Spring 5-15-2019

The Effect of Retrieval Practice on Vocabulary Learning for Children who are Deaf or Hard of Hearing

Casey Krauss Reimer
Washington University in St. Louis

WASHINGTON UNIVERSITY IN ST. LOUIS

Program in Speech and Hearing Sciences

Dissertation Examination Committee:
William Clark, Chair
Andrew Butler
Heather Grantham
Mark McDaniel
Amanda Ortmann
Mitchell Sommers

The Effect of Retrieval Practice on Vocabulary Learning for Children who are Deaf or Hard of Hearing

by
Casey Krauss Reimer

A dissertation presented to
The Graduate School
of Washington University in
partial fulfillment of the
requirements for the degree
of Doctor of Philosophy

May 2019
St. Louis, Missouri

Table of Contents

List of Figures

List of Tables

Acknowledgments

I am beyond thankful for the guidance, support, and mentorship from Heather Grantham. She always had my best interest in mind and knew how to guide me in the right direction to complete my goals. I am grateful to not only call Heather my mentor, but my friend as well. To William Clark, thank you for believing in me from the beginning and making the PACS environment such a welcoming space. I want to thank Mandy Ortmann for jumping at every chance to assist me and help me grow as a professional. Also, many thanks to the other members of my committee: Mark McDaniel, Mitch Sommers, and Andy Butler.

To my fellow National Leadership Consortium in Sensory Disabilities (NLCSD) scholars, thank you for offering expertise in areas where I lacked and making my graduate school years feel like a one great group project. Francis Anderson and other members of the Memory and Complex Learning Lab offered invaluable statistical analyses support and a place to bounce ideas off of, and for that, I thank them very much. I am also grateful to the teachers and administrators at schools in St. Louis who helped me recruit participants for this study.

Finally, I cannot begin to explain my gratitude for my family who supported me throughout these past few years. Particularly, my husband Ted who has been the ultimate father to our sweet Denny—taking extra Daddy duty through the working weekends and evenings. In addition, to my parents, in-laws, and extended family who were my constant cheerleaders and babysitters, I owe my degree to you. I am so lucky to call you my family.

Casey Reimer

Washington University in St. Louis

May 2019

ABSTRACT OF THE DISSERTATION

The Effect of Retrieval Practice on Vocabulary Learning for Children who are Deaf or Hard of Hearing

by

Casey Krauss Reimer

Doctor of Philosophy in Speech and Hearing Sciences

Washington University in St. Louis, 2019

Professor William Clark, Chair

The goal of the current study was to determine if students who are deaf or hard of hearing (d/hh) would learn more new vocabulary words through the use of retrieval practice than repeated exposure (repeated study). No studies to date have used this cognitive strategy—retrieval practice—with children who are d/hh. Previous studies have shown that children with hearing loss struggle with learning vocabulary words. This deficit can negatively affect language development, reading outcomes, and overall academic success. Few studies have investigated specific interventions to address the poor vocabulary development for children with hearing loss. The current study investigated retrieval practice as a potentially effective strategy to increase word-learning for children who are d/hh and who use spoken language. It was found that children with hearing loss recalled a greater number of new vocabulary words when using retrieval practice than repeated exposure after a two day retention interval. This study also examined factors that influence whether a child remembers or forgets a word after a retention interval. Children who did not have an additional diagnosis recalled more words than children with an additional diagnosis. Children who were more efficient learners—took fewer trials to learn the word—recalled more words than children who were less efficient learners. High level of parent education and aided speech perception scores were not significant predictors of the children remembering the new words. In summary, this study was the first to show that retrieval practice caused students with hearing loss to learn more new vocabulary words than repeated exposure.

Chapter 1: Introduction

Vocabulary is one of the most important parts of language. It impacts almost every aspect of daily life, from reading emails to following recipes, to having conversations with friends. The ability to learn vocabulary influences effective communication, speech perception, reading comprehension, social-cognitive development, theory of mind, and success in academic and workplace environments (Antia, Jones, Reed, & Kreimeyer, 2009; Fagan, 2016; Kyle & Harris, 2010; Lederberg, Schick, & Spencer, 2013). Vocabulary learning begins in infancy (e.g., Kuhl, Williams, Lacerda, Stevens, & Lindblom, 1992; Levine, Strother-Garcia, Golinkoff, & Hirsh-Pasek, 2016; Saffran, Aslin, & Newport, 1996; Tsao, Liu, & Kuhl, 2004) and continues throughout life without an age limit for learning (Fagan, 2016). Without the ability to acquire new vocabulary, communication break-downs and academic struggles are immanent.

For young children with typical hearing, the majority of vocabulary is learned incidentally. Many children pick up new vocabulary words through overhearing conversations, phone calls, songs, or playing games. This skill begins within the first year of an infant's life. Children who are deaf or hard of hearing (d/hh) do not have this luxury. Because of their hearing loss, they miss out on numerous opportunities to learn vocabulary before they even start school. Not only do young children with hearing loss struggle with learning vocabulary, but the delay can be persistent and continue to increase with age (Convertino, Borgna, Marschark, & Durkin, 2014; Sarchet, Marshark, Borgna, Convertino, Sapere, & Dirmyer, 2014).

Even with the advent of new technological hearing devices, early intervention, and newborn hearing screening, children with hearing loss are still falling behind their peers with typical hearing in regards to vocabulary learning (Davidson, Geers, & Nicholas, 2014; Lund, 2016; Yoshinaga-Itano, Sedey, Wiggin, & Chung, 2017). Yet, there are very few intervention studies to help guide vocabulary instruction for children who are d/hh (Luckner & Cooke, 2010; Lund, 2016). Due to the lack of studies, teachers of the deaf have little guidance on how to effectively teach vocabulary in their classrooms (Duncan & Lederberg, 2018).

This dissertation addresses the lack of intervention research in deaf education by using one of the most effective learning strategies in cognitive psychology—retrieval practice—with children who are d/hh and who use listening and spoken language (e.g., Brown, Roediger, & McDaniel, 2014; Butler, 2010; Carey, 2015; Karpicke, 2017; McDermott, Agarwal, D'Antonio, Roediger III, & McDaniel, 2014; Rickard & Pan, 2018; Roediger & Karpicke, 2006). Retrieval practice has been used successfully with children as young as three years old (Fritz, Morris, Nolan, & Singleton, 2007) and with vocabulary learning in classroom settings (Goossens, Camp, Verkoeijen, & Tabbers, 2014). Prior to this dissertation, retrieval practice had never been used with children who are d/hh. This dissertation also examines characteristics of children with hearing loss that affect vocabulary learning.

In this introduction, I will first provide general information about how we hear, degrees and types of hearing loss, how it is diagnosed, and interventions to address hearing loss. Then I will discuss vocabulary development and learning strategies for children with typical hearing and then the current state on vocabulary development and interventions for children with hearing loss. Finally, I will introduce retrieval practice, the evidence of it being used successfully in the classroom, and with atypical populations.

1.1 Hearing Loss

According to the Center for Disease Control and Prevention (CDC), 1.4 babies in every 1000 are born (congenital) with a hearing loss (CDC, 2019). Less than one percent of the students served under Part B (ages 3-21) of the Individuals with Disabilities Education Act (IDEA) have hearing loss (IES-NCES, 2018); thus, hearing loss is considered a low-incidence disability. Hearing loss can have detrimental impacts on auditory development and spoken language development if left untreated. Lederberg et al. (2013, p. 1) states that, “Language development has long been recognized as the most important area affected by hearing loss.” It has been found that in order for a child to successfully learn to listen and develop spoken language, the early diagnosis of hearing loss and implementation of intervention is essential (e.g., Connor, Craig, Raudenbush, Heavner, & Zwolan, 2006; Dettman et al., 2016; Hammes, Willis, Novak, Edmondson, Rotz, & Thomas, 2002; Hayes, Geers, Treiman, & Moog, 2009; Nicholas & Geers, 2007; Vohr Jodoin-Krauzyk, Tucker, Johnson, Topol, & Ahlgren, 2008; Yoshinaga-Itano, Sedey, Coulter, & Mehl, 1998). Before understanding how hearing loss can impact language development, it is important to understand how we hear, the types and severities of hearing loss, the process of diagnosing hearing loss, and intervention options.

1.1.1 How We Hear

Human ears have three parts that lead to the brain: outer ear, middle ear, and inner ear. These three sections work together in order to collect sound and send it to the brain to be perceived. The outer ear consists of the pinna, ear canal, and eardrum (tympanic membrane). The pinna is the part of the ear that is visible on the sides of the head. It helps to protect the ear canal and importantly, funnels sound waves down the ear canal. The pinna also helps the listener determine the direction sound is coming from. About one-inch long, the ear canal channels sound to the eardrum. The eardrum is located at the end of the ear canal and the beginning of the middle ear.

After sound travels down the ear canal, it hits the eardrum which is attached to the first of three tiny middle ear bones (ossicles). As the sound hits the eardrum, it vibrates differently depending on the pitch of the sound. The sound then travels through the ossicles and is amplified before it meets the oval window, which is where the inner ear begins.

The inner ear has two functions: hearing and balance. The cochlea is the part of the inner ear that focuses on hearing and the semicircular canals are part of the balance system. The cochlea is a fluid-filled, spiral-shaped bony structure with 2.5 turns. After the sound hits the eardrum and vibrates the middle ear ossicles, the smallest ossicle then vibrates the oval window causing the fluid in the cochlea to move. The cochlea is filled with thousands of hair cells that move based on the frequency of the stimulus. As the fluid moves in waves, the hair cells that correspond with the frequency of the sound bend. The hair cells then change the sound into electrical signals which go through the auditory nerve to the brain. The brain interprets these electrical signals as sound, perceives the meaning, and decides how to respond. Figure 1.1 displays the different parts of the ear.

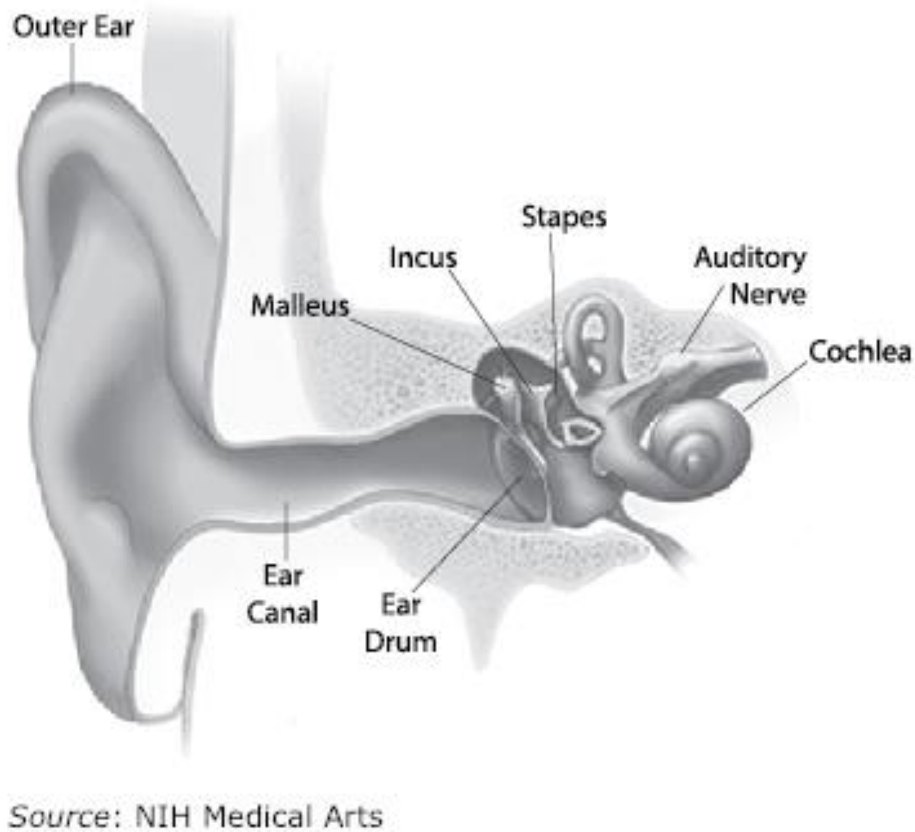


Figure 1.1. The Ear

Figure 1.1. Parts of the ear. From Medical illustrations by NIH, Medical Arts & Photography Branch. Retrieved March 5, 2019, from https://www.nidcd.nih.gov/health/how-do-we-hear.

1.1.2 Types and Degrees of Hearing Loss

The type of hearing loss is defined by where the problem occurs along the auditory pathway. There are three general types of hearing loss: sensorineural, conductive, and mixed. Sensorineural hearing loss is when there is damage to the cochlea or the auditory nerve, which connects the inner ear to the brain. Sensorineural hearing loss is permanent and is the most common type of hearing loss in children (ASHA, 2015b). Conductive hearing loss occurs when there is a problem or obstruction in the ear canal or middle ear space. The most common cause of conductive hearing loss in children is fluid in the middle ear space or otitis media (ear infection). Otitis media is the most frequently diagnosed disease in infants and young children (Dhooge, 2003). Unlike sensorineural hearing loss, conductive hearing loss is often temporary and can be addressed through medical treatment, surgery, or amplification. Mixed hearing loss, the third type of hearing loss, is a combination of sensorineural and conductive hearing loss. Due to the sensorineural component of mixed hearing loss, a degree of hearing loss will remain even if the conductive factor is resolved.

Hearing loss is also categorized by severity, which is measured in decibels hearing level (dB HL). Table 1.1 displays the range of degrees of hearing loss. The threshold of hearing, or the softest sound that is heard, is between 0-15 dB HL for children with typical hearing. In a quiet environment, conversational speech occurs between 45-60 dB HL, which is well above normal hearing (CDC, 2015). According to the CDC, the majority of children with congenital sensorineural hearing loss in the United States are reported to have at least a moderate degree of hearing loss (ASHA, 2015b). Therefore, these children are unable to fully hear or understand spoken language without an assistive hearing device.

Table 1.1 Degree of Hearing Loss

Degree of Hearing Loss	Hearing Loss Range (dB HL)
Normal	-10 to 15
Slight	16 to 25
Mild	26 to 40
Moderate	41 to 55
Moderately severe	56 to 70
Severe	71 to 90
Profound	91+

Note. Adapted from "Uses and Abuses of Hearing Loss Classification," by J. G. Clark, 1981, *American-Speech-Language-Hearing Association, 23,* p. 493-500.

Hearing loss can occur bilaterally (both ears) or unilaterally (one ear). A child can have varying degrees of severity and types of hearing loss in each ear as well (asymmetric loss). For example, a child may have a bilateral hearing loss with a moderate mixed loss in her left ear and a profound sensorineural loss in her right.

A child is either born with a hearing loss (congenital) or acquires it during childhood. Sixty percent of congenital hearing losses have a genetic cause (Davis & Davis, 2011). Of those genetic causes, 70% are non-syndromic, meaning there are no other clinical anomalies besides hearing loss. Half of the non-syndromic losses are due to Connexin 26, a variation in a gene which causes sensorineural hearing loss (Davis & Davis, 2011). The remaining 20-30% of genetic losses are syndromic, which can have concurrent developmental impacts alongside hearing loss. Syndromes that cause hearing loss include but are not limited to: Treacher-Collins, Waardenburg, Zellweger, Pendred, and Down's Syndrome. These children may have multiple disabilities or delays that, coupled with hearing loss, can negatively affect academic growth. It is important to note the difference between additional *diagnosis* and additional *disability*. Many studies have examined the negative impact of additional disability on language development for children with hearing loss (e.g., Boons, De Raeve, Langereis, Peeraer, Wouters, & van Wieringen, 2013; Marschark, Shaver, Nagle, & Newman, 2015; Yoshinaga-Itano et al., 2017). Most of these studies focus on *disabilities* that are not discovered until children are school-aged, such as developmental delay, learning disability, and attention deficit disorder.

The remaining 40% of congenital hearing loss can be caused by *in utero* infections (e.g., cytomegalovirus, rubella), auditory neuropathy spectrum disorder, outer/middle or inner ear malformations, maternal diabetes, or lack of oxygen (anoxia) (Davis & Davis, 2011). Cytomegalovirus (CMV), is the most common intrauterine infection (Roizen, 1999), and can cross over the placenta to affect the developing fetus. Babies who are affected can have congenital, progressive (becomes worse over time), fluctuating (degree varies), or delayed-onset hearing loss. However, it is still unclear how much CMV contributes to the overall prevalence of hearing loss for children in the United States (Davis & Davis, 2011).

Acquired hearing loss can be caused by ear infections, illnesses, ototoxicity, head trauma, and noise exposure. Illnesses that can cause permanent hearing loss include but are not limited to bacterial meningitis, measles, and chicken pox. There are over 200 known ototoxic medications that can damage the ear (Ortmann, 2018). In some cases, hearing loss can be reversed by ending the medication, but most ototoxic medications cause permanent damage the auditory system, resulting in sensorineural hearing loss and requiring intervention.

1.1.3 Devices

In order to measure the severity of hearing loss and determine appropriate auditory interventions, testing by an audiologist is required. To measure the degree of hearing loss in infants, signals of varying degrees of loudness and frequency are sent directly to the auditory nerve. For older children, signals are sent through the air for traditional behavioral testing. As the child responds to different signals, the audiologist notes the softest sounds (measured in decibels) that the child responds to at different frequencies (measured in hertz). The audiologist charts the responses on an audiogram. Once the softest audible decibel levels across multiple frequencies are determined, the hearing loss can be categorized as mild, moderate, severe, profound, or varying combinations. The audiologist then uses the audiogram to suggest appropriate hearing devices for the child to detect spoken language. At that time, the audiologist may also recommend seeing an otolaryngologist for further medical examination. Each hearing device is used for a different reason, and with the help of audiologists and otolaryngologists families make a decision about what device is appropriate for their child. There are three categories of hearing devices: hearing aids, cochlear implants, and bone anchored hearing aids.

In order to optimize listening time and promote auditory development, the earlier children wear hearing devices the better; in fact, infants can begin wearing hearing aids as young as four weeks old (ASHA, 2015a). There are numerous types of hearing aids, but many children wear a behind the ear (BTE) hearing aid that is worn on the pinna with an earmold fitting into the ear canal. Figure 1.2 displays different kinds of hearing aids. The microphones on the hearing aid detect sounds in the child’s environment, which are then amplified and sent to a speaker which delivers the sound to the ear. Hearing aids are typically used for a sensorineural loss (NIDCD, 2015). Children who have a hearing loss ranging from mild to severe can benefit from the amplification provided by hearing aids, though they still need intensive training on how to interpret speech sounds into spoken language. It is important to note, even with amplification, children with a more severe hearing loss do not perceive speech the same as their peers with typical hearing do (Lederberg et al., 2013). Hearing aids have limits on the amplification they can provide. Children with a profound hearing loss typically do not receive enough benefit from hearing aids to fully detect and develop spoken language. A cochlear implant is recommended for these children with a profound loss.

Figure 1.2. Hearing Aids

Figure 1.2. Five different types of hearing aids are pictured with their placement within the ear. Many children choose the Behind-the-ear (BTE) hearing aid. From Medical illustrations by NIH, Medical Arts & Photography Branch. Retrieved March 5, 2019, from https://www.nidcd.nih.gov/health/hearing-aids

Up until the 1990s, many children with profound hearing loss lacked sufficient access to sound to adequately develop spoken language (Moores, 2010). There was a paradigm shift in 1989 when the FDA approved the use of a cochlear implant by children over two years old. Currently cochlear implants are approved for children over the age of 12 months (NIH, 2018), and is commonly recommended for children with severe to profound sensorineural hearing loss. The cochlear implant, shown in Figure 1.3, has two main components: an external device that is placed behind the ear, and an internal receiver that is surgically implanted under the skin. The external device detects and processes sound, then transmits the signal across the skin via magnetic coupling to the internal device, which sends the signal to the auditory nerve by means of an electrode array that is inserted into the cochlea.

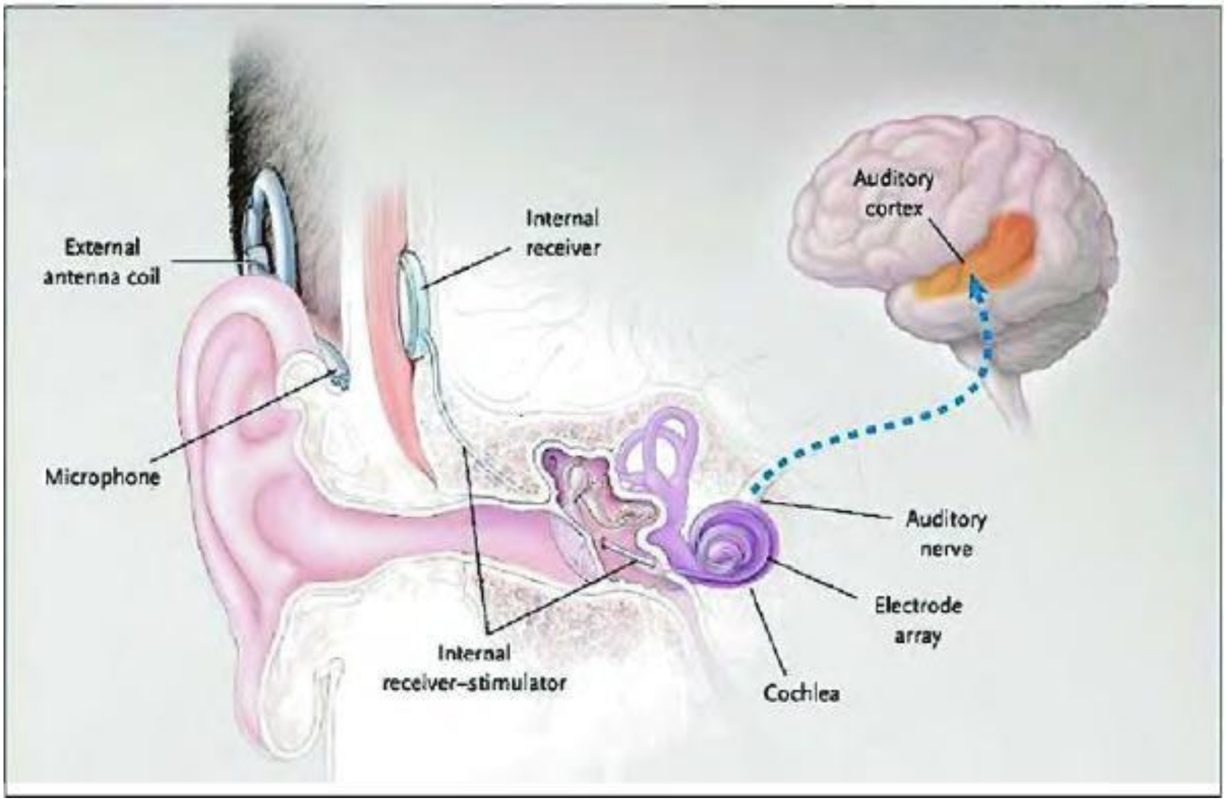


Figure 1.3. Ear with Cochlear Implant

Figure 1.3. Placement of a cochlear implant and representation of its relationship to the cochlea, auditory nerve, and auditory cortex. From “Cochlear implants,” by G. A. Gates, and R. T. Miyamoto, 2003, *New England Journal of Medicine, 349,* p. 41-423.

The third type of hearing device is a bone anchored hearing aid which received FDA approval in 1997 (Hagr, 2007). A bone anchored hearing aid can be used with a conductive or unilateral loss, or when there is malformation of the outer ear (atresia). Instead of conducting sound through the ear canal like a hearing aid, a bone anchored hearing aid transfers sound directly to the cochlea via bone conduction. The bone anchored hearing aid, shown in Figure 1.4, detects sounds in the environment then transmits those sound waves to the normal-functioning cochlea through vibrations of the skull, thus bypassing the damaged portions of the outer and/or middle ear. There are surgical and non-surgical options for a bone anchored hearing aid. Surgery is approved by the FDA for children older than five years old (Davids, Gordon, Clutton, & Papsin, 2007). Surgery entails having the bone anchored hearing aid implanted via a titanium abutment which connects the hearing aid onto the bone behind the pinna. Children who are younger than five years old are not cleared for surgery, because the child needs to develop sufficient bone thickness and quality first. These children wear the device on a soft headband.

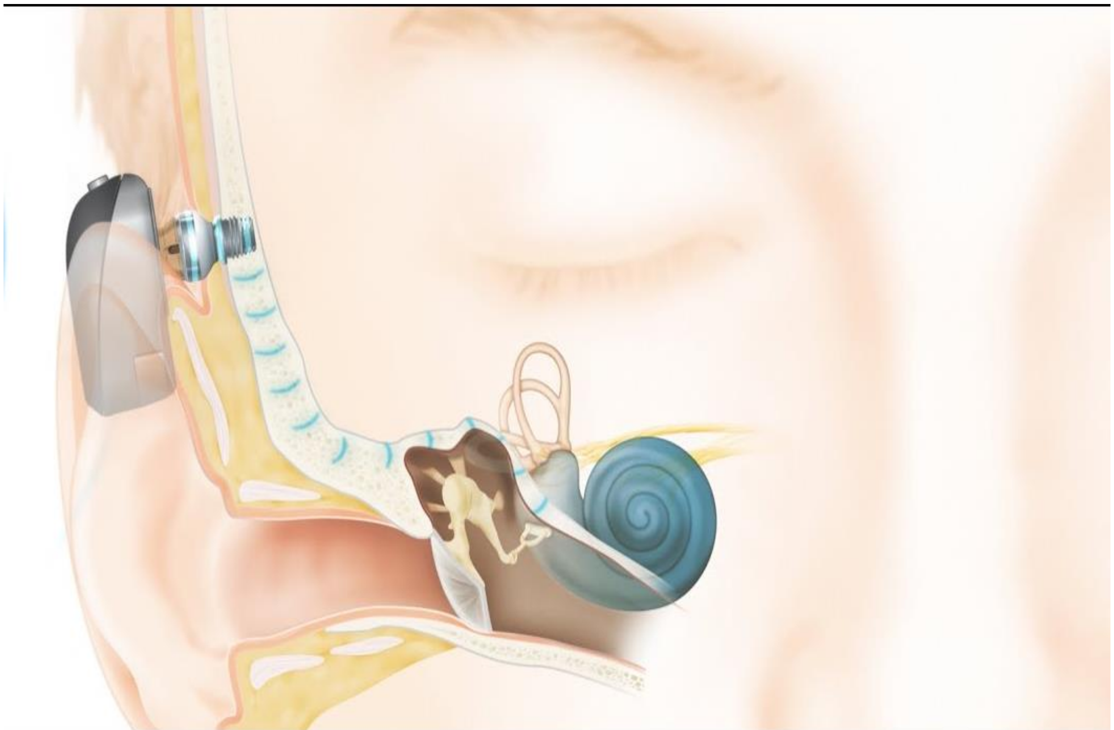


Figure 1.4. Bone Anchored Hearing Aid on Ear

Figure 1.4. Placement of a bone anchored hearing aid and how it interacts with the inner ear. From Medical illustrations by Cochlear Americas, Retrieved March 5, 2019, from https://www.cochlear.com/au/home/discover/baha-bone-conduction-implants.

