their hearing loss was identified. The median age of identification was 2.0 months (range: birth to 43 months). Hearing loss was confirmed by 6 months of age in 67% of the children. Acquired hearing loss was present in 12.5% of the children.

Age of intervention and amplification. All of the children participating in this study received intervention prior to enrollment in preschool programs. The median age was 7.0 months (range: birth to 44 months) for the initiation of intervention. All but one of the children had information available on the age of amplification fitting. The median age for amplification was 6.5 months (range: .5 to 44 months). For children with acquired loss, the age of identification, amplification and intervention were determined from the point at which the hearing loss was acquired. The ages for the identification, amplification, and initiation of intervention are presented as medians for each of the hearing loss categories in Table 1.2.

Table 1.2. Median age of identification, amplification and intervention in months by degree of hearing loss.

	Identification	Amplification	Intervention
Mild	1.5 (.25-29)	5.5 (1-30)	7.0 (1.0-30)
Moderate	2.0 (.25-41)	6.0 (0.5-42)	6.0 (.25-34)
Severe	8.0 (0.75-43)	10.0 (2-44)	11.0 (2-44)
Profound	10 (1-27)	13.0 (5-28)	13.0 (3-30)
Cochlear implant	2.5 (0.25-24)	6.0 (1.5-26)	5.0 (0.75-27)

Intervention. All of the children enrolled in the study received early intervention services related to their hearing loss through the Colorado Home Intervention Program (CHIP). This program provides family-centered home visits that include parent guidance and education about auditory, speech, language, and social-emotional development in children with hearing loss. These services are typically provided weekly. During the study, all of the children were enrolled in an educational program. These programs included classrooms for children with hearing loss, classrooms primarily with children who were hearing, or inclusive classrooms that had children with a variety of special needs as well as those who were typically developing.

Additionally, at the time of each testing, the families reported whether or not the child was enrolled in private therapy services. This information was available for 346 of the test sessions, and 45.4% ($n=157$) of the children were enrolled in therapy outside of the school setting at the time of their test session.

Ethnicity. The majority of the participants were non-Hispanic Caucasian (69.4%, $n=100$). The remaining participants were Hispanic (9.7%, $n=14$), Hispanic and non-Hispanic Caucasian (8.3%, $n=12$), Asian American (4.9%, $n=7$), African American (2.1%, $n=3$), or other mixed ethnicities/races (5.6%, $n=8$).

Gender. The participants in this study were 50.7% male ($n=73$) and 49.3% female ($n=71$).

Mode of Communication. English was the primary language of the home for all of the children participating in the study. In addition to spoken English, some families used some

Spanish (4.9%, n=7), sign language (54.2%, n=78), or another language (6.3%, n=9) in the home environment.

Procedure

The GFTA-2 is a standardized measure of speech production ability for ages 2 years to 21 years, 11 months. The norms are based on children with typical hearing. The test has a mean standard score of 100 and a standard deviation of 15. The GFTA-2 is widely used by speech language pathologists in pediatric settings (Flipsen, 2011). The child is shown a picture and asked to identify it. Each target word may have more than one phoneme that is assessed. For example, the word “carrot” is used to elicit the phonemes /r/ and /t/. There are 53 words that target 61 consonants in the initial, medial, and final position as well as consonant blends. All consonant phonemes of the English language are elicited with the exception of /ʒ/.

A speech pathologist familiar with working with young children with hearing loss administered the GFTA-2 as a part of a larger assessment protocol. The examiner administered the test following standard procedures as outlined in the assessment manual (Goldman & Fristoe, 2000) and videotaped the administration of the Sounds-in-Words subtest. Graduate students in linguistics at the University of Colorado, Boulder who had extensive phonetic transcription experience transcribed and scored the videotaped tests onto GFTA-2 scoring sheets. Each individual sound was entered into the database as a correct production, substitution, omission, distortion, addition, or cluster reduction. Any substitutions, omissions, distortions, additions, or cluster reductions resulted in the sound being scored as an incorrect production. Individual child

scores (raw scores and standard scores) were determined using the standard GFTA-2 scoring procedure. The child's chronological age was used when comparing to the normative scores.

All of the scored results for each tested sound were aggregated for each group of children with similar hearing loss (mild, moderate, severe, profound, and cochlear implant). This paper uses the definitions and thresholds of development established by Sander (1972). Each bar starts when more than 50% of the children produced a given phoneme accurately. The end of the bar is set at the point at which more than 90% of the children produced a given phoneme accurately. This study included children in preschool and the early school years. Because phoneme development starts early in life, a number of sounds had already been achieved by the age of four. Because it is unknown exactly when the 50% criterion was met, this is represented in the charts by the bar extending below the four year age level.

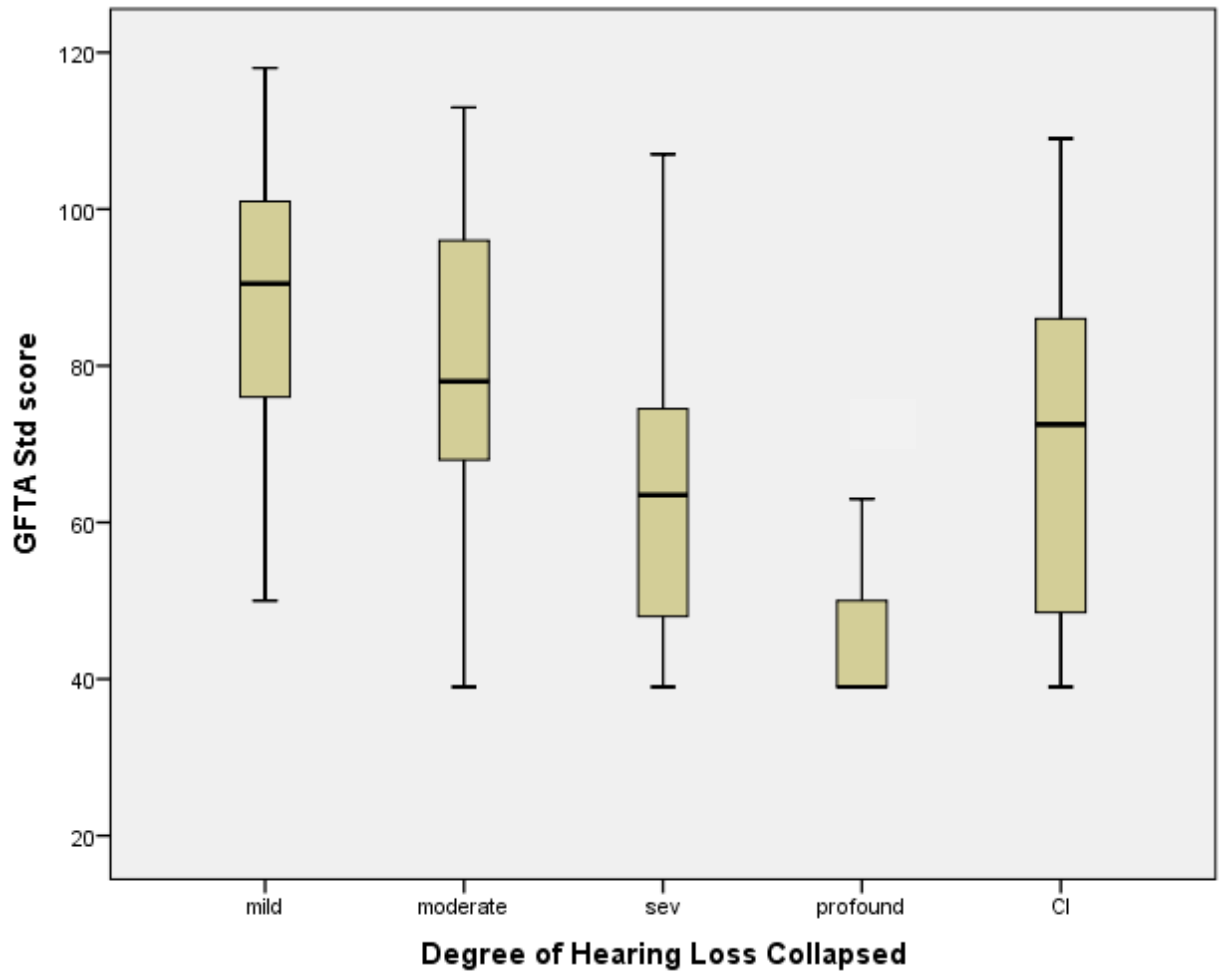
We examined individual sound or consonant expressions across the degree of hearing loss categories. This paper includes charts of phoneme development at the ages of four, five, six, and seven years of age for all of the hearing loss categories with the exception of one. This study had insufficient data to create separate age-group charts for children with profound hearing loss who used hearing aids. The charts follow the model set forth by Sander, beginning each bar for phoneme development at the age of emergence and ending the development bar at the age for mastery.

Results

As a general rule, when comparing phoneme development across groups with different levels of hearing loss, the severity of hearing loss was associated with either increased delay in

phoneme emergence, phoneme mastery, or both. This is evident in Figure 1.1 which illustrates that standard scores decrease as degree of hearing loss increases. Children with mild and moderate hearing losses had all of their sounds emerging at the 50% level by 8 years of age. In contrast, at 84 months of age, some sounds were never achieved at the 50% level for children with cochlear implants and those with severe hearing loss who used hearing aids. The population of children with mild and moderate hearing losses had mastered approximately half of the sounds (i.e., the sounds were produced accurately 90% of the time) by 7 years of age whereas the children with severe loss and those with cochlear implants reached the mastery criterion on less than 25% of the phonemes by the same age. The results for the individual hearing loss groups are discussed individually below and presented in Charts 1.1, 1.2, 1.3, and 1.4.

Figure 1.1. Box and whiskers plot of GFTA-2 standard scores by degree of hearing loss.



Mild Hearing Loss Category

The mild hearing loss category included 68 GFTA-2 tests from 26 children. The children with mild hearing loss had a mean standard score of 86.87 (*SD* 17.40, *range* 50-118).

Additionally, 72% of the tests fell in the average to above average range (i.e., a standard score of 85 or above). The mild hearing loss group mastered five phonemes by the age of 48 months (/p/, /m/, /h/, /w/, /b/). Because this was the first age of testing, the population had achieved the 50%

level of emergence for these sounds prior to the age of 48 months. The mild hearing loss group mastered the phonemes /n/, /d/ and /j/ at the age of 60 months. At 72 months, the children with mild hearing loss demonstrated mastery of /k/, /g/, /t/, and /ʤ/. This group had not yet mastered numerous phonemes by the age of 84 months (/ŋ/, /f/, /r/, /l/, /s/, /tʃ/, /ʃ/, /z/, /v/, /θ/, /ð/). The phoneme /f/ showed the most variability; it emerged for this group before the age of 48 months but was not mastered until after 84 months.

Moderate Hearing Loss Category

The moderate hearing loss category included 57 children contributing 130 samples to the study. Considering all assessments for this hearing loss category, the children had a mean standard score of 79.86 (*SD* 17.80, *range* 39-113). The percentage of children performing in the average range was 46.9%. The majority of sounds emerged prior to 48 months (/p/, /m/, /h/, /n/, /w/, /b/, /k/, /g/, /d/, /t/, /f/, /j/, /l/, /tʃ/, /ʃ/). Six phonemes emerged notably later (/ŋ/, /r/, /s/, /z/, /θ/, /ð/). At 48 months, the moderate hearing loss group had mastered the phonemes /m/, /h/, and /w/. This group mastered the phonemes /p/ and /b/ at 60 months and the phonemes (/k/ and /t/) at 72 months. At 84 months, the moderate hearing loss group demonstrated mastery of /n/, /g/, /d/, and /j/. At the end point of the study (84 months of age), the hearing loss group had not yet mastered the following sounds: /ŋ/, /f/, /r/, /l/, /s/, /tʃ/, /ʃ/, /z/, /j/, /v/, /θ/, /ð/.

Severe Hearing Loss Category

The severe hearing loss category included 40 samples from 15 children. The mean standard score for the group was 62.55 (*SD* 18.25, *range* 39-107). Fifteen percent of these children were performing in the average range. For the group of children with severe hearing loss, ten phonemes emerged before the age of 48 months (/p/, /m/, /h/, /n/, /w/, /b/, /g/, /d/, /t/,

/tʃ/). No sounds were mastered at 48 months or 60 months. At 72 months, the children with severe hearing loss mastered /p/, /h/, and /w/. This group had mastered three additional phonemes (/m/, /tʃ/ and /k/) at 84 months. Sixteen phonemes had not yet been mastered by the age of 84 months: /n/, /b/, /g/, /d/, /t/, /ŋ/, /f/, /j/, /r/, /l/, /s/, /ʃ/, /z/, /dʒ/, /v/, /θ/, /ð/. Five phonemes (/n/, /b/, /g/, /d/, /t/) showed great variability in this group. Fifty percent of the children were producing these sounds before 48 months but the 90% criterion for mastery was not met by 84 months. The children with severe hearing loss never reached the 50% criterion mark for the emergence of the sounds /z/, /θ/, and /ð/.

Cochlear Implant Category

There were 100 samples from 38 children in the cochlear implant category. For all assessments, the children with cochlear implants had a mean standard score of 68.72 (*SD* 21.06, *range* 39-109). Thirty-six percent of the tests fell in the average range. Nine sounds emerged prior to 48 months (/p/, /m/, /h/, /w/, /b/, /k/, /t/, /tʃ/, /ʃ/). The cochlear implant group first mastered a phoneme (/w/) at 60 months and mastered two more phonemes (/m/ and /h/) at 72 months. This hearing loss group still had yet to master the majority of phonemes at 84 months (/p/, /n/, /b/, /k/, /g/, /d/, /t/, /ŋ/, /f/, /y/, /r/, /l/, /s/, /tʃ/, /ʃ/, /z/, /j/, /v/). The phonemes /θ/ and /ð/ never reached the 50% criterion mark for emergence in this hearing loss category.

Profound Hearing Loss Category

The profound hearing loss category included 17 samples from 8 children. This was an insufficient number of children within each age category to consider the results by individual age groups. Therefore, this group is not represented in the charts below. Some observations can still be made from the data. As a group, the children with profound loss had a mean standard score of

46.18 (*SD* 10.261, *range* 39-71). No children performed in the average range on the GFTA-2 assessment.

The small sample of children with profound hearing loss were able to achieve an emerging level of production for some phonemes at an early age, including /p/, /w/, /h/ and /m/ at 48 months. However, this group was never able to achieve mastery of these same sounds over the course of the study. Other sounds that typically develop early, such as /n/, emerged at 84 months. Some sounds emerged at 60 months and others at 72 months. Notably, though some phonemes emerged at the 50% level, the percentage of children producing the sound correctly did not continue to improve as age increased. Some phonemes, such as /g/, /k/, /d/, and /ŋ/, never emerged at the 50% accuracy level. For the children with profound hearing loss, none of the phonemes were produced accurately by 90% of the group.

Chart 1.1: Development of phonemes for children with mild hearing loss: The beginning of the bar represents when 50% of the children were producing the sound and ends when 90% of the children were producing the sound. Bars extending below 48 months indicate that 50% of the children were producing the sound at some point before the age of 48 months. Bars extending above 84 months indicate that 90% of the children were not yet producing the sound by 84 months.

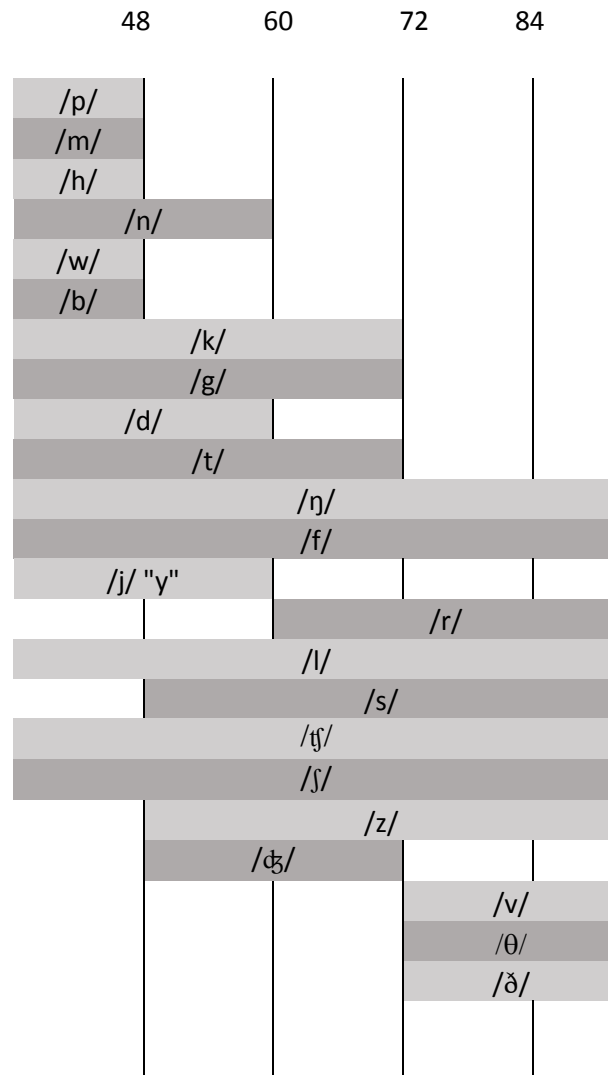


Chart 1.2: Development of phonemes for children with moderate hearing loss: The beginning of the bar represents when 50% of the children were producing the sound and ends when 90% of the children were producing the sound. Bars extending below 48 months indicate that 50% of the children were producing the sound at some point before the age of 48 months. Bars extending above 84 months indicate that 90% of the children were not yet producing the sound by 84 months.

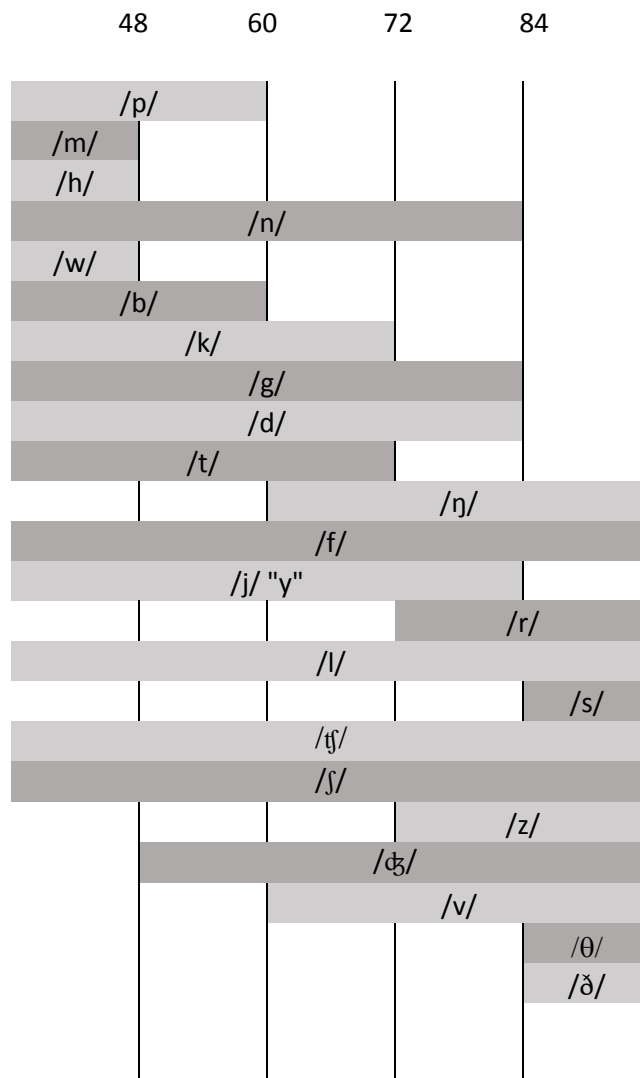


Chart 1.3: Development of phonemes for children with severe hearing loss: The beginning of the bar represents when 50% of the children were producing the sound and ends when 90% of the children were producing the sound. Bars extending below 48 months indicate that 50% of the children were producing the sound at some point before the age of 48 months. Bars extending above 84 months indicate that 90% of the children were not yet producing the sound by 84 months.

