12-2014

The Effect of Hearing Impairment on Word Processing of Infant- and Adult-Directed Speech

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Document Type
Dissertation

Degree Name
Doctor of Philosophy (PhD)

Program
Speech and Hearing Science

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DOI
10.21007/etd.cghs.2014.0262

The Effect of Hearing Impairment on Word Processing of Infant- and Adult-Directed Speech

A Dissertation
Presented for
The Graduate Studies Council
The University of Tennessee
Health Science Center

In Partial Fulfillment
Of the Requirements for the Degree
Doctor of Philosophy
From The University of Tennessee

By
Velma Sue Robertson
December 2014

ACKNOWLEDGEMENTS

The writing of this dissertation has been one of the most significant challenges I have ever had to face. It would not have been possible to complete the dissertation without the help, guidance, and support from the kind professors, colleagues, family and friends around me.

Above all, I would like to express my sincere gratitude to my advisor, Dr. Deborah von Hapsburg. Not only did she guide me through the whole process of dissertation writing, but also instilled in me, by example, the confidence and courage to overcome obstacles and persist in the face of challenges.

I would also like to show my gratitude to the other members on my committee, Dr. Patti Johnstone, Dr. Jessica Hay, Dr. Ilsa Schwarz, and Dr. Mark Hedrick, for their excellent guidance, advice and patience through numerous meetings and personal communication during the completion of my dissertation study.

In addition, I want to thank Dr. Megan Cuellar, who provided the voice for the stimuli, Drs. Anne Fernald and Virginia Marchman for their willingness to share their expertise and software. I want to thank John Berry for his encouragement and support, and the Hearing and Speech Foundation for providing funding for subject recruitment and equipment needs.

Finally, I want to express my special thanks to my husband, Michael Ginsburg, who offered his love and support throughout my graduate studies.

ABSTRACT

Objective. Little is known about how children with hearing loss (CHL) process words. The Emergent Coalition Model (ECM) of early word learning proposes that multiple cues (e.g., perceptual, social, linguistic) are used to facilitate word learning. Because hearing loss influences speech perception, different word learning patterns may emerge in CHL relative to children with normal hearing (CNH). One perceptual cue used by young children to access word learning is infant-directed-speech (IDS). Specifically, twenty-one month-olds can learn words in IDS but not in adult directed speech (ADS); however, by 27 months children can learn words in ADS. Currently, it is unknown how CHL process words in IDS and ADS. This study examined how CHL and CNH process familiar and novel words in IDS and ADS. A Looking-While-Listening paradigm was used. We predicted that: 1) CNH would show faster reaction time (RT) and higher accuracy than CHL, 2) word processing may show different patterns for familiar versus novel words, and 3) vocabulary size would be correlated with word processing skills.

Methods. Eleven children with bilateral, sensorineural hearing loss (M=32.48 months) using hearing aids or cochlear implants, and 11 CNH, matched for age, gender, and SES participated. Each child was tested in IDS and ADS on different days. At each visit, children were trained to map two novel labels to objects, counterbalanced across visits. Following training, accuracy and RT were assessed for both novel and familiar words. Vocabulary size was assessed using the McArthur-Bates Communicative Development Inventory.

Results. In the familiar word condition, for the CHL accuracy was significantly better in IDS than ADS, and RT was faster in IDS than ADS (but not significant). For CNH, accuracy was not different in IDS than in ADS, but RT was significantly faster in ADS than IDS. A significant speech type by group interaction was found (p <.05), for both accuracy and RT. Follow-up tests showed that CNH have higher accuracy and faster RTs than CHL. Results for familiar words suggest that while IDS may lead to more efficient speech processing for CHL, CNH are more efficient at processing ADS. In the novel word condition, only 10 CHL completed the task. For CHL, accuracy was marginally better in IDS than ADS, but no significant difference was observed in RT. For CNH no differences were seen in accuracy or RT between IDS and ADS. Analysis of Variance for RT showed that CNH have significantly faster RTs than CHL for novel word processing. For CHL, vocabulary size was negatively correlated with RT to familiar words in IDS and ADS, suggesting that children with larger vocabularies processed familiar words faster than children with smaller vocabularies. For the CHN, vocabulary size was marginally correlated with accuracy and RT to novel words in ADS.

Conclusions. This study demonstrates 1) the facilitative effects of IDS on word processing for young CHL, and 2) the relationship between word processing and expressive vocabulary in young children, suggesting that children with larger vocabularies are faster and more efficient at word processing tasks. The present findings suggest that CHL do not perform as well as their normal hearing peers on word

processing tasks in ADS. These findings provide empirical evidence that childhood hearing loss affects processing of IDS and ADS differently than for CNH.