As children grow up and are able to understand speech, audiologists conduct speech perception testing as well as the traditional testing with tones. Children typically have speech perception testing completed at pediatric audiology clinics in the hospital or in their school, if it is available. This testing is to determine the softest level of speech that a child can understand with and without his device(s). When a child wears his device(s) during the test it is called aided speech perception. If a child has a bilateral loss, each ear will be tested individually as well as both ears together (binaural). As children are able to comprehend more complex language, the speech perception tests increase in complexity. For example, a child who is a new user of a device is tested by having to repeat single words that he hears; whereas, a student who has been aided for a few years has to repeat sentences he heard using his devices. Many studies have found that speech perception abilities affect later language development, in a positive or negative manner (e.g., de Hoog, Langereis, van Weerdenburg, Keuning, Knoors, & Verhoeven, 2016; Dettman et al., 2016; Eisenberg, Fisher, Johnson, Ganguly, Grace, & Niparko, 2016; Geers & Nicholas, 2013).

1.1.4 Diagnosis & Intervention

In order to evade language and academic delays and increase chances of success for children who are d/hh, The Early Hearing Detection and Intervention Program (EHDI) was established under the Child Health Act of 2000. The goal of EHDI,

> "…is to maximize linguistic competence and literacy development for children who are deaf or hard of hearing. Without appropriate opportunities to learn language, these children will fall behind their hearing peers in communication, cognition, reading, and social-emotional development," (Joint Committee on Infant Hearing, 2007, p. 898).

EHDI also recommends that all states follow a set of guidelines called "the 1-3-6 guidelines": All infants should be screened for a hearing loss no later than 1 month of age, those who do not pass the screening should have an audiological evaluation by 3 months of age, and infants with confirmed hearing loss should receive intervention at no later than 6 months of age (1-3-6) (Joint Committee on Infant Hearing, 2007). Because the auditory system is fully functional at birth and babies with typical hearing can respond to sounds right away (Graven & Browne, 2008), identification of hearing loss needs to occur as soon as possible. Universal Newborn Hearing Screening (UNHS) was implemented in every state by 2005 (Joint Committee on Infant Hearing, 2007), and the 1-3-6 guidelines were recommended to early intervention state programs at that time. As of 2014, 97% of babies born in the US were screened for hearing loss (CDC-EHDI, 2014). A passive test called Automated Auditory Brainstem Response (AABR) is used to screen infants before they leave the hospital. A stimulus is sent into the ear of a sleeping baby. Measurements are taken through electrodes places on the head, which describe the effectiveness of the cochlea, auditory nerve, and brainstem. Prior to the implementation of EHDI and UNHS, the average age of identification for children with hearing loss was about three years old (Bess & Paradise, 1994), causing years of missed opportunities for language and auditory development. As of 2016, 75% of babies with hearing loss were diagnosed by three months old or younger (CDC-EHDI, 2016), which is significantly sooner than the children who were born before EHDI.

In addition to UNHS and the 1-3-6 guidelines, early intervention is a major and necessary aspect of EHDI. Simply giving a child assistive hearing devices at an early age will not result in age-appropriate speech and language. Nott, Cowan, Brown, and Wigglesworth (2009) examined trajectories of vocabulary development of toddlers with hearing loss and found that they learned their first 100 words slower and began using two-word combinations later than toddlers with typical hearing. They concluded, "…despite fitting of a device at an early age, hearing loss continues to impact early lexical acquisition and the emergence of word combinations," (Nott et al., 2009, p. 526). Children who are d/hh need to be taught how to use their devices for listening and communicating. This is done through working with early interventionists who are trained specifically to work with children who are d/hh. Intervention sessions occur at the baby's home and/or center-based programs where professionals work closely with families. In order for a child to develop appropriate listening and spoken language skills, families need to work not only with interventionists but also constantly at home with their child. "Intensive instruction is necessary to attempt to overcome the auditory deprivation that children born with hearing loss experience during the critical periods of speech and language development," (Bobzien, Richels, Schwartz, Raver, Hester, & Morin, 2015, p. 265). Families may feel overwhelmed beginning intensive therapy at such a young age, but early diagnosis allows for families to receive support and counseling services they may need in order to understand and cope with their child's hearing loss (Yoshinaga-Itano, 2003). During family support sessions, it is important to reiterate that the earlier the diagnosis, the earlier the age of amplification, and the earlier the age of intervention, the better the language and auditory outcomes will be for children with hearing loss (e.g., Connor et al., 2006; Dettman et al., 2016; Eisenberg et al., 2016; Hayes et al., 2009; Nicholas & Geers, 2006; Niparko et al., 2010; Vohr et al., 2008; Yoshinaga-Itano et al., 2017).

Part C of the Individuals with Disabilities Education Act (IDEA) is The Program for Infants and Toddlers with Disabilities that encompasses early intervention. It is a federal grant program that assists states in operating services for infants and toddlers with disabilities, ages from birth through 2 years, and their families. Part C was established by Congress in 1986 in recognition of "an urgent and substantial need" to: (a) enhance the development of infants and toddlers with disabilities, (b) reduce educational costs by minimizing the need for special education through early intervention, (c) minimize the likelihood of institutionalization and maximize independent living, and, (d) enhance the capacity of families to meet their child's needs (ECTA, 2019). The services for children who are d//hh and qualify for Part C include but are not limited to, the cost of therapy/intervention sessions, audiology examinations, and assistive technology devices such as hearing aids. Cochlear implants and the cost of surgery are not covered under Part C.

When children are diagnosed with hearing loss, another important decision for families is the how their child will communicate. Before cochlear implants and the technological advancements of hearing aids, oral communication or spoken language was difficult for children with profound hearing loss to acquire. Because these children could not hear speech, they struggled to successfully develop spoken language skills with hearing aids. Many preferred a signed language or a visual communication method. Currently, with the advancements in hearing technologies, implementation of newborn hearing screening, and adaptation of early intervention services, children with profound hearing loss now have better access to spoken language at a younger age and have the potential to be successful users of spoken language.

Figure 1.5 displays communication options along a continuum, with the amount of visual or signed language and spoken language varying as one moves along it. Starting on the left side with a fully visual language or signed language, American Sign Language (ASL) is the predominant signed language of Deaf communities in the United States. The foundations of ASL are handshape, movement, and placement. These three components, along with palm orientation and nonmanual signs (e.g., facial expression), determine the meaning of the sign (Ding & Martinez, 2009). ASL is a language that is separate and distinct from English. It has its own rules for pronunciation, word order, and complex grammar. A common occurrence for people who use

ASL is to be bimodal-bilingual, which when they are fluent in ASL and written English and/or spoken English.

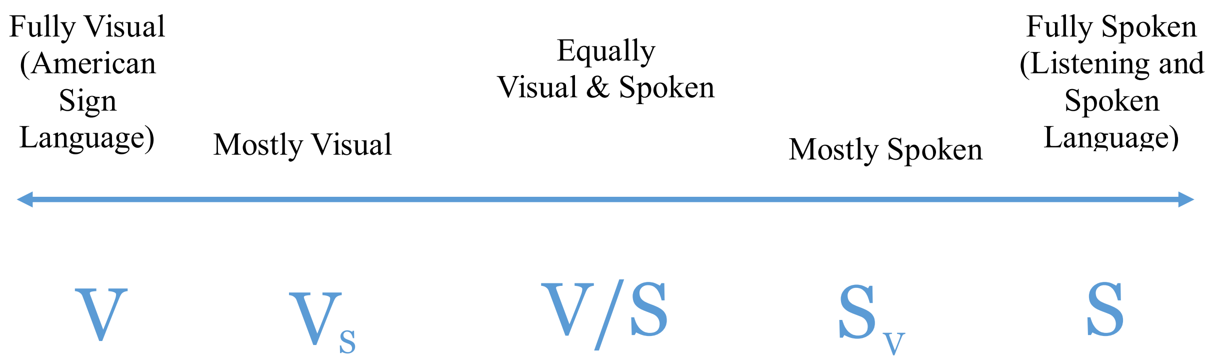


Figure 1.5. Communication Options

Figure 1.5. Communication options are displayed along a continuum. At the left end of the continuum is American Sign Language (ASL), which is a fully visual language. Listening and Spoken Language (LSL) is at the other end of the continuum as a fully spoken language. Between ASL and LSL are different communication options with varying levels of visual and spoken language. Adapted from “The Cochlear Implant Education Center: Perspectives on Effective Educational Practices,” by D. B. Nussbaum, and S. Scott, 2011, *Cochlear Implants: Evolving Perspectives*.

The remaining communication methods follow the rules of spoken and written English. When simultaneously using sign language along with spoken language, it is called sign supported speech or simultaneous communication (sim-com). Signing Exact English (SEE) is a visual communication system in which signs are used to match the grammar and vocabulary of

English, which is different than ASL. SEE is typically used in combination with spoken English as a form of sim-com. Another communication system is cued speech, where the speaker uses spoken language while also making hand cues near the face to distinguish certain phonemes that are difficult to lipread. Then the child with hearing loss typically responds using spoken language or cued speech. At the other end of the continuum from ASL, are children who primarily use spoken language to communicate. This method of communication is called oral communication (OC). For the remainder of this dissertation, I will be discussing children who use the oral communication method which also can be referred to as spoken language.

As previously mentioned, starting intervention as early as possible for children with hearing loss to develop language is recommended. That family-chosen intervention is covered under Part C of IDEA until a child turns three. When children turn three, they are transitioned out of early intervention (Part C), and if they qualify for continued services they will be seen under Part B of IDEA. At this age, children either enter a mainstream public program, a separate school for the deaf, or a residential school, depending on their language and auditory development, school district options, and parental choice. As of 2014, about 87% of school-aged students who are d/hh served under IDEA were enrolled in a regular school setting (IES-NCES, 2017). The children who are d/hh that qualified for continued services and attend a mainstream setting will be seen by classroom or itinerant teachers of the deaf. These services are based on their educational needs laid out in their Individualized Educational Program (IEP). Determined at their IEP meeting, students may receive services in their general education classrooms, may be pulled-out for services, or spend a percentage of the day in a self-contained classroom taught by a teacher of the deaf with other children who are d/hh. As of 2014, 60% of students who are d/hh were spending 80% or more of their day in a general education classroom (IES-NCES, 2017). This is a drastic change from the residential and separate schools for the deaf where many children were educated in the twentieth century.

No matter which communication modality, intervention, and school setting that are chosen by the families, the important aspect for children who are d/hh is that they are surrounded by language as early as possible. "An absence of early exposure to the patterns that are inherent in natural language, whether spoken or signed, produces life-long changes in the ability to learn language," (Kuhl, 2004, p. 831). It is essential to immerse children who are d/hh in language as soon and as often as possible.

1.2 Vocabulary

Vocabulary can be defined as the words we know and need to know in order to communicate effectively (Hermans & Spencer, 2015). Vocabulary knowledge is one of the most observable aspects of language and, "…the number of words in a child's vocabulary is an indicator of his or her linguistic health and a factor in his or her ability to use language in varied contexts and for multiple purposes," (Richgels, 2004, p. 473). Deficits in vocabulary can be evident in all aspects of life. Problems with vocabulary learning must be addressed early in a child's educational career, because vocabulary development early on in school has been shown to influence reading comprehension later in life (Cunningham & Stanovich, 1997; Tabors, Snow, & Dickinson, 2001).

On a broader note, greater vocabulary knowledge has been connected to higher academic and professional outcomes (Duncan et al., 2007). Vocabulary provides the foundation for higher-order thinking skills necessary for comprehending texts (Luckner & Cooke, 2010; Senechal &

Neuman, 2007). Children who have larger and more organized lexicons often find it easier to make inferences and to integrate information into the whole story (Senechal & Neuman, 2007). In fact, vocabulary is such a dire aspect of language and reading development that the National Reading Panel (NRP) labeled it as part of the Big Five—the five essential components to reading (phonemic awareness, phonics, fluency, vocabulary, and text comprehension). The NRP was commissioned by Congress to investigate the status of research-based knowledge on reading. A group of 14 learning scientists, college representatives, reading teachers, educational administrators, and parents produced a report and teacher guide describing the research supporting direct instruction of the Big Five (National Reading Panel, 2000). This report was aimed not only at teachers, but also school administrators and policymakers to help guide curriculum choices that are based on empirically-supported methods central to reading achievement.

The next section will discuss typical vocabulary development and vocabulary-learning interventions that are currently being used in the classroom for children with typical hearing. Then I will describe vocabulary development of children with hearing loss as well as interventions tested with children who are d/hh.

1.2.1 Typical Vocabulary Development

Studies have found that early vocabulary development predicts vocabulary outcomes later in school (Fagan, 2016; Marchman & Fernald, 2008; Walker, Greenwood, Hart, & Carta, 1994); in fact, numerous language outcomes of typically-hearing children are predicted by experiences and skills acquired during the first year of life (Levine et al., 2016). Babies begin to acquire basic auditory and linguistic skills prior to birth when the auditory system becomes functional at approximately 25-weeks gestation (Graven & Browne, 2008). During the first year of life, typically-developing infants show growth in speech segmentation, word learning, syntax acquisition, and both verbal and non-verbal communication (Levine et al., 2016). In addition, infants discover patterns in the audio-visual stream that assist in language development, such as seeing and hearing a door close (Bahrick, Lickliter, & Flom, 2004). Word-learning is one of the few areas of language development that begins in infancy and continues to grow into adulthood (Fagan, 2016).

Language-like behavior begins immediately after birth, as babies cry to indicate needs and desires. Infants quickly progress from cooing (vocalic sounds that resemble vowels) to canonical babbling (strings of consonant-vowel syllables such as “bababa” or “mamama”) to variegated babbling (combining different consonant-vowel syllables such as “mamalala” or “pabadaba”), finally resulting in the production of first words at around the child’s first birthday (Kuhl & Meltzoff, 1996). Around a year and a half old, a toddler is able to produce about 50 words, and then a vocabulary explosion occurs with toddlers comprehending approximately 500 words and producing 200 words by two years old (Turnbull & Justice, 2016). Typically-developing toddlers are already considered highly skilled word-learners by the time they have their third birthday (Lederberg & Spencer, 2001; Quittner, Cejas, Wang, Niparko, & Barker, 2016).

When children begin school, the majority of words they learn are based on their own experiences and refer to people, places, or things. As children transition from learning to read to reading to learn around the 3^{rd} or 4^{th} grade (Chall, 1983), they are able to learn new vocabulary indirectly through reading (Duke, Bennett-Armistead, & Roberts, 2003). Then, after 4^{th} grade, students are expected to read and understand abstract words like *percentage* and *volume* that come from their textbooks (Chall, 1983). Fifth graders who read for 20 minutes a day read almost 2 million more words per year than students who cannot or do not read outside of school (Anderson, Wilson, & Fielding, 1988; Cunningham & Stanovich, 1997). By the time children finish high school, they are able to understand and use about 60,000 words (Pinker, 1994). The vocabulary development for children with typical hearing is persistent from infancy through their school years. Beyond the classroom, continued vocabulary learning is necessary for success in postsecondary education, living independently, and employment. There is no critical window for vocabulary learning (Fagan, 2016), especially as individual motivation endures and new experiences that promote learning arise.

Researchers have investigated why some students are more successful at learning vocabulary than others. Certain characteristics affect vocabulary development for children with typical hearing such as gender (Bauer, Goldfield, & Reznick, 2002; Dale & Fenson, 1996; van Hulle, Goldsmith, & Lemery, 2004), birth order (Hoff, 2006), socioeconomic status (Dollaghan et al., 1999; Hart & Risley, 2003; Suskind, Suskind, & Lewinter-Suskind, 2015; Turnbull & Justice, 2016; Walker et al., 1994), and parent involvement (Hart & Risley, 2003; Suskind et al., 2015; Turnbull & Justice, 2016). In addition, student motivation and teaching strategies can affect vocabulary development.

1.2.1 Vocabulary Instruction for Children who are Typically Hearing

According to the NRP (2000), vocabulary should be taught indirectly and directly. More specific suggestions include teaching vocabulary using repetition and through learning in rich and varied contexts. Most vocabulary is learned indirectly through everyday experiences with oral and written language (National Reading Panel, 2000). Children learn vocabulary indirectly through having conversations, singing songs, and playing games with peers, family members, or teachers. In addition, children are able to overhear their parents talking about the grocery list or their brother and sister arguing about the rules to a board game, which offer opportunities for vocabulary growth. It is not just about the quantity of conversations between the child and partner; the quality of the input matters as well (Hart & Risley, 2003; Suskind et al., 2015; Weizman & Snow, 2001). Positive interactions and supportive words can help motivate children to want to learn and talk more, whereas prohibitions and criticisms may discourage a child (Suskind et al., 2015). When having a meaningful conversation with a child, conversational partners can model new vocabulary, expand on the child's utterance, provide prompts to extend their language, and fix breakdowns in the conversations (Luckner & Cooke, 2010).

For the past 75 years, research has shown a strong positive correlation between vocabulary and reading comprehension (e.g., Davis, 1944). For children with typical hearing, indirect vocabulary learning occurs through reading aloud and reading independently. Reading aloud can be done at any age. The benefits can be enhanced by discussing the context and vocabulary of the story before, during, and after reading. Then when children are able to read on their own, they can learn many new words independently from texts. The more children read, the more words they encounter, and the more word meanings they will learn (National Reading Panel, 2000). When students are read to and read independently, they will feel more confident with their reading abilities and are more likely to continue to read. Yet, the opposite is also true—when a student is not read to or does not read independently, he will feel less confident and is less likely to read. This is known as the "Matthew Effect" (Stanovich, 2009), where the rich get richer and the poor get poorer.

Even though most vocabulary is learned indirectly for children with typical hearing, direct vocabulary instruction is still necessary (National Reading Panel, 2000). Multiple studies have reported that direct, systematic instruction for school-age children with typical hearing represents a best practice for vocabulary instruction (e.g., Beck & McKeown, 2007; Coyne, Simmons, Kame'enui, & Stoolmiller, 2004). For example, while reading from a science textbook, a teacher can stop and directly address new vocabulary words. Direct instruction is important for children to learn high-frequency words that appear in texts (e.g., *obvious, complex,* or *establish*). Also, direct instruction is needed for difficult words representing complex concepts that are not part of everyday experiences. In-depth, direct vocabulary instruction can help students comprehend what they are hearing and reading, especially for children who have lower receptive vocabularies (Coyne et al., 2004). In a study examining the impact of direct vocabulary instruction during shared storybook reading (integrating vocabulary instruction with reading a story aloud) kindergartners with smaller initial receptive vocabularies learned more words than the children with larger vocabularies. These results show that is possible to "close the gap" between children with varying degrees of receptive vocabularies with direct instruction (Coyne et al., 2004). It is also recommended that a portion of regular classroom lessons be dedicated to explicit vocabulary instruction and educators integrate explicit vocabulary instruction into content-area curricula such as science and social studies (Gertsen, 2008; Kamil , Borman, Dole, Kral, Salinger, & Torgesen, 2008). The more students are exposed to, use, and work with new words in different contexts, the more likely they are to learn and retain the words (National Reading Panel, 2000).

Another aspect of direct vocabulary instruction is teaching students word-learning strategies, such as phonic analysis (using letter/sound correspondence), using context clues, reference tools like a dictionary, and structural analysis (using clues such as root words, prefixes, and suffixes) (National Reading Panel, 2000). Teachers are unable to provide instruction on every new vocabulary word, so students need to learn how to determine the meanings of new words themselves.

Specific strategies and interventions to target vocabulary development have been a focus of educational research. The NRP (2000) suggests teaching vocabulary by using technology or computer programs, pre-teaching vocabulary words (introducing words and their corresponding definitions prior to the set activity), task restructuring or repeated exposure, and substituting easy words for difficult words for low-achieving students. Using semantic maps or graphic organizers in content areas (e.g., math, science, and social studies) to show how new vocabulary relates to other ideas is another suggested strategy (Luckner, Bowen, & Carter, 2001). Besides activities for vocabulary instruction, specific strategies are suggested for effective teaching. Blachowicz, Fisher, Ogle, and Watts-Taffe (2006) suggest keeping learners actively involved in the generation of word meanings rather than passive receptors of information. Instruction should include both definitional as well as contextual information about the words. For example, not only teaching the definition of *volume* (amount of space an object occupies), but also having students measure the *volume* of different objects. Importantly, they suggest offering multiple exposures to the words and opportunities for the children to use them. Teachers may need specific interventions for students with poor vocabulary development, instead of general strategies and suggestions offered by the NRP. What Works Clearinghouse, for example, is a popular reference for teachers as a source of scientific evidence on educational programs and interventions, including vocabulary instruction (IES-NCEE, 2019). It is constantly updated with new studies investigating educational interventions.

Typically-hearing children who succeed in reading and school are those who have the skills to acquire words quickly through listening, direct instruction, and printed texts. Children with hearing loss are at a distinct disadvantage in vocabulary development because their listening skills are compromised. The next section will discuss how childhood hearing loss affects lexicon size, rate of vocabulary development, and processes for learning new words.

1.2.3 Vocabulary Development for Children who are Deaf or Hard of Hearing

On average, research suggests that vocabulary development and knowledge of children who are d/hh is poorer than peers with typical hearing. Students who are d/hh have been reported to be delayed in vocabulary acquisition, have smaller lexicons, acquire new words at a slower rate, and struggle with word-learning strategies (e.g., Harris, Terlektsi, & Kyle, 2017; Hermans, Wauters, Willemsen, & Knoors, 2015; Lederberg & Spencer, 2001; Luckner & Cooke, 2010; Lund, Douglas, & Schuele, 2015; Nott et al., 2009; Quittner et al., 2016; Yoshinaga-Itano et al., 2017). However, both vocabulary knowledge and vocabulary growth are highly variable areas among children who are d/hh (Hermans et al., 2015). In fact, some studies report that children who are d/hh and who use spoken language can develop vocabularies similar in size to those of hearing peers (Boons et al., 2013; Fagan, 2016; Geers et al., 2009; Geers & Nicholas, 2013; Houston et al., 2012; Lederberg, Prezbindowski, & Spencer, 2000; Peterson, Pisoni, & Miyamoto, 2010; Schorr, Roth, & Fox, 2008). The following paragraphs will describe why children who are d/hh are at risk for delayed vocabulary development, and then discuss the literature of mixed findings on vocabulary achievement and development.

Reasons for Delay in Vocabulary Development

There are numerous explanations as to why children with hearing loss are delayed in vocabulary development—specifically those who use listening and spoken language as their main form of communication. To begin, children who are d/hh have less total listening experience than their hearing peers of the same age (Tomblin, Barker, Spencer, Zhang, & Gantz, 2005). If they have not had access to spoken language due to hearing loss, they cannot be expected to produce it. For children with profound congenital hearing loss, even in the optimal situation of early identification and access to surgery, many do not gain access to sound until they receive cochlear implants at 12 months old. There are cases where cochlear implantation can occur before 12 months, as in the case of meningitis, which causes ossification (hardening) of the cochlea, and cochlear implantation needs to occur soon after diagnosis (Roland, Coelho, Pantelides, & Waltzman, 2008). But, there is debate as to whether implantation before 12 months of age has more potential risks for infants than potential benefits (Cosetti & Roland, 2010; Dettman et al., 2016; Miyamoto, Colson, Henning, & Pisoni, 2018). Because of the current FDA age requirement, though, many children with profound hearing loss do not have the opportunity to begin listening and learning spoken language until they are a year older than their typically hearing peers (Lund, 2016). Even infants who have been identified with milder losses, still miss out on both quantity and quality of auditory input while deciding on appropriate devices and intervention. Speech perception scores at six months old, for infants with and without hearing loss, have been found to affect expressive vocabulary outcomes later in life (e.g., de Hoog et al., 2016; Dettman et al., 2016; Eisenberg et al., 2016; Geers et al., 2013; Tsao et al., 2004).

Therefore, if children are missing out or have poor quality of auditory input during the first year of life, their vocabulary development will be affected as they grow up.

Children with hearing loss struggle to learn vocabulary incidentally like children with typical hearing from the beginning of life. Due to their relative inaccessibility to spoken language (e.g., difficulty perceiving speech, whether directed at them or overheard), young children with hearing loss miss out on opportunities to learn new words (Convertino et al., 2014). Cochlear implants can provide a child with auditory access to spoken language, but they cannot restore lost auditory and linguistic experiences. Thus, delays in vocabulary development can also be attributed to the impact of experiential deficits prior to cochlear implantation (Fagan, 2015).

Another negative impact of delayed auditory input is the potential of reorganization and developmental interruptions of the auditory system and cortical areas of the brain. Both functional and structural changes to the auditory nerve, brainstem, and cortex have been observed in animal and human models as a result of deafness (Gordon, Wong, Valero, Jewell, Yoo, & Papsin, 2011). If parts of the auditory system are not used early on in life, especially during a sensitive period of cortical development—periods of increased neuroplasticity—they will lose their intentioned function. Those unused areas can be permanently reorganized to other areas, such as to the visual or somatosensory system (Gordon et al., 2011; Sharma, Campbell, & Cardon, 2015). Sharma and colleagues (2002; 2007; 2015) concluded that children with less than 3.5 years of auditory deprivation (i.e., implanted by 3.5 years old or earlier), developed their auditory systems most similarly to children with typical hearing. They also found if a child did not have auditory stimulation by seven years old—the end of the sensitive period—their developmental trajectories were abnormal. The lack of auditory stimulation resulted in a reorganized auditory cortex unable to effectively process stimulation provided by cochlear implants. This is another argument for children with hearing loss to have access to auditory input through devices as early as possible.

Another predictive factor of vocabulary development for children with hearing loss is the amount and way parents interact with their children, even during the infant years (Desjardin & Eisenberg, 2007; Niparko et al., 2010; Spencer & Meadow-Orlans, 1996). It has been found that typically hearing parents use shorter phrases, have fewer turn-taking conversations, and use more directives and prohibitions with children who are d/hh in comparison to children with typical hearing, which can be detrimental to development (Fagan, 2016; Lederberg & Everhart, 2000; Levine et al., 2016; Lund et al., 2015).

Poor development of word-learning skills may be another reason for delayed language acquisition in children with hearing loss (Houston et al., 2012; Lund & Schuele, 2014). Infants with typical hearing begin developing strategies for parsing a stream of speech into words and mapping them onto the world during their first year of life (Levine et al., 2016). Children with hearing loss may not develop these skills as quickly as children with typical hearing (Davidson et al., 2014; Lund & Schuele, 2014), partially due to the delay of auditory input. In addition, even with amplification, access to acoustic information is degraded for children with hearing loss, and most word-learning opportunities likely take place in settings that are not acoustically treated (Lund & Schuele, 2014). The lack of access to acoustic information due to background noise or degraded auditory information may impede the building of phonological and semantic representations, which are instrumental in word-learning abilities (Lederberg et al., 2000). As a result of these difficulties, children with hearing loss have been found to demonstrate poorer word-learning abilities than children with typical hearing (Davidson et al., 2014; Lund, 2018; Lund & Schuele, 2014). If children who are d/hh do not have sufficient word-learning skills, they cannot be expected to develop comparable vocabulary knowledge to children with typical hearing.

As previously mentioned, vocabulary—specifically the size, growth, and learning abilities—are highly variable areas among children with hearing loss who use listening and spoken language (Hermans et al., 2015). The following paragraphs describe research in these three areas of expressive vocabulary development: (a) lexicon size; (b) rate of vocabulary growth; and (c) word-learning processes or strategies (Lederberg & Spencer, 2001). In subsequent paragraphs, I will only be discussing expressive (spoken) vocabulary studies. I will first describe a group of studies that found some children with hearing loss scoring similarly to peers with typical hearing; then I will present studies that showed significant delay for children who are d/hh.