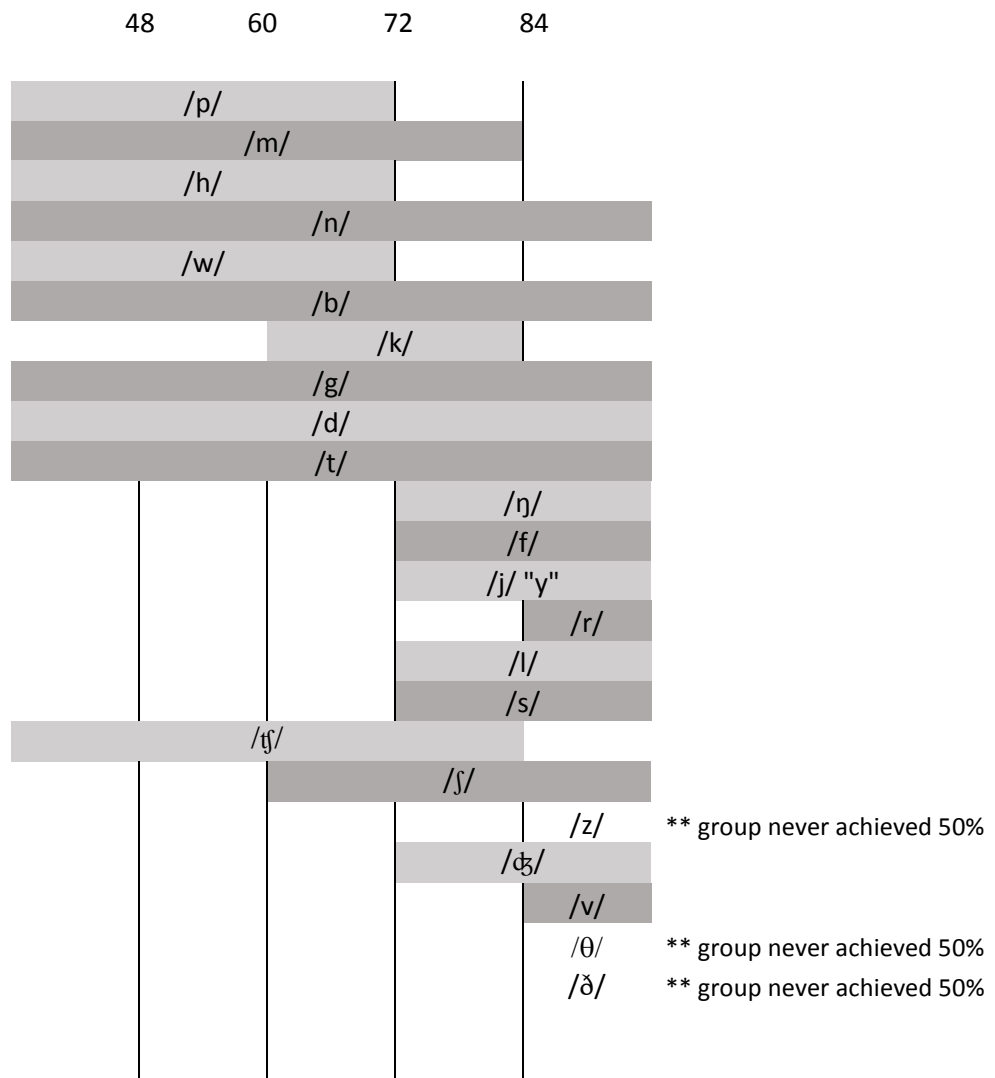
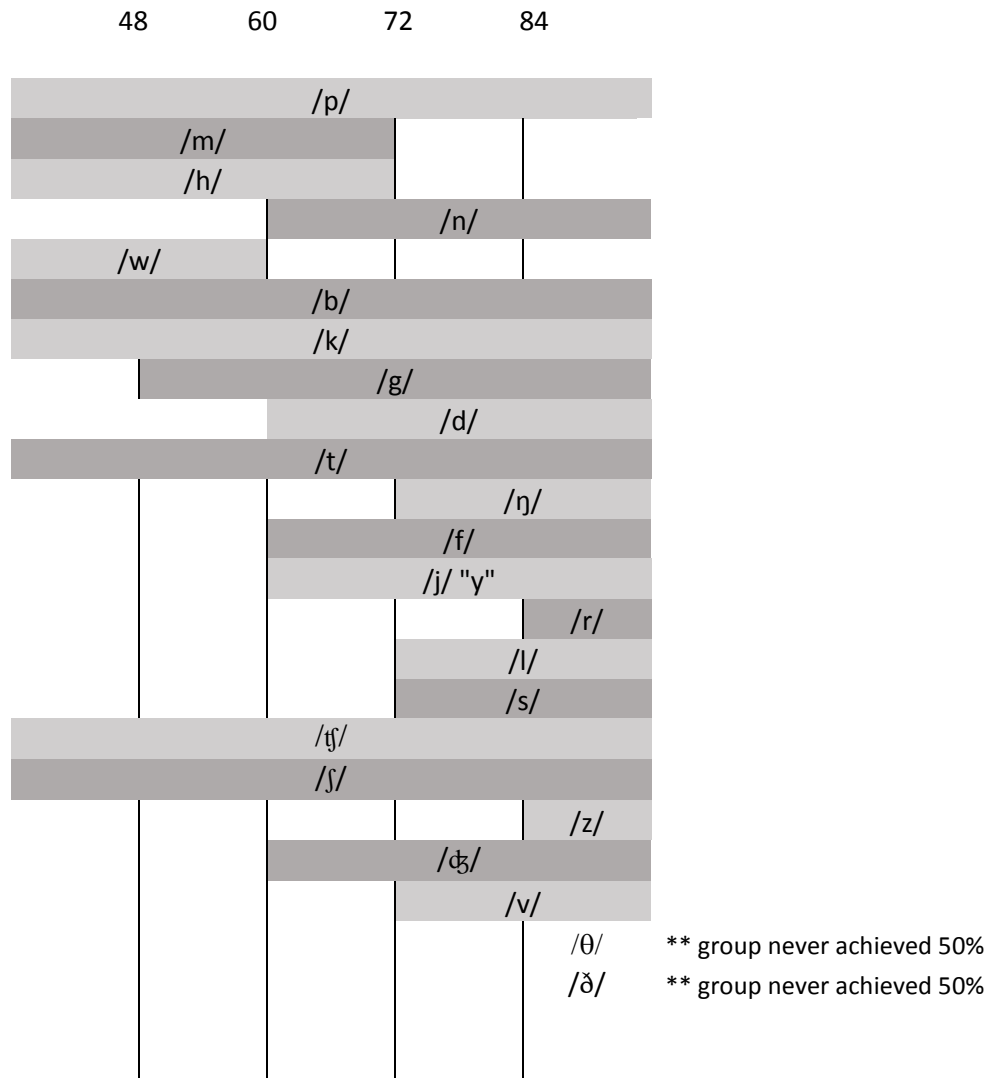


Chart 1.4: Development of phonemes for children with cochlear implants: The beginning of the bar represents when 50% of the children were producing the sound and ends when 90% of the children were producing the sound. Bars extending below 48 months indicate that 50% of the children were producing the sound at some point before the age of 48 months. Bars extending above 84 months indicate that 90% of the children were not yet producing the sound by 84 months.



Discussion

This study included 144 children who participated in 355 GFTA test sessions. They were tested at the ages of 48, 60, 72, and 84 months. The range of speech development for each degree of hearing loss (mild, moderate, severe, and cochlear implant) was visually presented in chart format using the criteria set forth by Sander (1972). The children with profound hearing loss who wore hearing aids were not presented in a chart because the sample size was insufficient to allow for generalizations about individual sounds to be made. Mastery by 90% of the children with profound hearing loss was not achieved for any of the phonemes, and if a sound emerged at the 50% level, it was on a significantly delayed timeline.

Comparison of Results to Previous Data from Same Age Peers

Generally speaking, the children with mild and moderate hearing loss followed the same general pattern of development as children who are typically developing. This observation is consistent with previous research (Moeller et al., 2007). Stops, nasals, and glides emerged and were mastered earlier, whereas fricatives and affricates were mastered later. When considering ages of mastery, children with mild and moderate losses generally mastered the “early-8” (Shriberg, 1993) first. The “middle-8” and “late-8”, however, did not develop in as orderly a sequence for these groups.

The children with severe loss who wore hearing aids and those with cochlear implants demonstrated emergence of some early developing sounds (/p/, /m/, /h/, /w/, and /b/) on a similar timeline to the children with mild to moderate losses; however, there was more variability in the duration of development. When considering sound classes, the children with more significant

hearing loss did not follow as consistent a pattern of development. These children also did not follow Shriberg's (1993) sequence of sound development. This finding is consistent with Ertmer and Goffman's (2011) report of speech production accuracy in young children with cochlear implants. The following is a more detailed discussion of each individual hearing loss category as compared with the data that Sander presented for typically hearing children.

Mild hearing loss. Children with mild hearing loss were found to have mastered the phonemes /p/, /m/, /h/, /b/, and /w/ by or before 48 months of age. These are sounds that are mastered early in hearing children as well. Because the first testing age in this study was 48 months, we cannot fully compare the age of mastery between the children with hearing loss and previous research on children with normal hearing.

Other sounds that hearing children master early were more difficult for children with mild hearing loss. For example, although hearing children master the phoneme /n/ by 36 months, children with mild hearing loss did not master this phoneme until 60 months. Two other phonemes (/k/ and /g/) also took an additional 24 months for mastery beyond the mastery threshold for typically developing children. Children with mild hearing loss took 12 months longer to master the following sounds compared with typically developing children: /d/, /ŋ/, /r/, /l/, /tʃ/, /ʃ/, and /θ/.

Because the last testing age for this study was 84 months (7 years), it is not possible to compare the mastery of children with hearing loss to their typically developing peers for certain late developing sounds. Children with typical speech development master /s/, /z/, /v/, and /ð/ at 8 years of age. In this study, the mild hearing loss group had not yet achieved mastery of these four sounds by the age of 7 years; however, we cannot say whether such mastery would have been achieved following an additional years' worth of measurements.

A noteworthy variation from typical development occurred with the phoneme /f/. Typically developing children emerge with this sound between the ages of 24 months and 36 months. They master it by the age of 48 months. The children with mild hearing loss demonstrated emergence of this sound before 48 months but had not mastered it at the age of 84 months. In contrast, the phonemes /b/ and /t/ were accurately produced by 90% of the children on the same timeline as typically developing children. The only phoneme that was mastered earlier by the children with mild hearing loss than that reported for hearing children was /ɕ/.

Moderate hearing loss. Children with moderate hearing loss in this study mastered the early developing phonemes /m/, /h/, and /w/ by or before 48 months of age. A direct comparison between the mastery of these sounds with typically developing children sounds is limited because the first testing age in this study was 48 months.

Numerous sounds emerged and were mastered later for children with moderate hearing loss compared with their typically developing peers. Notably, the phoneme /n/ is typically an early developing sound; however, 90% of the children with moderate hearing loss did not produce this phoneme accurately until 84 months of age. Other earlier developing sounds (/p/, /g/ and /d/) required an additional 24 to 36 months to master. Four phonemes (/ŋ/, /r/, /s/, and /z/) emerged 30 months or more after children with typical hearing.

The latest sounds to emerge in this hearing loss group were /s/, /θ/, and /ð/. All of these emerged at the age of 84 months. It is interesting to note that two of these sounds only carry speech sound frequency information at or above 5,000-6,000 Hz. Such observations may shed light on speech frequencies that would be beneficial for audiologists to closely monitor for this degree of hearing loss and age range. In addition to these three sounds, the children with moderate hearing loss did not achieve mastery of /ŋ/, /f/, /r/, /l/, /ʃ/, /ʒ/, /ɕ/, or /v/. The

phoneme /t/ was the only sound that emerged and was mastered on a similar timeline as that for typically developing children as presented by Sander (1972).

The children with moderate hearing loss were similar to those with mild hearing loss in regard to developing the “early 8” (Shriberg, 1993) first. However, these two groups did not develop the “middle 8” or “late 8” on a similar timeline. Though they share a similar overall pattern of development, children with mild hearing loss had more sounds emerging or mastered at the first testing age of 48 months. When comparing individual sounds, the children with moderate hearing loss mastered /t/ on the same timeline as children with mild hearing loss; otherwise, this group mastered sounds on a delayed timeline compared with children with mild hearing loss.

Severe Hearing Loss. Children with severe hearing loss mastered the phoneme /tʃ/ at the same age as children with typical speech development. However, this group mastered far fewer sounds by the end of this project compared with their typically developing peers, and the phonemes that they had mastered were delayed. In addition to /tʃ/, this hearing loss group only mastered the early developing sounds (/p/, /m/, /h/, /k/, /w/) during the time period of this study. In contrast, hearing children with typical speech master all sounds with the exception of /s/, /z/, /v/, and /ð/ by 7 years of age. The group of children with severe hearing loss mastered the early developing phonemes (with the sole exception of typically later-developing /tʃ/) on a timeline that was delayed by at least 36 months (and in some cases more than 48 months) compared with their typically hearing peers.

The emergence of sounds was also significantly delayed for the group of children with severe hearing loss. At the age of 48 months, 10 sounds (/p/, /m/, /h/, /n/, /w/, /b/, /g/, /d/, /t/, and

/tʃ/) had emerged for this group. In contrast, children with typically developing speech have either emerged with or mastered 19 sounds at the same age. Some phonemes (/ŋ/, /f/, /j/, /r/, /l/, /ʒ/, /v/, and /s/) emerged as late as 72 and 84 months for this hearing loss group. Notably, less than 50% of the children with severe hearing loss demonstrated correct production for three sounds (/z/, /θ/, and /ð/) during the testing ages of 48 to 84 months. Though these are later-emerging sounds for children with typical hearing, all three phonemes typically emerge by or before 60 months.

The timeline for speech sound development is extended in children with severe hearing loss compared to those with lesser degrees of loss. Children with severe loss have fewer sounds emerging early, and it takes longer to master the vast majority of sounds. Though the overall pattern of speech sound development is generally similar (earlier developing sounds emerging and being mastered before later developing sounds), the speech development of children with severe hearing loss shows more deviation from the typical pattern compared with the mild and moderate hearing loss groups.

Cochlear Implant Category

Children with cochlear implants mastered very few phonemes during the 48 to 84 month period of this test, and each mastery occurred on a delayed timeline compared with typically developing peers. For example, the phoneme /w/ was mastered 24 months after children with typically developing speech. Additionally, the group mastered the phonemes /m/ and /h/ 36 months later than typical development. The group of children with cochlear implants did not master any other sounds at the final test age of 84 months. This is particularly noteworthy for some of the early developing sounds such as /p/, /n/, /b/, and /k/.

The limited phoneme mastery of this group is surprising because literature and anecdotal observations from clinicians indicate that early-implanted children achieve intelligible speech. It is possible that a small number of children tested who had very limited speech skills skewed the results of the study for this hearing loss group. However, it is also possible that although children with cochlear implants are achieving intelligible speech, they are not achieving the same level of accuracy that children with typical speech achieve.

Children with cochlear implants demonstrated speech sound development most similar to children with severe hearing loss who wore hearing aids. Like the children with severe hearing loss, the children with cochlear implants had very few sounds emerging at the age of 48 months. The following sounds had emerged for this group at or before 48 months: /p/, /m/, /h/, /w/, /b/, /k/, /g/, /t/, /tʃ/, and /ʃ/. All of these sounds, with the exception of /tʃ/ and /ʃ/, are earlier developing sounds. The phoneme /tʃ/ was also observed to emerge early in children with severe hearing loss. Children with severe hearing loss and those with cochlear implants were the only hearing loss categories to have some sounds that never emerged during the testing ages of 48 to 84 months.

Considerations in Interpretation and Future Directions

The results of this study provide a number of avenues for consideration and future research. The presentation of speech sound data using emergence and mastery thresholds allows for direct comparisons with typically developing children. However, the available data limits the comparisons that can be made for particular early developing phonemes (/p/, /m/, /h/, /n/, and /w/) and late developing phonemes (/s/, /z/, /v/, and / ð /). The data available from this study observed children from 48 months to 84 months of age; however, Sander's data spanned a wider range of ages and charted sound development between 24 months and 96 months of age.

observed children from 48 months to 84 months of age; however, Sander's data spanned a wider range of ages and charted sound development between 24 months and 96 months of age.

Sample size is an important consideration in studies of children with hearing loss given the wide range of variability in speech outcomes that are consistently noted in this population (Eisenberg, 2007). A number of variables affect speech development for all children, such as individual motor development and linguistic development. However, additional factors related to hearing loss increase the variability of speech development in children who are deaf or hard of hearing such as whether the hearing loss is identified early or late, the appropriateness of the amplification fitting, and the consistency with which amplification is used. In the present study, each category of hearing loss, included 27 to 57 children contributing 40 to 130 assessments at different age intervals. Sander's (1972) reanalysis of the results of Templin (1957) and Wellman et al. (1931) included data from 15 children at age 2 and 60 children in each age category from three to eight years. Although the current study had a comparable overall number of children to Sander's previous research, given the potential for greater variability among children who are deaf or hard of hearing, the findings of this study would be strengthened with larger numbers of children at each test age and at each degree of hearing loss.

The age of hearing loss identification is of one of the variables that can affect the acquisition of speech sounds in children with the same level of hearing loss. In this study, the age of identification varied widely across the participants. Overall, the percentage of children included in this study whose hearing loss was identified before 3 months was 58.3%. This is similar to the 68.4% of children in 2009 who received their diagnosis of hearing loss before 3 months of age as reported by the Centers for Disease Control (CDC) (Centers for Disease Control, 2012). Because earlier interventions lead to better speech outcomes (Ambrose, 2014), a

sample of children who all met the guidelines for early screening, amplification, and intervention as recommended by the Joint Committee on Infant Hearing (American Academy of Pediatrics, 2007) would likely show better speech outcomes than those reported in this article.

The rigor in which speech sound accuracy was transcribed may have differentially affected outcomes in this study versus those from Sander. This study tested phoneme production through an elicited single word task similar to Wellman et al. (1931) and Templin (1957). However, in this study graduate students in linguistics transcribed the video samples. The graduate students were observed to be more critical than an evaluator scoring while administering an assessment. It is likely that an evaluator who is scoring while administering the test is more likely to “fill in” speech sounds that a child has omitted or to score a distorted sound as correct. Therefore, the results of this study should be considered as measuring speech production in children with hearing loss with a strict and rigorous standard as to what is considered accurate phoneme production.