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LIST OF ABBREVIATIONS

ADS   Adult directed speech

CHL   Children with hearing loss

CI   Cochlear implant

CNH   Children with normal hearing

dB   decibel

ECM   Emergentist Coalition Model

F0   Fundamental frequency

HI   Hearing impairment

IDS   Infant directed speech

IPLP   Intermodal preferential looking paradigm

LWL   Looking while listening paradigm

MCDI   McArthur-Bates Communicative Developmental Index

NH   Normal hearing

RT   Reaction time

SII   Speech intelligibility index

CHAPTER 1.   INTRODUCTION

Within a relatively short period of time infants go from producing one or two words a week at 12 months of age (Carey, 1978), to acquiring 10 to 20 new words a week by the end of the their second year (Bloom & Tinker, 2001; Clark, 1973; Ganger & Brent; 2004). What happens between the slow initial start to word learning and the accelerated rate within a 10 to 12 month span?   Before children learn to produce very many words they typically have a fairly large receptive vocabulary (Bates, Bretherton, Beeghly-Smith, & McNew, 1982; Benedict, 1979; Fenson, Dale, Reznick, Bates, Thal, & Pethick, 1994). By 12 months infants can segregate, individuate, and represent objects (Cohen & Oakes, 1993; Johnson, 2004; Wilcox, Schweinle, & Chapa, 2003) and by 14 months of age infants can learn word –object associations, one of the first steps in word learning (e.g., Fennell & Waxman, 2010; Pater, Stager, & Werker, 2004; Stager & Werker, 1997; Werker, Cohen, Lloyd, Casasola, & Stager, 1998; Werker, Fennell, Corcoran, & Stager, 2002; Yoshida, Fennell, Swingley, & Werker, 2009). A typical 14 month old has an expressive vocabulary of about 10 words but a receptive vocabulary of about 50 words and by 20 months they understand up to 300 words (Benedict, 1979; Nazzi & Bertonici, 2003).

Researchers have suggested a gradual lexical and syntactical organization occurs over the second year of life, leading to what has been referred to as a vocabulary spurt (Bloom & Tinker, 2001; Dapretto & Bjork, 2000; Walley, 1993). When the vocabulary spurt occurs, word learning becomes less laborious and infants demonstrate the ability to learn words following a single labeling event, known as fast mapping (Mayor & Plunkett, 2010).   What mechanisms do infants use to break the language barrier and begin learning words? Do they use the same mechanisms when they become proficient word learners? Over the last two decades researchers have been busy searching for answers to these questions in order to determine how infants become master word learners in such a short period of time.

Three theories on early word learning dominated the debate during the 1980's and 90's. Researchers focused on 1) a constraints/principles theory for early word learning (Markman, 1990; Merriman, Bowman, & MacWhinney, 1989; Waxman & Kosowski, 1990), 2) a social and pragmatic learning theory (Baldwin & Tomasello, 1998; Carpenter, Nagell, & Tomasello, 1998; Nelson, 1988), and 3) an associational mechanism theory to explain initial word learning (Plunkett, 1997; Samuelson & Smith, 1998; Smith, 1999). With each of these early theories a different single mechanism was proposed as responsible for the development of early word learning. The constraints theory focused on innate constraints to facilitate word learning, the social pragmatic theory focused on adult social cues for communication, and the associational mechanism theorists suggested associations made between spoken words and objects or actions facilitated initial word learning. None of these theories actually provided a comprehensive model for word learning that synthesized the various factors influencing word learning. From these initial research efforts, new theories have emerged that suggest a developmental sequence in which infants depend on different mechanisms at different time periods in the course

of early language acquisition (Golinkoff & Hirsh-Pasek, 2006; Hollich, Hirsh-Pasek, & Golinkoff, 2000; Namy, 2012). The three main classes of word learning theories proposed in the early research are reviewed and an integrative developmental model, the emergentist coalition model which has evolved from these previous models, is presented.