Lexicon Size

In a study of 60 children with cochlear implants all using listening and spoken language (*M* age = 4.5 years old), Geers and Nicholas (2013) reported that 82% of the sample scored within or above 1 standard deviation of the normative mean on the Expressive One Word Picture Vocabulary Test (EOWPVT) (Gardner, 2010). The vocabulary scores were significantly higher than scores for overall language, which suggests vocabulary may be easier to acquire than other aspects of language (e.g., syntax) for this population. The sample of children had parents with higher than average education levels and family income, and no child was reported as having an additional disability. Similar results were found by Geers, Moog, Biedenstein, Brenner, and

Hayes (2009), when they investigated the vocabulary knowledge of 153 children who received cochlear implants before their fifth birthday. The students all attended listening and spoken language programs across the United States. The mean score on the EOWPVT or Expressive Vocabulary Test (EVT) (Williams, 2007), was 90.67 for children aged 5-6.11 years old. Schorr, Roth, and Fox (2008) tested a wider age range of children with cochlear implants (5-14 years old) using the EVT and 66% of the sample scored within the average range. However, in this study, 100% of peers with typical hearing scored within the average range. In examining the size of expressive vocabularies of children with hearing loss, Boons et al. (2013) reported that 57% of the 70 children with cochlear implants scored within 1 standard deviation of the norm on the EOWPVT. They also examined the word classes of the children's expressive vocabularies and found no significant differences in their knowledge of nouns, verbs, or category words when compared to the children with typical hearing. Therefore, per these studies, children who are d/hh can achieve expressive vocabulary levels within the average range as compared to peers of the same age with typical hearing.

In contrast to the studies described above, the following investigations resulted in poorer overall outcomes for children who are d/hh and use listening and spoken language. As an overall picture of children with cochlear implants, Lund (2016) conducted a meta-analysis to evaluate whether these children demonstrated poorer expressive vocabulary scores than peers with typical hearing. By aggregating effect sizes of all the relevant studies that met the inclusion criteria, it was found that children with cochlear implants performed worse than peers with typical hearing by an average of 11.99 points on expressive vocabulary tasks. The majority of children who were included in this study were implanted prior to 30 months of age and still demonstrated a smaller overall expressive vocabulary size than peers with typical hearing.

Nicholas and Geers (2007) took language samples of 76 children with cochlear implants at ages 3.5 and 4.5 years old during 30-minute play sessions with their parents. The language samples of the children with cochlear implants were then compared with a control group of hearing children. On average, at both ages, children with cochlear implants had considerably smaller sized vocabularies than hearing peers. Even though none of these children had a developmental delay or medical condition other than hearing loss, and they all scored within the normal range on a nonverbal intelligence test, the majority of children still had smaller sized vocabularies than their peers with typical hearing.

Kyle, Campbell, and MacSweeney (2016) compared expressive vocabularies of 86 children who are d/hh with peers with typical hearing between the ages of 5-14 years old. The results from the EOWPVT were that, on average, children with hearing loss had significantly smaller expressive vocabulary scores then their peers with typical hearing. They also found, for both groups of children, that vocabulary significantly predicted reading accuracy and comprehension.

Geers et al. (2017) used the MacArthur Communicative Development Inventories (CDI) (Fenson, Marchman, Thal, Dale, & Reznick, 2007), a parent report, to measure the understood (receptive) and spoken (expressive) vocabulary of 97 children prior to cochlear implantation. The average age of implant was 21.4 months and the average number of receptive and expressive vocabulary words was only 14.2, which is remarkably behind the average typical hearing child who knows about 225 words at age 23 months (Fenson et al., 1994). Before these children received their implants, even at such a young age, they were already significantly behind their peers with typical hearing.

Yoshinaga-Itano, Sedey, Wiggin, and Chung (2017) investigated the impact of the 1-3-6 EHDI guidelines (screened for hearing loss by 1 month, diagnosed by 3 months, and intervention implemented by 6 months) on vocabulary knowledge for children who are d/hh and use a variety of communication methods (i.e., spoken language, ASL, sim-com). A multi-state study of 448 children with bilateral prelingual hearing loss was conducted. Using the CDI, it was found that the group who met all three EHDI guidelines and did not have an additional disability had a significantly larger vocabulary than children who only met one, two, or none of the guidelines. Yet, these children had a mean vocabulary quotient (vocabulary score relative to child's age) of only 82, which is substantially less than the expected mean of 100 for typically hearing children. Of great concern, 37% of this sample had vocabulary quotients less than 75. These are results from a large sample of children with hearing loss who have met the ideal deadlines, but on average, are still far behind their peers with typical hearing.

Several recent studies show that children who are d/hh start out at a distinct vocabulary disadvantage in the early years of life prior to appropriate amplification (Geers et al., 2017) and even when ideal timelines are met (Yoshinaga-Itano et al., 2017). Preschoolers and older children who are d/hh also have smaller vocabularies than typical hearing peers (Kyle et al., 2016; Nicholas & Geers, 2007), but factors such as early age at implant and spoken language instruction can lead to more successful vocabulary outcomes (Geers et al., 2017; Nicholas & Geers, 2007).

Rate of Vocabulary Growth

Currently, there is very little research describing the rate of expressive vocabulary growth for children who are d/hh and who use spoken language. There is even a smaller subset of studies observing children with hearing loss scoring within normal range or who are making more than one year's growth in one year's time. Because children with hearing loss start out at a disadvantage with the size of their expressive vocabularies, they must progress at a faster rate than would be expected. For example, a child who is considered "catching up" to his hearing peers is making 16 months' worth of growth in only 12 months' time; therefore, this child is closing the gap between his vocabulary knowledge and typically hearing peers of the same age. Fagan (2015) investigated the expressive vocabulary growth of nine children, all who had been implanted early (*M* age of implantation = 12.46 months). They were tested using the CDI (Fenson et al., 2007) at four months after cochlear implant activation and then 12 months after activation. It was found that the sample had reduced their delay in vocabulary knowledge from 12 months (delay at four-month test) to six months (delay at 12-month test) in a year's time. On average, this small sample of children was able to cut their delay in half, meaning they were "catching up" to their typical hearing peers in regards to expressive vocabulary acquisition.

Studies of vocabulary development for children with hearing loss have found delays related to both size and rate of growth. It has been reported for children with hearing loss that learning new vocabulary is dependent on previous vocabulary knowledge, and that a student who has a slower vocabulary learning trajectory will continue on that same trajectory (Fagan, 2016; Lederberg et al., 2000; Quittner et al., 2016). Nott et al. (2009) found evidence of poor vocabulary trajectories in a study of 24 children with hearing loss during the very early stages of vocabulary development. The purpose of the study was to compare the amount of time it took for children with hearing loss to develop their first 50 spoken words, second 50, and first 100 in comparison to children with typical hearing. Also, Nott and colleagues examined the development of two-word combinations. Parents recorded their child's first 100 words spoken, as well as any two-word combinations that were said during that time. Overall, children with hearing loss took an average of 8.9 months to learn their first 50 words compared to the hearing group who took seven months. To learn the second 50, the children who were d/hh took 3.6 months, which was more than twice the time the children with typical hearing took to learn their second 50 words (*M* = 1.7 months). Overall, to learn the total 100 words, children with hearing loss took an average of 12.5 months, versus the children with typical hearing who took 8.7 months. Two-word combinations emerged three months later in the group with hearing loss compared to peers with typical hearing.

Quittner, Cejas, Wang, Niparko, and Barker (2016) investigated the rate at which children with hearing loss learn novel words in a longitudinal study. Children with cochlear implants (*M* age at beginning of study = 2.2 years old) completed a novel word learning task before cochlear implantation, 6, 12, 24, and 36-months post-implantation. Before they could begin the task, the children had to have a vocabulary of 50 words as measured by the CDI (Fenson et al., 2007). It was reported that children with cochlear implants were significantly delayed (*Mdn* delay = 1.54 years) in novel word learning when compared to children with typical hearing. The children with cochlear implants did not develop at rates similar to children with typical hearing, also suggesting that this sample of children with cochlear implants do not appear to "catch up" with their peers. The average age of implantation was 2.2 years old, which is not as early as desired for cochlear implantation. Further, this group had a high proportion of lower income and lower parent education than the peers with typical hearing, which could account for the poor vocabulary development.

Harris, Terlektsi, and Kyle (2017) investigated vocabulary growth of 41 children (*M* age = 6.7 years old) with hearing loss who use spoken language, British signed language, and a combination sign and speech. Over a two-year period, the vocabulary age for the entire sample of children with hearing loss increased only by 8.5 months, compared to the sample of typical hearing peers who gained 33.5 months in vocabulary age over the same period. As mentioned previously, in order for children with hearing loss to "catch up" to their peers with typical hearing they need to make more than 12 months' progress in a year's time. This group of children did not even make 12 months' progress over two years; therefore, they were falling further behind the children with typical hearing.

According to the studies described above, not only are children who are d/hh starting off at a disadvantage with the size of their vocabularies (Kyle et al., 2016; Lund, 2016; Nicholas & Geers, 2007), but they are not progressing at a fast enough rate to "catch up" to their peers with typical hearing (Harris et al., 2017; Nott et al., 2009; Quittner et al., 2016).

Word-Learning Processes

Research about word-learning processes of children with hearing loss is limited, even more so for studies that require the children to expressively label the novel words. The few word-learning studies requiring students to expressively label newly learned words will be described in the intervention section. The studies below measure the children's receptive word-learning abilities, and are important to include because they help paint the picture of the word-learning abilities for children with hearing loss.

Lederberg, Prezbindowski, and Spencer (2000) assessed word-learning abilities of 19 children who are d/hh (*M* age = 5.1 years old). The students used simultaneous communication (sim-com)—a combination of spoken language and manual communication. Students learned new words in two contexts; the first required using a novel mapping strategy and the other assessed the ability to learn new words after minimal exposure when the object was explicitly labeled (rapid-word learning task). Novel mapping tasks assess children's ability to infer that a new word refers to a novel object. In the novel mapping context, three familiar objects were placed in front of the child as well as a novel object. The children were asked to point to an object that corresponded with a familiar word (e.g., "dog, dog, where is the dog?") and then for the nonsense word of the novel object (e.g., "dax, dax, where is the dax?"). The children were not told the label of the novel object beforehand. The procedure was the same in rapid-word learning task, except that the children were told the label of the novel object three times. Eleven out of 19 children successfully learned new words in both contexts (novel mapping and rapid-word learning). Five children learned new words only in the explicitly-labeled condition (rapid-word learning), and two didn't learn any of the new words. The seven children who struggled with learning new words in one or both conditions were tested two more times over an 18-month period. By the last test, all of the children had acquired the word-learning skills as measured by learning all of the new words. Overall, the children's performance on the two tasks seemed related to their vocabulary size at the time of the tests. The children with the larger vocabularies passed the tests by learning new words faster than the children with smaller vocabularies. These results show that children with hearing loss were able to acquire these vocabulary learning skills over time, but their ability to learn novel words depended on the size of their vocabularies. As a limitation, it is important to note the date of this study. In 2000, not all states had implemented Universal Newborn Hearing Screening and the FDA had just approved implanting children at 12 months old. Therefore, these children could have been identified and provided with amplification later than children are currently.

Houston, Stewart, Moberly, Hollich, and Miyamoto (2012) found similar results for some of their sample. The children with hearing loss (age range of 21.7 to 40.1 months) who were implanted around 12 months of age were able to learn new words in a novel word/novel object pairing task at similar rates to peers with typical hearing. Also, children who had better hearing prior to cochlear implantation performed on par with their peers. However, children who were implanted later than 12 months old or had less hearing prior to implantation learned words at a slower rate when compared to peers with typical hearing.

Although there is little current research about word-learning strategies in children who are d/hh, the above studies suggest that some children who are d/hh are able to learn new words through minimal exposure, which is similar to strategies used by hearing children (Houston et al., 2012; Lederberg et al., 2000). It appears that vocabulary size, early age at amplification, as well as better hearing prior to implantation are important predictors of the effectiveness of this strategy.

Similarly, to the word-learning studies described above, the following studies do not require the students to expressively label the new words. Yet, they are important to include because they describe the difficulties children with hearing loss face with word-learning processes. Davidson, Geers, and Nicholas (2014) assessed the word-learning abilities of elementary-aged children with cochlear implants in comparison to children with typical hearing.

Children with cochlear implants were divided into two different groups based on how well they understood speech using their implants: good audibility (GA) (N = 46), and poor audibility (PA) (N = 55). In a novel word-learning task, children were asked to learn six novel words from a story presented on the computer. Six different stories were used; therefore, there was a total of 36 novel words to be learned. The children were given a recognition task at the end of each story. The mean overall percent correct score for the GA group was 47%, and for the PA group was 41% in comparison to the children with typical hearing which was 63%. The mean scores for both groups of children with cochlear implants were significantly poorer than their aged-matched typically hearing peers. In addition, the children with cochlear implants did not learn the novel words with increased exposures to the extent that the children with typical hearing did. The children with typical hearing reached an average score of 81% correct by trial six (last trial in the story), in comparison to the GA's score of 65% and PA's score of 52%. However, it is important to note that learning 36 words in one session is a difficult task for young children with cochlear implants, and this is even true for children who have good audibility. Attempting to learn this many words could potentially cause learner fatigue and poorer scores.

Lund (2018) also found that a sample of children with cochlear implants scored worse on novel word-learning tasks when compared to typically hearing peers. On one task, children were shown a picture of a familiar object and one of an unfamiliar object. They were then asked to point to the picture that corresponded with the target word, which could either be a known word or a novel word. Lund found that the children with cochlear implants correctly labeled fewer unfamiliar objects with novel words than children with typical hearing, all of whom had almost perfect scores. The children with cochlear implants incorrectly assigned novel words to familiar pictures or familiar words with novel pictures. Assigning novel words to unfamiliar objects is a beginning step to learning new words. This is a skill that infants can typically develop in the first year of life (Estes, Evans, Alibali, & Saffran, 2007). Thus, the children with cochlear implants in Lund's study—who were on average 4.7 years old—were significantly behind their typically hearing peers. For the second task, familiar and unfamiliar toys were placed in front of the children to play with and they could ask questions about them. Of the 12 children with cochlear implants, only five inquired about any of the unfamiliar objects. Overall, the children with cochlear implants asked about fewer unfamiliar objects (either through spoken language, gestures, or facial movements) than the children with typical hearing. This is an important finding because children with typical hearing interact with their environment and inquire about the names of new objects by two years old, whereas the children with hearing loss were twice that age (Nelson, Holt, & Egan, 2004). Because this study did not include children with disabilities or children who's hearing loss was identified after 12 months old, these findings are limited to a specific sample of the population. According to these studies, children with hearing loss struggle to learn vocabulary in similar ways to children with typical hearing, despite their audibility level (Davidson et al., 2014; Lund, 2018).

As stated previously, some studies have found that children with hearing loss can develop vocabulary knowledge within the normal range or within 1 standard deviation of normal. However, it is important to note that with almost all of these findings there is a caveat. In some studies, only a percentage of children reach the average range, or, only children with certain characteristics have on par results. It is optimistic that at least some of the children are scoring within the normal range, but as a field it is important not to forget about the students that do not reach those scores. Researchers must continue to investigate why some children with hearing loss reach acceptable scores and others do not, as well as the specific characteristics that distinguish successful vocabulary learners. Also, teachers of the deaf know that scoring within the average range or 1 standard deviation within the mean will not permit children with hearing loss to "catch up" with their typically hearing peers. As previously stated, in order for children with hearing loss to have equivalent vocabulary knowledge as their peers, they need to make more than a year's progress in a year's time (Lund & Douglas, 2016). For example, an average score of 87 is within the normal range, but it is near the lower end of average, and will not be sufficient for the child to "catch up" his peers with typical hearing.

In summary, vocabulary is an important area of language with great developmental variability among children who are d/hh (Eisenberg et al., 2016). Vocabulary supports and predicts areas of development such as speech perception, reading comprehension, language comprehension, verbal and written communication, social-cognitive development, theory of mind, reading comprehension, school readiness, and academic outcomes (Antia et al., 2009; Fagan, 2016; Kyle & Harris, 2010; Lederberg et al., 2013). Importantly, vocabulary is an independent predictor of reading comprehension and accuracy (Harris et al., 2017; Kyle et al., 2016). As explained above, vocabulary is so important to reading development that the National Reading Panel chose it as one of the five areas to spend time and resources investigating (National Reading Panel, 2000). One avenue for indirectly learning new vocabulary words is through reading, but many children who are d/hh are known to struggle in both of these areas (e.g., Cawthon, 2011; Hermans et al., 2015; Moeller, Tomblin, Yoshinaga-Itano, Connor, & Jerger, 2007). Some children can have more positive results than others, but the findings amongst this population are extremely variable. More research about lexicon size, rate of growth, and word-learning processes is needed for this population.

If the goal for children with hearing loss is to develop vocabulary knowledge that is equivalent to children who are typically hearing, then children who are d/hh must learn words at a faster rate than their peers to "close the gap." Despite a clear need to use strategies to support rapid vocabulary growth, there are no evidence-based techniques described in the literature designed to help these students foster vocabulary development (Luckner & Cooke, 2010; Lund, 2016). Additionally, vocabulary instruction varies widely in the classroom, because teachers of the deaf have little information to guide their instruction (Duncan & Lederberg, 2018).

1.2.4 Vocabulary Interventions for Children who are Deaf or Hard of Hearing

Because children with hearing loss struggle to learn vocabulary incidentally like children with typical hearing, teachers must find strategies and interventions to use to surpass that deficit. Due to the variability of the population, finding the "tricky mix" (Marschark & Knoors, 2019, p. 3) of strategies for educating children with hearing loss is more complex than for a child with typical hearing. It would be helpful to look to research and evidence-based practices for guidance, but presently there are no evidence-based practices on vocabulary instruction specifically designed for children with hearing loss (Luckner, 2006). Luckner describes four primary challenges regarding the development and implementation of evidence-based practices for children with hearing loss: (a) hearing loss is a low-incidence disability, (b) the low-incidence nature leads to difficulties in conducting "gold standard" studies, (c) the field of deaf education has largely been fueled by emotion, and educational practices have been based on opinion, and (d) professionals who have the knowledge and experience to conduct research are employed in teacher preparation programs that do not provide time and expenses needed to conduct "strong evidence" types of studies. Due to these challenges and others, few researchers have conducted intervention studies. This section will describe the few expressive vocabulary studies that have used an intervention with children who are d/hh. It is important to note that an intervention implemented in one single study does not denote it as an evidence-based practice. There are many more requirements an intervention must meet in order for it to be classified as evidence-based (Odom, Brantlinger, Gersten, Horner, Thompson, & Harris, 2005; Thompson, Diamond, McWilliam, Snyder, & Snyder, 2005).

As an overall picture of the vocabulary research in the field, a meta-analysis was completed by Luckner and Cooke (2010) to examine the vocabulary research with children who are d/hh over a 41-year period (1967-2008). The meta-analysis included studies with children aged 3-21, omitting the earliest of learners that are currently driving research in the field (birth-3 years old). Forty-one studies of any type fit the inclusion criteria, but only 10 (24%) of the studies investigated the effectiveness of an intervention. Of the 10 intervention studies, only two were published after 2005. This is important to note because of the drastic changes in the population outcomes with the implementation of EHDI and UNHS in 2005, and cochlear implant FDA approval age reduction to 12 months in 2000. Of the 10 interventions that were studied, five demonstrated positive effects in a single study only; therefore, the positive evidence that was found would be considered small using the standards stated by the U.S. Department of Education Institute of Education Sciences (Odom et al., 2005) or as a "tentative evidence-based practice" (e.g., Thompson et al., 2005). From Luckner and Cooke's meta-analysis in (2010), very little could be drawn from the literature to direct teachers in effective strategies to use in the classroom.

As mentioned previously, the focus of this dissertation is expressive vocabulary development. The following four studies describe the current (2015+) expressive vocabulary intervention research that describe the population of children who are d/hh and born under EHDI. Bobzien et al. (2015) investigated whether preschoolers with hearing loss would learn novel vocabulary through repeated storybook reading sessions. Four children were studied in a multiple baseline design. This design involved establishing baseline measures for each participant of their knowledge of the new vocabulary that was to be taught in each story. Then, the independent variables (repeated storybook reading and explicit vocabulary strategies) were incrementally introduced to each participant. This design helps draw conclusions about the strength of the interventions employed (Riley-Tillman & Burns, 2011). Teachers were trained to use four explicit teaching strategies during the sessions in addition to repeated reading: (a) *verbal expansion*- elaborating on child's response by using the vocabulary word in sentences or repeating the child's phrase, (b) *word definition and/or word elaboration*- giving the meaning of the word/synonyms or link the word to child's life, (c) *cloze technique*- teacher omits final word of the sentence and child has to complete using the correct vocabulary word, and (d) *individual/choral responding*- teacher emphasizes the target word and asks the child to say it or asks a question that requires a response from all children together. In this study, all four children were amplified with cochlear implants or hearing aids before or at 13 months old and used spoken language. Due to the multiple baseline design, not all children were exposed to all five books; in fact, only one child had that opportunity. Six new vocabulary words were explicitly taught for each book and three were chosen as non-instructional words with no explicit teaching for comparison of learning.

It was found that in order for students to learn all six words, the stories had to be reread between five and eight times even when incorporating the explicit teaching strategies. All four children learned the target vocabulary faster and retained them longer than the non-instructional vocabulary, which was learned at a low rate across the stories. Reading the same book each day provided additional opportunities for auditory comprehension and vocabulary acquisition for the children with hearing loss in this study. Yet, with a small sample of four children, and with only one child receiving the intervention with five stories, it is difficult to generalize these findings outside of this specified sample.

Another aspect of the study was to examine the four explicit teaching strategies the teachers were trained to use. Overall, the strategies were used between 205 (*verbal expansions*) and 373 (*individual/choral reading*) times throughout the entire intervention. This range shows the variability of how strategies are used in the classroom, even within one setting and using the same materials. Bobzien and colleagues also did a post-intervention survey with the teachers. It was found that, "…they [teachers and paraprofessionals] believed that the intervention was worthwhile, that the project was worth the additional time required, that they would use similar interventions again, and that repeated reading and explicit teaching strategies were responsible for the vocabulary learning," (Bobzien et al., 2015, p. 276). These result show that teachers want, need, and welcome guidance in teaching vocabulary to children who are d/hh.

Lund, Douglas, and Schuele (2015) investigated whether varying degrees of semantic richness used by teachers of the deaf when teaching vocabulary would affect word-learning.

Eight children from a listening and spoken language-focused preschool participated in the 7-week, single-case, adapted alternating treatments, intervention study. All new vocabulary words were taught to the students using flashcards, but the amount of context provided with the words varied with condition. The three different semantic richness conditions used in the intervention included: "1. *Semantically Sparse*- teachers were instructed only to continue repeating the target vocabulary word in isolation or in sentences that gave little additional information (e.g., 'Popcorn! Look, popcorn!'), 2. *Semantically Rich*- teachers were instructed to provide additional linguistic semantic information about the target vocabulary word (e.g., 'Popcorn tastes salty! We make popcorn in the microwave.'), and 3. *Semantically Super Rich*- teachers were instructed to give children additional linguistic information and physical experience with the target word. For example, when teaching the word popcorn, the teacher might give the participant information about popcorn (as in Condition 2), and give the participant a piece of popcorn," (Lund et al., 2015, p. 168). Teachers administering the intervention were four master's-level teachers of the deaf. Conditions alternated week-by-week, but due to the odd number of weeks the intervention lasted, some children were exposed to certain conditions more than others. Also, because of school events and absences, only four children completed all seven weeks of the intervention.

Instead of using the number of words learned as the dependent variable, Lund et al. (2015) used the percent correct of sounds produced for each target word. This allowed children to get partial credit if they were able to accurately produce a portion of the vocabulary word. Overall, for most children there was a relation between the level of semantic richness given with the expressive labeling of the new vocabulary words. The findings indicate that inclusion of semantically rich information during instruction may improve expressive word-learning for children who are d/hh. The additional context clues may have helped the children to evoke imagery, semantic features, or a memory of experience with the new word. They concluded that providing children who are d/hh with a semantically rich context while directly teaching vocabulary could result in larger expressive vocabularies. Because of the study design, however, conclusions can only be drawn about children with hearing loss who fit a similar profile to the participants in this study. In addition, some children were exposed to certain conditions more than others (due to the odd number of weeks and absences during the intervention). Finally, teachers were instructed and trained to use the new vocabulary words only six times during the lessons, but post-hoc analysis showed that teachers produced the vocabulary words more in the *Semantically Super-Rich* and *Semantically Rich Conditions* than the *Semantically Sparse Condition*. Differing number of exposures could have impacted the children's learning in each condition.

Lund and Douglas (2016) continued to investigate different teaching strategies for vocabulary development with children who are d/hh. Using an adapted, alternating-treatments design, they compared the effects of three different vocabulary interventions; all of which had been suggested as possibilities to increase vocabulary knowledge. The three interventions included: (a) *Explicit, Direct Instruction*- introduction to the words, receptive practice, expressive practice (Lund et al., 2015; Moog, Stein, Beidenstein, & Gustus, 2003), (b) *Follow-in-Labeling*- the teacher only gave the label of an object once the child had showed interest (Kaiser & Roberts, 2013), and (c) *Incidental Exposure*- teachers placed pictures of objects around the classroom and throughout the day provided linguistic information about the objects. Nine children from a listening and spoken language-focused preschool participated in the six-week intervention where they were taught 30 new vocabulary words each week (10 per condition). Children were taught in all three conditions each day (4-day weeks), but teachers were not to spend more than 15 minutes in one condition. Overall, most children learned more words using *Direct-Instruction* than *Follow-in-Labeling*, and lastly *Incidental Exposure*. In fact, children learned an average of five more words in the *Direct-Instruction* condition than in the *Incidental Exposure* condition. This finding is consistent with other studies indicating the effectiveness of explicit instruction for vocabulary learning with children who are d/hh (Lund et al., 2015; Lund & Schuele, 2014). However, this study did not control for an equal number of exposures of the vocabulary words in each condition or time spent in each condition; therefore, certain conditions resulted in more exposures than others (direct = 10.14, follow-in-labeling = 8.53, incidental exposure = 7.05) and more time than others. In addition, the children were tasked to learning 30 new vocabulary words each week (180 over six weeks), which is large amount for young children with hearing loss (potentially causing learner fatigue).

Due to the lack of intervention research, various and contradictory recommendations are made regarding the best way to teach vocabulary to children with hearing loss. This can be confusing and discouraging for teachers of the deaf. Duncan and Lederberg (2018) conducted an observational, longitudinal study examining the effect of teacher talk in 25 different d/hh classrooms. On average, the children were about 1 standard deviation behind their peers with typical hearing in expressive vocabulary; therefore, the quality of instruction they were receiving needed to permit optimal growth. When examining instructional strategies used, it was found that, "…there were remarkable differences in vocabulary instruction among classrooms," (Duncan & Lederberg, 2018, p. 2988). In fact, some teachers set aside time for explicit vocabulary instruction, whereas others allowed for it to only occur spontaneously. As mentioned previously, direct vocabulary instruction is a necessary and important component for successful vocabulary development. This study provides evidence that teachers of the children who are d/hh need direction and guidance in order to promote the most optimal learning opportunities for their students.