A final consideration when interpreting the results of this study is the advancement of technology since the data were collected. Stelmachowicz, Pittman, Hoover, and Lewis (2001) found that the audibility of high-frequency consonants is limited by hearing aid bandwidth. They noted that these technology limitations particularly affected the ability of hearing aids to provide access to speech from female and child speakers. Children assessed in this study would have grown up with these limited bandwidth hearing aids. Since the data were collected, however, frequency transposition hearing aids are more commonly fit on pediatric patients (Glista, Scollie, Bagatto, Seewald, Parsa & Johnson, 2009; Wolfe, John, Schafer, Nyffeler, Boretzki & Caraway, 2010). Frequency transposition hearing aids may benefit children with more severe losses and those with high-frequency losses, meaning that the speech sound

outcomes reported in this article may be improved due to changes in technology (Glista et al., 2009; Wolfe et al., 2010). Frequency transposition hearing aids are not consistently reported in the literature to positively impact outcomes for children with hearing loss (Bentler, Walker, McCreery, Arenas, & Roush, 2014). Future research should include children who have access to these hearing aids to determine if there is an added value of this technology for speech sound development. In addition to technological improvements, children with hearing loss continue to be identified, amplified, and enter intervention services at earlier ages.

These data can be further analyzed to assess speech sound production on a child-by-child basis (rather than grouped by hearing loss categories). Ambrose and colleagues (2014) studied speech sound production in very young hearing aid users. They found that children with speech delays at 2 years did not resolve delays by the age of 3 years. It is possible that the children in this study who were not producing phonemes correctly at the age of 48 months had persistent trouble across each age of testing. Future work could consider the individual sound trajectories for each child. If the trend found by Ambrose and colleagues continues to be true (that early delays do not resolve with time), then there is a critical need to identify and intervene very early in speech sound development for children with hearing loss.

Further research is also important in investigating the source of variation in speech sound development. This study provided observations of the order of speech sound acquisition based on the degree of hearing loss. As the degree of hearing loss increased, the data in this study showed increased variation and delay in speech sound development. Further research could shed light on the root cause of this problem. Most commonly, therapists provide treatment under the assumption that audition is the root cause of speech errors for children with hearing loss. If this were the case, we would expect the errors to cluster around speech frequency patterns. It is also

possible that the lack of accurate auditory perception leads to the articulation error ultimately becoming a speech motor problem. Investigating this question could inform intervention models for children with hearing loss. These investigations may also help identify specific speech frequencies that audiologists should monitor during early school years as these speech sounds develop.

Although this study provides a new set of benchmarks for speech sound development, these benchmarks should not be interpreted as new norms or standards for children with hearing loss when making decisions about eligibility for or intensity of intervention. Children with hearing loss should continue to be compared with normative data for typically developing children when determining whether they are making adequate progress or should qualify for speech therapy services.

These new benchmarks can be used by audiologists to identify sounds that are at high risk for delayed or deviant development. With such information, audiologists may be more able to ensure that these sounds are available through a child's amplification and thus ensure that a lack of access to speech frequencies is not the reason for delayed speech production. If a child with hearing loss is not developing speech on a typical timeline, a speech therapist can use these benchmarks to determine if the child is falling within observed performance levels relative to children with the same degree of hearing loss. If a child's performance is below the average range for typical development and for their degree of hearing loss, a secondary disability, such as apraxia of speech, may be indicated. Below-average performance may also indicate an urgent need to determine whether amplification is fit appropriately or if the child's hearing loss has progressed.

In addition to speech pathologists and audiologists, the results of this study may be helpful for parents, deaf educators, and school administrators who work with children with hearing loss. The results of this study can be used as a reference point when therapists are determining eligibility for intervention services. Children with hearing loss are at risk for being disqualified from therapy services because they score within the average range on standardized testing at the age of three as they transition to school-based therapy. However, this study shows that a high proportion of children with hearing loss will have standard scores that fall outside the normal range at some point between four and seven years of age. These children are likely to require articulation therapy to remediate later developing sounds even if their standard scores are in the average range when they transition to preschool.

Parents need to be aware that even though a school district may not qualify their child for speech services, their child may need direct intervention to remediate some sound errors. After a child has entered the school system, parents may wish to request annual speech assessments as the child ages. Sounds produced in error at the age of 3 years may be developmentally appropriate. However, the same sounds may no longer be developmentally appropriate errors when the child is older. This research shows it is likely that later developing phonemes will not properly develop with more time for young children with hearing loss and so it is important to re-assess to determine whether intervention is warranted.

Summary

This study examined the consonant production skills of children with mild to severe hearing loss who use hearing aids as well as a group of children who use cochlear implants. We

compared these children's speech sound production with previous research reports of children with normal hearing who demonstrated typically developing speech. This study detailed individual speech sounds by the degree of hearing loss in chart format to illustrate developmental variability. The children generally demonstrated delayed development, and this delay increased with the severity of hearing loss. Some phonemes were still not produced by 90% of the group by the endpoint of this study (84 months). Overall, the children followed the same general pattern of speech sound development as children with typical speech (albeit on a delayed timeline); however, there were individual sounds that significantly deviated from a typical trajectory, such as /θ/ and /ð/. Children with mild hearing loss demonstrated speech sound development that most closely paralleled typical development. It is concerning that all children with hearing loss demonstrated delays regardless of degree of loss and type of amplification. Children with hearing loss should be monitored closely through the early school-age years, and intervention should be provided to help reduce the impact of hearing loss on speech sound development.

Acknowledgements

This study was supported by Maternal and Child Health, the Office of Education (H325D030031A, H32C030074), the University of Colorado - Boulder, the Colorado Home Intervention Program, and Colorado Department of Education. We wish to acknowledge the contributions of the following individuals to this project: Student transcribers and the participating families.

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CHAPTER III

Predicting Phoneme Growth in Young Children with Hearing Loss

Introduction

Widespread implementation of newborn hearing screening programs and advances in amplification technology over the last two decades have dramatically improved outcomes in speech sound development for young children with hearing loss (Eisenberg, 2007; Ertmer & Goffman, 2011; Fitzpatrick, Crawford, Ni, & Durieux-Smith, 2011; Warner-Czyz et al., 2010). Notwithstanding gains in outcomes for children with hearing loss, these children continue to have delayed speech-sound production compared with their typically hearing peers. To better understand the cause of these delays, it is important to be able to describe the trajectory of speech development in children with hearing loss and to understand which child variables (both demographic and developmental) are associated with speech-sound development. This paper uses longitudinal data from children with various levels of hearing loss to create speech-sound predictive growth models.

General Speech Development in Children with Hearing Loss

The implementation of universal newborn hearing screening (UNHS) has helped ensure the early identification of hearing loss in children (American Academy of Pediatrics, 2007; JCIH, 2007). Early hearing detection and intervention (EHDI) guidelines (currently established

in all U.S. states and territories) recommend access to intervention for children with hearing loss by six months of age. Additionally, FDA-approved cochlear implantation at 12 months (a policy change adopted in 2000) provides children with severe and profound hearing loss access to appropriate hearing technology by the end of the first year of life.

Children diagnosed prior to these advancements, regardless of their degree of hearing loss, had significantly poorer speech production than children with typical hearing (Boothroyd, 1978; Gordon, 1987; Markides, 1970; Mavilya, 1972; Monsen, 1978; NIH Consensus Statement, 1995). Access to early and appropriately fit technology for young children with hearing loss aids in the development of speech production skills (Blamey, Barry & Jacq, 2001; Serry & Blamey, 1999). Significant progress in speech sound development has been noted as compared to historical outcomes, which can be attributed in large part to UNHS, EHDI, and early cochlear implantation (CAHE Review Team, 2007; Moeller, 2000; Schachter et al., 2002; Yoshinaga-Itano, Baca, & Sedey, 2010). However, despite these advancements, children with all degrees of hearing loss continue to demonstrate lower accuracy and persistent delays in speech sound acquisition compared with their typically hearing peers (Ertmer & Goffman, 2011; Ertmer, Kloiber, Jung, Kirleis, & Bradford, 2012; Moeller et al., 2007; Warner-Czyz & Davis, 2008; Warner-Czyz, Davis, & MacNeilage, 2010).

Examples in the literature of these delays were presented by Moeller et al. (2007) who reported that even early-identified children with mild hearing loss had delayed phoneme production, with fricatives and affricates being the most difficult to produce. Delays have been reported in early-identified children as young as 12 months (McGowan, Nitttrouer, & Chenausky, 2008) and 24 months (Ambrose, Berry, Walker, Harrison, Oleson, & Moeller, 2014). Overall, for all degrees of hearing loss, the rate of development of consonants is delayed, and the delay

increases with degree of hearing loss (NIH Consensus Statement, 1995; Robbins et al., 1991; Wiggin, Sedey, Awad, Bogel, & Yoshinaga-Itano, 2013).

One principal question that is still being addressed in current research is whether children with hearing loss are making gradual progress that is simply delayed compared with their typically developing peers or whether children with hearing loss reach a plateau in their speech sound development. This question is important because it could inform when intervention should be initiated in children with hearing loss. Shriberg (1994) reported that speech sound errors are considered deviant in children with typical hearing after 8 years of age. Accurately describing the timing and pattern of speech-sound development trajectories for young children with hearing loss would help in measuring the effectiveness of amplification and intervention strategies. Moreover, if there is an age at which young children with hearing loss are no longer expected to make progress in speech sound development, intervention should be instituted prior to this time rather than using a “wait and see” approach to determine the initiation of speech therapy services.

Cochlear Implant Speech Sound Trajectory Literature

To date, speech sound developmental trajectories have been described in very few studies. Those that are available have primarily focused on children with cochlear implants with little information available regarding the speech sound trajectories of children with mild-to-severe hearing loss who use hearing aids (Ambrose et al., 2014; Fitzpatrick, Crawford, Ni, & Durieux-Smith, 2011; Holte et al., 2012; Tomblin, Oleson, Ambrose, Walker, & Moeller, 2014; von Hapsburg & Davis, 2006). The available reports on children with cochlear implants do not necessarily agree. Some indicate that speech skills plateau over time, whereas others indicate

that children with hearing loss make gradual progress in speech sound development over many years. These differences in results may be due to variations in study methodology.

Serry and Blamey (1999) described phonetic inventory development in 9 children during the first 4 years of cochlear implant use. When comparing the children with cochlear implants with hearing children displaying typical speech development, they found systematic but slower progress in the children with cochlear implants. Blamey, Barry, and Jacq (2001) extended this work with two more years of data so that they could specifically investigate the rate of inventory development. Their study found a probable plateau in the sixth year following cochlear implantation. Using a different method of analysis, the same conversational speech samples were analyzed by Blamey, Barry, Bow Sarant, Paatsch, and Wales (2001). They found that speech acquisition was incomplete six years following implantation, but they did not observe a plateau in development.

Tomblin, Peng, Spencer, and Lu (2008) analyzed spontaneous speech samples of children with cochlear implants using segmented regression models. Later speech outcomes could be predicted based on performance after 4 years of device experience. They also studied the accuracy of speech over an 8-year period post-implantation. Improvement was noted for the first 6 years post implantation but not thereafter.

The findings of Tomblin et al. (2008) were consistent with those of Connor et al. (2006) who found that children implanted before the age of seven years showed sustained growth up to the final testing age of 5 years post-implantation. They estimated speech-sound development curves for these children using hearing aids based on pre-operative scores to simulate how they would have performed without cochlear implants. As would be expected, the children with cochlear implants developed speech sounds at a faster rate (both measured by the slope and

acceleration of the curve) than the authors estimated the same children would have achieved without cochlear implantation. The authors also found that children who received cochlear implants before 2 ½ years of age exhibited early bursts of growth in consonant production accuracy.

Taken together, the aforementioned studies indicate that children with cochlear implants make progress in speech-sound development over the first few years post-cochlear implantation. Depending on the study, after four to six years, children either plateau or begin to make substantially reduced speech-sound development progress. Additional studies are necessary to reconcile whether the developmental trajectories of children with hearing loss reach a plateau.

There is additional information in the literature regarding speech sound development growth in children with cochlear implants. For example, Bouchard, Le Normand, and Cohen (2007) recorded spontaneous speech productions at 6, 12, and 18 months following cochlear implantation. They generally found that consonant visibility initially influenced the order of speech-sound production in these children. Over time, however, the patterns of development were similar to those in children with typical hearing.

Speech Sound Development in Children with Hearing Aids

Though very few studies have followed the long-term trajectories of children with hearing aids, some observations can be made from related studies. Yoshinaga-Itano and Sedey (2000) reported descriptive information on phonetic inventory size for children with all degrees of hearing loss. The authors grouped the children into hearing loss categories (mild-moderate, moderately-severe, severe, and profound) and reported the number of different consonant types for each group over time. From 14 months to 43 months, groups of children with mild-moderate, moderately severe, and severe hearing loss were found to have very different numbers of

consonant types. At 43 months, the number of consonants expressed by each group of children began to converge. By 55 to 60 months, the average child in each group produced most of the consonants of English during a 25-minute speech sample. This study showed that children with various degrees of hearing loss have different developmental trajectories, that children with any degree of hearing loss can make progress in speech sound development from 14 to 60 months, and that children with a hearing loss that is mild to severe typically develop most of the consonants of English.

Goldman Fristoe Test of Articulation – 2

More recently, Ambrose and colleagues (2014) investigated young hearing aid users with mild-to-severe hearing loss and reported on their phonetic inventories. Most notably, they found that speech scores at age two were positively correlated with Goldman Fristoe Test of Articulation – 2 (GFTA-2) (Goldman & Fristoe, 2000) scores obtained at age 3, indicating that children who demonstrated stronger speech skills at age 2 are likely to continue to demonstrate strong speech skills at 3 years of age. They found that 39% of the children with hearing loss demonstrated below average scores at age 3 (compared with the expected 16% for children who are typically developing).

Other researchers have used the GFTA-2 to assess speech performance levels in children with hearing loss. Flipsen (2011) found this to be an appropriate assessment tool for children with cochlear implants; the children tested did not experience floor effects and were able to complete testing without significant modifications to the test manual instructions. He reported scores based on hearing age and chronological age. When considering performance based on chronological age, 4 of 15 children achieved scores within the normal range.

Similarly, Buhler, DeThomasis, Chute, and DeCora (2007) tested a small sample of children with cochlear implants ranging in age from 51 to 57 months. Two children were found to have scores in the average range. Though both studies demonstrated meaningful scores for all of the participants, the majority of the children performed below the average range.

The GFTA-2, as a single-word articulation test, has also been used to investigate the relationship between speech intelligibility and formal articulation testing in children with hearing loss. Children with speech disorders and normal hearing produce phonemes with substantially higher accuracy in single words compared with connected speech production (Dubois and Bernthal, 1978; Johnson, Winney, & Pederson, 1980). Children with hearing loss ranging from mild to profound also demonstrated that word-level articulation tests do not provide reliable speech intelligibility estimates (Ertmer, 2010).

Purpose

Hearing loss increases the likelihood that a child will not achieve appropriate speech production due to reduced access to auditory information. Although previous research has provided information describing speech-sound production in children with hearing loss, less information is available regarding the factors influencing the developmental process. This paper addresses two research questions relevant to this development:

1. Do demographic characteristics such as degree of hearing loss, maternal level of education, and expressive vocabulary level predict speech growth trajectories in young children with hearing loss?
2. Is the child's consonant inventory when they were 27 to 33 months old predictive of GFTA-2 performance? Performance is measured according to the raw score at the first

test session (intercept), and the rate of growth is measured between the ages of 4 to 7 years old.

Method

Participants

The following criteria were used to determine eligibility for participation in this research project: (1) cognitive ability within average range, (2) no disabilities impacting speech/language development, (3) permanent bilateral hearing loss, (4) resident of the state of Colorado, (5) parents with normal hearing, (6) primary home language of English, and (7) prior participation in the early intervention assessment program within the state. Children were excluded from the study if they presented with auditory neuropathy, unilateral hearing loss, or disabilities impacting speech/language development.

Children with permanent bilateral hearing loss between the ages of four and seven years ($M = 63.71$ months; $SD = 11.47$ months) participated in this study. To determine each participant's degree of hearing loss, this study used unaided pure tone average (PTA: average of hearing thresholds at 500, 1,000, and 2,000 Hz) in the better hearing ear. The study divided participants into the following five hearing loss groups: mild (better ear PTA: 26-40 dB HL), moderate (better ear PTA: 41-55 dB HL), severe (better ear PTA: 56-90 dB HL), profound (better ear PTA: > 90 dB HL), and cochlear implant.

A total of 207 GFTA-2 assessments were generated for 69 children at ages four, five, six, or seven years. Children were included in the analysis if they had three assessments during the study. If a child had four assessments, the first three were used in analysis. Summary

characteristics of the group of children are presented in Table 2.1 with specific information about hearing loss in Table 2.2.

Table 2.1. Number of participants (and percent) exhibiting each demographic characteristic

<i>Child Characteristic</i>	<i>Total Sample (N=69)</i>
<i>Gender</i>	
Male	41 (59.4)
Female	28 (40.6)
<i>Ethnicity/Race</i>	
Caucasian	45 (65.2)
Asian American	3 (4.3)
Hispanic	8 (11.6)
Caucasian/Hispanic	10 (14.5)
Other mixed ethnicity	3 (4.3)
<i>Mode of communication</i>	
Auditory verbal/auditory oral, no signs	24 (34.8)
Primarily auditory oral, occasional signs	36 (52.2)
Signs and speaks	9 (13.0)
<i>Confirmation of hearing loss ≤ 6 months</i>	42 (60.9)
<i>Degree of hearing loss</i>	
Mild (26-40 dB HL or <26 dB HL with 1 or more thresholds ≥ 30 dB HL)	15 (21.7)
Moderate (41-55 dB HL)	24 (34.8)
Moderate-severe to severe (56-90 dB HL)	8 (11.6)
Profound (>90 dB HL)	4 (5.7)
Cochlear Implant	18 (26.1)
<i>Mother's education</i>	
No high school diploma	3 (4.3)
High school diploma	27 (39.1)
Vocational or Associates degree	9 (13.0)
B.A. or graduate degree	30 (43.5)

Table 2.2 Median (and range) of age of identification, amplification and intervention in months by the degree of hearing loss

	Identification	Amplification	Intervention
Mild (n=15)	1.5 (.5-29)	11 (2-30)	8 (1-30)
Moderate (n=24)	2.75 (.25-41)	8 (2-42)	9 (1.5-33)
Moderate-severe to severe (n=8)	11 (1-43)	12.5 (2-44)	15 (2-44)
Profound (n=3)	25 (1.5-27)	27 (5-28)	28 (7-30)
Cochlear implant (n=19)	6 (.5-24)	11 (1.5-26)	10 (.75-27)

Assessment Tools

Spontaneous Language Sample

A 25-minute parent-child interaction was videotaped in the child's home. This language sample was transcribed into Logical International Phonetics Program (LIPP) (Oller & Delgado, 1990), a computer program dedicated to phonetic transcription and analysis, by graduate students in linguistics at the University of Colorado, Boulder. An inventory of consonants produced was compiled using LIPP for each child. A total of 25 consonants were considered. The mean inter-coder reliability for the consonant inventory across a random sample of 26 transcripts was 90.63% (range: 68.75-100%).