Based upon several studies by Markman and colleagues, the constraints/principles theory suggests that children are predisposed to have cognitive constraints or biases to help narrow the options for word learning (Markman, 1990). Markman and colleagues proposed a set of three constraints that include: a "whole object" constraint which reduces the ambiguity of label reference and assists the rapid vocabulary growth spurt observed toward the end of the 2nd year, a taxonomic bias constraint which groups referents into similar kinds of objects or groups rather than individual word labels (Markman & Hutchinson, 1984), and a mutual exclusivity constraint that allows objects to have only one name (Markman, 1990; Merriman et al., 1989). More constraints for early word learning were proposed, including a noun-category constraint (Waxman & Kosowski, 1990) and a contrast bias (Clark, 1983). In support of the theory, Markman and Wachtel (1988) showed that 3 year-old children, when given the option, would assign a label to a whole object over individual object parts if they did not already have a label for the whole object. Woodward (1992) showed that 18-month olds will assign a label to a whole object rather than an interesting non-object substance (such as a film of a lava flow), thus showing more attention to the less interesting labeled object rather than the more interesting substance. In spite of evidence suggesting infants use constraints in word learning, the constraints model does not address how the infant acquires the constraints.

Golinkoff, Mervis, and Hirsh-Pasek (1994) sought to unify the constraints/principles model and present the constraints in a developmental framework. Their developmental principles model consisted of a two-tiered developmental sequence of lexical principles. This developmental model provided organization to the various constraints proposed by previous researchers. The first tier of principles was thought to initiate word learning and included reference (words stand for objects), extendibility (words extend beyond the individual item labeled), and object scope (words refer to objects). The second tier principles evolve from the first tier principles and include: conventionality (child expects that words are used to refer to things), categorical scope (words are extended based on taxonomic similarity), and novel name-nameless category (new words refer to un-named objects). Golinkoff et al. suggested these principles undergo change with language experience and enable initial word learning. Even though the developmental principles model gave some explanation as to how the constraints may be organized, it did not address other cues for word learning such as social and pragmatic cues.

By stark contrast, the social-pragmatic view of word learning emphasizes the role of adult language experts as guiding the child toward salient features of objects, events, and actions through parent (caregiver)-child interactions (Baldwin & Tomasello, 1998; Bloom, 1993; Carpenter, Nagell, & Tomasello, 1998; Nelson, 1988). Bloom (1993) suggested that adults set up the child's world, providing the language model about objects

and events the child shows interest in, guiding them to word learning. Evidence for this view was shown by Baldwin (1995) with 19-month olds. In this study infants depended on the speaker to refer to an object before they would attach a label to it. Tomasello and Barton (1994) demonstrated 19-month olds' reliance on the adult's social cues to label one object over another. The adult pretended to look at a particular object, scowling at other objects, and then eventually smiling when the "correct" object had been located. Later, the infants were tested on a multiple-object comprehension task in which the infant gave a verbal response, labeling the object that the adult had indicated was the correct one. Akhtar and Tomasello (1996) reported on a series of studies highlighting 24-month olds' sensitivity to social cues in which they demonstrated that the infants relied on the speaker's referential intentions rather than the actual pairing of an object to a referent. Based on empirical findings demonstrating infants' sensitivity to social and pragmatic cues, researchers supporting this theory have proposed that children do not require constraints to narrow the options for word-to-world mappings; rather the adult structures the environment for the young learner (Baldwin & Tomasello, 1998). While there is abundant evidence that infants are sensitive to social cues in the first year of life, studies have shown that reliance on social cues for word learning does not occur until the 2nd year of life (Hollich et al., 2000; Pruden, Hirsh-Pasek, Golinkoff, & Hennon, 2006). The response to this argument is that infants are fundamentally social creatures, demonstrating social engagement with adults in the first year that is necessary to propel them toward novel word learning (Carpenter et al., 1998).

A third perspective on the question of how infants begin word learning, known as the associationist view, was first introduced by Smith (1995). Domain general attentional learning, like perceptual saliency, and association learning processes were suggested to be the mechanisms that infants initially use for word learning. From this perspective, attention to patterns in linguistic input can be associated with words and referents to start the word learning process, rather than the need for constraints or social knowledge (Plunkett, 1997; Samuelson & Smith, 1998; Smith, 1995, 1999). Smith (1999) suggests that lexical domain specific learning biases are present for word learning; however, they emerge from domain general learning mechanisms of attention and association. By the associationistic account of word learning, each new word learned contributes to the infant's knowledge of the relationship between objects and referents, strengthening some associations and weakening others, and in the process adds to the attention to object properties. An example of domain general attentional mechanisms preceding the domain specific mechanisms was provided in a word learning study by Namy and Waxman (1998). These researchers introduced 18-month olds and 24-month olds to objects associated with either a nonlinguistic symbolic gesture or a novel word. Both groups of children learned the novel word-object associations, but a different pattern of learning emerged in the gesture-object association. The 18-month olds interpreted the gestures, like the words, for the names of objects but the 26-month olds did not learn the gesture-object association, thus supporting the prediction that an initial domain general mechanism develops into a more domain specific mechanism. Further support for the critical role of domain general mechanisms in word learning was provided by Plunkett, Sinha, Moller, and Strandsby (1992). They suggested that no new social or constraint mechanisms emerge during the 2nd year of life when vocabulary accelerates. Rather, they

suggest that small gradual changes occur in the neural system that causes dramatic shifts in learning and thus cause the acceleration of vocabulary development known as the vocabulary spurt.