The lack of evidence-based practices and intervention research in the field of deaf education forces teachers to rely on other populations for teaching strategies. Both Williams (2012) and Luckner and Cooke (2010) list specific vocabulary interventions (that were designed for children with typical hearing) to implement with children who are d/hh. Moeller (2007, p. 741) suggests that, "Strategies used in cognitive psychology with young children could be harnessed to address a variety of unanswered questions," with vocabulary learning for children who are d/hh. Retrieval practice is one such strategy, and has some of the most robust findings among cognitive psychology learning strategies (e.g., Brown et al., 2014; Carey, 2015; Lang, 2016; Pan & Rickard, 2018; Roediger & Karpicke, 2006). It has never been used with children who are d/hh before this dissertation, but due to its successes with children with typical hearing, it was chosen for investigation.

1.3 Retrieval Practice

In today's educational setting, when the word *testing* is used, it is usually associated with assessment. Students can become anxious and withdrawn when teachers say they will be using testing in the classroom (Lang, 2016). In addition, when teachers hear the word *testing*, they tend to think of all the negative connotations, and the baggage that comes with testing (Carey, 2015). The learning strategy retrieval practice does require testing, but it is not for the purpose of assessment; instead, it is used as a learning tool. This section will describe what retrieval practice is, the explanations for why it is a powerful learning strategy, and populations that have benefitted from its implementation.

Retrieval practice, also known as *test enhanced learning,* or *the testing effect,* not only measures knowledge of the student, but testing also changes and strengthens that knowledge (Karpicke & Roediger, 2008). Whenever information is retrieved or recalled from memory, that knowledge is changed because retrieving knowledge improves one's ability to retrieve it again in the future (Karpicke & Roediger, 2008; Karpicke & Zaromb, 2010). Repeated retrieval makes memories more durable and creates knowledge that can be retrieved more efficiently, in multiple settings, and applied to a wider variety of problems (Brown et al., 2014). When knowledge is successfully retrieved, neural paths to that specific piece of information strengthen and additional paths form; therefore, in the future, recall is faster and easier. It is also replaced in a different way than before, because the memory has newer, stronger, and different connections (Carey, 2015). Thus, retrieval practice, or testing, is important and beneficial for learning and retention.

Studies of retrieval practice commonly employ a three-phase experimental design that begins with (a) initial study of to-be-learned materials (e.g., word lists, vocabulary, text passages), followed by (b) training on those materials via retrieval practice or a re-exposure control condition (e.g., restudy), and ending with (c) a final assessment after a specified retention interval. Numerous studies have found that, at final assessment, materials that were initially practiced through retrieval are better remembered than those that were not (Agarwal et al., 2014; Butler, 2010; Fritz et al., 2007; Karpicke & Roediger, 2008; McDaniel, Agarwal, Huelser, McDermott, & Roediger, 2011; McDaniel et al., 2012; Rickard & Pan, 2018).

Retrieval is beneficial for more than just memorizing facts. It also improves students' complex thinking and application skills, students' organization of knowledge, and students' transfer of knowledge to new concepts (Agarwal, 2018). The learner may feel as if learning is more difficult and strenuous with retrieval, but slower, effortful retrieval actually leads to long-term learning (Agarwal, 2018). The concept known as desirable difficulties involves introducing an appropriate amount of difficulty in learning, which can increase long-term retention and transfer of knowledge (Bjork, 1988; Bjork & Kroll, 2015; Carey, 2015; McDaniel & Butler, 2011; Roediger & Karpicke, 2006). The learner's background knowledge and ability need to be considered, as well as the type of processing generated by the difficulty (McDaniel & Butler, 2011). Retrieval practice, when implemented appropriately—with specific learners in mind—can promote long-term retention. In other words, retrieval practice is desirably difficult.

An important benefit of retrieval practice is reducing the influence of the illusion of fluency. The illusion of fluency occurs when a student thinks he knows the required material, but in reality has not learned the material in a deep and meaningful manner. Restudying causes this illusion because a student recognizes what he has previously read and mistakes it for knowing that material (Brown et al., 2014). "The fluency illusion is so strong that, once we feel we've nailed some topic or assignment, we assume that further study won't help. We forget that we forget," (Carey, 2015, p. 82). The fluency illusion makes students poor judges of what they know, do not know, and what they still need to learn. However, when a student is retrieving information, he is doing something harder and different than when he restudies. The extra work deepens the resulting storage and retrieval strength.

Feedback is another aspect of testing that is central to learning. There are conflicting studies about the timing of feedback—whether immediate or delayed is more effective (Butler, Karpicke, & Roediger, 2007; Butler & Roediger, 2008) but nonetheless, it is very beneficial for learning (Butler & Roediger, 2008; Lang, 2016; Weinstein, Sumeracki, & Caviglioli, 2018). Marsh, Fazio, and Goswich (2012) tested the inclusion versus exclusion of feedback after multiple-choice quizzes with young children. On the delayed assessment, a negative testing effect was found, in that children were more likely to choose a lure (incorrect answer) when feedback was not given after the quizzes. However, the negative testing effect was diminished for the group where feedback was given after the quizzes. "Giving students corrective feedback after tests keeps them from incorrectly retaining material they have misunderstood and produces better learning of the correct answers," (Brown et al., 2014, p. 44). Feedback gives students perspective on what they know, what they do not know, and what they still need to learn.

How many rounds of retrieval with feedback are enough to ensure learning? What is the perfect number of tests and how often should the tests occur in order to produce long-term retention (Rawson & Dunlosky, 2011)? These questions about retrieval practice are related to a companion idea of learning efficiency, which is the relationship between learning rate and retention (Zerr et al., 2018). A student who is an efficient learner is one who is able to quickly learn material and recall it with high accuracy. Currently, little is known about how rate of learning and retention are related to each other. A study done by Zerr et al. (2018) set out to investigate learning rate and retention in adults using a foreign-language, paired-associates task. They found that quicker learners—students requiring fewer rounds of initial testing to correctly recall a word or reach criterion—also retained better learning after one day, two days, and three years. They also found that the single best predictor of long-term retention was learner speed. At each retention interval, the quicker learner retained more, even though reaching criterion in fewer tests meant less exposure to (fewer opportunities to study and be tested on the material). This is directly related to retrieval practice in thinking about the number of tests that are needed for long-term retention. With the use of testing, researchers are beginning to show that faster learning results in better long-term retention.

In addition to the benefits from feedback, there are other valuable indirect effects of retrieval practice. When students know they will be quizzed on the lecture and reading material, their attendance in class may improve, they may increase their studying and complete their reading assignments before class, and it can help increase attentiveness during class (Leeming, 2002). The actual retrieval practice activities and feedback given can help students eliminate their illusion of fluency with the material and increase their metacognitive awareness. Also, low-stake quizzing and more frequent quizzing helps lower test anxiety for students (Agarwal et al., 2014; Smith, Floerke, & Thomas, 2016; Weinstein et al., 2018).

Retrieval practice has been around for centuries. Aristotle, considered one of the fathers of western philosophy, was known to understand how repeatedly recalling information strengthens the memory (Brown et al., 2014; Lang, 2016). The first large scale study investigating retrieval practice with elementary school children was published by Arthur Gates (1917). He asked third, fifth, sixth, and eighth graders to study brief American biographies. Some students reread the material while others were instructed to look up from the biography and recite the material to themselves (a testing condition). After the learning period, the children were asked to write down what they could remember and then again three to four hours later. All the groups who had recited the material to themselves showed better retention than those who had simply reread the passage (Brown et al., 2014; Carey, 2015; Gates, 1917; Roediger & Karpicke, 2006). Another seminal study was conducted by Spitzer (1939) with over 3000 sixth graders in Iowa. Students studied articles and were then tested on the material at various times before a final retention test two months later. Spitzer found that the students who took the tests soon after reading the passage did the best on the final exam, whereas the groups who took their first tests two weeks or more after studying scored much lower. Spitzer found a testing effect with this group, but also discovered that it should be used sooner rather than later to mitigate forgetting (Brown et al., 2014; Carey, 2015; Roediger & Karpicke, 2006; Spitzer, 1939). The interest in testing and reducing forgetting continued in the line of memory research throughout the 20th century. Only in the late 20th century did it take off in the field of educational research and start entering actual classrooms.

Now, testing is viewed as among the most effective educational techniques that is currently implemented in classrooms (Brown et al., 2014; Carey, 2015; Pan & Rickard, 2018; Roediger & Pyc, 2012). Retrieval practice doesn't have to be done with formal tests in the classroom. In order to implement retrieval practice without much additional work, teachers can use low-stakes quizzing, free recall activities, opening or closing questions in class, or clickers to answer questions in class. Independently, students can write out everything they know on a piece of paper (brain dump), create concept maps from memory of the reading or lecture material, explain what they can remember to a peer or teacher, or quiz themselves with flashcards. Researchers have been able to implement retrieval practice successfully through many different mediums, but are still trying to determine why it is so beneficial to learning.

1.3.1 Why Does Retrieval Practice Work So Well?

The mechanisms behind the benefits of retrieval practice are not entirely understood (Karpicke, 2017; Lehman & Malmberg, 2013; Roediger & Butler, 2011; Weinstein et al., 2018), but there are numerous theoretical explanations as to why it is so beneficial to learning. Early theories posited that retrieval practice simply causes overlearning of the material due to overexposure (Thompson, Wenger, & Bartling, 1978), but this theory has been discredited numerous times by experiments comparing restudy versus retrieval (e.g., Roediger, Agarwal, McDaniel, & McDermott, 2011; Roediger & Butler, 2011; Roediger & Karpicke, 2006). As described earlier, retrieval practice may be effective because it introduces a desirable amount of difficulty to learning—desirable difficulty hypothesis (e.g., Bjork, 1988; Bjork & Kroll, 2015; Roediger & Karpicke, 2006). Because testing requires greater effort or depth of processing, it results in deeper and more durable learning (Brown et al., 2014). Another theory behind the success of retrieval practice is transfer appropriate processing, which indicates that if a student is required to recall information on a test, they will learn the information better if practiced on the same type of test (Karpicke, 2017; Kolers & Roediger, 1984; McDaniel, Friedman, & Bourne, 1978). For example, if a student practices the material through multiple choice quizzes, then she will have better transfer of knowledge on a multiple-choice final assessment than a short-answer assessment (McDaniel, Anderson, Derbish, & Morrisette, 2007).

A relatively new theory is called elaborative retrieval (Carpenter, 2009). Elaborative retrieval suggests that when an individual retrieves an item, semantic elaboration occurs and enhances the recall. That is, when a student is given a cue and is then required to recall a target, she will produce several additional items that are semantically related to the cue. The combination of all the items are incorporated in addition to the target forming an elaborated memory that is more memorable for future recall (Karpicke, 2017).

Finally, the episodic context account attempts to explain the results of retrieval practice based on four assumptions (Karpicke, 2017). First, people are assumed to encode information about specific items in addition to the temporal or episodic context in which those items occurred (Howard & Kahana, 2002). Second, when retrieving those items from memory, people try to restore the original episodic context that is associated with that item (Lehman & Malmberg, 2013). Then when an individual is able to retrieve an item, information of the present context is added to the original context representation. Lastly, when retrieval is needed again in the future, the updated context representations help in recalling those items and memory is improved (Karpicke, 2017). Research continues into which of these four theories (or a combination of more than one) can be credited for the benefit of retrieval practice.

1.3.2 Retrieval Practice with School-Aged Children

Few classroom studies using retrieval practice have been conducted, especially with young school-aged children. Classroom studies are difficult to conduct because they often lack the control over variables that laboratory studies can offer, yet they are important studies to tackle (Roediger & Karpicke, 2006). As mentioned previously, in elementary school, children are beginning to read material and implement strategies on their own in order to learn from what they are reading; therefore, it is essential to examine the effectiveness of retrieval practice in elementary school children. If research shows that young children can benefit from this strategy, then integration of retrieval practice in the classroom could be extremely beneficial for students' learning (Karpicke, Blunt, Smith, & Karpicke, 2014). This section will describe studies that investigated retrieval practice in classroom-type settings with children.

With the benefit of retrieval practice being shown repeatedly in laboratory settings, Roediger, Agarwal, McDaniel, and McDermott (2011) felt that testing in an educational setting seemed the natural next step, especially since testing is already a part of the classroom experience. Using text and materials from sixth-grade social studies curricula, Roediger and colleagues designed a set of studies to investigate the impact of retrieval practice. In the first experiment, 142 students were given a pre-quiz before the teacher's lecture, a post-quiz after the teacher's lecture, and a review quiz two days later. For the initial classroom quizzes, half of the target facts were tested in a multiple-choice format (tested condition) and half of the facts were not tested (nontested condition). Then, to measure long-term retention, a chapter exam (generally given two days after the review quiz) and a final semester exam (depending on when the chapter exam was given, the final exam was 1-2 months later) were administered. The chapter exam consisted of a free recall exam where students were asked to write down everything they remembered from the chapter. Then, students completed a multiple-choice exam which contained all of the tested and nontested items. On the chapter and final semester exams, a testing effect was found. Students remembered more of the material that was practiced through testing than the material that was not. Because feedback was given with the initial classroom quizzes, Roediger and colleagues wanted to make sure the effect was due to the actual retrieval of the material not simply just reviewing material from the quizzes. In the second experiment, they investigated whether repeated quizzing would permit greater learning on a chapter exam in comparison to repeated studying; in addition, a third condition was included in which some materials were neither repeatedly studied nor repeatedly quizzed for comparison. They again found a testing effect on the chapter exams for the tested material in comparison to the other two conditions. This second experiment provided evidence that the act of retrieval caused the increased learning of the material, not the reviewing. These results were integral in showing that retrieval practice could be implemented in a classroom with authentic materials.

Lipowski, Pyc, Dunlosky, and Rawson (2014) investigated whether retrieval practice benefitted first and third graders learning using a free recall measure in a within-subjects design. Children were presented with 32 pictures of objects they were familiar with over two sessions (16 presented in each condition): *restudy* (SSSSS) and *retrieval practice* (STSTS), with S referring to *study* and T referring to *test* sessions. Then the children were asked to recall as many objects as they could remember five minutes after they completed each learning session. Participants completed the second session approximately one week after the first session. For the second session, students were assigned to the learning condition that they did not complete in the first session. Both age groups showed a testing effect, recalling more objects from the retrieval practice condition than restudy. In addition, the majority of third graders, when asked what condition they learned more from, thought they learned more through retrieval practice than restudy. This is significant in that even at early ages, students understand the benefits of testing. Retrieval practice has been found to help long-term retention, but the retention interval in this study was only five minutes. If the experimenters had tested the children after a longer interval, a larger effect may have been found.

Karpicke, Blunt, Smith, and Karpicke (2014) studied whether retrieval techniques that have been shown to be beneficial for college students could be effective for fourth graders. In the first experiment, they presented three activities to fourth graders: (a) retrieval through generating a concept map, (b) free recall, and (c) cued recall. It was found that there was essentially no testing effect for these activities in comparison to the condition with no retrieval activity. Karpicke and colleagues then altered the activities to provide more support for the students in the remaining experiments. Results showed a positive testing effect for the fourth graders, but it depended on the level of support given in the activity. These findings support the claim that more research is needed to identify and develop retrieval-based learning activities that work in educational settings for young children. Also, there is a need for better understanding the appropriate structure and scaffolding of activities required for this population to learn effectively.

To this point, I have described research that shows retrieval practice helps children learn and retain content, such as social studies topics, presented in the classroom. However, one might wonder whether retrieval practice is effective for learning new vocabulary in a classroom-study. Goossens, Camp, Verkoeijen, and Tabbers (2014) were the first to show a positive effect of testing in a classroom-based setting for vocabulary learning with elementary school children. Sixty elementary school children in the Netherlands participated in this study. Twenty new vocabulary words were taught between two different contexts (story and word-pair associations) and two conditions: *retrieval practice* (SSSSTST) and *restudy* (SSSSSSS). Children were taught ten words in each condition. One week after the learning sessions, cued recall and recognition tests were administered to the students. On the cued recall tests, the children recalled more words from the retrieval practice condition than in the restudy condition for both contexts. However, they did not find a testing effect for the recognition test. The recognition test was administered following the cued recall test, so the students already had to retrieve the words (synonyms) for the cued recall test, likely influencing scores on the recognition test. Regardless, retrieval practice appears to be an effective technique for children to use when learning new vocabulary words.

Although school-aged populations are an obvious source for investigating the benefits of retrieval practice, younger populations are of great interest as well. Preschoolers are tasked with learning many new concepts, especially new vocabulary words, and thus could also benefit from using retrieval practice strategies. Fritz, Morris, Nolan, and Singleton (2007) studied of the effect of retrieval practice with the youngest population to date. Sixty-two students, ages 3.10-4.10 years old, from three different preschools participated in a learning activity. The children were prompted to learn the names of six different stuffed animals across three conditions: (a) *Expanded Retrieval*- intervals between quizzing of the animal's name are gradually increased—for example, after initial introduction of the animal there was one time interval between the next quiz, then two, then three, then seven (1 – 2 – 3 – 7), (b) *Massed Elaboration*- equal amount of time spent talking about each stuffed animal with one introduced after another—for example, 40 seconds talking about animal 1, then 40 seconds talking about animal 2, then 40 seconds talking about animal 3; and (c) *Re-Presentation*- same spaced schedule of expanded retrieval but with no quizzing of the animal's name—the experimenter simply repeated the name of the animal to the student. Fritz and colleagues controlled for an equal number of exposures and time spent with each animal in each condition. The children were provided with immediate feedback in the expanded retrieval condition. They were tested immediately following the task and 24 hours later by having to name each stuffed animal. Students in the expanded retrieval practice condition were able to remember more animal names than the other two conditions at the immediate and the delayed assessment. This study shows that retrieval practice can even benefit very young learners. However, due to the between-groups design of the study, it could be argued that all three groups did benefit from a testing effect, because they were tested immediately on all animals before their one-day retention test.

Even though retrieval practice requires more effort from students, they are able to reap the benefits as early as preschool (Fritz et al., 2007). Importantly, students as young as third grade are able to understand the benefits of testing as well (Lipowski et al., 2014). If retrieval practice is implemented at young ages, it could help diminish the negative connotations that are associated with testing. As mentioned earlier, traditional testing can cause anxiety for students, but in a survey of nearly 1,500 middle school and high school students, 72% of the students' reported a decrease in their test anxiety by the end of the year due the implementation of frequent quizzing (Agarwal et al., 2014; Brown et al., 2014). Thus, retrieval practice not only increases retention for children, but it also increases students' comfortability with testing.

1.3.3 Retrieval Practice with Atypical Populations

As mentioned above, there are relatively few studies investigating the use of retrieval practice with young children. There is even a smaller set of studies on the use of retrieval practice for children who are atypical learners. To my knowledge, there is only one study examining the effect of testing on populations outside of general education. Coyne, Borg, DeLuca, Glass, and Sumowski (2015) investigated whether retrieval practice is an effective memory strategy for children with traumatic brain injuries (TBI). TBIs can affect cognitive and academic achievement in children and to date there are no validated memory treatments for this population. Because retrieval practice has been used successfully for adults with TBIs (Sumowski et al., 2010), it was hypothesized that it could be an effective strategy for children with TBIs. Fifteen children with varying severities of TBIs, all with below average capacity for learning and memory, participated in the study. Children learned 24 verbal paired-associates and 24 face-name pairs across three conditions: (a) *Retrieval Practice*; (b) *Spaced Practice* (pairings separated in time by other items); and (c) *Massed Practice* (the same pairing shown numerous times in a row). The children were then tested 25 minutes later. It was found that all 15 children recalled more information in the retrieval practice condition than the other two conditions. If retrieval practice has been shown to work with children with TBIs, it could be hypothesized that retrieval practice would benefit other atypical populations—specifically children with hearing loss.

In summary, hearing loss has been shown to negatively affect expressive vocabulary development for children who are d/hh and who use listening and spoken language (e.g., Harris et al., 2017; Hermans et al., 2015; Lederberg et al., 2000; Luckner & Cooke, 2010; Lund et al., 2015; Nott et al., 2009; Quittner et al., 2016; Yoshinaga-Itano et al., 2017). Yet, there are few interventions for teachers of the deaf to look to for guidance in vocabulary instruction (Bobzien et al., 2015; Duncan & Lederberg, 2018; Luckner, 2006; Luckner & Cooke, 2010; Lund & Douglas, 2016; Lund et al., 2015). Retrieval practice is an effective learning strategy for children with typical hearing (Fritz et al., 2007; Goossens et al., 2014; Karpicke et al., 2014; Lipowski et al., 2014; Roediger et al., 2011), but has not been used with children who are d/hh. The next chapter will describe how this dissertation aimed to fill the need of intervention research with a robust learning strategy.

Chapter 2: Experiment

2.1 Study

Children who are d/hh have been shown to have smaller vocabularies, develop vocabulary at a slower rate, and show decreased benefit from vocabulary learning strategies as children with typical hearing (e.g., Harris et al., 2017; Hermans et al., 2015; Lederberg & Spencer, 2001; Luckner & Cooke, 2010; Lund et al., 2015; Nott et al., 2009; Quittner et al., 2016; Yoshinaga-Itano et al., 2017). As described in Chapter 1, there are few vocabulary studies and even fewer intervention studies addressing this area of concern for children with hearing loss. This study addresses the dearth of intervention studies by investigating the use of a vocabulary word-learning strategy with children who have hearing loss. The overarching goal of the study was to determine whether children who are d/hh are able to learn more new words through retrieval practice than repeated exposure (repeated study). This is innovative work because there are no studies using retrieval practice with children who are d/hh.

The analyses in this study will inform the field of deaf education about the effectiveness of two learning strategies: retrieval practice and repeated exposure. The field of cognitive psychology will also benefit from learning about a new population using one of the most robust learning strategies investigated to date: retrieval practice. In addition, the analyses will determine if certain characteristics of children who are d/hh may be significant predictors of final recall.

The specific research questions of this study are as follows:

1. Do children who are d/hh learn more new words through retrieval practice than repeated exposure?
2. Do child, family, or audiological characteristics affect vocabulary learning for children who are d/hh? If so, which characteristics are significant predictors of vocabulary learning?

I hypothesized that children who are d/hh would learn more new words through retrieval practice than repeated exposure. I also hypothesized that retrieval practice would be most effective for those children who took fewer trials to learn the words, had better aided speech perception scores, did not have an additional diagnosis other than hearing loss, and who had highly educated parents.

2.2 Method

2.2.1 Participants

With full IRB approval from Washington University School of Medicine in St. Louis, participants were recruited from two d/hh schools in the greater St. Louis area that ascribe to a listening and spoken language philosophy—emphasizing intensive instruction in speech and language. This philosophy focuses on teaching children to talk and listen while using hearing amplification devices (e.g., hearing aids and cochlear implants) as well as visual information (e.g., facial expressions, lip movements, gestures). Participants were recruited through a parent-information session as well as an informational letter that was sent home to families of children who attended the schools. Seventeen families consented for their child or grandchild to participate in the study. One was dropped from the study due to consistent absences. Therefore, a total of 16 students participated in the study. Inclusion criteria for the students included: (a) having a diagnosed hearing loss, (b) using spoken language as a primary form of communication, (c) being between the ages of 5.0-8.11 years old, and (4) attending Extended School Year (ESY) programs (summer school).

The mean age of the students at the beginning of the study was 6.67 years with a range of 5.08-8.83 years. Thirteen of the students had binaural sensorineural hearing loss, two had binaural conductive loss, and one student had a sensorineural hearing loss in one ear and mixed loss in the other. Students' hearing loss ranged from mild to profound, with one child displaying within normal limits hearing in one ear. The mean age when first aided was 1.75 years with a range of 0.25 to 3.92 years old. All of the participants were born after the Early Hearing Detection and Intervention (EHDI) legislation; therefore, they would have been screened for hearing loss immediately after birth and had the option for early intervention services if needed. Table 2.1 shows participants' demographic characteristics.

Table 2.1.

Participant Information

Characteristic	Categorical Level	Frequency	%
Gender	Boys	10	62.5
	Girls	6	37.5
Additional Diagnosis	No	9	56.3
	Yes	7	43.8
Highest Parent Education Level	8th Grade	1	6.3
	High School	1	6.3
	Some College	8	50
	Bachelor's (4-year degree)	4	25
	Graduate School	2	12.5
Devices	Bilateral Cochlear Implant	8	50
	Unilateral Cochlear Implant	1	6.25
	Bilateral Hearing Aid	5	31.25
	Bilateral Baha	1	6.25
	Bimodal	1	6.25

Aided speech perception testing results were gathered retrospectively from school charts. The most recent tests and scores were reported by the parents, guardians, or the school administrators on the demographic questionnaire. Scores from different speech perception tests were reported for the students. The score that was chosen for analysis was binaural (both ears) if provided or the ear with the best score from the most complex aided speech perception test. Aided speech perception tests varied in both the complexity and delivery of the stimuli (i.e. right, left or both ears).

In order to appropriately compare scores from different speech perception tests, each test was converted to a scale of 0-600 based on complexity. This scale was developed following the hierarchical speech recognition (perception) index created by Wang et al. (2008). Wang et al. (2008) developed an age-appropriate hierarchical speech recognition index to track the progress of children's speech recognition over time. As children's aided speech perception skills improve with time, they are given more complex tests. The simplest aided speech perception test that was reported for students in this study was The Word Intelligibility by Picture Identification (WIPI) (Ross & Lerman, 1970) and the most complex was the AzBio Sentence Test (AzBio) (Spahr & Dorman, 2004). For example, Child #9 scored a 52% in the binaural condition on the WIPI, so that child was given a score of 52. Child #6 scored a 74% on the AzBio, so that child was given a score of 574. The mean aided speech perception score was 376.125 with a range of 52-583 (*SD* = 148.15). The floor for the aided speech perception scores is 0 and the ceiling is 600, which was not reported for any participant. Table 2.2 displays the name of the speech perception test along with the appropriate scaling.

Table 2.2.

Speech Perception Tests in Order of Complexity

Speech Perception Test	Scaled Score
The Word Intelligibility by Picture Identification (WIPI)	0-100
Multisyllabic Lexical Neighborhood Test (MLNT)	100-200
Lexical Neighborhood Test (LNT)	200-300
Consonant-Nucleus-Consonant (CNC)	300-400
Hearing in Noise Test for Children (HINT-C)	400-500
AzBio Sentence Test (AzBio)	500-600

2.2.2 Materials

Demographic Questionnaire

Parents, guardians, or school administrators of the participants were asked to complete a questionnaire, which was used to gather information about family and child characteristics (e.g., degree and type of hearing loss, age first aided, parent education, additional diagnosis). See Appendix A for the questionnaire.

iPad Scenes

An Apple iPad was used to display the stimuli. Five different themes were chosen from the application *Make a Scene*: jungle, safari, farm, ocean, and arctic (Innivo, 2013). This application is currently used in classrooms at both schools where the study took place. Students are familiar with using the application on the iPad, so this was not new to them. Four target words were selected from each theme for a total of 20 stimuli. A picture scene was created for each theme on the iPad application. Within each thematic scene, children saw images of the four target words. The same four scenes were used for all participants. The order of administration of themes and words was randomized between the students to eliminate a possible word or theme effect. The five iPad scenes are displayed in Appendix B.