Goldman Fristoe Test of Articulation – 2 (GFTA-2)

The GFTA-2 is a standardized measure of speech production ability for ages 2 years to 21 years 11 months. The norms are based on children with typical hearing. Scores are given as percentile ranks, standard scores, and age equivalents. The test has a mean standard score of 100 and a standard deviation of 15. The GFTA-2 is widely used by speech language pathologists in pediatric settings (Flipsen, 2011). The child is shown a picture and asked to identify it. Each target word may have more than one phoneme being elicited. For example, the word “carrot” is used to elicit the phonemes /r/ and /t/. There are 53 words that target 61 consonants in the initial, medial, and final position as well as consonant blends. All phonemes of the English language are elicited with the exception of /z/. Individual child scores (raw scores and standard scores) were determined using the standard GFTA-2 scoring procedure. Raw scores represent the total number of errors a child makes during testing. A larger raw score indicates a higher number of speech errors. A raw score of zero indicates that the child made no errors during the test. The

child's chronological age was used when determining normative scores. Assessment results are shown in Table 2.3, Figure 2.1 through Figure 2.4. Results are shown by the degree of hearing loss and presented using standard scores.

Table 2.3. Mean, standard deviation & range of assessment scores by the degree of hearing loss
Notes. N's vary slightly due to missing assessment data. Standard scores are a mean of 100 and a standard deviation of 15. Intelligibility rating was scored on a 6-point scale.

	<i>EOWPVT</i> Standard Scores	<i>GFTA-2</i> Standard Scores	Intelligibility Rating 6-point scale	<i>Leiter-R</i> Standard Score
Mild (<i>n</i> =45)	M=105.64 SD=15.88 (75-135)	M=84.96 SD=18.29 (50-118)	M=1.40 SD=0.62 (1-3)	M=102.87 SD=16.22 (82-136)
Moderate (<i>n</i> =72)	M=95.82 SD=18.16 (54-132)	M=79.40 SD=17.27 (39-113)	M=1.67 SD=.73 (1-4)	M=104.67 SD=16.94 (81-140)
Moderate-severe to severe (<i>n</i> =24)	M=76.67 SD=18.05 (54-108)	M=58.83 SD=12.92 (39-80)	M=2.75 SD=1.07 (1-4)	M=110.00 SD=8.94 (98-129)
Profound (<i>n</i> =10)	M=71.9 SD=15.34 (54-100)	M=42.40 SD=6.06 (39-56)	M=3.33 SD=1.34 (2-5)	M=86.30 SD=5.56 (81-98)
CI (<i>n</i> =56)	88.46 SD=17.66 (54-132)	62.0 SD=17.09 (39-91)	2.33 SD=1.18 (1-5)	108.02 SD=13.11 (82-137)

Figure 2.1. Box and whisker plot of GFTA-2 standard scores by degree of hearing loss for all assessment test points

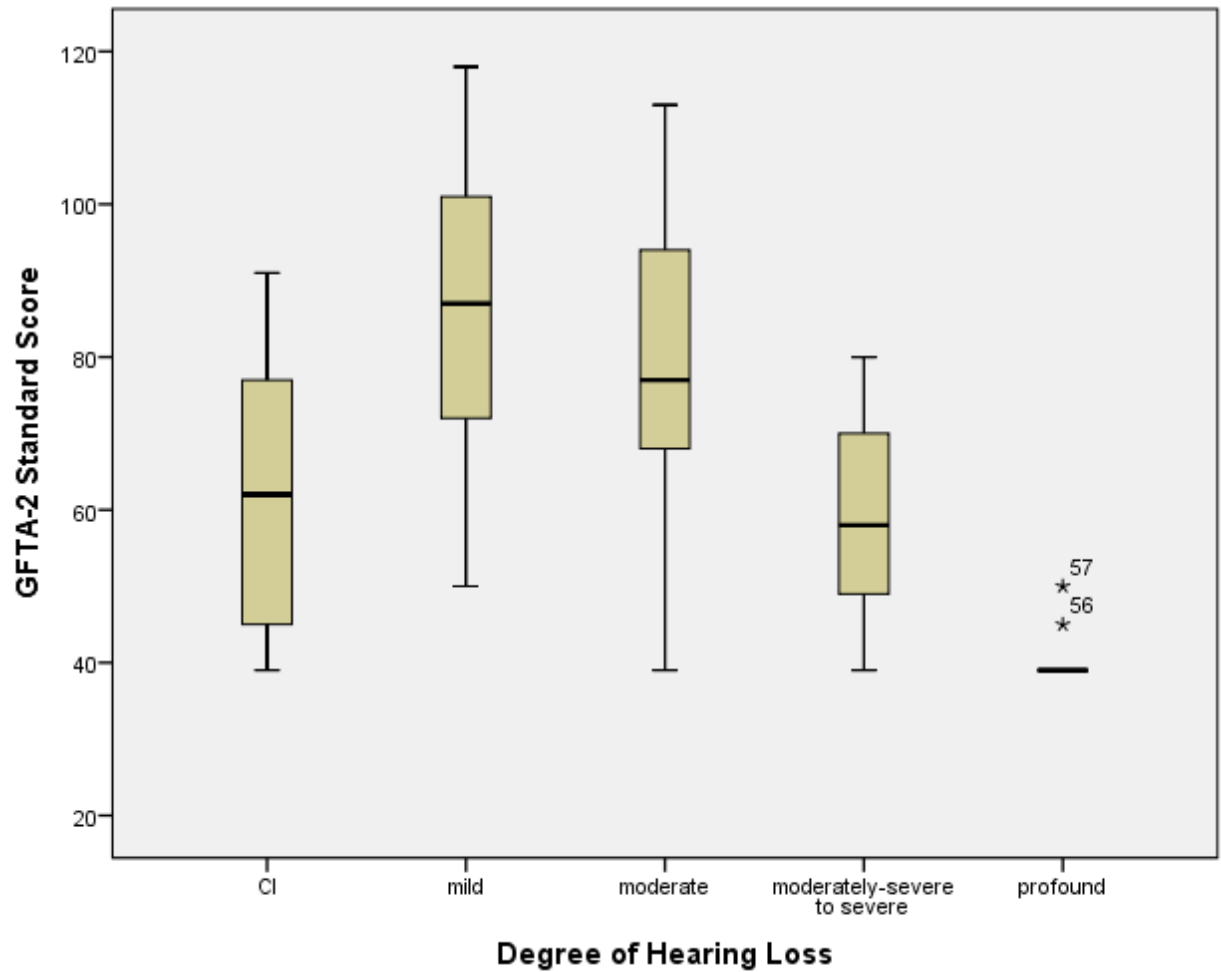


Figure 2.2. Box and whisker plots of GFTA-2 standard scores by degree of hearing loss at the first assessment

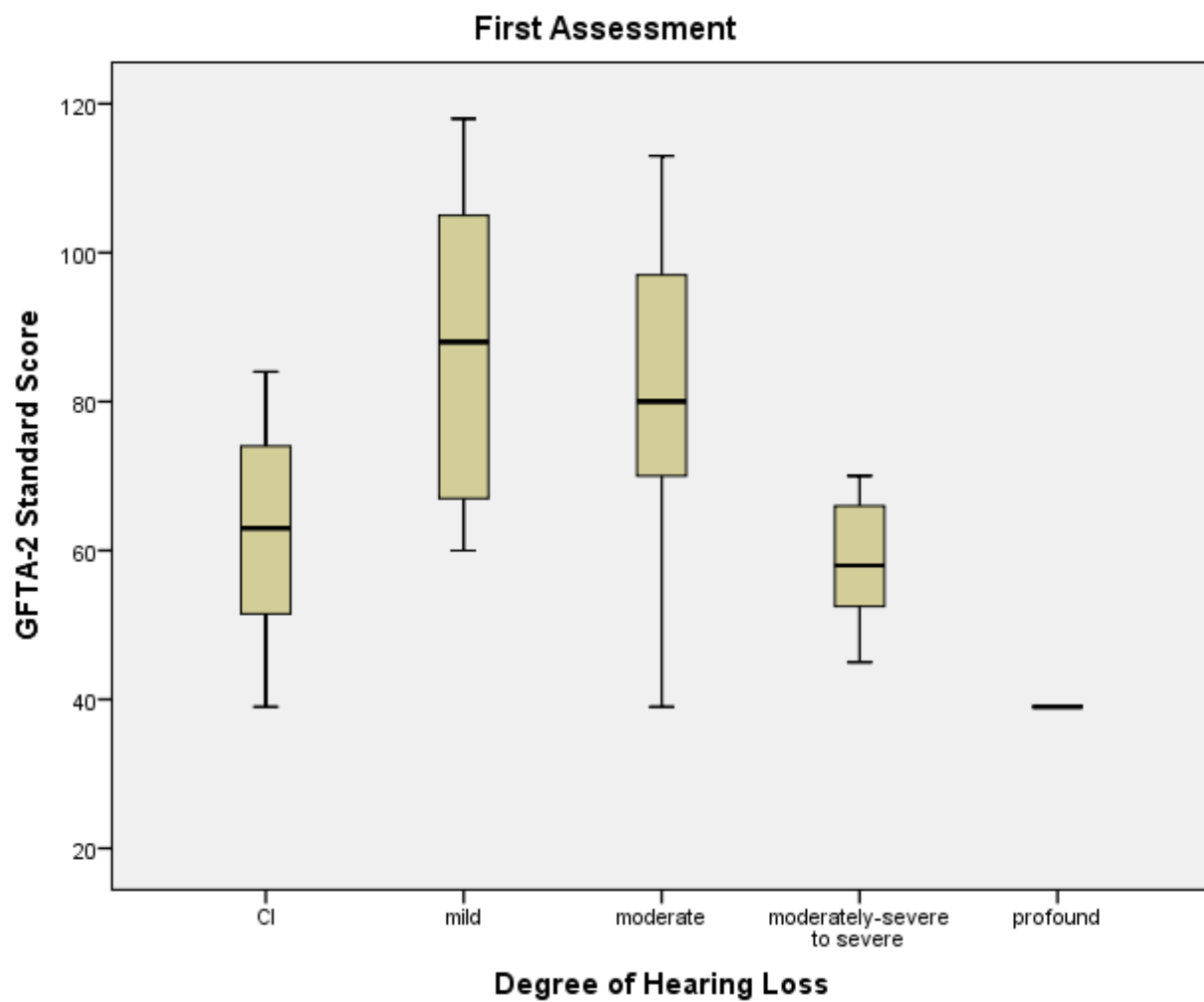


Figure 2.3. Box and whisker plots of GFTA-2 standard scores by degree of hearing loss at the second assessment

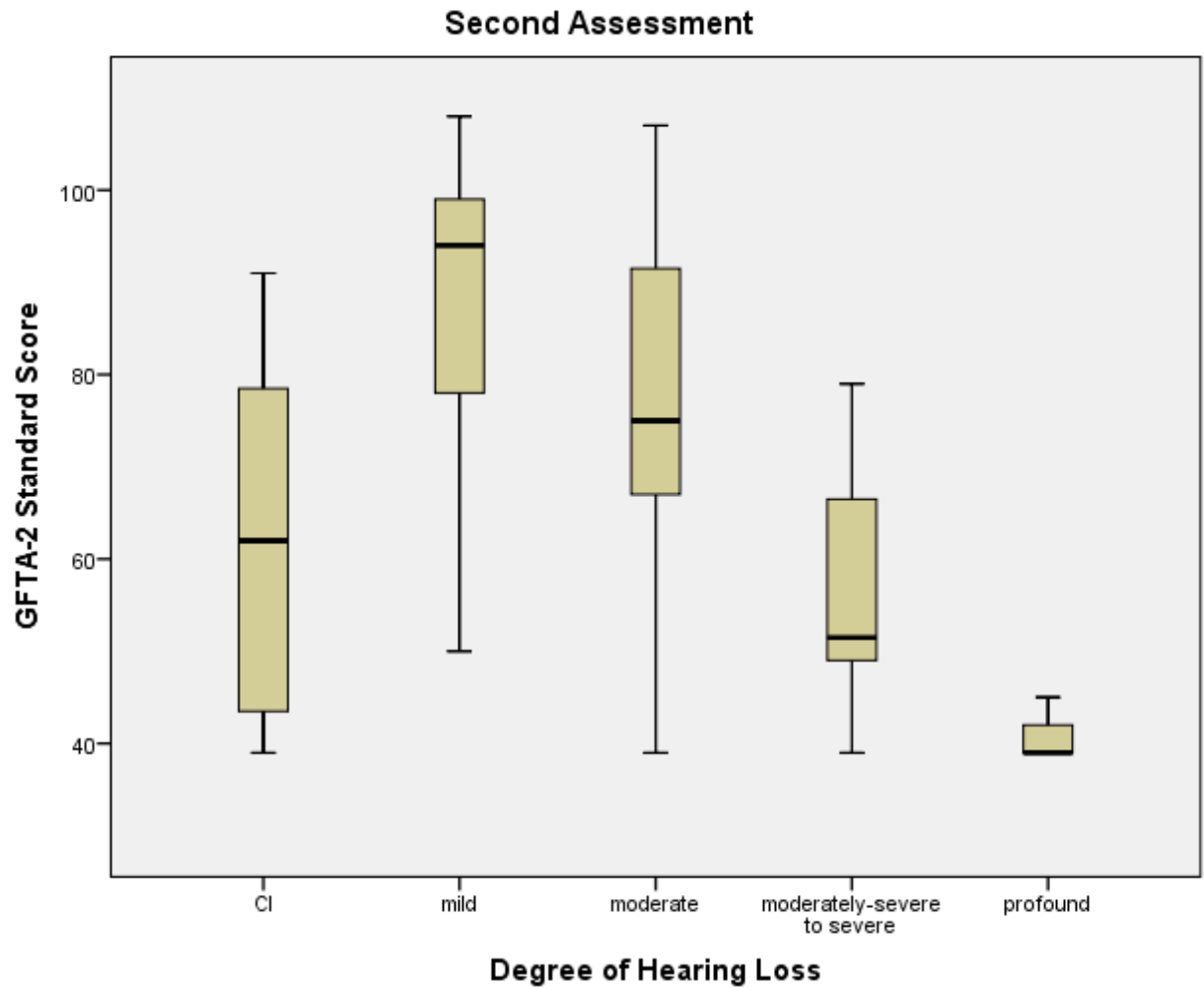
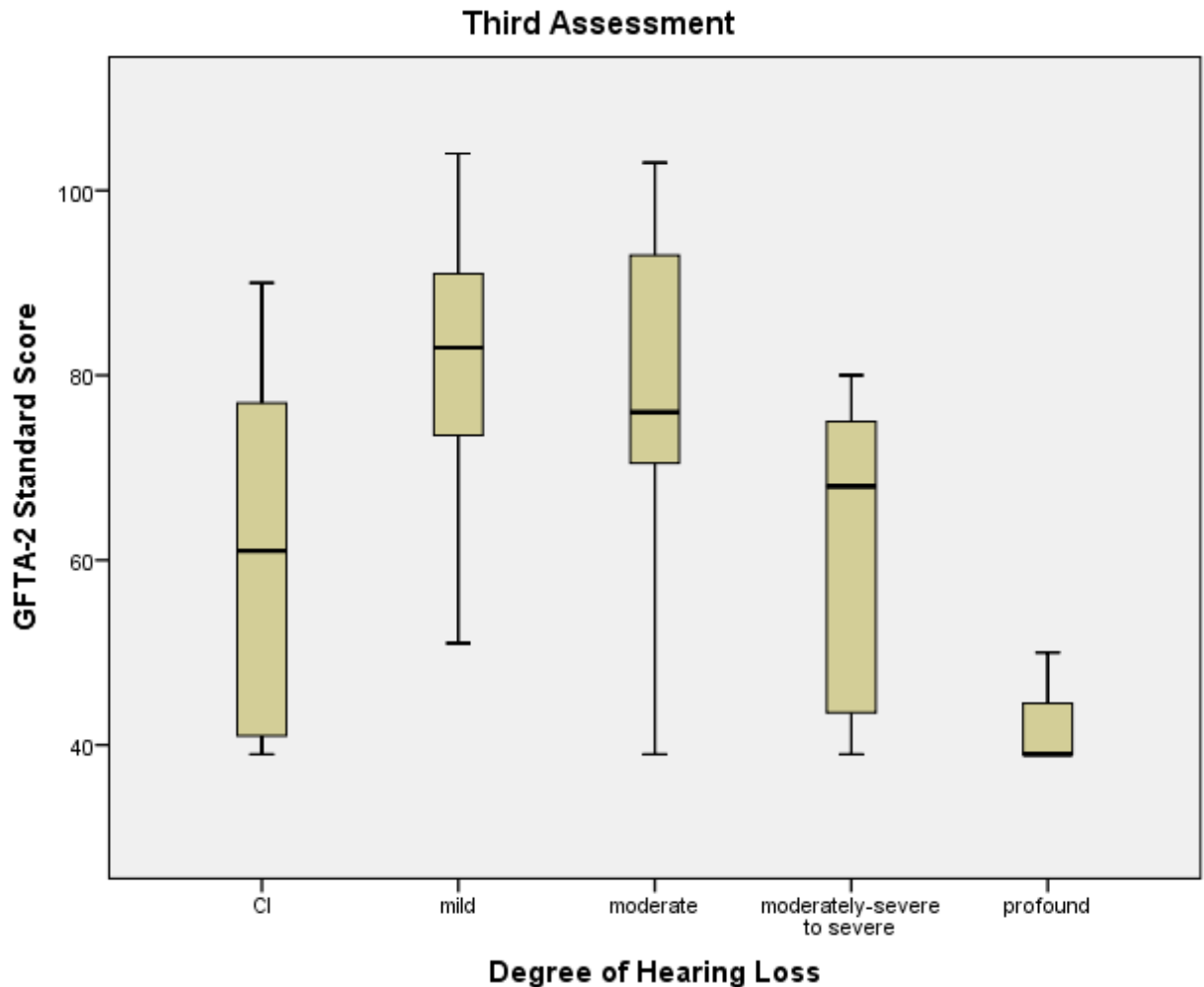


Figure 2.4. Box and whisker plots of GFTA-2 standard scores by degree of hearing loss at the third assessment



Leiter-R

An intelligence test was administered to assess the student's general range of intellectual functioning. The Leiter International Performance Scale-Revised (Leiter-R; Roid & Miller, 1997) is a non-verbal measure of global intelligence. The Leiter-R is for children ages 2 years to 21 years. It has a score range of 30 to 170 with a mean of 100 and standard deviation of 15. The

Full Scale IQ score indicates non-verbal global intellectual functioning and was used in the analysis.

Expressive One Word Picture Vocabulary Test (EOWPVT)

The Expressive One Word Picture Vocabulary Test, 2000 ed. (EOWPVT; Brownell, 2000), is a norm-referenced, individually administered test that measures expressive vocabulary by asking the child to name what is visually represented in pictures. It is designed for children ages 2 years to 18 years 11 months. Scores can be reported in terms of standard scores, percentiles, and/or age-equivalent scores. Standard scores were used in this analysis.