Despite the evidence to support each viewpoint, none of the theories provided a comprehensive account that addressed the constraints, the domain-general mechanisms, the domain-specific mechanisms, and the obvious social cues used by infants. Each mechanism proposed was shown to play a crucial role in early word learning. As a result, there has been a shift toward more integrative theories of word learning in the last decade (Hollich et al., 2000; Mayor & Plunkett, 2010; Namy, 2012). One of these newer approaches, the Emergentist Coalition Model (ECM; Golinkoff & Hirsh-Pasek, 2006; Hollich et al., 2000), integrates the concepts presented in the constraints/principles, the associationistic, and the social-pragmatic theories. They proposed three new concepts for word learning. One, that infants get input from multiple sources for word learning, e.g. perceptual, social, and linguistic cues. Two, the reliance on these inputs shifts across development, even though all cues are initially present in the input. Three, each principle or constraint is emergent, changing over time. For example, early in development a word will be mapped to the most salient object to the infant due to perceptual cues being dominant. Over time infants will use social cues to map words to objects, relying on another person's eye gaze or point of view to determine which object is being named. Previous theories addressed the word learning process in 18-month olds or older children. Hollich et al. suggest that first-word learners need to be included in the model. Research from 7 to 12-month old infants substantiates the ECM hypothesis that emergent cues are present much earlier than previous theories acknowledged, embracing domain-general attentional factors such as the young infant's ability to associate correlations between multimodal inputs (Namy, 2012).

According to the ECM even though early attentional and perceptual cues are dominant, early social and linguistic cues are available to the word learner and are critical to word learning. Early communicative cues include: eye gaze (Morales, Mundy, & Rojas, 1998); attentional cues (Gogate & Bahrick, 1998); and pointing (Leung & Rheingold, 1981; Murphy & Messer, 1977). Early linguistic cues acknowledged by the ECM as being the precursors to word learning include: different sensitivity to speech versus nonspeech sounds (Balaban & Waxman, 1997); segmentation and prosody cues (Aslin, Jusczyk, & Pisoni, 1998; Jusczyk & Aslin, 1995), metrical stress cues (Jusczyk, Cutler, & Redanz, 1993), phonotactic cues (Jusczyk, Luce, & Charles-Luce, 1994), and statistical probability cues (Saffran, Aslin, & Newport, 1996). The infant uses this coalition of cues available in the input, not equally utilizing the cues but shifting reliance on the cues over time. With language experience they construct more complex principles for word learning. In the ECM the weighting on cues progresses from perceptual cues and associative mechanisms beginning around 10 months, to reliance on social cues around 18 to 24 months, and finally to linguistic cues by 3 years of age (Brandone, Pence, Golinkoff, & Hirsh-Pasek, 2007; Golinkoff & Hirsh-Pasek, 2006; Hollich et al., 2000; Nurmsoo & Bloom, 2008). Pruden et al. (2006) found that 10 month olds rely on the perceptual salience of an object in word-object associations while ignoring social cues from the speaker. By 12 months, babies attend to social cues but do not use them for

word learning (Hollich et al., 2000). Social cues from speakers become a primary cue for word learning at 18 to 24 months. Finally, preschoolers consider linguistic and pragmatic skills over social cues when learning a new word (Nurmsoo & Bloom, 2008).