Stimuli

Each word was three syllables or less. The words were chosen because they were thought to be unknown to the age range of participants, based on personal experience as a teacher of the deaf. Three additional master's level teachers of the deaf affirmed the list of selected words. As previously mentioned, all 20 words and five themes were randomized between participants to eliminate a potential word and theme effect. Table 2.3 lists the five themes with their corresponding words. Note that the word "sloth" from the jungle theme was omitted from the analyses due to the prior knowledge of the word by multiple children in the study; therefore, a total of 19 words for 16 children were analyzed.

Flashcards

Each stimulus was reproduced on a 5 x 7 flashcard with the same picture from the application. Examples of the flashcards are displayed in Appendix C.

Table 2.3.

Themes and Corresponding Words

Theme	**Farm**	**Artic**	**Ocean**	**Jungle**	**Safari**
Words	Kid Spade Hay bale Calf	Narwhal Puffin Caribou Beluga	Sardine Prawn Manta ray Cuttlefish	Platypus Lemur Anteater *Sloth	Hyena Aardvark Gazelle Meerkat

Note. Sloth was removed from analyses because a number of children knew the word at the start of the study.

2.2.3 Procedures

Prior to collecting data for this experiment, a pilot study was conducted with three children with typical hearing. I tested the children with typical hearing to see if they could learn nonsense words with the materials and procedures I would be using for this dissertation. Overall, the children recalled 50% of the words after a week-long retention interval. All three children learned more words in the retrieval practice condition than repeated exposure. The proportion of words recalled in the retrieval practice condition was 67% compared to the 33% recalled in the repeated exposure condition.

Some changes were made to the materials and procedures from the pilot study. The same application, *Make a Scene*, was used for the experiment, but different themes were chosen. In addition, the pilot study used nonsense words, but the dissertation used actual animal labels. This change was made to make the experimental methods more like authentic classroom lessons. Also, due to scheduling availability, the retention interval for the pilot study was one week versus the two day retention interval in the experiment. The retention interval was shortened for the children with hearing loss to make sure the students did not hit floor and they would be able to successfully recall the words. Fritz et al (2007) employed a two day retention interval when using retrieval practice with preschoolers, and they successfully recalled the names of stuffed animals. A future study could look at adding an additional week-long retention interval to see if children who are d/hh could recall words after a longer delay. Lastly, the children in the pilot study were only given four rounds to learn each word in the practice session, whereas the children with hearing loss were given 10. Again, this change was made to maximize the opportunities for the students with hearing loss to successfully learn the words.

The parents, guardians, or school administrators of children who are d/hh were given the demographic questionnaire to complete during or after the study and they were encouraged to answer all of the questions. Testing took place at two schools for the deaf in classrooms that were treated to reduce interference of background noise. Students were place in optimal positions to listen and see the speaker, either next to or directly across from the speaker. All of the testing was done during the 4-6 week Extended School Year (ESY) summer school program in 2018. The testing sessions were completed before, during, or after the half-day school sessions. All of the students completed the required tasks in 5 to 10 sessions depending on the ESY schedule of the students' school. Words were spread out in multiple sessions to avoid listening fatigue for the students. The study included a learning session for each theme and then an assessment session for that theme two days later. Figure 2.1 displays an example of the testing schedule.

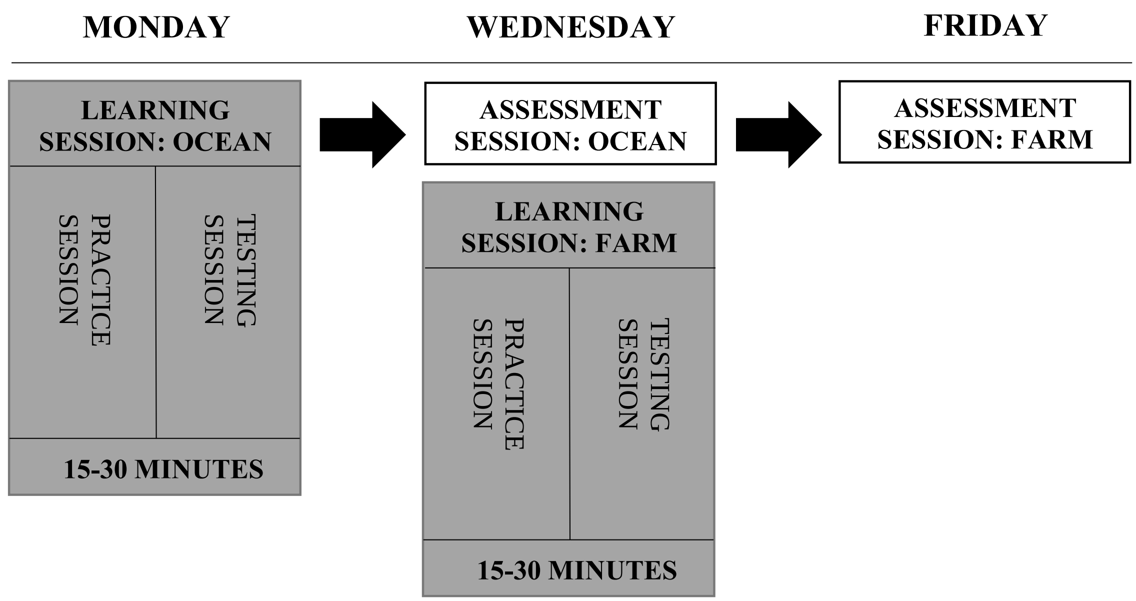


Figure 2.1. Weekly Testing Schedule

Figure 2.1. An example of a testing schedule with the themes *ocean* and *farm.* A student was introduced to four words from the *ocean* theme on Monday during the learning session. The learning session was divided between the practice and testing session. The total time required varied by the number of rounds the student needed to recall the new words. Two days later, Wednesday, the student was assessed on the four *ocean* words, only taking a few minutes. The process was then repeated for the *farm* theme—learning session Wednesday and assessment session two days later on Friday. This schedule was repeated for all five themes.

I and another master's level teacher of the deaf administered the sessions. Training for the research assistant occurred a week prior to the intervention, over a four-hour period. Scripts for all five themes were followed to ensure as much similarity amongst the two administrators. Each child had their own specific set of five scripts. An example of the full script can be found in

Appendix D. At the beginning of each session, the students' hearing devices were verified to be functioning properly. This was done by either asking the student if they were working or by doing a listening check.

Each thematic learning session was divided into a practice session and a testing session. The goal for the practice session was for the students to expressively recall each word one time per theme. This gave the students an opportunity to initially learn the words before manipulating the vocabulary learning conditions (retrieval practice and repeated exposure) during the testing session. The goal for the testing session was to implement the two conditions: retrieval practice and repeated exposure.

Learning Session: Practice Session

During the practice session, the child was introduced to a theme, and four words to go with that theme, on the iPad using the *Make a Scene* application. The students were shown the scene on the iPad while the words were described. Each word was expressively labeled four times within contextual sentences for the student and then the student expressively labeled each word one time; therefore, the student was exposed to each word five times. Below is an example of the script.

Script 1: 4 exposures + 1 child imitation

PI: My name is Casey. Thank you for coming to play with me for a short time today. Today we are going to talk about different animals that live in the ocean. We are also going to play a game. First, we are going to start with the iPad to look at the different animals in the ocean. You are going to learn the names for 4 new animals.

*PI: (show student iPad scene with four animals) Look at the purple **manta ray**. It looks like a star with a long tail. Do you want to touch the **manta ray**?*

S: Yes/No

*PI: Tell me, **manta ray**.*

S: Manta ray.

*PI: Bye **manta ray**.*

*PI: Next is the **cuttlefish**. The **cuttlefish** is dark purple and has four tentacles or arms. Do you want to touch it?*

S: Yes/No

*PI: Tell me, **cuttlefish**.*

S: Cuttlefish.

*PI: See ya later **cuttlefish**.*

*PI: This is a **prawn**. The **prawn** is very small and orange. Do you want to touch it?*

S: Yes/No

*PI: Tell me, **prawn**.*

S: Prawn.

*PI: Bye **prawn**.*

*PI: Lastly, I see a **sardine**. The light blue **sardine** is swimming with its friends. Do you want to touch it?*

S: Yes/No

*PI: Tell me, **sardine**.*

S: Sardine.

*PI: Bye **sardine**.*

If the child incorrectly pronounced the word, additional expressive presentations were given and the child repeated the word until a correct pronunciation was made. After introducing all four words, the child had a two-minute distractor break. During this time, the child played a game, colored, or played on the iPad. After the two-minute break, the student was shown the same scene on the iPad and asked to recall each word as it was pointed out. The child was encouraged to guess if he was unsure of the label. It was noted which word(s) the child correctly recalled and which word(s) were not. The practice session was repeated until all four words were correctly recalled. If the practice session was repeated, the experimenter omitted the correctly labeled words from the script. For example, if the child correctly recalled “sardine” and “cuttlefish,” but did not know “manta ray” or “prawn,” the practice session was repeated only with “manta ray” and “prawn.” After six rounds of the practice session, the distracter break was decreased from two minutes to one minute, due to time constraints and concern of learner fatigue. The child was given 10 opportunities, or rounds, to correctly label each word. If the child did not accurately recall the word after 10 rounds, the lack of recall was noted for that specific word. The number of practice rounds necessary for the child to recall each word was documented. The average number of rounds for this session was 4.42 rounds (*SD* = 3.12). This concluded the practice session of the learning session. After the practice session, another two-minute break was given to the students before the testing session began. The learning sessions (practice + testing) took between 15-30 minutes to complete depending on how many rounds were required by the students to correctly recall the words during the practice session. Figure 2.2 displays an example of the breakdown of the learning session.

LEARNING SESSION: OCEAN	
PRACTICE SESSION (1-10 Rounds as Needed) Theme: Ocean 1. Manta ray 2. Cuttlefish 3. Prawn 4. Sardine	**TESTING SESSION** Retrieval Practice: TSTSTS 1. Manta ray 2. Cuttlefish Repeated Exposure: SSSSSS 1. Prawn 2. Sardine
15-30 MINUTES	

Figure 2.2. Learning Session

Figure 2.2. The learning session was divided between the practice and testing session. The speaker began with the practice session on the iPad. Once the student recalled each new word one time, they moved onto the testing session. Flashcards with the same pictures of the animals were used. The four words were divided between two conditions: retrieval practice and repeated exposure.

Learning Session: Testing Session

During the testing session, the four words were divided between retrieval practice and repeated exposure with two words per condition. The conditions during the testing session were counterbalanced within each student to eliminate a potential condition effect. During this session, the child was shown flashcards with the same pictures from the thematic scene on the iPad.

The repeated exposure condition consisted of six rounds of study (SSSSSS) for two of the four words per theme; for example, “manta ray” and “cuttlefish”. The child was shown one flashcard at a time, was provided the label, and asked to repeat it. To set the student up for optimal success, the child had visual input through the flashcards, auditory input from being told the label, and was required to expressively label the word. Below is an abbreviated example of the ocean repeated exposure script.

Repeated Exposure Condition: 1 exposure + 1 child imitation (SSSSSS)

PI: We are going to look at the ocean animals again. This time we aren't going to use the iPad though, we are going to use flashcards. The same animals are on the flashcards. I will show you two of the animals first and then we will work with the other two. We are going to look at them six different times so you can learn all their names. Are you ready?

S: Yes/No

Study 1

PI: (shows first card). This is a ***manta ray.*** *Can you tell me?*

S: Manta ray.

PI: Good job. (shows second card). This is a ***cuttlefish****. Can you tell me?*

S: Cuttlefish.

PI: That's right!

Study 2

PI: (shows first card). This is a ***manta ray.*** *Can you tell me?*

S: Manta ray.

PI: Good job. (shows second card). This is a ***cuttlefish****. Can you tell me?*

S: Cuttlefish.

PI: That's right!

The remaining two words in the theme were tested in the retrieval practice condition; for example, “prawn” and “sardine”. A child was shown the first flashcard and asked to name the word (test). The child was encouraged to guess if she was unsure of the label. Feedback was given to the child immediately. If the child did not recall the correct label or did not know the answer, the correct label was given. If the child correctly identified the word, the word was also expressively enforced. Therefore, the word was expressively labeled one time during the retrieval practice condition whether the child correctly recalled it or not. The process was repeated for the other vocabulary word assigned to retrieval practice. Similar for the study portion of the repeated exposure condition, there then was a round of study (study) where the child was shown both flashcards again. The labels were provided one time and the child was asked to repeat the words. The sequence of test-study was repeated two more times for a structure of TSTSTS. Below is an abbreviated example of the ocean retrieval practice script.

Retrieval Practice Condition: 1 exposure + 1 child imitation (TSTSTS)

PI: We are going to look at the last two ocean animals now using the flashcards. I am going to show you an animal and I want you to try to tell me its name. If you don’t remember that’s okay, but I want you to guess. Are you ready?

S: Yes/No

Circle if correct & note child's response

Test 1

PI: (shows first flash card). What is that?

S: Prawn/Guess/I don't know.

*PI: That's right, **prawn.**/That is a **prawn.***

PI: (shows next card). What is that?

S: Sardine/Guess/I don't know.

*PI: That is a **sardine**!/That's okay, that is a **sardine.***

PI: You are doing such a great job. We are going to look at the same two animals again to try and really learn their names. Are you ready?

S: Yes/No

Study 1

*PI: (shows first flash card). This is a **prawn.** Can you tell me?*

S: Prawn.

*PI: Yes. (shows next card). This is a **sardine.** What is that?*

S: Sardine.

PI: Way to go. Now I want you to tell me what they are again. Remember, I will show you one animal at a time and I want you to try your best to remember what it is. If you know what it is I want you to tell me, but if you don't that's okay- I want you to guess. Are you ready?

S: Yes/No

Assessment Session

The retention interval for the new words was two days following the learning session. To assess recall, the same flashcards of the four words were presented in the same order. The child was asked to recall the words or guess if she was unsure. Feedback was given immediately. Assessment sessions took one to two minutes to complete. The learning sessions (practice and testing sessions) and assessment sessions were repeated with the additional four themes for a total of 20 words. If children were absent on their scheduled days, the sessions were made up on alternate days.

2.2.4 Statistical Methods

To analyze whether retrieval practice was an effective learning strategy with this specialized population, hierarchical linear modeling (HLM) was used for analyses. HLM was chosen because the response variables are nested: Sessions (i.e., retrieval practice or repeated exposure items; Level 1) are nested within students (Level 2) which have certain characteristics (e.g., aided speech perception score). HLM was also chosen to analyze the effect of condition on final recall because of its ability to analyze responses even with missing data. Because the primary dependent variable of final recall was dichotomous (recall- 1, or not- 0), logistic regression was used instead of general linear regression. Logistic HLM was then applied using the *glmer* function in the *R* package *lme4* (Bates, Maechler, Bolker, & Walker, 2015).

In addition to analyzing the effect of condition on final recall, there were other predictor variables of interest. The additional variables that were chosen *a priori* were: highest level of parental education, aided speech perception scores, the presence of an additional diagnosis other than hearing loss, and number of rounds to recall in the practice session. As mentioned previously in this dissertation, rounds to recall speaks to the learning efficiency of the student. A student who is an efficient learner or shows positive learning efficiency requires fewer rounds to learn words with a higher recall accuracy. This was of interest because it has not been investigated with children who are d/hh, but has been explored as a predictive variable in the retrieval practice literature with children who are typically hearing (Karpicke & Roediger, 2008; Rawson & Dunlosky, 2011; Zerr et al., 2018). The other variables—parent education, aided speech perception scores, and additional diagnosis—were of interest because previous research has shown them to be predictors of vocabulary development of children with hearing loss (e.g., Boons et al., 2013; de Hoog et al., 2016; Dettman et al., 2016; Geers & Nicholas, 2013; Marschark et al., 2015; Tsao et al., 2004; Yoshinaga-Itano et al., 2017). The continuous predictors (rounds, parent education) were grand-mean centered and aided speech perception was converted into a z-score.

Logistic regression lends itself to easy interpretation using odds ratios (*OR*; Hosmer Jr., Lemeshow, & Sturdivant, 2013) which is the odds that an outcome will occur (in this case, recalling the stimulus), compared to the odds of the outcome not occurring for a one unit increase of a certain predictor. For example, an *OR* of 1.5 would indicate that the odds of recalling a word are 1.5 times greater than not recalling a word, for a 1 unit increase in a predictor (e.g., 1 *SD* increase in speech perception). In logistic regression, *OR*s can also be interpreted as effect sizes. All predictor variables, as well as interactions amongst the variables, were entered to develop a final recall model.

2.3 Results

The overarching goal of the study was to determine whether children who are d/hh are able to learn more new words through retrieval practice than repeated exposure. In addition, I wanted to investigate if certain student characteristics were significant predictors of final recall.

2.3.1. Research Question 1

Do children who are d/hh learn more new words through retrieval practice than repeated exposure?

Overall, 44% of the words were recalled after the two day retention interval. The percent of words recalled in the retrieval practice condition was 47% compared to 40% recalled in the repeated exposure condition. When broken down by individual student, 11 out of 16 participants recalled more words that were learned through retrieval practice in comparison to repeated exposure. Every student learned at least one new word through retrieval practice; whereas, three students did not recall any words that were taught in the repeated exposure condition. Figure 2.3 shows the percent correct of final recall for each student by condition.

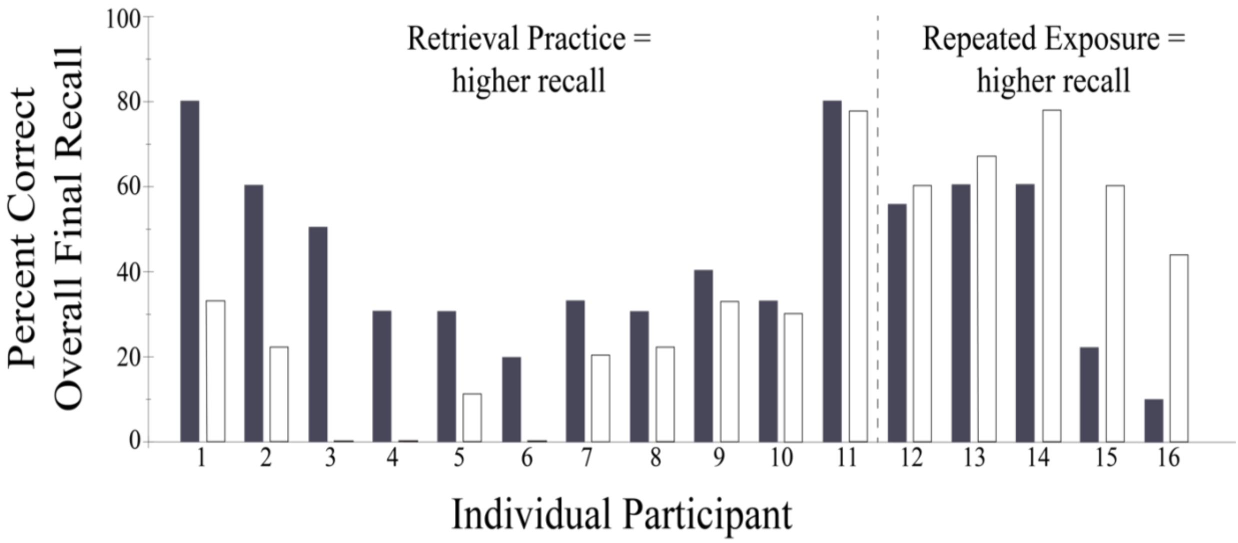


Figure 2.3. Final Recall for Each Participant

Figure 2.3. The final recall (percent correct) for each student is shown, separated by condition. The solid bars display the recall of new words that were taught through retrieval practice, while the open bars display the recall of words taught using repeated exposure. Students to the left of the dotted line (1-11) learned more words with retrieval practice and students to the right of the dotted line (12-16) learned more words with repeated exposure.

To compare the significance of condition on final recall, the variable was entered into the logistic regression model that is described in further detail under *Research Question 2*. Therefore, this effect accounts for, and is independent from, the other predictors (e.g., aided speech perception). Condition (retrieval practice versus repeated exposure) was found to be a significant predictor of final recall. Participants were twice as likely to recall a word two days later if retrieval practice was used rather than repeated exposure ($OR = 2.01$, $p = 0.02$). This result supports my hypothesis that children who are d/hh would learn more new words through retrieval practice than repeated exposure.

2.3.2 Research Question 2

Do child, family, or audiological characteristics affect vocabulary learning for children who are d/hh? If so, which characteristics are significant predictors of vocabulary learning?

In addition to condition, parent education, additional diagnosis, rounds to recall, and aided speech perception scores were analyzed as predictor variables of interest in this study. To better understand these variables, Table 2.4 displays the correlation coefficients between the five factors.

Table 2.4

Correlation Table of the Predictors

	Parent Education	Additional Diagnosis	Rounds	Condition	Speech Perception
Parent Education	1.00				
Additional Diagnosis	0.23	1.00			
Rounds	-0.17	0.05	1.00		
Condition	0.02	-0.003	0.04	1.00	
Speech Perception	0.29	-0.02	-0.14	-0.0002	1.00

Note. Condition is a level 1 factor. Parent Education, Additional Diagnosis, Rounds, and Speech Perception are level 2 factors.

It is also important to highlight the basic descriptive statistics of the predictor variables. The level 2 factors included whether the student had an additional diagnosis other than hearing loss, their aided speech perception scores, their highest parent education level, and number of rounds to recall. As reported by parents or school administrators on the demographic questionnaire, 44% of the students had an additional diagnosis, such as Waardenburg Syndrome, Zellweger Syndrome, and Cytomegalovirus (CMV). Parent education was coded 1-5 based on the highest level of education by either parent reported: eighth grade or less (1), high school (2), some college (3), bachelor's degree/4-year college (4), and graduate degree (5). For this study, the average parent education level was a bachelor's degree. As described earlier, aided speech perception scores represent the binaural condition or the score from the best ear and were given a score out of 600, based on the hierarchical scale developed by Wang et al. (2008). The mean aided speech perception score was 376 with a range of 52-583.

Rounds to recall in the practice sessions is a level 2 factor. Students were given 10 rounds to correctly recall each word. In order to optimize the amount of data, students who did not successfully recall a word during the practice session were given a score of 10 instead of omitting the specific word for that student. The average number of rounds a student took to recall a word was 4.42 (*SD* = 3.12, range = 1-10).

Condition is a level 1 factor and is best described through proportions: 51% of the words were practiced in the retrieval practice condition. Retrieval practice represented 51% of the words because "sloth" was omitted from the analyses. Although the words were randomly presented, "sloth" was practiced more times in the repeated exposure condition, so when it was removed from the analyses, the proportion of words in repeated exposure decreased.

The five predictor variables (parent education, additional diagnosis, rounds, condition, and speech perception) were analyzed in the same logistic regression model. Interactions between condition and speech perception, condition and rounds, and condition and additional diagnosis were examined as well. From a review of the literature, aided speech perception, and presence of an additional diagnosis had feasible reasoning to affect the outcome of condition, whereas the level of parent education did not, so that interaction was not analyzed. When running the model with five predictor variables as well as the three interactions, none of the interactions were significant. All three interactions were omitted from the final model. Table 2.5 displays the final model for final recall of the words.

Table 2.5

Final Recall Model

	FINAL RECALL		
Predictors	*Odds Ratios*	*CI*	*p*
(Intercept)	0.47	0.26 – 0.82	**0.009**
Condition: Repeated Exposure (0) Retrieval Practice (1)	2.01	1.14 – 3.55	**0.016**
Aided Speech Perception	0.96	0.66 – 1.39	0.830
Rounds	0.61	0.53 – 0.7	**<0.001**
Parent Education	1.22	0.83 – 1.79	0.320
Additional Diagnosis: No (0) Yes (1)	0.44	0.21 – 0.92	**0.03**
Random Effects			
σ^2	3.29		
$\tau_{00\ ID}$	0.15		
ICC $_{ID}$	0.04		
Observations	304		
Marginal R^2 / Conditional R^2	0.440 / 0.466		

The intercept term (0.47) refers to the log-odds of correctly recalling a word with all variables at a value of 0. Three predictor variables were significant in the final logistic regression model: condition, rounds, and additional diagnosis. As mentioned earlier, students were twice as likely to recall a word two days later if it had been practiced using retrieval practice rather than repeated exposure (*OR* = 2.01, $p = 0.02$). The number of practice rounds needed to learn the word was also a significant predictor of final recall (*OR* = 0.61, $p < 0.001$). For every increase of round in the practice session, a student was nearly half as likely to recall the word during the assessment session; therefore, if a student required more rounds to learn the words, they were less likely to recall the vocabulary word two days later. The third significant predictor of final recall was the presence of an additional diagnosis other than hearing loss (*OR* = 0.44, $p = 0.03$). If a student had an additional diagnosis (e.g., Waardenburg Syndrome, CMV, Zellweger Syndrome), they were more than half as likely to recall the word, regardless of the condition the stimulus was presented. Notably, aided speech perception was not a significant predictor for final recall with this sample of students. This means that after controlling for all other variables, children with varying scores of aided speech perception had the same odds of likelihood for recalling the learned label. Highest level of parent education was also not a significant factor in predicting final recall.

To summarize the results of the analyses, children with hearing loss were more likely to recall a word when practiced using retrieval practice than repeated exposure, when they needed fewer rounds to recall the word during the practice phase, and if they did not have an additional diagnosis.

Chapter 3: Discussion

Children with typical hearing begin developing vocabulary during infancy, mostly through incidental learning. But children who are d/hh are often not able to learn vocabulary incidentally like their peers. Because of this problem, children who are d/hh start off at a disadvantage beginning in the first few years of life. This delay can be persistent and increase as they get older (Convertino et al., 2014; Sarchet et al., 2014). In fact, it has been found that children with hearing loss do not use word-learning strategies as proficiently as children with typical hearing (Davidson et al., 2014; Houston et al., 2012; Lund, 2018; Lund & Schuele, 2014). If children who are d/hh cannot learn vocabulary as efficiently or in the same way as children with typical hearing (e.g., incidentally from their environment), they cannot be expected to develop a lexicon comparable to peers with typical hearing (Lund & Schuele, 2014). Therefore, children who are d/hh need vocabulary interventions to address this problem area; unfortunately, only a few studies have implemented vocabulary interventions in classroom settings (Bobzien et al., 2015; Luckner & Cooke, 2010; Lund, 2016; Lund & Douglas, 2016; Lund et al., 2015). Due to the lack of intervention research in deaf education, I looked to cognitive psychology for an effective learning strategy. Retrieval practice is a successful learning strategy that has been used in the classroom, with young children, for vocabulary learning, and with an atypical population (e.g., Coyne et al., 2015; Fritz et al., 2007; Goossens et al., 2014; Karpicke & Roediger, 2008; McDaniel et al., 2011; McDermott et al., 2014; Roediger et al., 2011). This was the first study to use this strategy with children with hearing loss who use listening and spoken language.

The overarching goal of this dissertation was to determine whether children who are d/hh are able to learn more new words through retrieval practice than repeated exposure. In addition, specific characteristics of the participants were analyzed to determine their effect on expressive vocabulary learning.

3.1 Research Question 1

Do children who are d/hh learn more new words through retrieval practice than repeated exposure?

I hypothesized that children who are d/hh would learn more new words through retrieval practice than repeated exposure. This hypothesis was supported by my study's results. Eleven out of 16 students recalled more words, after a two day retention interval, that were practiced using retrieval practice in comparison to repeated exposure. Students were twice as likely to recall a word using retrieval practice than repeated exposure. This is a large effect. Because condition was the only variable that was manipulated in the intervention study, a causal relationship can be drawn between condition and final recall—retrieval practice caused increased vocabulary learning for children who are d/hh. It is important to note that all of the students learned new vocabulary words through retrieval practice, whereas there were three students who did not learn any new words through repeated exposure (subjects 3, 4, and 6).