Speech Intelligibility Checklist

Intelligibility was judged by the examiner at the time of assessment. The speech intelligibility rating is a 6-point scale that describes the child's speech intelligibility. Each point has the following description:

- 1 – I always or almost always understand the child's speech with little or no effort
- 2 – I always or almost always understand the child's speech; however, I need to listen carefully
- 3 – I typically understand about half of the child's speech
- 4 – I typically understand about 25% of the child's speech
- 5 – The child's speech is very hard to understand. I typically understand only occasional, isolated words and/or phrases
- 6 – I almost never understand the child's speech
- NR – No rating (Speech intelligibility could not be judged because the child is producing few or no word approximations)

Description of Variables

Children were assessed using the aforementioned assessments. The parents also completed a demographic form to report child and family information. Audiological information was provided by each child's managing audiologist. A description is provided in Table 2.4 for variables included in analysis. Children were grouped into two hearing loss groups for analysis.

Children with mild or moderate hearing loss were placed in the first group. Children with moderately-severe, severe, or profound hearing loss using hearing aids and children using cochlear implants were placed in the second group.

Table 2.4. Description of specific variables included in the data analysis.

Independent Variable	Description of Variable
Degree of hearing loss	Children were placed into hearing loss categories based upon their pure tone average (PTA). Children were then placed into one of two groups for analysis. Children with mild or moderate hearing loss were placed in the first group. Children with moderately-severe and severe hearing loss who used hearing aids and all children who used a cochlear implant were placed in the second group.
Non-verbal cognitive ability (IQ)	Children were divided into three groups based on their IQ score on the LEITER-R. The “high IQ” group had scores above the average range (>115), the “average IQ” had scores in the average range (85-115), and the “low average IQ” group had scores between 81 and 84.
EOWPVT standard score	The standard scores of each child at the time of testing on the EOWPVT.
Intelligibility	The speech intelligibility rating given by the examiner at the time of testing.
Assessment number	The child’s first, second, or third assessment between the ages of 4 years and 7 years. This was used as the time marker during analysis.
Maternal level of education	Four categories (less than a high school education, high school education, Vocational or Associate degree, bachelor’s degree or greater) were created based on the highest educational degree obtained by the mother.
Age of identification of hearing loss	Children were placed in two groups based on whether they were identified by or after 6 months of age.

Analysis

For this study, we used hierarchical linear modeling (HLM) (Raudenbush & Bryk, 2002) to model growth in speech production as measured by GFTA-2 raw scores over time. This statistical technique is appropriate because it accounts for the shared variance in hierarchically structured data and simultaneously investigates relationships between and within levels of group data. Additionally, it is robust for unequal group sizes and can accommodate missing data (Raudenbush & Bryk, 2002).

In this study, HLM enabled the examination of specific child characteristics via two models. For the first research question, concurrent testing and demographic variables were analyzed to determine whether specific demographic characteristics predicted speech sound development in young children with hearing loss. For the second research question, consonant inventory scores from the birth to 3 period were analyzed to ascertain if early speech skills predicted later speech ability. No data were missing for the first research question. Nineteen children did not have a LIPP assessment between 27 and 33 months and were excluded from the analysis for the second research question.

HLM was used to estimate speech sound production growth models (Raudenbush & Bryk, 2002). The Level 1 model estimates within-person growth in speech sounds. These results define the timeline of GFTA-2 gains across the entire sample to determine a typical pattern. The Level 2 model considers between-person parameters to evaluate variability in the Level 1 parameters in relation to traits that vary across persons.

Research Question #1: Concurrent Variables Model

Do demographic characteristics such as degree of hearing loss, maternal level of education, and expressive vocabulary level predict speech growth trajectories in young children with hearing loss?

Our specific interest for the first research question centered on the degree of hearing loss. Other demographic and assessment results were included in this model to obtain a deeper understanding of children with hearing loss. First, we confirmed variability in the outcome variable (GFTA raw score) using the equation $GFTARAW_{ti} = \pi_{0i} + e_{ti}$. The results indicated that the use of HLM was warranted, $\chi^2(67) = 1,149.87, p < .001$.

Level 1 Model: Random Intercepts Model/Unconditional Growth Model

Next, we tested the relationship between the outcome variable (GFTA raw score) and the level-1 predictor variable (time).

$$GFTARAW_{ti} = \pi_{0i} + \pi_{1i} * (TIME_{ti}) + e_{ti}$$

Where

$GFTARAW_{ti}$ is the GFTA-2 Raw Score or number of speech sound errors

π_{0i} is the intercept

π_{1i} is the time slope representing the growth rate of GFTA-2 raw scores

$TIME_{ti}$ is the assessment number

e_{ti} is the error term

This Random Intercepts Model/Unconditional Growth Model was used to create a baseline for speech development over time, which we compared with subsequent conditional models. Error terms were selected to build the assumption into the model that GFTA raw scores

vary from child to child and that the strength of the relationship between time points and GFTA raw scores varies between groups. A statistically significant relationship was found between GFTA raw scores and time, $b = -7.29$, $p < .001$. The effect size was determined by calculating the variance explained by time in the GFTA raw score, $r^2 = .557$. This would be considered a large effect size. Building this model in HLM shows that the development of speech sounds over time explains 56% of the variance in GFTA-2 raw scores.

Level 2 Model: Random Intercepts and Slopes Model

Next, we constructed a model to test for interactions between predictor variables. Of specific interest was the relationship between the GFTA-2 raw score (level-1 outcome variable) and language ability, degree of hearing loss, intelligibility, IQ, maternal level of education, chronological age (level-2 predictor variables). Using HLM growth curve modeling, level 1 defined the trajectory of growth over time, and level 2 defined the deflections from this trajectory that are attributable to the demographic characteristics. All of the variables were simultaneously entered in the level 2 model. Maternal level of education, IQ, and identification of hearing loss by 6 months of age, were not significant predictors of GFTA-2 raw scores. Therefore, these three variables were removed from the model. The following final model best predicts the slope and intercept of GFTA-2 raw scores for children with hearing loss:

$$\begin{aligned}\pi_{0i} &= \beta_{00} + \beta_{01}*(EOW2SS_i) + \beta_{02}*(INTELLTH_i) + \beta_{03}*(MILDORNO_i) + r_{0i} \\ \pi_{1i} &= \beta_{10} + \beta_{11}*(EOW2SS_i) + \beta_{12}*(INTELLTH_i) + \beta_{13}*(MILDORNO_i) + r_{1i}\end{aligned}$$

Where

π_{0i} is the intercept of child i 's change trajectory

π_{1i} is the time slope of child i 's change trajectory

β_{00} is the population average given the level 2 predictor values

β_{01} is the population average difference in level 1 intercept for a 1 unit difference in the level 2 predictor

β_{10} is the population average of the level 1 slopes given the level 2 predictor

β_{11} is the population average difference in the level 1 slope given a 1 unit difference in the level 2 predictor

$EOW2SS_i$ is the level 2 predictor of the Expressive One Word Standard Score

$INTELLTH_i$ is the level 2 predictor of Intelligibility

$MILDORNO_i$ is the level 2 predictor of Degree of Hearing Loss

r_{0i} is the level 2 residuals in intercept across all individuals

r_{1i} is the level 2 residuals in slope across all individuals

All variables significantly contributed to the model and can be viewed in Table 2.5. These variables are graphically depicted in Figures 2.5, 2.6, and 2.7. The results indicate that the degree of hearing loss, EOWPVT scores, and intelligibility influence the strength of the relationship between time and GFTA-2 raw scores.

Table 2.5. Final estimation of fixed effects for research question #1

Fixed Effect	Coefficient	Standard Error	t -ratio	Approx. $d.f.$	p -value
For INTRCPT1, π_0					
Intercept	49.94	13.46	3.71	64	<0.001
EOWPVT	-0.39	0.10	-3.79	64	<0.001
Intelligibility	4.28	2.03	2.11	64	0.039
Degree of Hearing Loss	15.03	3.74	4.01	64	<0.001
For Slope, π_1					
Intercept	-15.43	4.60	-3.36	132	0.001
EOWPVT	0.11	0.04	3.10	132	0.002
Intelligibility	1.72	0.70	2.48	132	0.02
Degree of Hearing Loss	-3.87	1.28	-3.02	132	0.003

Figure 2.5. Mean GFTA-2 raw scores as a function of degree of hearing loss in 5 categories

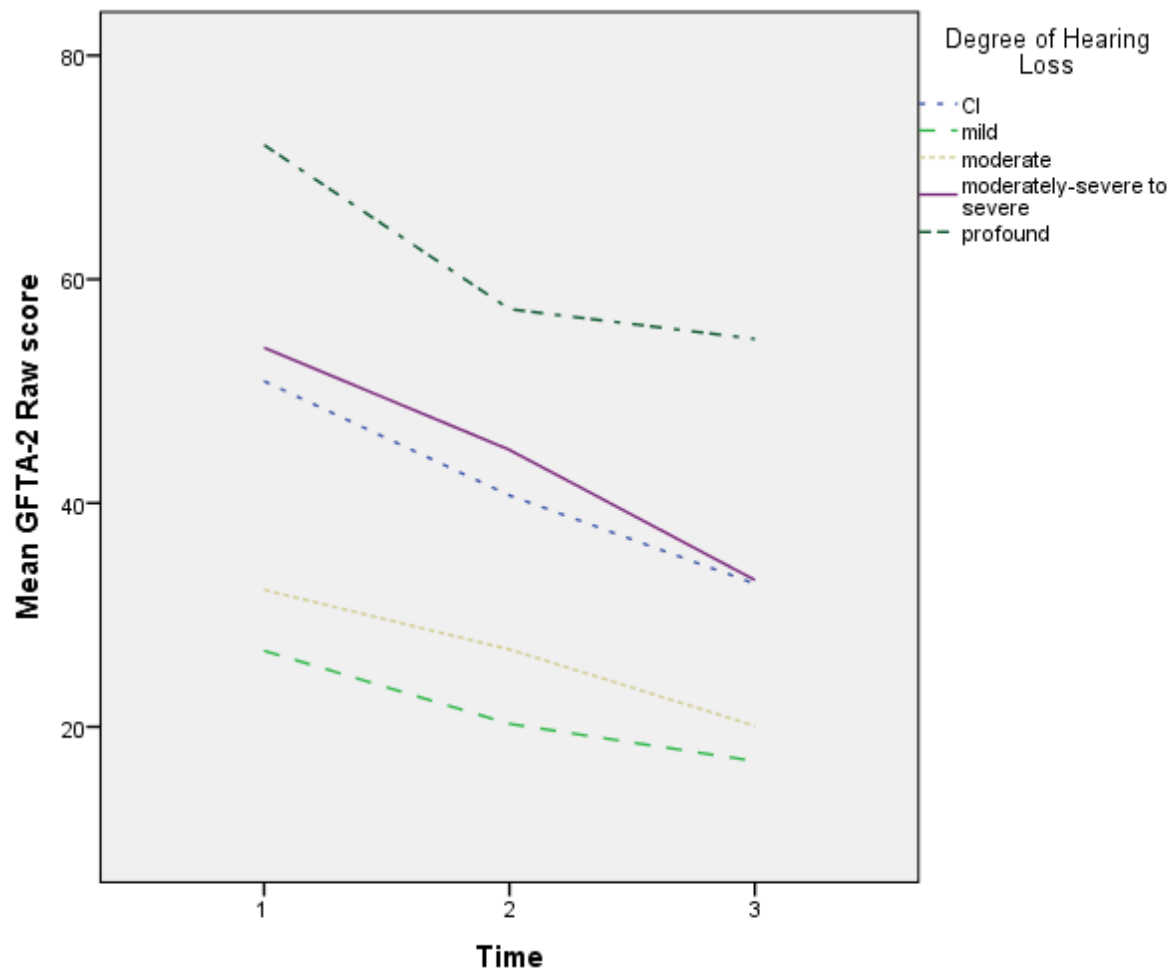


Figure 2.6. Mean GFTA-2 raw scores as a function of degree of hearing loss collapsed into two categories

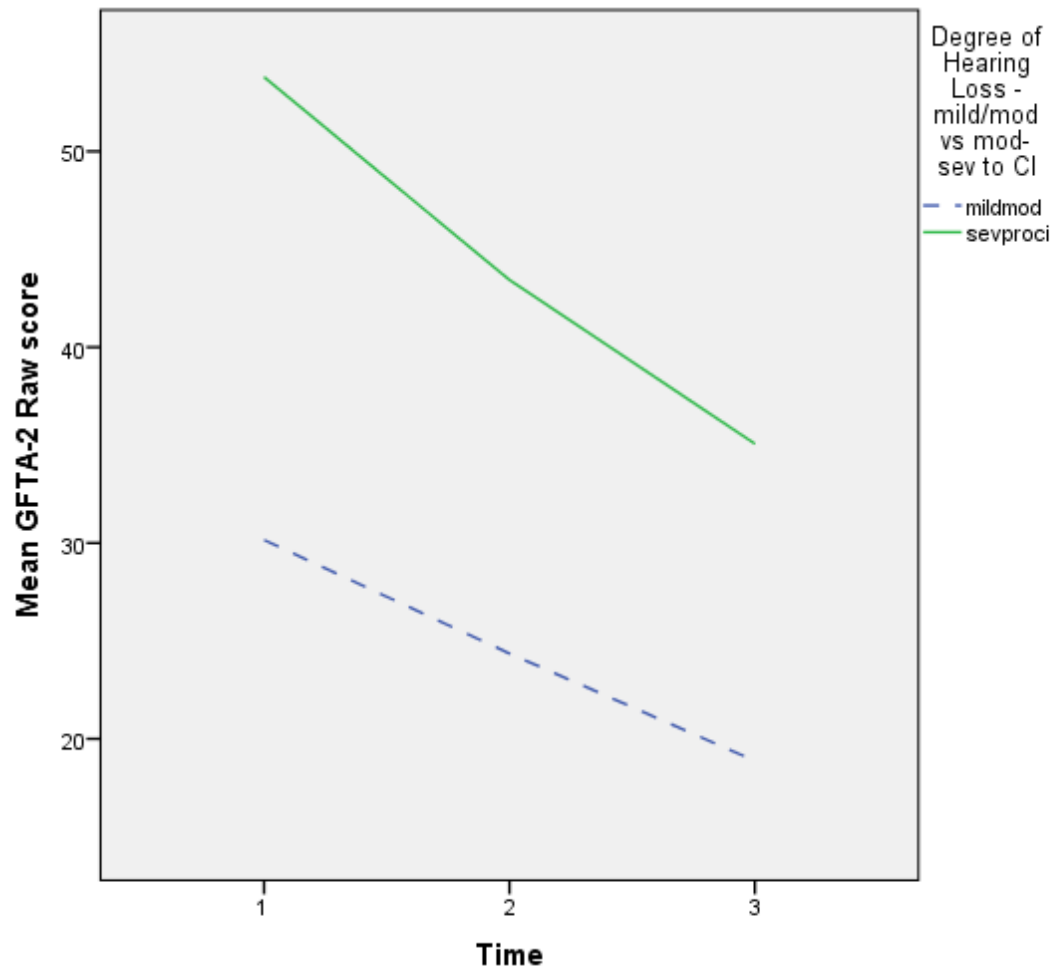
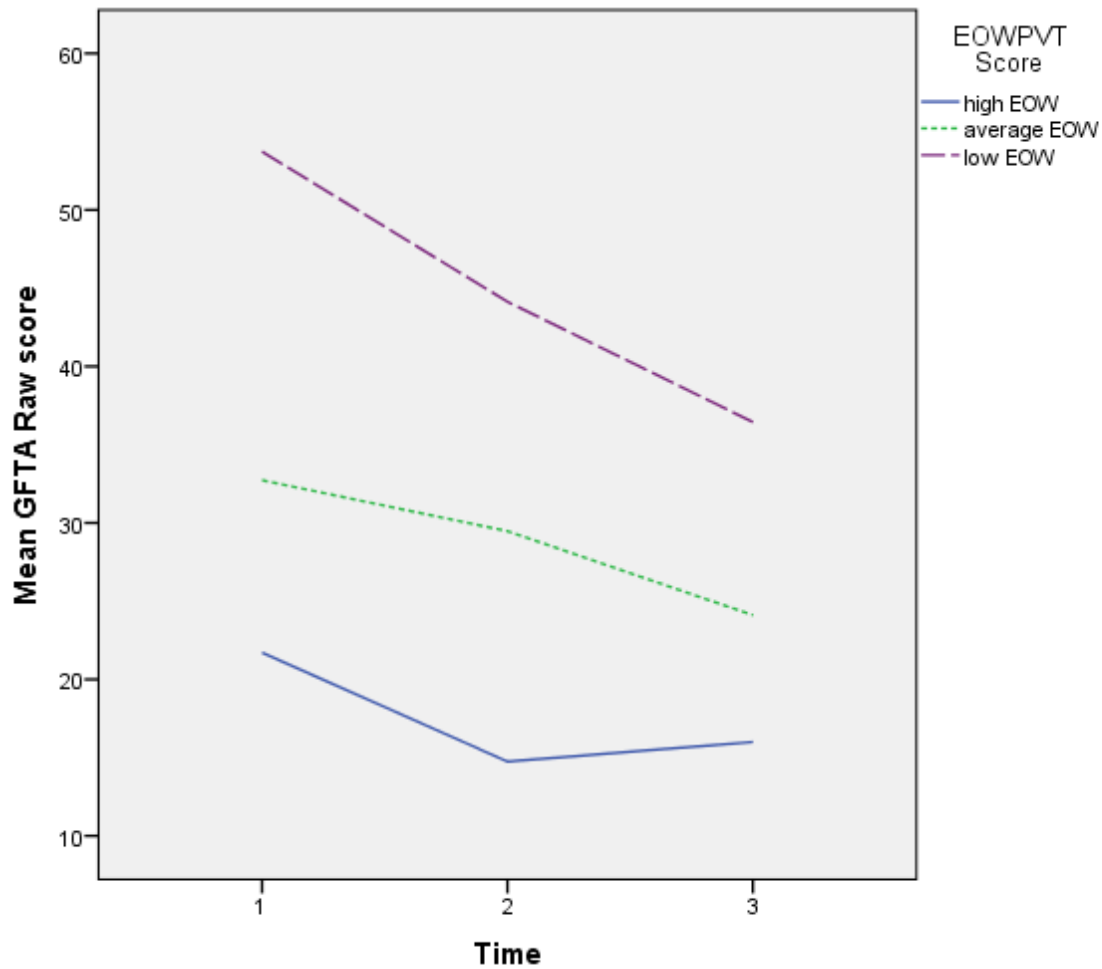


Figure 2.7. Mean GFTA-2 raw scores as a function of EOWPVT standard score



Research Question #2: Prediction Model

Is the number of consonants produced when the children were 27 to 33 months old predictive of GFTA-2 performance? Performance is measured by raw score on the GFTA-2 at the first test session (intercept), and rate of growth is measured between the ages of 4 to 7 years old.

We again confirmed variability in the outcome variable (GFTA raw score) using the following equation for the children who had early speech sound production data: $GFTARAW_{ij} = \beta_{0j} + r_{ij}$. There is variance in the outcome variable by the level-2 groupings, and the use of HLM is supported, $\chi^2(49) = 335.70, p < .001$.