During this study, whether through retrieval practice, repeated exposure, or both conditions, all of the children learned new vocabulary words. This shows that with explicit instruction, children with hearing loss are able to learn vocabulary. Because both retrieval practice and repeated exposure are explicit teaching strategies, my study supports the idea that explicit teaching is beneficial for children who are d/hh. It would be interesting to design a study including a third condition with no explicit teaching.

The positive retrieval practice results are important for the field deaf education in regards to future research as well as classroom practices. As mentioned earlier, there are few studies that investigate vocabulary interventions in the field of deaf education. Teachers of the deaf are in need of effective strategies for their students (Duncan & Lederberg, 2018). These findings begin to give evidence for the use of an intervention in the classroom. In addition, because the current study is the first to measure retrieval practice with children who are d/hh, this is a successful addition to cognitive psychology literature as well.

3.2 Research Question 2

Do child, family, or audiological characteristics affect vocabulary learning for children who are d/hh? If so, which characteristics are significant predictors of vocabulary learning?

In addition to condition (retrieval practice and repeated exposure), I hypothesized that the number of rounds to recall in the practice session, presence of an additional diagnosis other than hearing loss, highest level of parent education, and aided speech perception scores would be significant predictors of final recall. Number of rounds to recall and additional diagnosis were significant predicting factors, but parent education and aided speech perception scores were not.

Children with hearing loss start at a disadvantage with vocabulary in comparison to their peers with typical hearing; therefore, teachers of the deaf feel an urgency to fit as much into a school-day as possible. The mindset is that there is no time to waste when teaching children who are d/hh. Rounds to recall was an interesting factor in this study because it is all about being efficient with learning. A student who is an efficient learner would require fewer rounds to learn a word during the practice session. The results from this study indicate that with every additional round a student needed to learn a word, she was about half as likely to recall that word two days later. The more efficient learners were the students who remembered more vocabulary words and were quicker to do so. This finding is convergent with the learning efficiency theory described earlier, and with studies that have been conducted with college students with typical hearing. This is important for teachers of the deaf to be cognizant of because some students with hearing loss may learn words at a different rate than others.

The analysis also showed that children who have an additional diagnosis are at a disadvantage for vocabulary learning when compared to children with hearing loss who did not have an additional diagnosis. From this sample, children with Waardenburg Syndrome, Zellweger Syndrome, and Cytomegalovirus were about half as likely to recall a word after the two day retention interval in comparison to the group without an additional diagnosis. As mentioned earlier, an additional diagnosis can have concurrent developmental impacts with hearing loss, including learning delays. This shows that teachers of the deaf need to be aware of additional diagnoses and that children with them may struggle with learning vocabulary more than others.

It is important to distinguish between additional diagnosis and additional disorder or disability. I chose to use additional diagnosis because of the age of the children (5-8 years old). Some disabilities are not diagnosed until early-middle elementary school. If the participants had an additional disability categorized as a Specific Learning Disability (e.g., Dyslexia, Nonverbal Learning Disability) or Other Health Impairment (e.g., Attention-Deficit/Hyperactivity Disorder), they may not have been diagnosed yet. In addition, sometimes families of children with hearing loss may only be able to focus on their child’s hearing loss and struggle with exploring the possibility of other potential disabilities their child may have. In comparison, a child with an additional diagnosis may have had that identification since birth, therefore making it simpler to report on the demographic questionnaire.

Highest level of parent education has been used as a variable to describe the socioeconomic status of a family. Instead of asking families to report their annual household income, parent education was asked for this study. Parent education and socioeconomic status have been shown to predict vocabulary development for children with hearing loss (e.g., Geers et al., 2009; Geers, Nicholas, & Moog, 2007; Yoshinaga-Itano et al., 2017); therefore, it was unexpected that parent education was not a significant predictor variable. A possible explanation for this null effect is that there was not much variability in the sample. Fourteen of the 16 students' parents had some level of college education or more.

Another surprising result was that aided speech perception scores did not reach significance. I expected that children with better aided speech perception scores would remember more vocabulary words two days later. Aided speech perception scores have been shown to affect overall language development for children with hearing loss who use listening and spoken language (e.g., de Hoog et al., 2016; Dettman et al., 2016; Eisenberg et al., 2016). Yet, few studies specifically examining word-learning strategies of children who are d/hh have reported aided speech perception scores as a significant predictive factor of word-learning abilities (Davidson et al., 2014). There are feasible explanations as to why speech perception did not reach significance and directly affect the final recall of the new words. Because scores were reported by families or school administrators, the most current scores may not have been available for this study, therefore not accurately describing the child's current listening ability.

Also, since I did not conduct the speech perception testing myself, the reliability of these measures is a limitation. For this study, all students were tested in optimal listening conditions: noise-treated classrooms, seated next to or directly across from the speaker, and with full access to visual information from the speaker's face. This would have allowed all students the best access to sound, potentially reducing the effect of aided speech perception scores on learning. In addition, due to the small sample size of this study, the statistical analyses performed may have lacked sufficient power to detect the effect of aided speech perception on final recall of the new words. The small sample size also results in a lack of variability of aided speech perception scores for analyses. Because children who have better audibility tend to have higher speech perception scores, and subsequently tend to develop language more on par with their peers with typical hearing, it is important to examine the impact of aided speech perception on word-learning skills in future studies.

In summary, rounds to recall or learning efficiency and presence of additional diagnosis were significant predictors of vocabulary learning for this sample of children who are d/hh; whereas, parent education and aided speech perception scores were not.

3.3 Implications for the Classroom

Overall, eleven out of sixteen participants in this study learned more words from retrieval practice than repeated exposure. These results begin to provide evidence for a learning strategy that teachers of the deaf can use in the classroom. For children with hearing loss, the results from this dissertation show that the way in which words are taught matters (Lund & Douglas, 2016). Because there are few intervention studies focusing on vocabulary learning for children who are d/hh, this is an important study for the field of deaf education. Below I will describe how retrieval practice could be implemented in different settings. I will also describe potential barriers for using retrieval practice with children who are d/hh.

One of the positive aspects of retrieval practice is that it can be used in many settings and subject areas, and can be implemented in a variety of ways. Children with hearing loss are taught in different settings depending on what's described in their Individualized Educational Program (IEP). They can be taught in a general education classroom with pull-out services, self-contained classroom with other children who are d/hh, or a separate school for the deaf. A classroom teacher can use retrieval practice to increase learning with all of her students, with and without hearing loss, through verbally asking questions during lessons or read-alouds, requiring students to recall something learned in class before dismissal to recess, integrating frequent low-stakes quizzing, or playing quiz-show games. An itinerant teacher can quiz a student who is d/hh while playing memory games with flashcards of learned vocabulary during pull-out sessions.

This study showed that retrieval practice is beneficial for vocabulary learning. Children with hearing loss typically receive specified time for vocabulary instruction, especially in content-areas such as science, social studies, and math. One of the reasons children with hearing loss may struggle in content-area classes is due to the difficulty of the vocabulary. Itinerant teachers can use retrieval practice to practice content-specific vocabulary with students, or they can teach students how to use retrieval practice on their own. As mentioned earlier, there are too many unknown words that children come across for teachers to teach individually; therefore, it is important that students have a variety of word-learning strategies they can use independently.

Even for the youngest learners, early interventionists can incorporate retrieval practice into their sessions. They can make a game out of naming toys, for example. Early interventionists could have a bag with play food and quiz the child on each label of the food he pulls out of the bag. Retrieval practice is a strategy that can be taught to parents to work with their child as well. It is important for the parents to understand the effectiveness of the strategy though.

An important part of retrieval practice is having the student attempt to recall the answer, or in this study the vocabulary word. During both the learning and assessment phase, the students were encouraged to guess the label to the word instead of just saying, “I don’t know.” Guessing, even if incorrect, increases a student’s likelihood of correctly identifying that word in the future (Carey, 2015). The act of guessing itself engages the mind in a different and more demanding way than straight memorization, which can strengthen the routes to the correct answers (Carey, 2015). Therefore, teachers or early interventionists need to encourage their students to guess, but also give them a safe space to be incorrect.

As mentioned earlier, feedback is a crucial part of retrieval practice. In order to combat the worry of grading large amounts of quizzes, students can grade each other’s quizzes, teachers can use web-based quizzing where the quizzes are automatically graded, or they could have students use clickers to answer questions during class-time so grading is not necessary. Teachers need to remember that quizzes should be low-stakes; therefore, quiz length should be limited in general. Teachers can also verbally give feedback during classroom activities, lessons, or games that incorporate testing. Whether feedback is immediate or delayed, the important thing is that it is part of retrieval practice (Butler et al., 2007; Butler & Roediger, 2008).

In addition to grading large amounts of quizzes, there are other barriers that need to be considered for implementing retrieval practice in the classroom. The first is the idea of increased testing in the classroom. Teachers and students need to understand that the tests are used for learning, not only for assessing. Once students understand the benefits of the strategy, and that the quizzes are low-stakes, then they can begin to trust in the strategy. Students may initially feel increased testing anxiety, but as mentioned earlier, repeated quizzing actually helps to eliminate that anxiety once students understand the strategy (Agarwal et al., 2014). The illusion of fluency and the concept of desirable difficulties need to be explained to students—even though quizzing may be harder than re-reading their text, it is more beneficial for learning. This study used retrieval practice with students as young as five years old; if retrieval practice is introduced to children at young ages, then testing will be a normal part of their learning instead of an added potential stressor.

A worry of additional work for the teacher is a potential barrier of implementing retrieval practice. It may be extra work initially to create the quizzes or to adapt teaching methods in order to integrate quizzing into everyday teaching. This being said, written quizzes should be short in length, and learning how to incorporate retrieval questions verbally into classroom discussions, read-alouds, or science lessons, will ultimately help the teachers know what the students understand and what they do not. For example, if, during a read-aloud, a teacher asks his students what the definition of a previously taught vocabulary word is, but none of the students know the answer, the teacher can adapt his teaching to address that specific word. Even though the idea of retrieval practice has been around for centuries, increased testing in the classroom has not been widely adapted in educational settings for children both with and without hearing loss. In order for this strategy to become common practice, buy-in from teachers and students alike needs to occur. Once the benefits are understood, there are many ways to incorporate this robust learning strategy.

3.4 Limitations & Future Directions

There are several limitations to this experiment which need to be addressed. First of all, sample size is a typical issue in deaf education research. Hearing loss is a low-incidence disorder with deafness affecting 1.4 babies in every 1000 births (CDC, 2019); therefore, recruitment and sample size are issues when conducting research. All three kinds of hearing devices, degrees, and types of hearing loss were included in the study to gain a larger sample size. Also, children with an additional diagnosis were included because it was a predictive factor I wanted explore for this study and to increase the sample size. Future studies would have a larger sample of children to test the use of retrieval practice for vocabulary learning.

Secondly, all of the participants used listening and spoken language; therefore, the results cannot be generalized to children who are d/hh that use any degree of manual communication (e.g., American Sign Language, Signed Exact English, Total Communication). I chose to work with children who use listening and spoken language because that is where my expertise lies. Because this is the first study to use retrieval practice with children who are deaf, it was important to keep the mode of communication the same for all participants. It would be interesting to see if retrieval practice produced as large of an effect with children who are d/hh and who use different forms of communication other than spoken English.

Thirdly, there was a sizable age range (aged 5.0- 8.11) of children who participated in the study, adding variability to the sample. Because deafness is a low-incidence disability, I included an age range to help increase the sample size. Young children were recruited because, as described earlier, in order for children with hearing loss to catch up to their typically hearing peers, intervention needs to begin early. Fritz et al. (2007), showed that children as young as three years old could benefit from retrieval practice. However, three-year olds were not chosen for this study because the children needed to have a language foundation in order to understand the task, adequate aided speech perception to hear the task, and appropriate behavior to sit through the task. Future studies could focus on different aged children with hearing loss to see if retrieval practice was beneficial at other ages as well.

Fourth, due to scheduling constraints, there was only one final assessment of the words. Because retrieval practice is beneficial for long-term learning, if the retention interval was longer, or additional assessment days were added, a stronger benefit from retrieval practice in comparison to repeated exposure could have been found (Brown et al., 2014). Future studies could include multiple assessment phases with longer assessment periods.

Fifth, I did not have students' current language levels or nonverbal intelligence tests. This information was not accessible from either participating school. Bouwmeester and Verkoeijen (2011) found that some children benefit from retrieval practice more than others. Additional studies have examined the effect of learning strategies on recall and found that learners with varying abilities have varying levels of benefit from the different strategies (McDaniel, Hines, & Guynn, 2002). Because students' vocabulary foundation has been shown to affect vocabulary growth for children with hearing loss (Fagan, 2016; Lederberg et al., 2000; Quittner et al., 2016), it would be interesting to investigate language and IQ scores as predictive factors.

An additional limitation is the manner in which the retrieval practice condition was designed: TSTSTS. Since I had three study sessions intermixed within the retrieval practice condition, it was not solely a testing condition. It would be interesting to see if and how the results from this study would alter if I used six rounds of testing (TTTTTT) with no study between.

Another limitation comes from the desirable difficulty hypothesis (for some tasks, the more difficult it is, the deeper the learning that will occur). Retrieval practice was implemented right after the initial learning of the material, but delayed retrieval after the initial practice phase could have led to better retention because retrieval would have been more difficult for the learner (Brown et al., 2014). If I had additional research assistants and more time with the students, I could have included an additional time period between initial learning and implementation of retrieval practice.

As mentioned earlier, appropriate levels of scaffolding and support need to be given to the students for retrieval practice to be beneficial. "It seems that in order for retrieval practice to work well with students of any age, we need to make sure that students are successful," (Weinstein et al., 2018, p. 128). It is possible that students in this study did not feel successful or have enough support to reap the benefits of retrieval practice. Balancing the amount of difficulty with student success is a challenge when incorporating retrieval practice in the classroom (Karpicke et al., 2014; Weinstein et al., 2018). Just as Karpicke et al. offered more scaffolding with their tasks, future studies with children who are d/hh could alter the amount of support given to see if a different outcome arises.

Despite the robust findings obtained in this experiment, especially with such a small sample size, this intervention needs to be replicated in order to begin to meet the gold standards of an evidence-based strategy (Odom et al., 2005).

In conclusion, this study resulted in positive findings in an area of critical need for children with hearing loss—expressive vocabulary learning. Retrieval practice is a strategy that can be brought into classrooms with little effort from the teachers but result in large gains for the students. This dissertation brings new information to two different fields that have potential for continued collaboration: deaf education and cognitive psychology.

References

Agarwal, P. K. (2018). Retrieval practice & bloom's taxonomy: Do students need fact knowledge before higher order learning? *Journal of Educational Psychology*.

Agarwal, P. K., D'Antonio, L., Roediger, H. L., McDermott, K. B., & McDaniel, M. A. (2014). Classroom-based programs of retrieval practice reduce middle school and high school students' test anxiety. *Journal of Applied Research in Memory and Cognition*, *3*(3), 131–139.

Anderson, R. C., Wilson, P. T., & Fielding, L. G. (1988). Growth in reading and how children spend their time outside of school. *Reading Research Quarterly*, *23*(3), 285–303.

Antia, S. D., Jones, P. B., Reed, S., & Kreimeyer, K. H. (2009). Academic status and progress of deaf and hard-of-hearing students in general education classrooms. *Journal of Deaf Studies and Deaf Education*, *14*(3), 293-311.

ASHA. (2015a). Hearing aids for children. Retrieved February 28, 2019, from https://www.asha.org/public/hearing/hearing-aids-for-children/

ASHA. (2015b). Type, degree, and configuration of hearing loss. *Audiology Information Series*.

Bahrick, L. E., Lickliter, R., & Flom, R. (2004). Intersensory redundancy guides the development of selective attention, perception, and cognition in infancy. *Current Directions in Psychological Science*, *13*(3), 99–102.

Bates, D., Maechler, M., Bolker, B., & Walker, S. (2015). lme4: Linear mixed-effects models using Eigen and S4 (Version 1.1-7.2014).

Bauer, D. J., Goldfield, B. A., & Reznick, J. S. (2002). Alternative approaches to analyzing individual differences in the rate of early vocabulary development. *Applied Psycholinguistics*, *23*(3), 313–335.

Beck, I. L., & McKeown, M. G. (2007). Increasing young low-income children's oral vocabulary repertoires through rich and focused instruction. *The Elementary School Journal*, *107*(3), 251–271.

Bess, F. H., & Paradise, J. L. (1994). Universal screening for infant hearing impairment: Not simple, not risk-free, not necessarily beneficial, and not presently justified. *Pediatrics*, *93*(2), 330–334.

Bjork, R. A. (1988). Retrieval practice and the maintenance in knowledge. *Practical Aspects of Memory: Current Research and Issues*, *1*, 396–401.

Bjork, R. A., & Kroll, J. F. (2015). Desirable difficulties in vocabulary learning. *The American Journal of Psychology*, *128*(2), 241–252.

Blachowicz, C. L. Z., Fisher, P. J. L., Ogle, D., & Watts-Taffe, S. (2006). Theory and research into practice: Vocabulary: Questions from the classroom. *Reading Research Quarterly*, *41*(4), 524–539.

Bobzien, J. L., Richels, C., Schwartz, K., Raver, S. A., Hester, P., & Morin, L. (2015). Using repeated reading and explicit instruction to teach vocabulary to preschoolers with hearing loss. *Infants & Young Children*, *28*(3), 262–280.

Boons, T., De Raeve, L., Langereis, M., Peeraer, L., Wouters, J., & van Wieringen, A. (2013). Expressive vocabulary, morphology, syntax and narrative skills in profoundly deaf children after early cochlear implantation. *Research in Developmental Disabilities*, *34*(6), 2008–2022.

Bouwmeester, S., & Verkoeijen, P. P. J. L. (2011). Why do some children benefit more from testing than others? Gist trace processing to explain the testing effect. *Journal of Memory and Language*, *65*(1), 32–41.

Brown, P. C., Roediger, H. L., & McDaniel, M. A. (2014). *Make it stick*. Harvard University Press.

Butler, A. C. (2010). Repeated testing produces superior transfer of learning relative to repeated studying. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *36*(5), 1118–1133.

Butler, A. C., Karpicke, J. D., & Roediger, H. L. (2007). The effect of type and timing of feedback on learning from multiple-choice tests. *Journal of Experimental Psychology: Applied*, *13*(4), 273–281.

Butler, A. C., & Roediger, H. L. (2008). Feedback enhances the positive effects and reduces the negative effects of multiple-choice testing. *Memory & Cognition*, *36*(3), 604–616.

Carey, B. (2015). *How we learn: The surprising truth about when, where, and why it happens*. Random House Publishing Group.

Carpenter, S. K. (2009). Cue strength as a moderator of the testing effect: The benefits of elaborative retrieval. *Journal of Experimental Psychology: Learning, Memory, and Cognition,* 35(6), 1563-1569.

Cawthon, S. W. (2011). Education of deaf and hard of hearing students and accountability reform: Issues for the future. *American Annals of the Deaf*, *156*(4), 424–430.

CDC. (2015). Understanding Hearing Loss: About Sound | CDC. Retrieved February 28, 2019, from https://www.cdc.gov/ncbddd/hearingloss/sound.html

CDC. (2019). Data and Statistics About Hearing Loss in Children | CDC. Retrieved February 28, 2019, from https://www.cdc.gov/ncbddd/hearingloss/data.html

CDC-EHDI. (2014). *2014 Hearing Screening Summary* (p. 2). EDHI. Retrieved from www.cdc.gov/ncbddd/hearingloss/ehdi-data.html

CDC-EHDI. (2016). *Summary of 2014 National CDC EHDI Data* (p. 5). Retrieved from https://www.cdc.gov/ncbddd/hearingloss/2014-data/2014_ehdi_hsfs_summary_h.pdf

Chall, J. S. (1983). *Stages of reading development*. McGraw-Hill.

Connor, C. M., Craig, H. K., Raudenbush, S. W., Heavner, K., & Zwolan, T. A. (2006). The age at which young deaf children receive cochlear implants and their vocabulary and speech-production growth: Is there an added value for early implantation? *Ear and Hearing*, *27*(6), 628–644.

Convertino, C., Borgna, G., Marschark, M., & Durkin, A. (2014). Word and world knowledge among deaf learners with and without cochlear implants. *The Journal of Deaf Studies and Deaf Education*, *19*(4), 471–483.

Cosetti, M., & Roland, J. T. (2010). Cochlear implantation in the very young child: Issues unique to the under-1 population. *Trends in Amplification*, *14*(1), 46–57.

Coyne, J. H., Borg, J. M., DeLuca, J., Glass, L., & Sumowski, J. F. (2015). Retrieval practice as an effective memory strategy in children and adolescents with traumatic brain injury. *Archives of Physical Medicine and Rehabilitation*, *96*(4), 742–745.

Coyne, M. D., Simmons, D. C., Kame'enui, E. J., & Stoolmiller, M. (2004). Teaching vocabulary during shared storybook readings: An examination of differential effects. *Exceptionality*, *12*(3), 145–162.

Cunningham, A. E., & Stanovich, K. E. (1997). Early reading acquisition and its relation to reading experience and ability 10 years later. *Developmental Psychology*, *33*(6), 934–945.

Dale, P. S., & Fenson, L. (1996). Lexical development norms for young children. *Behavior Research Methods, Instruments, & Computers*, *28*(1), 125–127.

Davids, T., Gordon, K. A., Clutton, D., & Papsin, B. C. (2007). Bone-anchored hearing aids in infants and children younger than 5 years. *Archives of Otolaryngology–Head & Neck Surgery*, *133*(1), 51–55.

Davidson, L. S., Geers, A. E., & Nicholas, J. G. (2014). The effects of audibility and novel word learning ability on vocabulary level in children with cochlear implants. *Cochlear Implants International*, *15*(4), 211–221.

Davis. (1944). Fundamental factors of comprehension in reading. *Psychometrika*, *9*(3), 185–197.

Davis, A., & Davis, K. (2011). Descriptive epidemiology of childhood hearing impairment. In *Comprehensive Handbook of Pediatric Audiology, Second Edition* (pp. 85–111). Plural Publishing.

de Hoog, B. E., Langereis, M. C., van Weerdenburg, M., Keuning, J., Knoors, H., & Verhoeven, L. (2016). Auditory and verbal memory predictors of spoken language skills in children with cochlear implants. *Research in Developmental Disabilities*, *57*, 112–124.

Desjardin, J. L., & Eisenberg, L. S. (2007). Maternal contributions: Supporting language development in young children with cochlear implants. *Ear and Hearing*, *28*(4), 456–469.

Dettman, S. J., Dowell, R. C., Choo, D., Arnott, W., Abrahams, Y., Davis, A., … Briggs, R. J. (2016). Long-term communication outcomes for children receiving cochlear implants younger than 12 months: A multicenter study. *Otology & Neurotology: Official Publication of the American Otological Society, American Neurotology Society [and] European Academy of Otology and Neurotology*, *37*(2), 82–95.

Dhooge, I. J. M. (2003). Risk factors for the development of otitis media. *Current Allergy and Asthma Reports*, *3*(4), 321–325.

Ding, L., & Martinez, A. M. (2009). Modeling and recognition of the linguistic components in american sign language. *Image and Vision Computing*, *27*(12), 1826–1844.

Dollaghan, C. A., Paradise, J. L., Janosky, J. E., Pitcairn, D. N., Kurs-Lasky, M., Campbell, T. F., & Feldman, H. M. (1999). Maternal education and measures of early speech and language. *Journal of Speech, Language, and Hearing Research*, *42*(6), 1432–1443.

Duke, N. K., Bennett-Armistead, V. S., & Roberts, E. M. (2003). Bridging the gap between learning to read and reading to learn. In *Literacy and young children: Research-based practices* (pp. 226–242).

Duncan, Dowsett, C. J., Claessens, A., Magnuson, K., Huston, A. C., Klebanov, P., … Japel, C. (2007). School readiness and later achievement. *Developmental Psychology*, *43*(6), 1428–1446.

Duncan, M., & Lederberg, A. R. (2018). Relations between teacher talk characteristics and child language in spoken-language deaf and hard-of-hearing classrooms. *Journal of Speech, Language, and Hearing Research*, *61*(12), 2977–2995.

ECTA. (2019). Part C of IDEA. Retrieved February 28, 2019, from http://ectacenter.org/partc/partc.asp

Eisenberg, L. S., Fisher, L. M., Johnson, K. C., Ganguly, D. H., Grace, T., & Niparko, J. K. (2016). Sentence recognition in quiet and noise by pediatric cochlear implant users: Relationships to spoken language. *Otology & Neurotology:Official Publication of the American Otological Society, American Neurotology Society [and] European Academy of Otology and Neurotology*, *37*(2), 75–81.

Estes, K. G., Evans, J. L., Alibali, M. W., & Saffran, J. R. (2007). Can infants map meaning to newly segmented words?: Statistical segmentation and word learning. *Psychological Science*, *18*(3), 254–260.

Fagan, M. K. (2015). Cochlear implantation at 12 months: Limitations and benefits for vocabulary production. *Cochlear Implants International*, *16*(1), 24–31.

Fagan, M. K. (2016). Spoken vocabulary development in deaf children with and without cochlear implants. In *The Oxford Handbook of Deaf Studies in Language* (pp. 132–145).

Fenson, L., Dale, P. S., Reznick, J. S., Bates, E., Thal, D. J., Pethick, S. J., … Stiles, J. (1994). Variability in early communicative development. *Monographs of the Society for Research in Child Development*, *59*(5), i–185.

Fenson, L., Marchman, V. A., Thal, D. J., Dale, P. S., & Reznick, J. S. (2007). *MacArthur-bates communicative development inventories: User's guide and technical manual*. Baltimore, MD: Brookes.

Fritz, C. O., Morris, P. E., Nolan, D., & Singleton, J. (2007). Expanding retrieval practice: An effective aid to preschool children's learning. *The Quarterly Journal of Experimental Psychology*, *60*(7), 991–1004.

Gardner, M. F. (2010). *EOWPVT-R: Expressive one-word picture vocabulary test, revised*. United States: Pearson.

Gates, A. I. (1917). Recitation as a factor in memorizing. *Arch Psychol*, *6*(40), 112–121.

Geers, A. E., Davidson, L., Uchanski, R., & Nicholas, J. (2013). Interdependence of linguistic and indexical speech perception skills in school-aged children with early cochlear mplantation. *Ear and Hearing*, *34*(5), 562–574.

Geers, A. E., Mitchell, C. M., Warner-Czyz, A., Wang, N.-Y., Eisenberg, L. S., & The CDaCI Investigative Team. (2017). Early sign language exposure and cochlear implantation benefits. *Pediatrics, 140*(1).

Geers, A. E., Moog, J. S., Biedenstein, J., Brenner, C., & Hayes, H. (2009). Spoken language scores of children using cochlear implants compared to hearing age-mates at school entry. *Journal of Deaf Studies and Deaf Education*, *14*(3), 371–385.

Geers, A. E., & Nicholas, J. G. (2013). Enduring advantages of early cochlear implantation for spoken language development. *Journal of Speech, Language, and Hearing Research*, *56*(2), 643–655.