Level-1 Model: Random Intercepts Model

Next, we tested the relationship between the outcome variable (GFTA raw score) and the level-1 predictor variable (time) using the following equation

$$GFTARAW_{ij} = \beta_{0j} + \beta_{1j} * (TIME_{ij}) + r_{ij}$$

Where

$GFTARAW_{ti}$ is the GFTA-2 Raw Score

β_{0j} is the intercept

β_{1j} is the time slope representing the growth rate of GFTA-2 raw scores

$TIME_{ij}$ is the assessment number

r_{ij} is the error term

The results support the relationship between GFTA-2 raw scores and time, $b = -6.74, p < .001$. GFTA-2 raw scores are lower (i.e., better) over time. The effect size was determined by calculating the variance explained by time in GFTA raw score, $r^2 = .509$, which would be considered a large effect size. Building this model explains 51% of the variance in the GFTA-2 raw scores.

Level-2 Model: Random Intercepts and Slopes Model

A final model was constructed to determine whether the rate of growth and intercept of GFTA-2 scores could be predicted according to an early speech sound production measurement. The following model was used:

$$\beta_{0j} = \gamma_{00} + \gamma_{01}*(PRELIPP2_j) + u_{0j}$$

$$\beta_{1j} = \gamma_{10} + \gamma_{11}*(PRELIPP2_j) + u_{1j}$$

Where

β_{0j} is the intercept of child i 's change trajectory

β_{1j} is the time slope of child i 's change trajectory

γ_{00} is the population average given the level 2 predictor values

γ_{10} is the population average difference in level 1 intercept for a 1 unit difference in the level 2 predictor

γ_{01} is the population average of the level 1 slopes given the level 2 predictor

γ_{11} is the population average difference in the level 1 slope given a 1 unit difference in the level 2 predictor

$PRELIPP2_j$ is the level 2 predictor variable of total consonants

u_{0j} is the level 2 residuals in intercept across all individuals

u_{1j} is the level 2 residuals in slope across all individuals

The results of this analysis support that the slope ($b = 0.64, p < .001$) and intercept ($b = -3.33, p < .001$) of GFTA-2 raw scores can be predicted using a measurement of consonant inventory between the ages of 27 to 33 months. Results are displayed in Table 6. This model also indicates a cross-level interaction, which means that the total number of consonants influences the strength of the relationship between GFTA-2 scores over time. Meaning, the existing relationship between GFTA-2 scores and time becomes stronger when the total number of consonants is added to the equation.

Table 2.6. Final estimation of fixed effects for research question #2

Fixed Effect	Coefficient	Standard Error	<i>t</i> -ratio	Approx. <i>d.f.</i>	<i>p</i> -value
For INTRCPT1, β_0					
Intercept	91.63	7.22	12.70	48	<0.001
PRELIPP2	-3.33	0.46	-7.28	48	<0.001
For Slope, β_1					
Intercept	-16.42	2.19	-7.49	98	<0.001
PRELIPP2	0.64	0.14	4.59	98	<0.001

Discussion

The results of this study demonstrate that children with all degrees of hearing loss improve in their speech sound production between the ages of 4 and 7 years. We were particularly interested in examining which factors best predict the rate of growth (slope) and intercept for speech sound development. Two models were derived during the analysis. We first examined concurrent testing and demographic factors to determine which demographic variables impact development. We also considered a second model to determine whether speech ability at 27 to 33 months of age could predict later speech development. The results from each of the study questions and some of the implications are discussed below.

Predicting the rate of growth and intercept of speech sound development based on demographic characteristics

As part of the model for predicting speech sound development based on selected demographic characteristics, we tested six different variables for statistical significance. Three of the variables—all of which can be affected by intervention and therapy—were found to be statistically significant. Importantly, and perhaps contrary to conventional wisdom and other studies, certain immutable demographic characteristics were not found to be statistically significant. These findings are a reason for optimism and for a renewed focus on intervention.

The three factors found to be statistically significant predictors of speech-sound development in the concurrent model were the EOWPVT standard score, intelligibility rating by the therapist, and degree of hearing loss. Specifically, higher EOWPVT scores, better intelligibility ratings, and lesser degrees of hearing loss were associated with better GFTA-2

scores over time. The finding that the vocabulary score contributed to better speech outcomes supports findings from previous literature for both children with hearing loss (Ambrose et al., 2014; Obenchain et al., 2000) and those with typical hearing (Stoel-Gammon, 1998). Consistent with Tobey et al.'s (2003) findings, speech intelligibility was highly related to correct consonant production. The results are also consistent with historic and current literature showing that greater degrees of hearing loss are associated with increased errors in production (Flipsen, 2011; Gordon, 1987; Yoshinaga-Itano & Sedey, 2000). This study adds to a growing body of work indicating that young children with hearing loss require high-quality auditory access to develop typical speech.

Additional demographic factors were considered in the model and found to be not significantly related to speech-sound outcomes, at least when the other variables were considered. These factors included nonverbal intelligence, maternal level of education, and identification of hearing loss by 6 months of age. This finding was different from the work of Tobey et al. (2003) who found that nonverbal intelligence, socioeconomic status, and implant characteristics influenced speech production. The difference in findings may be due to the fact that the subjects in Tobey et al.'s study were older and all had profound hearing loss using cochlear implants. The impacts of maternal level of education, socioeconomic status, and age of identification may be mediated by access to early intervention, as found by Yoshinaga-Itano (2000). As in the current study, previous research by Yoshinaga-Itano and Sedey (1998) showed that the identification of hearing loss by 6 months was not a predictor of speech sound production for children in Colorado.

The results of the current study are promising because they indicate that immutable demographic characteristics can be overcome by intervention from a deaf educator or speech

pathologist. An interventionist is not able to impact a child's innate cognitive abilities. Nor can an interventionist affect the maternal level of education or the age at which hearing loss is confirmed. However, the remaining variables (those significantly related to speech-sound production) are areas that a therapist or educator can positively impact. Through intervention, vocabulary and speech intelligibility can be directly targeted and improved. Although a child's degree of hearing loss cannot be changed, an interventionist can help maximize auditory access in an effort to mitigate the difference found by degree of hearing loss. This can be done by ensuring auditory access to all speech sounds and that the amplification is worn during all waking hours.

The findings in this study are in some ways disconcerting because dramatic differences between outcomes remain for children with different degrees of hearing loss. Theoretically, amplification has the potential to equalize the child's auditory access to spoken language, at least in quiet. Given technological gains, hearing loss is not an immutable characteristic. These findings highlight the importance of empowering families to aggressively monitor and maximize hearing through amplification. An interventionist can play a positive role in monitoring for progressive hearing loss, ensuring auditory access to speech frequencies, checking amplification for working batteries, troubleshooting amplification as needed, and providing consistent feedback to the managing audiologist.

Speech sound errors and poor speech intelligibility have the potential to negatively affect many aspects of a child's development. Children who have persistent disordered speech patterns may have difficulty learning to read and spell (Catts, 1989). Children who are typically developing reach 100% conversational intelligibility by the age of 4 years (Coplan & Gleason, 1988; Flipsen, 2006). Children who have very poor intelligibility will likely have difficulties

with decoding and spelling (Larrivee & Catts, 1999; Snowling & Stackhouse, 1983).

Additionally, poor speech intelligibility has been found to negatively impact social competence in preschool children with hearing loss (Most, Ingber, & Heled-Ariam, 2012.) Parents may want to request extra monitoring in the areas of decoding, spelling, and social development if their child has poor speech sound production.

Predicting rate of growth and intercept of speech sound development based on early speech sound production

The second model considered whether speech sound production between the ages of 27 months and 33 months could predict the rate of growth and intercept of GFTA-2 raw scores when children were 4 years to 7 years old. Early consonant inventories were found to be predictive of later speech sound production abilities. This finding is consistent with and extends the work of Ambrose et al. (2014), who found that early speech assessment scores at age 2 predicted speech production scores at age 3.

The results of this study combined with the findings of Ambrose et al. (2014) significantly challenge the “wait and see” approach that early intervention often takes with regard to speech sound development. If a child’s speech production at the time of transition from early intervention to school-age services predicts their rate of growth over the next 4 years, treatment plans should be designed accordingly with an aggressively proactive approach to intervention.

Additional Considerations

This study adds to the growing body of literature that shows that children with hearing loss can be successfully evaluated using the GFTA-2 (Buhler et al., 2007; Chin and Kaiser, 2000; Flipsen, 2011). Knowing that children with hearing loss can be assessed using the GFTA-2, we

can begin to precisely compare how they are performing relative to their hearing peers. Flipsen found that 4 out of 15 of the children tested in his study, or 27%, had standard scores in the average range. He only tested children with cochlear implants. Similarly, in this study, 26% of the children with hearing losses ranging from mild to severe (including those with cochlear implants) had scores in the average range. However, the number of children scoring within the average range significantly varied depending on the degree of hearing loss. The highest percentage of scores in the average range was 51% for the children with mild losses.

Another method to compare speech development in children with hearing loss to that of typically developing children is to consider consonant percentage accuracy. Typically developing children reach slightly below 100% accuracy for consonant development by 6 to 8 years of age (Menyuk, 1972; Shriberg et al., 1994). Despite the fact that children with hearing loss make continuous progress over the study period, their scores do not approach 100%. The closest hearing loss group includes children with mild hearing loss. Children in this group reach an average of approximately 85% accuracy

Some studies use hearing age, or the length of time that a child has their cochlear implant or hearing aids, as a proxy for chronological age. In this study, we did not consider hearing age because we do not want to instill a false sense of outcomes for young children with hearing loss. Hearing age can provide an alternate method to assess the performance of young children with hearing loss who may show encouraging progress to providers or parents. However, by the time those children reach school age, as was the case for the children in this study, a hearing age adjustment is generally not appropriate if the child received amplification and intervention early in life. Additionally, if our ultimate goal and expectation is that young children with hearing loss will achieve age-appropriate milestones, chronological age norms should be used.

School-age services present a number of unique challenges that parents should be aware of as they transition out of early intervention. Notably, caseloads for school speech therapists are typically high. To be eligible for therapy services, a child must perform significantly below his or her peer group. Most of the children in this study were intelligible at some level and therefore may not qualify for speech therapy services at school. Moreover, once children enter school-age services, they may no longer be served by a speech pathologist who specializes in hearing loss. General speech pathologists may not have access to the same skillset in amplification monitoring. A team approach may be necessary to ensure that general speech pathologists receive appropriate training or to ensure that each child has sufficient time allocated for an itinerant teacher to monitor amplification on a frequent interval.

Children with hearing loss often do not qualify for speech services because the sounds that they are not producing accurately are typically considering “later developing” phonemes. What is often not considered, however, is the quantity of later developing phonemes that are produced incorrectly. Whereas a hearing child may have difficulty with one later developing sound (typically /r/ or /s/) as they enter school, children with hearing loss frequently have several later-developing sounds in error. The assertion that this is not typical is supported by the below-average standard scores many of the children obtained on the GFTA both in the current study and previous research. When determining eligibility for speech therapy as a child enters school, it is critical to look beyond the specific phonemes the child has not yet achieved and administer an articulation test that includes normative information. This provides a more accurate picture of the child’s speech production ability relative to what is expected for his/her age.

Whereas the “wait and monitor” philosophy works for the majority of hearing children who will develop all of the phonemes of English by age 6 to 8 (Shriberg et al. 1994), there are

many phonemes that 90% of a group of children with hearing loss have not developed by age 7 and some sounds that even 50% of the children are not producing accurately by 7 years of age (Wiggin, 2015). Thus, it appears that the natural acquisition of speech seen in the majority of hearing children is not the norm among most children with hearing loss. This supports the need for direct speech intervention if our goal is for children with hearing loss to accurately produce the full complement of English phonemes.

Limitations and Future Directions

This study has some inevitable limitations that are inherent to large-scale studies of children with hearing loss. Because hearing loss is a low incidence disability, substantial time is required to recruit a sizable sample. Though the children in this study received the same sequence of identification, amplification, and intervention as a child born today, these data were collected between 1997 and 2004. Thus, all of the children were born after state legislation for the implementation of universal newborn hearing screening. It could be anticipated that advancements in amplification and improvements in service delivery will improve the outcomes reported in this article.

Future work should continue to investigate developmental theories, such as those in the work of Menyuk (1972) and Shriberg, Gruber, and Kwiatkowski (1994), which showed that children who are typically developing master the sounds native to their language between 4 and 8 years old. Shriberg and colleagues suggest that errors persisting beyond the age of 8 years are abnormal because continual growth is no longer expected after the age of 8. According to this theory, speech development for children with hearing loss would be expected to plateau at age 8 regardless of hearing age. The current results show that children with hearing loss make continual progress between the ages of 4 to 7 years but that the progress is negatively impacted

by hearing loss and that significant hearing loss worsens the impact. Additional years of data collection are necessary to determine whether children with hearing loss plateau at a chronological age of 8 years or at a hearing age of 8 years.

As researchers learn more about hearing loss, the aspects of speech, language, and audition have been shown to be increasingly interrelated. Future studies with this sample will include information on auditory skill ability. Notably, this study found that vocabulary helped predict speech sound development. The amount of parent talk has been shown to predict vocabulary (Gilkerson & Richards, 2008); thus, future work could consider whether a parent talk variable was a significant predictor of sound production development. If this variable increased the amount of variance accounted for in the HLM analysis, this would represent an additional aspect that a provider could impact through parent education and modeling. This study and the potential for such future knowledge underscore the importance of early and proactive intervention for young children with hearing loss.

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CHAPTER IV

The Value of Educational Programming and Exploring the Impact of Parent Education:

Why is continuing summer service vital for children with hearing loss?

Introduction

Language Acquisition in Typically Developing Children

The importance of rich language stimulation in child development has been thoroughly established (Chapman, 2000; Hart & Risley, 1995; Rowe, 2008). Quality language environments are associated with stronger language outcomes, which in turn are associated with improved educational outcomes (Hoff, 2003; Pan, Rowe, Singer, & Snow, 2005). Conversely, children without a quality language environment are at risk for lower IQ, reduced academic achievement, and delayed language acquisition (Topping, Dekhinet, & Zeedyk, 2011). Unfortunately, not all children have access to rich language environments, and the amount and quality of language spoken in homes varies dramatically (Gilkerson & Richards, 2009; Hart & Risley, 1995).

Optimal language acquisition depends upon engaged parents (Topping, Dekhinet, & Zeedyk, 2013) providing a high quality and quantity of language to the child (Hart & Risley, 1995; Huttenlocher, Haight, Bryk, Seltzer, & Lyons, 1991). Quality language input includes exposure to varied vocabulary and extended discourse with cognitive and linguistic stimulation

(Dickinson, 2001). When children are exposed to a greater quantity and quality of language in the home environment, they hear more grammatical, phonological, and lexical complexity (Blackwell, 2005; Goodman, Dale, & Li, 2008; Hart & Risley, 1995, 1999). Similarly, exposure to more adult language gives children increased opportunities to develop lexical processing skills (Hurtado, Marchman, & Fernald, 2008).

A child's home language environment matters beyond early childhood and continues to impact educational outcomes during school-age years. For second grade students, the quality of a child's home language environment remains predictive of a child's vocabulary, whereas school language exposure does not (Dickinson & Tabors, 2001). A child's vocabulary, in turn, is the best predictor of literacy at the end of third grade (Hemphill & Tivnan, 2008). The relationship between the home language environment, vocabulary development, and literacy underscores the importance of access to quality language environments for school-age children.

Language Environments for Children with Hearing Loss

Children with hearing loss need access to quality language environments as much as, if not more than, typically hearing children (Vohr, Topol, Watson, St Pierre, & Tucker, 2014). Children with hearing loss often have language acquisition delays due to reduced auditory access, and maximizing the language that is available is important for producing optimal outcomes. Stronger home language environments are associated with higher language test scores for school-age children with hearing loss (Vohr et al., 2014).

Measuring Language Environment

Language environment can be measured through a variety of different assessment tools such as videotape analysis, parent questionnaires, and teacher observation checklists. Each measurement tool provides different types of information. All three of these assessment tools

provide a “snapshot” into the child’s language environment. Parent questionnaires and teacher observation checklists show the language environment through the lens of the person completing the forms. Videotape analysis, due to the time-consuming nature and expense, is typically limited to a short time sample of the child’s language environment.

Language environment can be measured in a continuous, direct, and objective way using Language Environment Analysis (LENA) (Xu et al., 2008). This is a tool that identifies key aspects of the language environment such as adult word count (AWC), conversational turns (CTC), and child vocalizations (CVC). It has been shown to effectively measure language environments for a variety of populations such as, children who are language delayed (Oller et al., 2010), children with autism spectrum disorder (Burgess, Audet, Harjusola-Webb, 2012; Dykstra et al., 2013; Warren et al., 2010), children with hearing loss (Wiggin, Gabbard, Thompson, Goberis, & Yoshinaga-Itano, 2012), and daycare language environments (Soderstrom & Wittebolle, 2013).

Summer Learning Loss

A substantial body of literature has demonstrated that all children lose skills during the summer months. In a meta-analysis, Cooper, Nye, Charlton, Lindsay, and Greathouse (1996) quantified this phenomenon and concluded that the amount of learning loss during summer vacation was equal to that learned during one month of instruction. Some children showed little or no academic growth over the summer, whereas other students lost up to three months of learning.

The negative impact of long summer vacation has been addressed by policy statements such as the National Education Commission on Time and Learning (1993), which advocated for adjustments to school calendars to better reflect the changes in American society and student

learning. Additional evidence from Sargent and Fidler (1996) indicated that summer learning is especially needed by children with learning disabilities. Although many states mandate extended school year programming for children with learning disabilities (Katsiyannis, 1991), such programming does not typically extend to preschool or children with hearing loss. Katsiyannis identified a number of hurdles to providing extended school year services, including funding, standards of regression/recoupment, data collection, and judging the quality of the present programming.

Substantial emphasis has been placed on studying differences in the seasonality of children's learning across social lines (Alexander, Entwisle, & Olson, 2001). A smaller body of literature addresses summer learning loss in children with special needs. It is difficult to measure the effect of summer learning loss in such children because "special needs" is a broad term that encompasses a variety of disabilities and severities. Additionally, summer learning loss for children with limited language can be difficult to measure because standardized language tests do not detect fine changes in skill levels and can often only be administered once every 6 to 12 months.

Counteracting Summer Learning Loss Through Parent Involvement and "Time-on-Task"

One possible solution to counteract detrimental summer learning losses is summer school for children who continue to exhibit language delays. Cooper, Charlton, Valentine, and Muhlenbruck (2000) examined summer programs and found that structured and strategically planned programs lead to positive effects on student outcomes.

Effective summer programs can counteract summer learning loss by increasing the "time-on-task". Carroll (1963) proposed that true learning depends on the amount of time a student spends actively engaged in the learning process compared with the amount of time the student

needs in order to learn. Extending the ideas of Carroll's work suggests that increasing the time children with hearing loss spend in rich language environments (by providing high-quality preschool time) will improve their language skills.