Geers, A. E., Nicholas, J. G., & Moog, J. S. (2007). Estimating the influence of cochlear implantation on language development in children. *Audiological Medicine*, *5*(4), 262–273.

Gertsen, R. (2008). Assisting students struggling with reading: Response to intervention and multi-tier intervention in the primary grades, 60.

Goossens, N. A. M. C., Camp, G., Verkoeijen, P. P. J. L., & Tabbers, H. K. (2014). The effect of retrieval practice in primary school vocabulary learning. *Applied Cognitive Psychology*, *28*(1), 135–142.

Gordon, K. A., Wong, D. D. E., Valero, J., Jewell, S. F., Yoo, P., & Papsin, B. C. (2011). Use It or lose It? lessons learned from the developing brains of children who are deaf and use cochlear implants to hear. *Brain Topography*, *24*(3), 204.

Graven, S. N., & Browne, J. V. (2008). Auditory development in the fetus and infant. *Newborn and Infant Nursing Reviews*, *8*(4), 187–193.

Hagr, A. (2007). BAHA: Bone-anchored hearing aid. *International Journal of Health Sciences*, *1*(2), 265–276.

Hammes, D. M., Willis, M., Novak, M. A., Edmondson, D. M., Rotz, L. A., & Thomas, J. F. (2002). Early identification and cochlear implantation: Critical factors for spoken language development. *Annals of Otology, Rhinology & Laryngology*, *111*(5), 74–78.

Harris, M., Terlektsi, E., & Kyle, F. E. (2017). Concurrent and longitudinal predictors of reading for deaf and hearing children in primary school. *The Journal of Deaf Studies and Deaf Education*, *22*(2), 233–242.

Hart, B., & Risley, T. R. (2003). The early catastrophe: The 30 million word gap by age 3, *27*(1), 4–9.

Hayes, H., Geers, A. E., Treiman, R., & Moog, J. S. (2009). Receptive vocabulary development in deaf children with cochlear implants: Achievement in an intensive auditory-oral educational setting. *Ear and Hearing*, *30*(1), 128–135.

Hermans, M., & Spencer, P. E. (2015). *The Oxford Handbook of Deaf Studies in Language*. Oxford University Press.

Hermans, M., Wauters, L., Willemsen, M., & Knoors, H. (2015). Vocabulary acquisition in deaf and hard-of-hearing children: Research and interventions. In *The Oxford handbook of deaf studies in language*.

Hoff, E. (2006). How social contexts support and shape language development. *Developmental Review*, *26*(1), 55–88.

Hosmer, D. W. J., Lemeshow, S., & Sturdivant, R. X. (2013). *Applied Logistic Regression*. John Wiley & Sons.

Houston, D. M., Stewart, J., Moberly, A., Hollich, G., & Miyamoto, R. T. (2012). Word learning in deaf children with cochlear implants: Effects of early auditory experience. *Developmental Science*, *15*(3), 448–461.

Howard, M. W., & Kahana, M. J. (2002). A distributed representation of temporal context. *Journal of Mathematical Psychology*, *46*(3), 269–299.

IES-NCEE. (2019). WWC | Find What Works! Retrieved February 28, 2019, from https://ies.ed.gov/ncee/wwc/

IES-NCES. (2017). *Fast Facts*. U.S. Department of Education, National Center for Education Statistics. Retrieved from https://nces.ed.gov/fastfacts/display.asp?id=59

IES-NCES. (2018). The Condition of Education - Preprimary, Elementary, and Secondary Education - Elementary and Secondary Enrollment - Children and Youth With Disabilities - Indicator. Retrieved February 28, 2019, from https://nces.ed.gov/programs/coe/indicator_cgg.asp

Innivo. (2013). *Make a scene*. English.

Joint Committee on Infant Hearing. (2007). Year 2007 Position Statement: Principles and Guidelines for Early Hearing Detection and Intervention Programs. *Pediatrics*, *120*(4), 898–921.

Kaiser, A. P., & Roberts, M. Y. (2013). Parent-implemented enhanced milieu teaching with preschool children who have intellectual disabilities. *Journal of Speech, Language, and Hearing Research*, *56*(1), 295–309.

Kamil, M. L., Borman, G. D., Dole, J., Kral, C. C., Salinger, T., & Torgesen, J. (2008). *Improving adolescent literacy: Effective classroom and intervention practices.* National Center for Education Evaluation and Regional Assistance.

Karpicke, J. D. (2017). *Retrieval-based learning: A decade of progress*.

Karpicke, J. D., Blunt, J. R., Smith, M. A., & Karpicke, S. S. (2014). Retrieval-based learning: The need for guided retrieval in elementary school children. *Journal of Applied Research in Memory and Cognition*, *3*(3), 198–206.

Karpicke, J. D., & Roediger, H. L. (2008). The critical importance of retrieval for learning. *Science*, *319*(5865), 966–968.

Karpicke, J. D., & Zaromb, F. M. (2010). Retrieval mode distinguishes the testing effect from the generation effect. *Journal of Memory and Language*, *62*(3), 227–239.

Kolers, P. A., & Roediger, H. L. (1984). Procedures of mind. *Journal of Verbal Learning and Verbal Behavior*, *23*(4), 425–449.

Kuhl, P. K. (2004). Early language acquisition: Cracking the speech code. *Nature Reviews Neuroscience*, *5*(11), 831–843.

Kuhl, P. K., & Meltzoff, A. N. (1996). Infant vocalizations in response to speech: Vocal imitation and developmental change. *The Journal of the Acoustical Society of America*, *100*(4), 2425–2438.

Kuhl, P. K., Williams, K. A., Lacerda, F., Stevens, K. N., & Lindblom, B. (1992). Linguistic experience alters phonetic perception in infants by 6 months of age. *Science*, *255*(5044), 606–608.

Kyle, F. E., Campbell, R., & MacSweeney, M. (2016). The relative contributions of speechreading and vocabulary to deaf and hearing children's reading ability. *Research in Developmental Disabilities*, *48*, 13–24.

Kyle, F. E. & Harris, M. (2010). Predictors of reading development in deaf children: A 3-year longitudinal study. *Journal of Experimental Child Psychology*, *107*(3), 229–243.

Lang, J. M. (2016). *Small teaching: Everyday lessons from the science of learning* (First). San Francisco, CA: Jossey-Bass.

Lederberg, A. R., & Everhart, V. S. (2000). Conversations between deaf children and their hearing mothers: pragmatic and dialogic characteristics. *The Journal of Deaf Studies and Deaf Education*, *5*(4), 303–322.

Lederberg, A. R., Prezbindowski, A. K., & Spencer, P. E. (2000). Word-learning skills of deaf preschoolers: The development of novel mapping and rapid word-learning strategies. *Child Development*, *71*(6), 1571–1585.

Lederberg, A. R., Schick, B., & Spencer, P. E. (2013). Language and literacy development of deaf and hard-of-hearing children: Successes and challenges. *Developmental Psychology*, *49*(1), 15–30.

Lederberg, A. R., & Spencer, P. E. (2001). Vocabulary development of deaf and hard of hearing children. In *Context, cognition, and deafness* (pp. 88–112).

Leeming, F. C. (2002). The exam-a-day procedure improves performance in psychology classes. *Teaching of Psychology*, *29*(3), 210–212.

Lehman, M., & Malmberg, K. J. (2013). A buffer model of memory encoding and temporal correlations in retrieval. *Psychological Review*, *120*(1), 155–189.

Levine, D., Strother-Garcia, K., Golinkoff, R. M., & Hirsh-Pasek, K. (2016). Language development in the first year of life: What deaf children might be missing before cochlear mplantation. *Otology & Neurotology:Official Publication of the American Otological Society, American Neurotology Society [and] European Academy of Otology and Neurotology*, *37*(2), 56–62.

Lipowski, S. L., Pyc, M. A., Dunlosky, J., & Rawson, K. A. (2014). Establishing and explaining the testing effect in free recall for young children. *Developmental Psychology, 50*(4), 994–1000.

Luckner, J. L., Bowen, S., & Carter, K. (2001). Visual teaching strategies for students who are deaf or hard of hearing. *Teaching Exceptional Children*, *33*(3), 38–44.

Luckner, J. L., & Cooke, C. (2010). A summary of the vocabulary research with students who are deaf or hard of hearing. *American Annals of the Deaf*, *155*(1), 38–67.

Luckner, J. L. (2006). Evidence-based practices with students who are deaf. *Communication Disorders Quarterly, 28*(1), 49–52.

Lund, E. (2016). Vocabulary knowledge of children with cochlear implants: A meta-analysis. *Journal of Deaf Studies and Deaf Education*, *21*(2), 107–121.

Lund, E. (2018). Pairing new words with unfamiliar objects: Comparing children with and without cochlear implants. *Journal of Speech, Language, and Hearing Research*, 1–12.

Lund, E., & Douglas, W. M. (2016). Teaching vocabulary to preschool children with hearing loss. *Exceptional Children, 83*(1), 26–41.

Lund, E., Douglas, W. M., & Schuele, C. M. (2015). Semantic richness and word learning in children with hearing loss who are developing spoken language: A single case design study. *Deafness & Education International*, *17*(3), 163–175.

Lund, E., & Schuele, C. M. (2014). Effects of a word-learning training on children with cochlear implants. *The Journal of Deaf Studies and Deaf Education*, *19*(1), 68–84.

Marchman, V. A., & Fernald, A. (2008). Speed of word recognition and vocabulary knowledge in infancy predict cognitive and language outcomes in later childhood. *Developmental Science*, *11*(3), 9–16.

Marschark, M., & Knoors, H. (2019). Sleuthing the 93% solution in deaf education. In *Evidence-based practice in deaf education* (pp. 1–32).

Marschark, M., Shaver, D. M., Nagle, K. M., & Newman, L. A. (2015). Predicting the academic achievement of deaf and hard-of-hearing students from individual, household, communication, and educational factors. *Exceptional Children*, *81*(3), 350–369.

Marsh, E. J., Fazio, L. K., & Goswick, A. E. (2012). Memorial consequences of testing school-aged children. *Memory*, *20*(8), 899–906.

McDaniel, M. A., Agarwal, P. K., Huelser, B. J., McDermott, K. B., & Roediger, H. L. (2011). Test-enhanced learning in a middle school science classroom: The effects of quiz frequency and placement. *Journal of Educational Psychology*.

McDaniel, M. A., Anderson, J. L., Derbish, M. H., & Morrisette, N. (2007). Testing the testing effect in the classroom. *European Journal of Cognitive Psychology*, *19*(4–5), 494–513.

McDaniel, M. A., Friedman, A., & Bourne, L. E. (1978). Remembering the levels of information in words. *Memory & Cognition*, *6*(2), 156–164.

McDaniel, M. A., Hines, R. J., & Guynn, M. J. (2002). When text difficulty benefits less-skilled readers. *Journal of Memory and Language*, *46*(3), 544–561.

McDaniel, M. A., Wildman, K. M., & Anderson, J. L. (2012). Using quizzes to enhance summative-assessment performance in a web-based class: An experimental study. *Journal of Applied Research in Memory and Cognition*, *1*(1), 18–26.

McDaniel, M. A., & Butler, A. C. (2011). A contextual framework for understanding when difficulties are desirable. In *Successful remembering and successful forgetting: A festschrift in honor of Robert A. Bjork* (pp. 175–198). New York, NY, US: Psychology Press.

McDermott, K. B., Agarwal, P. K., D'Antonio, L., Roediger, H. L., & McDaniel, M. A. (2014). Both multiple-choice and short-answer quizzes enhance later exam performance in middle and high school classes. *Journal of Experimental Psychology: Applied*, *20*(1), 3.

Miyamoto, R. T., Colson, B., Henning, S., & Pisoni, D. (2018). Cochlear implantation in infants below 12 months of age. *World Journal of Otorhinolaryngology - Head and Neck Surgery*, *3*(4), 214–218.

Moeller, M. P., Tomblin, J. B., Yoshinaga-Itano, C., Connor, C. M., & Jerger, S. (2007). Current state of knowledge: Language and literacy of children with hearing impairment. *Ear and Hearing*, *28*(6), 740–753.

Moog, J. S., Stein, K. K., Beidenstein, J., & Gustus, C. (2003). *Teaching activities for children who are deaf and hard of hearing. A practical guide for teachers*. St. Louis, MO: Moog Center for Deaf Education.

Moores, M. (2010). The history of language and communication issues in deaf education. *The Oxford Handbook of Deaf Studies, Language, and Education, 2*, 17–30.

National Reading Panel. (2000). *Report of the National Reading Panel: Teaching children to read: An evidence-based assessment of the scientific research literature on reading and its implications for reading instruction: Reports of the subgroups*. US: National Institute of Child Health and Human Development, National Institute of Health.

Nelson, D. G. K., Holt, M. B., & Egan, L. C. (2004). Two- and three-year-olds infer and reason about design intentions in order to categorize broken objects. *Developmental Science*, *7*(5), 543–549.

Nicholas, J. G., & Geers, A. E. (2006). Effects of early auditory experience on the spoken language of deaf children at 3 years of age. *Ear and Hearing*, *27*(3), 286–298.

Nicholas, J. G., & Geers, A. E. (2007). Will they catch up? the role of age at cochlear implantation In the spoken language development of children with severe-profound hearing loss. *Journal of Speech, Language, and Hearing Research*, *50*(4), 1048–1062.

NIDCD. (2015). Hearing Aids. Retrieved February 28, 2019, from https://www.nidcd.nih.gov/health/hearing-aids

NIH. (2018). NIH Fact Sheets - Cochlear Implants. Retrieved February 28, 2019, from https://report.nih.gov/NIHfactsheets/ViewFactSheet.aspx?csid=83

Niparko, J. K., Tobey, E. A., Thal, D. J., Eisenberg, L. S., Wang, N.-Y., Quittner, A. L., … The CDaCI Investigative Team. (2010). Spoken language development in children following cochlear implantation. *Journal of the American Medical Association*, *303*(15), 1498–1506.

Nott, P., Cowan, R., Brown, P. M., & Wigglesworth, G. (2009). Early language development in children with profound hearing loss fitted with a device at a young age: Part I--the time period taken to acquire first words and first word combinations. *Ear and Hearing*, *30*(5), 526–540.

Odom, S. L., Brantlinger, E., Gersten, R., Horner, R. H., Thompson, B., & Harris, K. R. (2005). Research in special education: Scientific methods and evidence-based practices. *Exceptional Children*, *71*(2), 137–148.

Ortmann, A. (2018). *Etiologies of hearing loss*. Washington University in St. Louis.

Pan, S. C., & Rickard, T. C. (2018). Transfer of test-enhanced learning: Meta-analytic review and synthesis. *Psychological Bulletin*, *144*(7), 710–756.

Peterson, N. R., Pisoni, D. B., & Miyamoto, R. T. (2010). Cochlear implants and spoken language processing abilities: Review and assessment of the literature. *Restorative Neurology and Neuroscience*, *28*(2), 237–250.

Pinker, S. (1994). *The language instinct: How the mind creates language*.

Quittner, A. L., Cejas, I., Wang, N.-Y., Niparko, J. K., & Barker, D. H. (2016). Symbolic play and novel noun learning in deaf and hearing children: Longitudinal effects of access to sound on early precursors of language. *PLOS ONE*, *11*(5).

Rawson, K. A., & Dunlosky, J. (2011). Optimizing schedules of retrieval practice for durable and efficient learning: How much is enough? *Journal of Experimental Psychology: General*, *140*(3), 283–302.

Richgels, D. J. (2004). Theory and research into practice: Paying attention to language. *Reading Research Quarterly*, *39*(4), 470–477.

Rickard, T. C., & Pan, S. C. (2018). A dual memory theory of the testing effect. *Psychonomic Bulletin & Review*, *25*(3), 847–869.

Riley-Tillman, T. C., & Burns, M. K. (2011). *Evaluating educational interventions: Single-case design for measuring response to intervention*. Guilford Press.

Roediger, H. L., Agarwal, P. K., McDaniel, M. A., & McDermott, K. B. (2011). Test-enhanced learning in the classroom: Long-term improvements from quizzing. *Journal of Experimental Psychology: Applied*, *17*(4), 382.

Roediger, H. L., & Butler, A. C. (2011). The critical role of retrieval practice in long-term retention. *Trends in Cognitive Sciences*, *15*(1), 20–27.

Roediger, H. L., & Karpicke, J. D. (2006). The power of testing memory: Basic research and implications for educational practice. *Perspectives on Psychological Science*, *1*(3), 181–210.

Roediger, H. L., & Pyc, M. A. (2012). Inexpensive techniques to improve education: Applying cognitive psychology to enhance educational practice. *Journal of Applied Research in Memory and Cognition*, *1*(4), 242–248.

Roizen, N. J. (1999). Etiology of hearing loss in children: Nongenetic causes. *Pediatric Clinics of North America*, *46*(1), 49–64.

Roland, J. T., Coelho, D. H., Pantelides, H., & Waltzman, S. B. (2008). Partial and double-array implantation of the ossified cochlea. *Otology & Neurotology: Official Publication of the American Otological Society, American Neurotology Society [and] European Academy of Otology and Neurotology*, *29*(8), 1068–1075.

Ross, M., & Lerman, J. (1970). A picture identification test for hearing-impaired children. *Journal of Speech and Hearing Research*, *13*, 44–53.

Saffran, J. R., Aslin, R. N., & Newport, E. L. (1996). Statistical learning by 8-month-old infants. *Science*, *274*(5294), 1926–1928.

Sarchet, T., Marschark, M., Borgna, G., Convertino, C., Sapere, P., & Dirmyer, R. (2014). Vocabulary knowledge of deaf and hearing postsecondary students. *Journal of Postsecondary Education and Disability*, *27*(2), 161–178.

Schorr, E., Roth, F., & A. Fox, N. (2008). A comparison of the speech and language skills of children with cochlear implants and children with normal hearing. *Communication Disorders Quarterly*, *29*, 195–210.

Senechal, D. K., & Neuman, S. B. (2007). *Handbook of early literacy research*. Guilford Press.

Sharma, A., Campbell, J., & Cardon, G. (2015). Developmental and cross-modal plasticity in deafness: Evidence from the P1 and N1 event related potentials in cochlear implanted children. *International Journal of Psychophysiology*, *95*(2), 135–144.

Sharma, A., Dorman, M. F., & Spahr, A. J. (2002). Rapid development of cortical auditory evoked potentials after early cochlear implantation. *Neuroreport*, *13*(10), 1365–1368.

Sharma, A., Gilley, P. M., Dorman, M. F., & Baldwin, R. (2007). Deprivation-induced cortical reorganization in children with cochlear implants. *International Journal of Audiology*, *46*(9), 494–499.

Smith, A. M., Floerke, V. A., & Thomas, A. K. (2016). Retrieval practice protects memory against acute stress. *Science*, *354*(6315), 1046–1048.

Spahr, A. J., & Dorman, M. F. (2004). Performance of subjects fit with the Advanced Bionics CII and Nucleus 3G cochlear implant devices. *Archives of Otolaryngology--Head & Neck Surgery*, *130*(5), 624–628.

Spencer, P. E., & Meadow-Orlans, K. P. (1996). Play, language, and maternal responsiveness: A longitudinal study of deaf and hearing infants. *Child Development*, *67*(6), 3176–3191.

Spitzer, H. F. (1939). Studies in retention. *Journal of Educational Psychology*, *30*(9), 641–656.

Stanovich, K. E. (2009). Matthew effects in reading: Some consequences of individual differences in the acquisition of literacy. *Journal of Education*, *189*(1–2), 23–55.

Sumowski, J. F., Wood, H. G., Chiaravalloti, N., Wylie, G. R., Lengenfelder, J., & Deluca, J. (2010). Retrieval practice: A simple strategy for improving memory after traumatic brain injury. *Journal of the International Neuropsychological Society*, *16*(6), 1147–1150.

Suskind, D., Suskind, B., & Lewinter-Suskind, L. (2015). *Thirty million words: Building a child's brain: Tune in, talk more, take turns*. Dutton.

Tabors, P. O., Snow, C. E., & Dickinson, D. K. (2001). Homes and schools together: Supporting language and literacy development. In *Beginning literacy with language: Young children learning at home and school* (pp. 313–334). Baltimore, MD, US: Paul H Brookes Publishing.

Thompson, C. P., Wenger, S. K., & Bartling, C. A. (1978). How recall facilitates subsequent recall: A reappraisal. *Journal of Experimental Psychology: Human Learning and Memory*, *4*(3), 210–221.

Thompson, Diamond, K. E., McWilliam, R., Snyder, P., & Snyder, S. W. (2005). Evaluating the quality of evidence from correlational research for evidence-based practice. *Exceptional Children*, *71*(2), 181–194.

Tomblin, J. B., Barker, B. A., Spencer, L. J., Zhang, X., & Gantz, B. J. (2005). The effect of age at cochlear implant initial stimulation on expressive language growth in infants and toddlers. *Journal of Speech, Language, and Hearing Research*, *48*(4), 853–867.

Tsao, F.-M., Liu, H.-M., & Kuhl, P. K. (2004). Speech perception in infancy predicts language development in the second year of life: A longitudinal study. *Child Development*, *75*(4), 1067–1084.

Turnbull, K. L. P., & Justice, L. M. (2016). *Language development from theory to practice* (3 edition). Upper Saddle River, New Jersey: Pearson.

van Hulle, C. A., Goldsmith, H. H., & Lemery, K. S. (2004). Genetic, environmental, and gender effects on individual differences in toddler expressive language. *Journal of Speech, Language, and Hearing Research*, *47*(4), 904–912.

Vohr, B., Jodoin-Krauzyk, J., Tucker, R., Johnson, M. J., Topol, D., & Ahlgren, M. (2008). Early language outcomes of early-identified infants with permanent hearing loss at 12 to 16 months of age. *Pediatrics*, *122*(3), 535–544.

Walker, D., Greenwood, C., Hart, B., & Carta, J. (1994). Prediction of school outcomes based on early language production and socioeconomic factors. *Child Development*, *65*(2), 606–621.

Wang, N.-Y., Eisenberg, L. S., Johnson, K. C., Fink, N. E., Tobey, E. A., Quittner, A. L., & Niparko, J. K. (2008). Tracking development of speech recognition: Longitudinal data from hierarchical assessments in the childhood development after cochlear implantation study. *Otology & Neurotology : Official Publication of the American Otological Society, American Neurotology Society [and] European Academy of Otology and Neurotology*, *29*(2), 240–245.

Weinstein, Y., Sumeracki, M., & Caviglioli, O. (2018). *Understanding how we learn: A visual guide* (1st edition). Routledge.

Weizman, Z. O., & Snow, C. E. (2001). Lexical input as related to children's vocabulary acquisition: Effects of sophisticated exposure and support for meaning. *Developmental Psychology*, *37*(2), 265–279.

Williams, C. (2012). Promoting vocabulary learning in young children who are d/Deaf and hard of hearing: Translating research into practice. *American Annals of the Deaf*, *156*(5), 501–508.

Williams, K. T. (2007). *EVT-2: Expressive vocabulary test, second edition.* United States: Pearson.

Yoshinaga-Itano, C. (2003). From screening to early identification and intervention: Discovering predictors to successful outcomes for children with significant hearing loss. *Journal of Deaf Studies and Deaf Education*, *8*(1), 11–30.

Yoshinaga-Itano, C., Sedey, A. L., Coulter, D. K., & Mehl, A. L. (1998). Language of early- and later-identified children with hearing loss. *Pediatrics*, *102*(5), 1161–1171.

Yoshinaga-Itano, C., Sedey, A. L., Wiggin, M., & Chung, W. (2017). Early hearing detection and vocabulary of children with hearing loss. *Pediatrics*, *140*(2).

Zerr, C. L., Berg, J. J., Nelson, S. M., Fishell, A. K., Savalia, N. K., & McDermott, K. B. (2018). Learning efficiency: Identifying individual differences in learning rate and retention in healthy adults. *Psychological Science*, *29*(9), 1436–1450.