Additionally, summer programming can be used to increase parent involvement. There is a well-documented connection between parent involvement and student achievement for typically developing children and children with hearing loss dating back to Coleman and colleagues in 1966. More recently, Fan and Chen (2001) and Jeynes (2003, 2005, 2007) conducted separate meta-analyses documenting the statistically significant relationship between parent engagement and student achievement. Specific effective parenting behaviors that were identified by Fan and Chen (2001) included setting expectations and holding aspirations for student achievement, communicating with the school or teacher, communicating with children about school, participating in school activities, and setting expectations that support education in home activities. Calderon (2000) found that both parent involvement and parent communication skills positively contribute to language and academic performance in the early school years.

The connection between family involvement and educational success means that promoting parent engagement is one method to minimize achievement gaps. Notably, parent training has been shown to be an effective method to change the form and content of child language (Girolametto & Weitzman, 2006; Law, Garret, & Nye, 2004). Studies analyzing preschools with home visit components, moreover, have demonstrated that such programs produce positive outcomes by increasing parent involvement (Karoely, Kilburn, & Cannon, 2005; Love et al., 2005; Reynolds et al., 2007; Schweinhart et al., 2005). Home visits enable increased and individualized communication between teachers and parents, create an opportunity to encourage parents to hold high aspirations for their children, and facilitate the carryover of

academic activities in the home environment. The connection between parent engagement and child outcomes is also evident in the literature for children with hearing loss.

This exploratory research considers summer preschool attendance and parent involvement as methods to counteract summer learning loss. More specifically, this study describes and compares quantitative characteristics of the home and school language environments for young children with hearing loss as well as the impact of parent education on the home language environment.

Research Questions

1. Does attending a summer preschool program create the opportunity for children to access more language as measured by adult word count (AWC) and conversational turn count (CTC)?
2. Can parent education increase adult word count (AWC) or conversational turn count (CTC) during a summer preschool program?

Methods

Recruitment

Children were recruited from a private summer preschool program for children with hearing loss. All of the children attended a public or private preschool program during the academic year. Academic year placements included mainstream classrooms, auditory-oral classrooms, or total communication classrooms. The eligibility criteria for participation in the preschool program included (1) children between the ages of 3 to 5 years old; (2) deaf or hard-

of-hearing using appropriate hearing technology; (3) additional disabilities were carefully considered at the time of application to determine potential for spoken language and appropriateness for the preschool setting; (4) English spoken language level of 18 months to 4 years; (5) participation in pre & post speech/language and learning assessment; (6) participation in entire 6-week preschool session and (7) parent participation in all parent information sessions. All children who participated in the summer preschool program were included in the research study. Informed consent was obtained from the parents for the evaluation and recordings with Language Environment Analysis (LENA) devices (Xu, et al., 2008).

Description of Preschool Program

The preschool program was a 6-week summer auditory-oral preschool program designed to help address summer learning loss for young children with hearing loss (Wiggin, Gabbard, Thompson, Goberis, & Yoshinaga-Itano, 2012). A maximum of eight students were enrolled each summer, and the children attended school 3 half-days per week. The classroom was led by a master deaf educator who was supported by two speech-language pathologists with expertise in deafness. The classroom followed a thematic curriculum targeting vocabulary and language development.

The preschool was designed to include a significant parent involvement component. During the 6-week preschool program, the parents were required to attend 3 parent education sessions that provided information on hearing technology, LENA, language strategies, and literacy. The parents were also required to attend an observation of the classroom and participate in individual family-child therapy sessions. Daily journals were written at school and home to facilitate communication between parents and educators. Newsletters were sent home for each

thematic unit with the target vocabulary and explanation of the activities in the classroom. Materials were sent home including a copy of the story book and toys related to the theme to help parents in carrying over vocabulary at home. Data was collected over 4 summers from 2011 to 2014.

Assessment

Background Information

Audiologic information was collected via medical record review and audiological testing prior to participation in the preschool. Demographic data were collected for participants including the maternal level of education.

Language Testing

Child language was assessed using the Clinical Evaluation of Language Fundamentals – Preschool, Second Edition (CELF-P2), a standardized language test for children that is normed for typically developing children. The subtests use scaled scores with a mean of 10 and standard deviation of 3. The core language score has a mean of 100 and a standard deviation of 15. Testing was completed in spoken language by a speech-language pathologist who was familiar with the assessment and who worked with young children with hearing loss.

Language Environment Recording

The language environment in the preschool and home was measured using the Language Environment Analysis digital language processor (DLP) (LENA). The LENA DLP weighs 2 ounces and is worn by the child in a cotton vest or t-shirt specifically designed for recording. The device records for up to 16 hours (Ford, Baer, Xu, Yapanel, & Gray, 2008).

The LENA analysis software was used to analyze the audio recordings; the software also uses algorithms to characterize the language environment. LENA calculates conversational turns (CTCs), child vocalizations (CVCs), adult word count (AWC), the percentage of meaningful language, the percentage of television/automated speech, and the percentage of silence. Detailed descriptions of these measures can be found in Oller et al. (2010) and Xu et al. (2008).

Each feature of language is calculated in the analysis software through specific speech-identification algorithms (Ford, Baer, Xu, Yapanel, & Gray, 2008; Gilkerson and Richards, 2008). CTCs are reciprocated speech segments between any adult and the target child that occur within 5 seconds. The CVCs represent the estimated number of words or speech vocalizations of at least a 50-m/sec duration surrounded by a minimum of 300 m/sec of silence or separated by other sounds. The AWC represents the estimated number of words spoken within the range of the DLP. The percentage of meaningful language is calculated to include discernable language from adults and language from another child. Distant speech and unclear speech are not included in the percentage of meaningful language. Silence includes background noise, quiet, or electronic media with an average dB sound pressure level of < 32 dB.

Normative data for LENA are from a cohort of English-speaking families with children through the ages of 48 months and were validated by trained transcribers. Reliability between the automated software and transcriber reports as reported by the LENA Foundation (Yapanel, Xu, & Gray, 2009) was 82% correct for an adult speaker and 76% for the target child.

LENA Recording Schedule

A baseline LENA recording was taken prior to entry into the preschool program. This recording was a full-day recording of the child in his or her home environment. The parents

were provided with the LENA recorder, a specialized LENA t-shirt, an instruction page on how to turn on the device and a daily log to document their activities during the day. They were instructed to turn the device on at the beginning of the day when they put cochlear implants or hearing aids on their child. No information was provided about the LENA system or the measurements taken by the device. They were not informed about the type of data collected by the LENA recorder. The parents were instructed to have their child wear the device on an ordinary day. This recording set a baseline to use when comparing home and school environments.

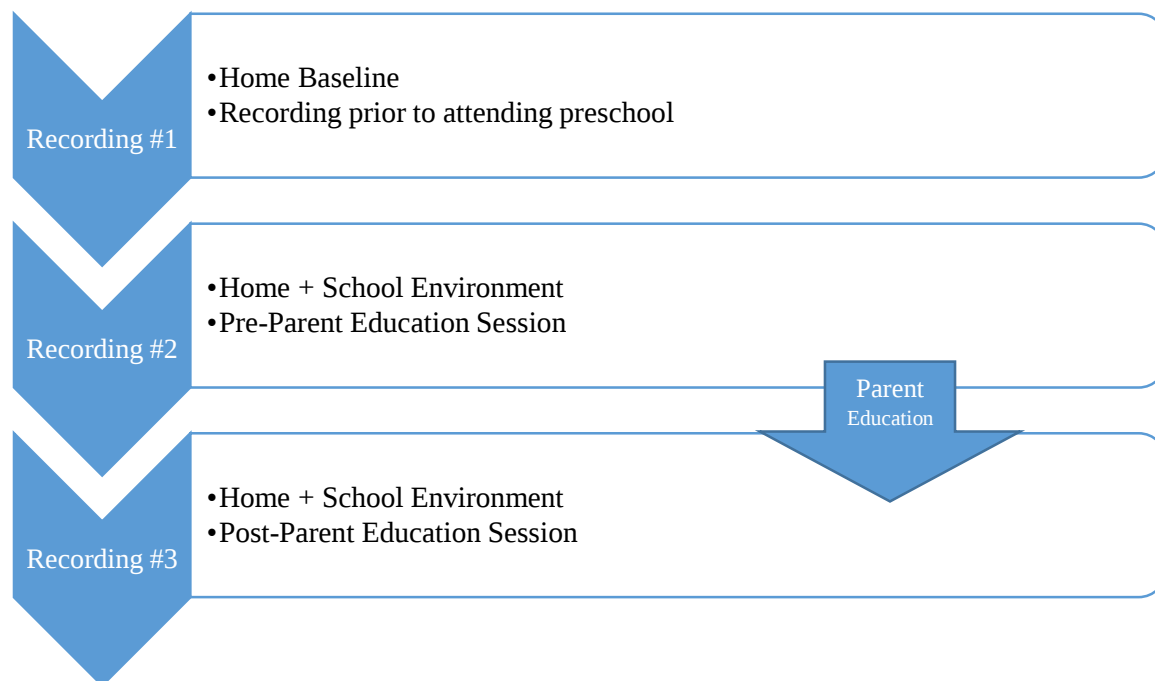
The second recording was taken at the beginning of the preschool program. This recording included 2 ½ hours in the preschool environment; the remainder of the recording was in the home environment. As with the first recording, the parents were provided with the LENA materials and a daily log to document their activities during the day, and they were instructed to turn the device on at the beginning of the day. Again, the parents were told only that the device was one of the components of the preschool program—they were provided with no information on the LENA system or the measurements taken by the device. The second recording with exposure to preschool but no exposure to the LENA reports allowed us to gather a first measurement in the preschool environment.

The final recording was taken after the parents had received feedback on their LENA recordings and parent education on language strategies. A description of the information provided to the parents during the education session is detailed below. Again, the parents were provided the same equipment and instruction to start recording when they put hearing equipment on the child. This recording followed the same format as the second recording and included 2 ½ hours of recording in the preschool environment with the remainder of the recording in the home

environment. The third recording with exposure to preschool and exposure to the LENA reports allowed us to compare the impact of parent education on the home language environment.

The complete recording schedule is illustrated in Figure 1.

Figure 3.1. LENA recording schedule



Intervention

Parents were required to participate in parent education sessions as a part of the preschool program. The parent education sessions were led by the master deaf educator and two speech pathologists who worked with the children in the preschool program. After a baseline recording taken in the home environment and a recording taken at the beginning of the preschool program, the parents participated in a language-focused educational intervention lasting 90 minutes. The session included information on LENA and provided individual LENA feedback reports for the

baseline recording taken in the home environment with graphic representations and quantitative measurements of the child’s language environment.

Specific strategies were also discussed with the parents for increasing the AWC, CTC, and CVC. Examples of strategies discussed include auditory first, scaffold to success, auditory closure, silly sabotage, open-ended questions, scaffolding questions down to success, predictions, use it or lose it!, checking for comprehension, plus one – give it back expanded, pause for processing, and close with auditory. A brief description of each strategy can be found in Table 1. The strategies target both the quality and quantity of the language in the home environment.

Table 3.1. Description of strategies for increasing language in the home as discussed during parent education sessions

<i>Strategy</i>	<i>Description</i>
Auditory first	Present information through audition prior to offering gestures or visual supports.
Auditory closure	Give the child opportunities to fill in missing information. For example, “There are clouds in the _____”
Open-ended questions	Ask questions that prompt thoughtful and more detailed answers.
Scaffolding questions down to success	Do not drop a learning opportunity if a child cannot answer a question. If the child is not successful in answering, bring the question down to a level that he/she will be successful with and then teach them.
Predictions	Ask the child to make predictions to help generate spontaneity.
Silly sabotage	Suggest the “wrong” answer so that the child spontaneously offers the “right” answer.
Use it or lose it!	Give the child an opportunity to use a new vocabulary word or concept immediately after learning it.
Checking for comprehension	Continually monitor for comprehension during conversations and books by asking questions and giving the child an opportunity to demonstrate knowledge.
Plus one – give it back expanded	Take what the child says and add to the word or phrase with additional information.
Pause for processing	Give the child time to think through answering a question prior to providing the answer.
Close with auditory	Be sure to finish an interaction with an auditory-only model of the word or concept if a visual support or gesture is used.

Parents were asked to identify times of the day that had low language based on their individualized LENA report and to select a strategy to apply during those times. The family was asked to set a goal for increasing AWC and CTC. Parents were sent home with copies of their individualized LENA reports, a list of language strategies, and their goal sheet.

Participants

Twenty-one children from the Marion's Way Preschool Program were included in the study. This group consisted of all children who were deaf or hard-of-hearing between the ages of 3 to 5 years old who were using appropriate hearing technology with no significant additional disabilities that impacted their acquisition of spoken English. All of the children had an English spoken language level of 18 months to 4 years. Table 2 provides relevant background details on individual subjects as well as their language evaluation score. The following description includes all of the children that participated in the study.

Table 3.2. Participants.

	Gender	Age	HL Category	Acquired or Congenital	Age of HL confirmation	CELF-P2 Core Standard Score	Maternal level of education
<i>Child ID</i>							
C101*	F	39 mos	Mild	Acquired	15 mos	102	18 years
C102*	M	66 mos	Severe	Congenital	1 mo	57	12 years
C103*	F	38 mos	Moderately severe	Acquired	18 mos	114	18 years
C107*	F	51 mos	Cochlear Implant	Acquired	11 mos	90	16 years
C145 ^{†*}	M	55 mos	Cochlear Implant	Congenital	1.25 mos	67	12 years
C146 ^{†*}	F	62 mos	Moderate	Congenital	1.25 mos	69	12 years
C148 ^{†*}	M	57 mos	Moderate	Congenital	1 mo	81	12 years
C149 ^{††*}	F	59 mos, 71 mos	Cochlear Implant	Unknown	39 mos	69	18 years
C150 [†]	M	36 mos	Moderate	Congenital	.50 mos	105	16 years
C151 ^{††*}	M	43 mos, 55 mos	Mild	Congenital	3 mos	92	16 years
C186 ^{†*}	F	48 mos	Profound (Hearing Aids)	Congenital	.75 mos	57	12 years
C187 ^{††*}	F	42 mos, 54 mos	Profound (Hearing Aids)	Congenital	.25 mos	61	5 years
C188 ^{†*}	M	47 mos	Mild	Congenital	1 mo	111	16 years
C204 ^{†*}	M	53 mos	Cochlear Implant	Acquired	24 mos	90	16 years
C247 [†]	M	60 mos	Moderate	Congenital	1 mo	86	14 years
C252 ^{†*}	F	69 mos	Cochlear Implant	Congenital	4 mos	55	16 years
C260*	F	49 mos	Cochlear Implant	Congenital	9 mos	86	18 years
C261 [†]	F	61 mos	Cochlear Implant	Acquired	1 mo	63	12 years
C263 ^{†*}	F	45 mos	Moderate	Congenital	1 mo	108	18 years

[†]Indicates the child was included in analysis 1.

^{††}Indicates the child was included twice in analysis 1 from two separate summer programs.

*Indicates the child was included in analysis 2.

Maternal level of education. Maternal level of education was used as an indicator of socioeconomic status. The mean education level for the total group was 14.85 years (range: 5-18 years). More specifically, 5% ($n = 1$) had less than a high school education, 25% ($n = 5$) had a high school diploma, 10% ($n = 2$) had at least some college education or post high school education, and 60% ($n = 12$) had a bachelor's degree or higher.

Degree of hearing loss. The participants' degrees of hearing loss were determined using the pure tone average (PTA: average of hearing thresholds at 500, 1,000, and 2,000 Hz) in the better hearing

ear. The participants were divided into five groups: cochlear implant, profound (better ear PTA: > 90 dB HL), severe (better ear PTA: 71-90 dB HL), moderate (better ear PTA: 41-70 dB HL), and mild (better ear PTA: 26-40 dB HL). Seven participants were categorized as having a cochlear implant, 2 as profound, 1 as severe, 6 as moderate, and 4 as having mild hearing loss. All children utilized hearing aids or cochlear implants that were verified to ensure best fit by the program audiologist prior to attending preschool. Additionally, the children were fit with personal FM systems that were worn at home and school during the preschool program.

Age of identification, intervention, and amplification. The mean age at which hearing loss was identified was 5.46 months (range: .25 to 39 months). The average age of intervention was 10.31 months (range: .25 to 39 months). The average age of amplification was 11.65 months (range: 1-42 months).

Ethnicity. The majority of the participants were Caucasian (80%, $n = 16$). Of the remaining participants, 5% ($n = 1$) were Hispanic, 5% ($n = 1$) were African American, 5% ($n = 1$) were Asian American, and 5% ($n = 1$) were mixed ethnicity.

Presence of additional disabilities. Only children with families and interventionists/teachers who reported no additional disabilities interfering with speech and/or language development were included in this analysis. One child had a diagnosis of high functioning autism but had speech and language scores within normal limits.

Gender. The participants in this study were 45% male ($n = 9$) and 55% female ($n = 11$).

Mode of communication. All families included in the study reported that they used spoken language when communicating with their child. Some of the families supported spoken language with sign language. Three children came from bilingual homes (English/Spanish, English/Arabic, and English/Russian/Sign).

Intervention program. All of the children enrolled in the study attended a preschool program during the academic year that either used total communication or an oral communication modality.

Procedures

Three assessments were completed prior to attending the preschool program. First, an audiological assessment was performed to verify the degree of hearing loss and the fit of amplification. Second, the CELF-P2 was administered as a part of the speech and language assessment. At the time of the speech and language assessment, a LENA device was sent home with the family. The family was asked to record one typical day prior to the preschool program. The parents were only told how to turn on the device. They were given no information about what LENA would measure during the day of recording. The parents were blind to the purpose of LENA for this recording and did not know the specific measurements that would be taken by the device. The LENA devices were returned by each family at the beginning of the preschool program.

A second LENA recording was taken during the first two weeks of preschool. The parents were provided with no information or feedback reports from the first LENA recording prior to the second recording. Again the parents were blind to the purpose of LENA for this recording and did not know the specific measurements that would be taken by the device. The parents were asked to start recording when the child put his or her amplification on in the morning. The child attended preschool for 2 ½ hours and then spent the remaining day in the home environment.

The third LENA recording was taken after the parents attended a parent education session about increasing language in the home environment and the LENA system. This recording was

performed in the same sequence as the second recording. The LENA device was turned on when the child's amplification was put on in the morning. The child attended preschool for 2 ½ hours and spent the remainder of the day in the home environment.

Results

Statistical Analyses

Two primary analyses were conducted. First, one day spent in the home language environment was compared with one day during which the child attended preschool and spent the remaining time in the home environment (paired samples *t*-test). Second, the impact of parent education was considered by comparing one day before and one day after the parents attended a parent education session on facilitating language and LENA (paired samples *t*-test).

Amount of language in school (Home vs. School + Home Comparison)

For this analysis, the baseline recording taken prior to preschool was compared with that taken at the beginning of preschool. Children were included in this analysis if they had a recording prior to attending the preschool program and a recording at the beginning of preschool prior to the parent education session. Seventeen children were included in this analysis. The recording taken at the beginning of preschool included 2 ½ hours in school and the remainder of the day at home. The recording schedule is illustrated in Figure 1. The word counts on these two days were compared to determine whether attending a summer preschool program creates the opportunity for children to access more language.