Appendix A

Demographic Questionnaire

PLEASE COMPLETE AS FULLY AS POSSIBLE ABOUT EACH STUDENT:

NAME:___________________________

BIRTHDATE:_______________________

GENDER:_________

MOST RECENT AUDIOLOGICAL INFORMATION:

AIDED SPEECH PERCEPTION SCORES %:

R: ________

L: ________

BINAURAL: ________

DEGREE OF HEARING LOSS:

R: ________

L: ________

TYPE OF HEARING LOSS:

R: ________

L: ________

TYPE OF DEVICES:

R: ________

L: ________

AGE AT FIRST AIDED:

R: ________

L: ________

IF AVAILABLE:

ADDITIONAL DIAGNOSIS: YES / NO

IF YES, PLEASE SPECIFY: ____________________

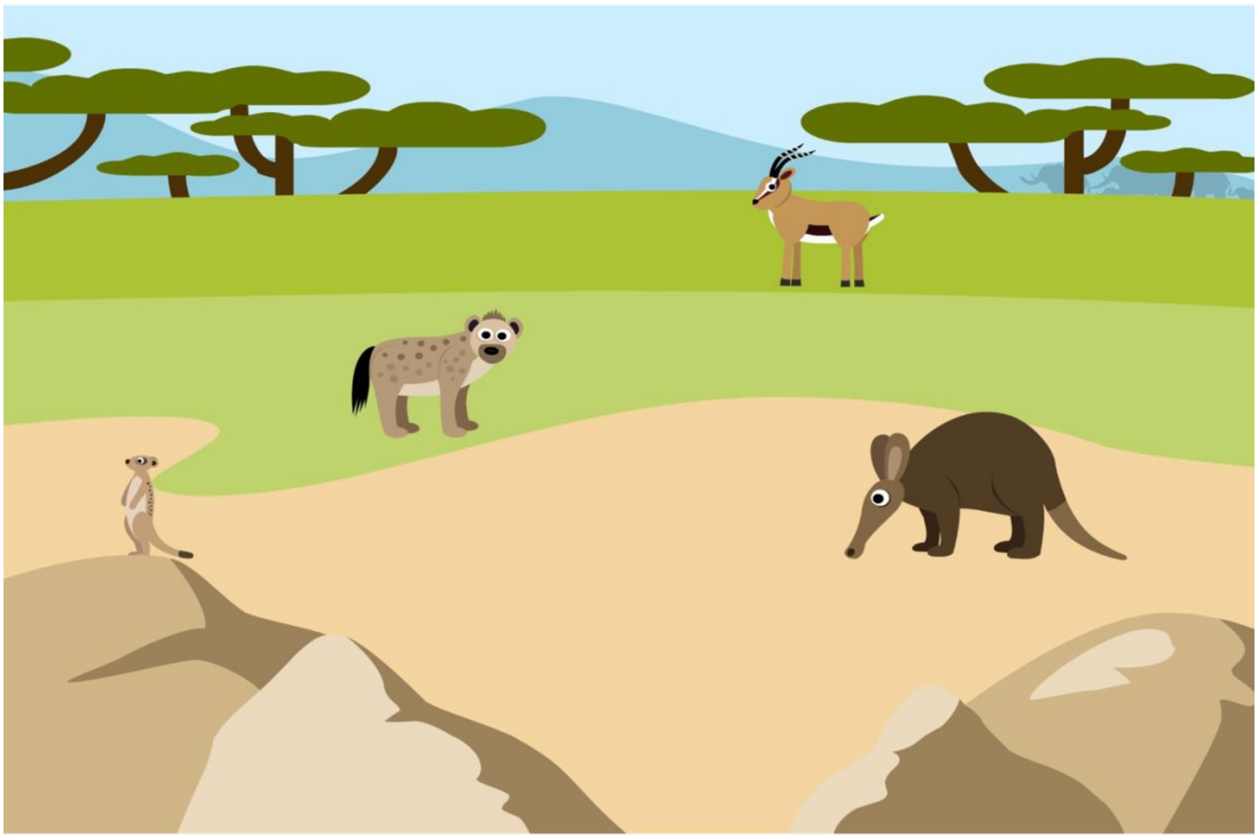
HIGHEST COMPLETED PARENT EDUCATION LEVEL (CIRCLE ONE):

HIGH SCHOOL   ASSOCIATE'S (2 YEAR)   BACHELOR'S (4 YEAR)

GRADUATE DEGREE   OTHER______________

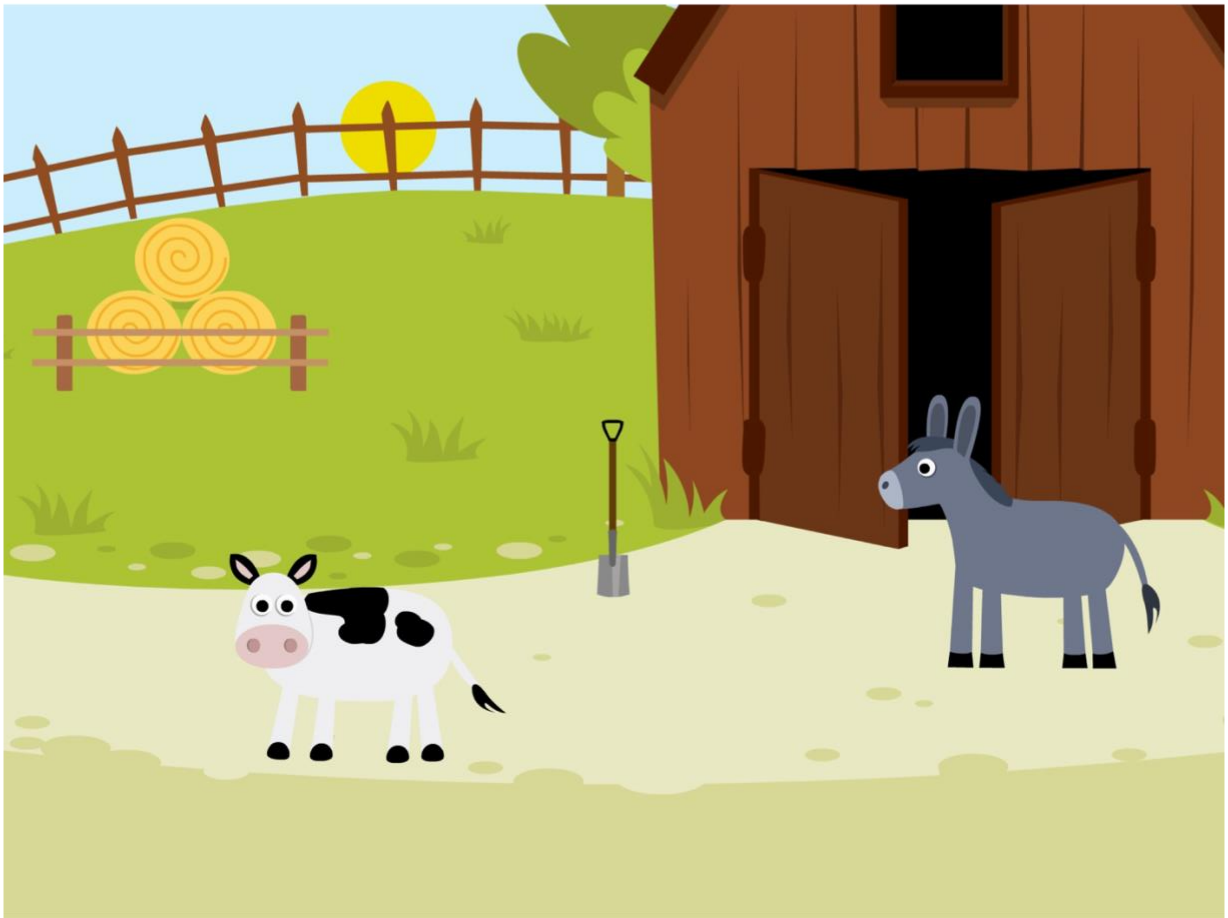
Appendix B

iPad thematic scenes with stimuli from *Make a Scene* application

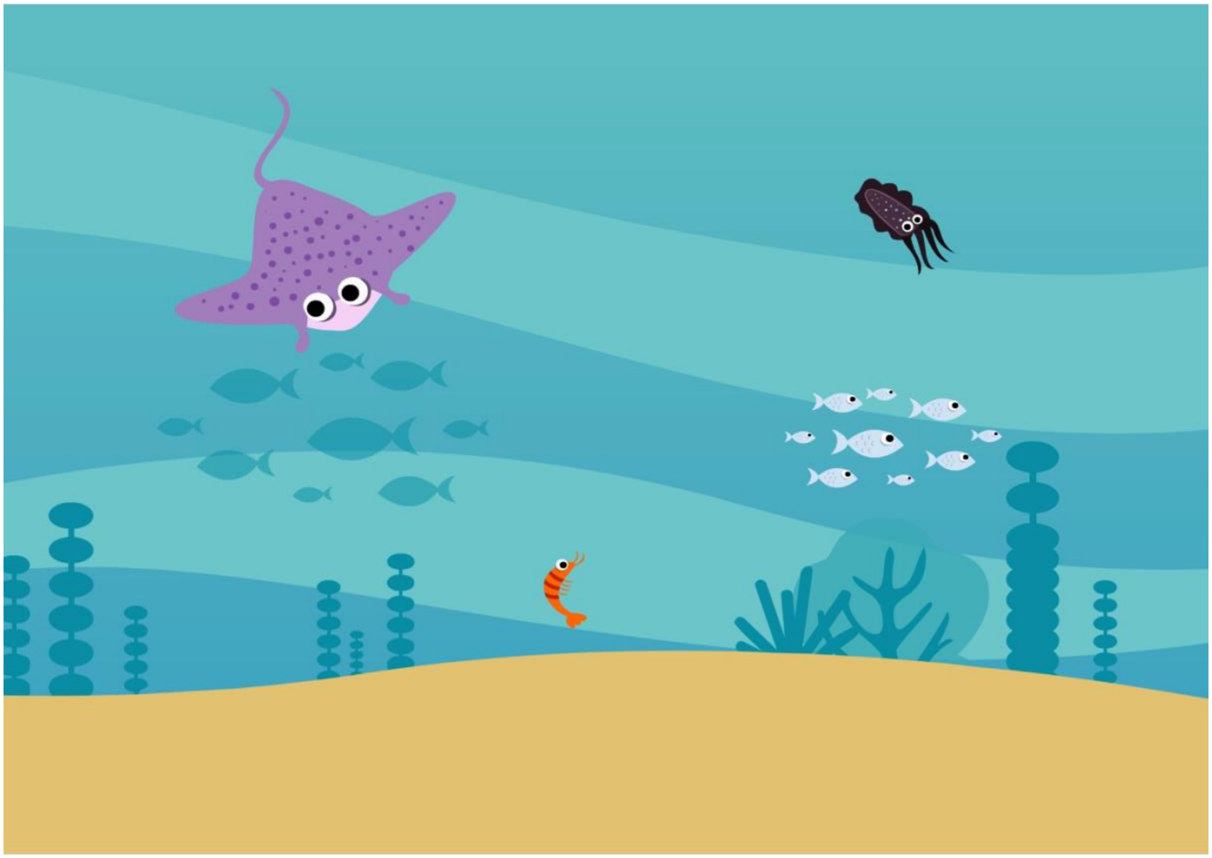


Safari: meerkat, hyena, gazelle, aardvark

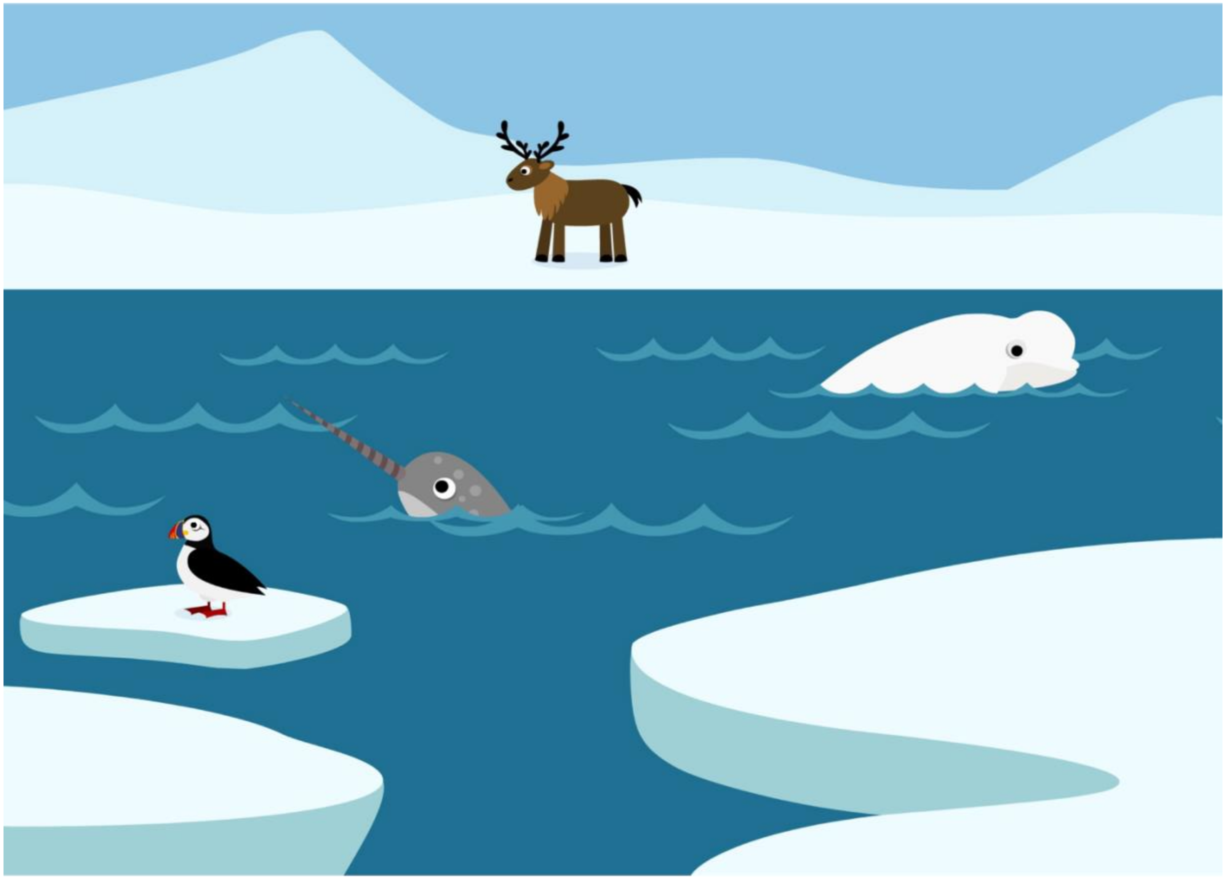
Jungle: lemur, platypus, anteater, sloth



Farm: calf, spade, hay bale, kid



Ocean: prawn, sardine, cuttlefish, mata ray



Arctic: puffin, narwhal, caribou, beluga

Appendix C

Vocabulary flashcards

Desert: aardvark, hyena, meerkat, gazelle

Jungle: lemur, anteater, sloth, platypus

Farm: hay bale, calf, spade, kid

Ocean: manta ray, cuttlefish, sardine, prawn

Arctic: caribou, beluga, narwhal, puffin

Appendix D

Example of learning session script

Practice Session Script #1: 4 exposures + 1 child imitation

PI: My name is Casey. Thank you for coming to play with me for a short time today. Today we are going to talk about different animals that live in the ocean. We are also going to play some games, but first we are going to start with using the iPad to look at the different animals in the ocean. You are going to learn the names for 4 new animals.

PI: Look at the purple **manta ray**. It looks like a star with a long tail. Do you want to touch the **manta ray**?

S: Yes/No

PI: Tell me, **manta ray**.

S: Mantaray.

PI: Bye **manta ray**.

PI: Next is the **cuttlefish**. The **cuttlefish** is dark purple and has four tentacles or arms. Do you want to touch it?

S: Yes/No

PI: Tell me, **cuttlefish**.

S: *Cuttlefish.*

PI: See ya later **cuttlefish**.

PI: This is a **prawn**. The **prawn** is very small and orange. Do you want to touch it?

S: Yes/No

PI: Tell me, **prawn**.

S*: Prawn.*

PI: Bye **prawn**.

PI: Lastly, I see a **sardine**. The light blue **sardine** is swimming with its friends. Do you want to touch it?

S: Yes/No

PI: Tell me, **sardine**.

S*: Sardine.*

PI: Bye **sardine**.

PI: Good job learning all about the four new ocean animals. Now, we are going to draw a picture/color/do a puzzle. *(2-minute break).*

Practice Session Script #1 Cont.

-Give label for animal after every child attempt-if child says correct label repeat it, but if doesn't know it give feedback right away (through labeling).

PI: Now we are going to look at the ocean animals again. When I point to an animal, I want you to tell me its name. If you don't remember, I want you to guess. Ready?

(PI circle if student correctly labels/identifies animal)

PI: (points to **manta ray**). What is that?

S: *Manta ray/Guess/I don't know.*

PI: That's right, **manta ray.**/That is a **manta ray**.

PI: (points to **cuttlefish**). What is that?

S: *Cuttlefish/Guess/I don't know.*

PI: That is a **cuttlefish**!/That's okay, that is a **cuttlefish.**

PI: (points to **prawn**). What is that?

S: *Prawn/Guess/I don't know.*

PI: Good job, that is a **prawn.**/That is a **prawn.**

PI: (points to **sardine**). What is that?

S: *Sardine/Guess/I don't know.*

PI: Yes, that is a **sardine.**/Good try, that is a **sardine.**

Correct:	**manta ray**	**cuttlefish**	**prawn**	**sardine**

-Note which animals the child labeled correctly and incorrectly. For next round, drop off every word the child labeled correctly.

<u>Practice Session Script #2: 4 exposures + 1 child imitation</u>

PI: We are going to look at our new ocean animals again. We may not talk about all of them this time.

PI: I see the **manta ray**. The big purple **manta ray** is flat with a long tail. Do you want to touch the it?

S: Yes/No

PI: Tell me, **manta ray**.

S: Manta ray.

PI: Bye **manta ray**.

PI: That is the **cuttlefish**. The **cuttlefish** has white spots and four tentacles or arms. Do you want to touch it?

S: Yes/No

PI: Tell me, **cuttlefish**.

S: *Cuttlefish.*

PI: See ya later **cuttlefish**.

PI: I see a **prawn**. The tiny **prawn** has red stripes and a big tail. Do you want to touch it?

S: Yes/No

PI: Tell me, **prawn**.

S*: Prawn.*

PI: Bye **prawn**.

PI: I see a **sardine** swimming with its friends. It is small and likes to stay in a group. Do you want to touch the **sardine**?

S: Yes/No

PI: Tell me, **sardine**.

S*: Sardine.*

PI: Bye **sardine**.

PI: Good job learning all about the four ocean animals. Now, we are going to draw a picture/color/do a puzzle. *(2-minute break).*

<u>Practice Session Script #2 Cont.</u>

-Give label for animal after every child attempt-if child says correct label repeat it, but if doesn't know it give feedback right away (through labeling).

PI: Now we are going to look at the ocean animals again. When I point to an animal, I want you to tell me its name. If you don't remember, I want you to guess. Ready?

(PI circle if student correctly labels/identifies animal)

PI: (points to **manta ray**). What is that?

S: *Manta ray/Guess/I don't know.*

PI: That's right, **manta ray.**/That is a **manta ray**.

PI: (points to **cuttlefish**). What is that?

S: *Cuttlefish/Guess/I don't know.*

PI: That is a **cuttlefish**!/That's okay, that is a **cuttlefish.**

PI: (points to **prawn**). What is that?

S: *Prawn/Guess/I don't know.*

PI: Good job, that is a **prawn.**/That is a **prawn.**

PI: (points to **sardine**). What is that?

S: *Sardine/Guess/I don't know.*

PI: Yes, that is a **sardine.**/Good try, that is a **sardine.**

Correct: manta ray cuttlefish prawn sardine

-Note which animals the child labeled correctly and incorrectly. For next round, drop off every word the child labeled correctly.

-Repeat until student correctly labels all 4 words using Script 1 then Script 2.

Repeat: <u>Practice Session Script #1: 4 exposures + 1 child imitation</u>

PI: Let's look at the jungle animals again. We are going to talk about the ones you haven't learned their name.

PI: Look at the purple **manta ray**. It looks like a star with a long tail. Do you want to touch the **manta ray**?

S: Yes/No

PI: Tell me, **manta ray**.

S: Manta ray.

PI: Bye **manta ray**.

PI: Next is the **cuttlefish**. The **cuttlefish** is dark purple and has four tentacles or arms. Do you want to touch it?

S: Yes/No

PI: Tell me, **cuttlefish**.

S: *Cuttlefish.*

PI: See ya later **cuttlefish**.

PI: This is a **prawn**. The **prawn** is very small and orange. Do you want to touch it?

S: Yes/No

PI: Tell me, **prawn**.

S*: Prawn.*

PI: Bye **prawn**.

PI: Lastly, I see a **sardine**. The light blue **sardine** is swimming with its friends. Do you want to touch it?

S: Yes/No

PI: Tell me, **sardine**.

S*: Sardine.*

PI: Bye **sardine**.

PI: Good job learning all about the four ocean animals. Now, we are going to draw a picture/color/do a puzzle. *(2-minute break).*

Repeat: Practice Session Script #1 Cont.

-Give label for animal after every child attempt-if child says correct label repeat it, but if doesn't know it give feedback right away (through labeling).

PI: Now we are going to look at the ocean animals again. When I point to an animal, I want you to tell me its name. If you don't remember, I want you to guess. Ready?

(PI circle if student correctly labels/identifies animal)

PI: (points to **manta ray**). What is that?

S: *Manta ray/Guess/I don't know.*

PI: That's right, **manta ray./**That is a **manta ray**.

PI: (points to **cuttlefish**). What is that?

S: *Cuttlefish/Guess/I don't know.*

PI: That is a **cuttlefish**!/That's okay, that is a **cuttlefish.**

PI: (points to **prawn**). What is that?

S: *Prawn/Guess/I don't know.*

PI: Good job, that is a **prawn.**/That is a **prawn.**

PI: (points to **sardine**). What is that?

S: *Sardine/Guess/I don't know.*

PI: Yes, that is a **sardine.**/Good try, that is a **sardine.**

Correct: mantaray cuttlefish prawn sardine

-Note which animals the child labeled correctly and incorrectly. For next round, drop off every word the child labeled correctly.

Repeat: **<u>Practice Session Script #2: 4 exposures + 1 child imitation</u>**

PI: We are going to look at our new ocean animals again. We may not talk about all of them this time.

PI: I see the **manta ray**. The big purple **manta ray** is flat with a long tail. Do you want to touch the it?

S: Yes/No

PI: Tell me, **manta ray**.

S: Manta ray.

PI: Bye **manta ray**.

PI: That is the **cuttlefish**. The **cuttlefish** has white spots and four tentacles or arms. Do you want to touch it?

S: Yes/No

PI: Tell me, **cuttlefish**.

S: *Cuttlefish.*

PI: See ya later **cuttlefish**.

PI: I see a **prawn**. The tiny **prawn** has red stripes and a big tail. Do you want to touch it?

S: Yes/No

PI: Tell me, **prawn**.

S*: Prawn.*

PI: Bye **prawn**.

PI: I see a **sardine** swimming with its friends. It is small and likes to stay in a group. Do you want to touch the **sardine**?

S: Yes/No

PI: Tell me, **sardine**.

S*: Sardine.*

PI: Bye **sardine**.

PI: Good job learning all about the four ocean animals. Now, we are going to draw a picture/color/do a puzzle. *(2-minute break).*

Repeat: <u>Practice Session Script #2 Cont.</u>

-Give label for animal after every child attempt-if child says correct label repeat it, but if doesn't know it give feedback right away (through labeling).

PI: Now we are going to look at the ocean animals again. When I point to an animal, I want you to tell me its name. If you don't remember, I want you to guess. Ready?

(PI circle if student correctly labels/identifies animal)

PI: (points to **manta ray**). What is that?

S: *Manta ray/Guess/I don't know.*

PI: That's right, **manta ray.**/That is a **manta ray**.

PI: (points to **cuttlefish**). What is that?

S: *Cuttlefish/Guess/I don't know.*

PI: That is a **cuttlefish**!/That's okay, that is a **cuttlefish.**

PI: (points to **prawn**). What is that?

S: *Prawn/Guess/I don't know.*

PI: Good job, that is a **prawn.**/That is a **prawn.**

PI: (points to **sardine**). What is that?

S: *Sardine/Guess/I don't know.*

PI: Yes, that is a **sardine.**/Good try, that is a **sardine.**

Correct: manta ray cuttlefish prawn sardine

-Note which animals the child labeled correctly and incorrectly. For next round, drop off every word the child labeled correctly.

-Repeat until student correctly labels all 4 words using Script 1 then Script 2.

If child needs more exposures (did not label all four words), go back to script #1. Keep track of number of rounds required for child to label each animal. Make Notes Here:

PI: You are doing such a great job, so we are going to take a little break to go get a drink of water from down the hall (*2-minute break).*

<u>Testing Session:</u>

Repeated Exposure Condition: 1 exposure + 1 child imitation (SSSSSS)

PI: We are going to look at the ocean animals again. This time we aren't going to use the iPad though, we are going to be using flashcards. The same animals are on the flashcards. I will show you two of the animals first and then we will work with the other two. We are going to look at them 6 different times so you can learn all their names. Are you ready?

S: Yes/No

S1

PI: (shows first card). This is a **manta ray.** Can you tell me?

S: *Manta ray.*

PI: Good job. (shows second card). This is a **cuttlefish**. What is that?

S: *Cuttlefish.*

PI: That's right!

S2

PI: (shows first card). This is a **manta ray.** Can you tell me?

S: *Manta ray.*

PI: Good job. (shows second card). This is a **cuttlefish**. What is that?

S: *Cuttlefish.*

PI: That's right!

S3

PI: (shows first card). This is a **manta ray.** Can you tell me?

S: *Manta ray.*

PI: Good job. (shows second card). This is a **cuttlefish**. What is that?

S: *Cuttlefish.*

PI: That's right!

S4

PI: (shows first card). This is a **manta ray.** Can you tell me?

S: *Manta ray.*

PI: Good job. (shows second card). This is a **cuttlefish**. What is that?

S: *Cuttlefish.*

PI: That's right!

S5

PI: (shows first card). This is a **manta ray.** Can you tell me?

S: *Manta ray.*

PI: Good job. (shows second card). This is a **cuttlefish**. What is that?

S: *Cuttlefish.*

PI: That's right!

S6

PI: (shows first card). This is a **manta ray.** Can you tell me?

S: *Manta ray.*

PI: Good job. (shows second card). This is a **cuttlefish**. What is that?

S: *Cuttlefish.*

PI: That's right!

PI: You are working so hard and doing such a great job.

<u>Testing Session Cont.:</u>

Retrieval Practice Condition: 1 exposure + 1 child imitation (TSTSTS)

PI: We are going to look at the last two ocean animals now using the flashcards. I am going to show you an animal and I want you to try to tell me its name. If you don't remember that's okay, but I want you to guess. Are you ready?

S: Yes/No

Circle if correct & note child's response

T1

PI: (shows first flash card). What is that?

S: *Prawn/Guess/I don't know.*

PI: That's right, **prawn.**/That is a **prawn.**

PI: (shows next card). What is that?

S: *Sardine/Guess/I don't know.*

PI: That is a **sardine**!/That's okay, that is a **sardine.**

PI: You are doing such a great job. We are going to look at the same two again to try and really learn their names. Are you ready?

S: Yes/No

S1

PI: (shows first flash card). This is a **prawn.** Can you tell me?

S: *Prawn.*

PI: Yes. (shows next card). This is a **sardine.** What is that?

S: *Sardine.*

PI: Way to go. Now I want you to tell me what they are again. Remember, I will show you one animal at a time and I want you to try your best in remembering what it is. If you know what it is I want you to tell me, but if you don't that's okay- I want you to guess. Are you ready?

S: Yes/No

Circle if correct & note child's response

T2

PI: (shows first flash card). What is that?

S: *Prawn/Guess/I don't know.*

PI: That's right, **prawn.**/That is a **prawn.**

PI: (shows next card). What is that?

S: *Sardine/Guess/I don't know.*

PI: That is a **sardine**!/That's okay, that is a **sardine.**

PI: You are doing such a great job. We are going to look at the same two again to try and really learn their names. Are you ready?

S: Yes/No

S2

PI: (shows first flash card). This is a **prawn.** Can you tell me?

S: *Prawn.*

PI: Yes. (shows next card). This is a **sardine.** What is that?

S: *Sardine.*

PI: Way to go. Now I want you to tell me what they are again. Remember, I will show you one animal at a time and I want you to try your best in remembering what it is. If you know what it is, I want you to tell me but if you don't that's okay- I want you to guess. Are you ready?

S: Yes/No

Circle if correct & note child's response

T3

PI: (shows first flash card). What is that?

S: *Prawn/Guess/I don't know.*

PI: That's right, **prawn.**/That is a **prawn.**

PI: (shows next card). What is that?

S: *Sardine/Guess/I don't know.*

PI: That is a **sardine**!/That's okay, that is a **sardine.**

PI: You are doing such a great job. We are going to look at the same two again to try and really learn their names. Are you ready?

S: Yes/No

S3

PI: (shows first flash card). This is a **prawn.** Can you tell me?

S: *Prawn.*

PI: Yes. (shows next card). This is a **sardine.** What is that?

S: *Sardine.*

PI: We are all finished learning about ocean animals. Thank you for working so hard for me today. You did a great job. I hope you had fun. You get to pick a prize for being such a good student.

<u>Appendix E</u>

Example of assessment session script

<u>Ocean: Assessment Session</u>

PI: Thanks for seeing me again. Today is going to be really quick. Do you remember the other day how we learned the names of four ocean animals? We used the iPad and flashcards. Today we are going to use the same flashcards and I am going to ask you what the names of the animals are. I want you to try your best to remember, but if you don't remember you can just take a guess. Are you ready?

S: Yes

PI: (shows **manta ray).** What is that?

S: *Manta ray/Guess/I don't know.*

PI: Good job, that is a **manta ray.**/That is a **manta ray.**

PI: (shows **cuttlefish**). What is that?

S: *Cuttlefish/Guess/I don't know.*

PI: That's right, **cuttlefish.**/That is a **cuttlefish.**

PI: (shows **prawn**). What is that?

S: *Prawn/Guess/I don't know.*

PI: Yes, that is a **prawn.**/Good try, that is a **prawn.**

PI: (shows **sardine**). What is that?

S: *Sardine/Guess/I don't know.*

PI: That is a **sardine**!/That's okay, that is a **sardine.**

Correct: manta ray cuttlefish prawn sardine

PI: You did such a fantastic job! Thank you for working so hard learning the ocean animals.