A paired samples *t*-test indicated that the children on average had access to significantly more language when they attended preschool for part of the day. When considering AWC, $t(16) = -4.85$, $p = .000$, and $d = 1.18$, which is an effect size much larger than typical using Cohen's (1988) guidelines. CVC was also found to be statistically significant: $t(16) = 2.68$, $p = .016$, and $d = .65$. The difference, although significant, is typical using Cohen's (1988) guidelines. AWC significantly increased with the addition of preschool, whereas the CVC significantly decreased. CTC was not statistically different for the preschool day compared with the non-preschool day; however, there was a small difference in the means with conversational turns increasing by 11.70 on average on the day the children were recorded in the preschool setting. Results are displayed in Table 3.2 and Figures 3.2, 3.3, and 3.4.

Table 3.3. *Descriptive Statistics and t-test results for the amount of language in the school environment.* * $p < .05$, ** $p < .001$.

LENA Measure	Pretest		Posttest		n	95% CI for Mean Difference	t	df
	M	SD	M	SD				
Adult Word Count (AWC)	17,767.00	5,080.65	27,391.29	7,839.26	17	-13,835.02, -5,413.57	-4.85**	16
Conversational Turn Count (CTC)	849.18	336.38	838.88	298.12	17	-214.35, 234.93	.097	16
Child Vocalization Count (CVC)	3,740.35	1,545.79	2,684.41	945.10	17	222.15, 1,889.74	2.69*	16

Figure 3.2. Adult Word Count (AWC) in the home environment vs. home and school environment

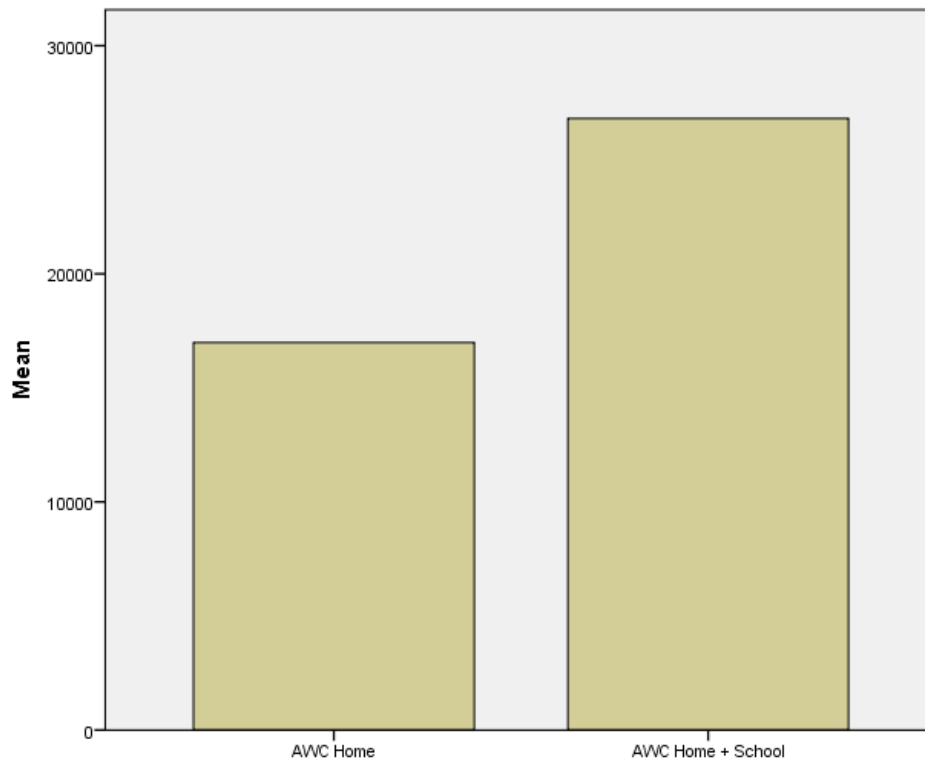
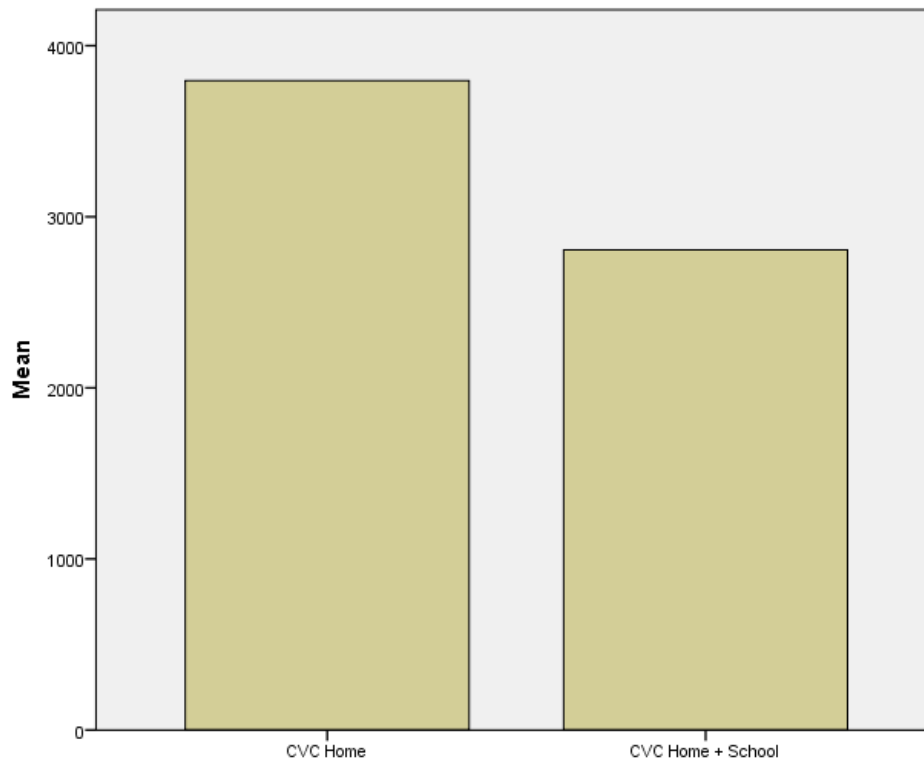


Figure 3.3. Child Vocalization Count (CVC) in the home environment vs. home and school environment



Impact of Parent Education (pre-parent ed vs. post-parent ed)

For this analysis, a recording taken at the beginning of preschool was compared with one taken after the parents participated in a parent education session. Both recordings were taken while the child was attending preschool. Children were included in this analysis if they had a recording taken before and after the parent education session, it was their first summer attending the preschool, and they did not have an older sibling who had previously attended the program. This criterion ensured that parents had not received the information about LENA during a prior summer. Sixteen children were included in this analysis.

Each recording day included 2 ½ hours in school and the remainder of the day at home. These two days were compared to determine whether parent education can effectively increase

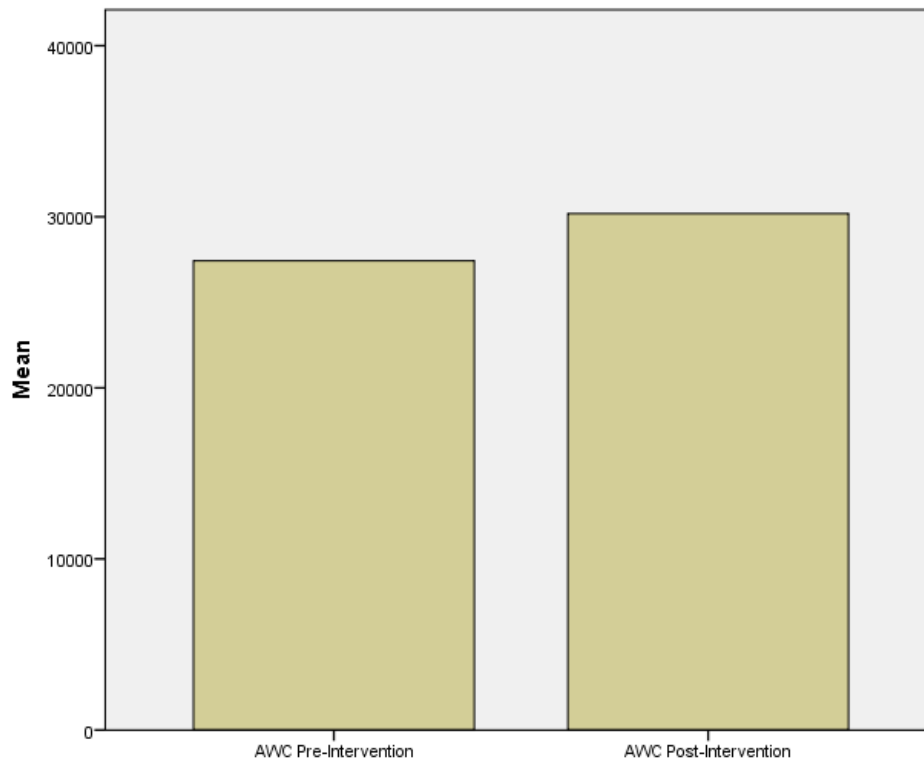
language in the home environment. At the outset, we compared the AWC and CTC during the two recorded school days. No significant differences were found between the two recording days for the time spent at school. Thus, the differences reported below can be interpreted as changes occurring in the home environment.

A paired samples t-test indicated that, when considering AWC, the children had access to significantly more language after their parents attended an education session. The results of the analysis when considering AWC were $t(15) = -2.30$, $p = .036$, and $d = .58$, which is typical using Cohen's (1988) guidelines. CTC and CVC were not found to be significantly different after the parents attended the education sessions. However, a difference in means was noted for CTC, with an average of 81.5 more turns occurring during the recording after the parents attended the parent education session. CVC remained constant across the two recordings. Results are displayed in Table 3.3 and Figures 3.5, 3.6, and 3.7.

Table 3.4. *Descriptive statistics and t-test results for the amount of language after attending parent education.* * $p < .05$

LENA Measure	Pretest		Posttest		n	95% CI for Mean Difference	t	df
	M	SD	M	SD				
Adult Word Count (AWC)	27,427.25	7,467.06	30,180.06	6,891.16	16	-5,301.93, -203.69	-2.30*	15
Conversational Turn Count (CTC)	885.19	317.64	966.69	221.15	16	-268.24, 105.24	-.930	15
Child Vocalization Count (CVC)	2,902.88	1011.71	2,899.00	856.09	16	-550.15, 557.90	.015	15

Figure 3.4. Adult Word Count (AWC) before and after parent education



Discussion

Overall, the results of this preliminary study of the language environments suggest that the children with hearing loss who participated in this study were exposed to a higher quantity of adult language due to access to summer preschool programming and that the home language environment could be impacted through parent education that included LENA feedback. The use of LENA enabled the collection of full-day language samples from the school and home environments. This study adds to the growing small body of literature that shows LENA to be an effective measurement tool for assessing the school environment (Burgess, Audet, & Harjusola-

Webb, 2013; Dykstra, et al., 2013; Irvin, Hume, Boyd, McBee, & Odom, 2013) and impact of intervention on caregivers (Suskind et al., 2013; Zhang et al., 2015).

Notably, LENA effectively measured the changes in child language environment during a short-term preschool program. It can be challenging to document changes in developmental domains on a short-term basis. As accountability in the schools drives the need for more outcomes measures, it is helpful to have additional tools that can measure change in a time-efficient manner.

Amount of language in school (Home vs. School + Home Comparison)

Research has defined “typical” summer learning loss for an average student with age-appropriate skills (Cooper et al., 1996). Defining summer learning loss for children who are language delayed carries additional challenges. Children with hearing loss who start preschool with a language delay are particularly vulnerable as they are not in a position to lose skills over the summer because they are already operating in a skills deficit. Children who are typically developing may have some “buffer” to overcome summer learning loss; however, a child with a language delay does not. Further, due to reduced auditory access, a child with hearing loss may not be able to access all of the language in his/her child’s environment. This may compound the absence of structured educational opportunities during the summer.

Summer school programming is one possible mechanism for counteracting summer learning loss. This study showed that AWC was greater in the preschool environment compared with the home environment for the children that participated in this study. This finding is consistent with findings from preschool environments for children with Autism Spectrum Disorder (Burgess et al, 2013). Increased language available to children with hearing loss in the school environment provides additional evidence of the specific benefit of summer educational

programming. Prevention, as a rule, is easier than remediation. Thus, these findings support the use of summer school for potentially reducing the achievement gap for children with hearing loss prior to entering elementary school.

The results of this study raise questions regarding a “recipe” for an optimal language environment. More adult words are not necessarily better when it is at the expense of conversational turns or engaged language interactions. The ideal balance of AWC, CTC, and CVC during a child’s day remains unknown. Dave Sindrey (1997) proposed that the ideal balance of shared communication during a speech therapy session is 1/3 parent talk, 1/3 child talk, and 1/3 therapist talk.

Different environments have different ideal percentages of time spent in adult talk, child talk, and conversational turns. A classroom environment with a larger number of children does not allow for as many conversational turns per child; however, children in this scenario have the opportunity to learn from peers. In contrast, the home environment enables more one-on-one communication where conversational turns can be maximized. Over time, research may be able to define the ideal balance of AWC, CTC, and CVC so that parents and teachers can use LENA as a feedback tool to determine whether they are creating the ideal language learning environment. Continued work to define the optimal home language environment is important because this environment is critically linked to development in a variety of domains (Dickinson & Tabors, 2001; Hemphill & Tivnan, 2008; Vohr et al., 2014).

Impact of Parent Education (pre-parent ed vs. post-parent ed)

This study showed that parent education effectively improved the home language environment. This is consistent with the findings of Suskind et al. (2013) and Zhang et al. (2015) who also used LENA feedback as a tool to increase adult language production in the

home environment. This finding leads to a number of follow up questions that would benefit from additional study. How long does this behavior change last in the parents? What frequency is necessary to impact long-term behavior change in parents? Is it possible to provide an education program that encourages parents to grow with their child's language abilities? Do parents need specialized instruction at various levels of their child's development? Answering such questions can help pinpoint key intervention components and further develop the literature on the potential for improving child language outcomes through parent-implemented language interventions (Roberts & Kaiser, 2011).

Additional Considerations

This pilot study has a number of limitations. There was no control group. A control group would have allowed us to isolate the effects of preschool and parent education on the results. Additionally, each of the children in the study participated in early-childhood intervention between the ages of birth to 3 years, which means that their families had previously been taught language facilitation strategies. The extent to which parents continue to use the strategies they are taught during early intervention is unknown. It is also unknown how well parents are able to scaffold their language strategies upward as the language of their child becomes more sophisticated. Qualitative analysis is necessary to answer such questions.

Furthermore, the sample was not random. The sample was self-selected by those interested in enrolling their child in a summer preschool program, and the group has restricted variability in the maternal level of education. The study participants may have access to more and higher quality language in the home environment than we would expect in a random sample of children with hearing loss. If this is the case, there may be an even greater difference between the home and school environment in a more diverse sample.

In addition to the sample being a self-selected set of participants, the parents also had a very high baseline average for the group. For example, they were at the 90th percentile for AWC at baseline. The high starting point has the potential to impact analysis. When baseline is high, it is harder to improve as there is less room for change. Gilkerson and colleagues (2015) found no change in behavior for a group of parents who started above the 50th percentile. In this study, the results where differences between the means were noted but not found to be statistically significant may still be important findings.

Using LENA, we were unable to assess qualitative changes in parent language as a result of parent education. An important issue to bear in mind with this type of quantitative recording is the potential for the Hawthorne effect to influence parent behavior (Suskind et al., 2013). The Hawthorne effect is the potential for an individual to modify or improve an aspect of their behavior in response to their knowledge of being observed. Using the full-day recordings for analysis helps reduce the likelihood of the impact because it is challenging to maintain increased language input for ten or more hours. Longer term follow-ups with a greater number of LENA recordings are necessary to determine whether the parents were able to maintain the changes in their behavior.

Very few published studies have used LENA to analyze children with hearing loss in this age group. The results of this study demonstrate that this new technology can be an effective tool to evaluate language in the children's natural environment. Future studies would benefit from increasing sample size, including children at younger ages, taking multiple baseline recordings, using a control group that does not receive access to summer preschool or parent education, recruiting parents that may not be as highly motivated, recruiting a broader range of

families that are not limited by the preschool inclusion criteria, and taking post-program recordings to measure long-term impacts of change.

The importance of this future work cannot be overstated. Intervention and parent education provide remarkable opportunities to change a child's trajectory by enriching their early language environment. As children transition from early intervention services (IDEA Part C) to school services (IDEA Part B), parental involvement remains important even though the roles of parents in a child's day may shift. Research has clearly demonstrated the link between early child language experiences and later academic performance (Calderon, 2000; Topping, Dekhinet, & Zeedyk, 2011); thus, researchers and clinicians need to work together to develop efficient and effective tools to improve the home language environments of school-age children. Furthermore, policymakers and researchers must collaborate to overcome existing hurdles so that summer preschool programming can help prevent summer learning loss for children with hearing loss.

Acknowledgements

We are grateful to all of the families who participated in the Marion's Way preschool program and to the teachers, staff, and donors who made the program possible. We would especially like to mention the work of Dianne Goberis and Nanette Thompson.

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CHAPTER V

Conclusion

This paper presented three studies that when taken together, describe and predict speech development and demonstrate the impact of intervention for young children with hearing loss.

Describing Phoneme Development in Young Children with Hearing Loss

This study investigated consonant development in the spoken language of 144 children with hearing loss between 48 and 84 months of age. Children with mild, moderate, severe, and profound degrees of bilateral hearing loss, including those with cochlear implants, were evaluated using the Goldman Fristoe Test of Articulation-2 (GFTA-2). Using the data from 355 different test sessions, the age at which 50% and 90% of each group of children produced the various consonants of English is reported. Order of English consonant acquisition appeared to be broadly similar to children with typical hearing. Results are discussed comparing children across hearing loss categories as well as comparing the children with hearing loss to previous research describing typical speech development in hearing children. This study **described** speech development in young children with hearing loss.

Predicting Phoneme Growth in Young Children with Hearing Loss

Important policy initiatives have reduced age of diagnosis and intervention for young children with hearing loss over the last 20 years. Even with systematic improvements and advancements in technology, children with hearing loss continue to have delayed speech-sound production compared with their typically hearing peers. We examined speech-sound growth models to determine what demographic variables can predict the rate and shape of development. Additionally, we considered whether speech sound production at 27 to 33 months could predict later Goldman Fristoe Test of Articulation-2 scores. This study showed that speech development can be **predicted** and the clinical implications for such findings are discussed.

The Value of Educational Programming and Exploring the Impact of Parent Education:

Why is continuing summer service vital for children with hearing loss?

This study measured the differences between the home and school language environments and quantified the impact of parent education during a summer preschool program. Language samples were collected from each child using Language Environment Analysis (LENA). Adult Word Count, Conversational Turn Count, and Child Vocalization Count were compared. The results of the study indicated that children are exposed to significantly more adult words when they attend a preschool program. Additionally, LENA results indicated that parent language can be positively impacted through parent education. This study shows that the language available to young children with hearing loss can be **impacted** through summer preschool and parent education.

This work furthers the field specializing in deafness by providing information that is clinically relevant for professionals and parents working with young children with hearing loss.

Professionals and parents can use the phoneme development charts to monitor progress in speech sound development. Children who are at high risk for speech sound delays can be identified earlier as a result of the data presented. And, through use of LENA, the language environment for children can be enhanced.

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