Consistent with the ECM is the research suggesting acoustic cues boost language learning for young listeners. Speech directed to infants and toddlers is noticeably different than the speech used when talking to adults. Infant directed speech (IDS), used almost reflexively in most cultures throughout the world, shares similar characteristics across languages. The acoustic characteristics of IDS when compared to adult directed speech (ADS) include greater variation in the fundamental frequency (F_0) range, longer duration and hyper-articulation of vowels, slower tempo, and higher amplitude (Cooper & Aslin, 1990; Fernald & Simon, 1984; McRoberts & Best, 1997; Stern, Spieker, Barnett, & MacKain, 1983). IDS is generally thought to serve important social, attentional, and language related functions (Cooper & Aslin, 1990). The lively exaggerated tempo of IDS has been shown to capture and maintain the infant's attention to speech (Fernald & Simon, 1984; Papousek, Papousek, & Symmes, 1991). In laboratory studies, using preferential looking times or visual habituation paradigms, young infants look longer at visual stimuli when listening to IDS over ADS, suggesting a preference for IDS (Cooper & Aslin, 1990; Fernald, 1985; Pegg, Werker, & McLeod, 1992; Robertson, von Hapsburg, & Hay, 2013; Werker & McLeod, 1989). In addition to the attentional influences of IDS, research has suggested IDS facilitates language acquisition. Linguistic cues unique to IDS have been shown to facilitate language acquisition in infants with normal hearing sensitivity including simpler sentence structure (i.e. shorter utterances, more repetitions, restricted vocabulary), a high proportion of questions (Newport, Gleitman, & Gleitman, 1977; Soderstrom, Blossom, Foygel, & Morgan, 2008), speech discrimination (Liu, Kuhl, & Tsao, 2003), syntax acquisition (Kemler Nelson, Hirsh-Pasek, Jusczyk, & Cassidy, 1989), word segmentation (Thiessen, Hill, & Saffran, 2005), and word recognition (Singh, Nestor, Parikh, & Yull, 2009). Studies that link IDS to word-learning will be reviewed in detail in the literature review.

Because the ECM is a developmental theory, experience with language plays a major role. Infants with normal hearing sensitivity begin their auditory development before birth, and experience much of language learning through the auditory modality. Listening experience during the first year of life sets the stage for word learning and language development through an audition. However, infants with hearing impairment (HI) have a drastically different experience with sound and language than do typically developing infants. How does an early altered state of auditory development impact the role of experience in the word learning and language development process? Do HI infants follow the same word-learning path as their typically developing language peers? Studying word processing in the context of hearing impairment may contribute to the role of listening experience and developmental theories such as the ECM. The focus of the present work will examine the effect of hearing loss on infants' ability to learn and process words from IDS and ADS speech. Understanding the role of experience in word processing in children with hearing loss (CHL) will inform aspects of the ECM and provide vital information for rehabilitation of CHL.

CHAPTER 2.   LITERATURE REVIEW

Over the last couple of decades, objective experimental methods have been developed to assess early word learning abilities in infants (Fernald, Zangl, Portillo, & Marchman, 2008; Kemler Nelson, Jusczyk, Mandel, Myers, Turk, & Gerken, 1995; Schafer & Plunkett, 1998; Stager & Werker, 1997; Werker et al., 1998). Results suggest that around the age of 14 months, infants can reliably associate a novel label to an object with relatively short exposure to the label-object association when simple linguistic stimuli are used. From this research, knowledge on the progression and developmental framework of early word learning has emerged. We now know that infants use a variety of cues to learn words and that these cues change with language experience and development of higher level linguistic processing. However, there are still only a few studies that have implemented objective experimental methods to study the effect of early hearing impairment on word learning (Grieco-Calub, Saffran, & Litovsky, 2009; Houston, Pisoni, Kirk, Ying, & Miyamoto, 2003; Houston, Stewart, Moberly, Hollich, & Miyamoto, 2012; Houston, Ying, Pisoni, & Kirk, 2003). The goals of this review are to (1) present an overview of methods used to assess early word learning, (2) present research in the area of early word processing as it relates to congenital hearing impairment, and (3) present a review of the research of investigating IDS and its role in word learning.

Methodology in Early Word Learning Studies

Within the last decade several methods using a preferential visual fixation task have been refined and used to explore infants' ability to associate labels with objects. In preferential visual fixation tasks, infants are presented with a visual object paired simultaneously with auditory stimuli; and the amount of time the infant spends looking at the object while listening to the auditory stimuli is taken as a measure of listening preference. Three of these methods, the switch design (Stager & Werker, 1997; Werker et al., 1998), the intermodal preferential looking paradigm (IPLP; Hollich et al., 2000; Schafer & Plunkett, 1998), and the looking-while-listening (LWL) procedure (Fernald et al., 2008), will be reviewed briefly. The goal of the review is to allow the reader to understand the procedures used to examine word learning in infants, to understand the measures obtained, and to provide crucial background for understanding the subsequent literature on word-learning and the design proposed in the present study.

The switch habituation task (Werker et al., 1998) consists of a habituation phase followed by a test phase.   The purpose of the habituation phase is to expose the infant to the word-object pairings that will be used in the test phase. During this phase, the infant is presented with two object-word pairs, each pair presented separately in a trial, and their looking time is measured while they listen. The trials are presented until the infant becomes familiar with the objects, as indicated by a decline in looking time (i.e., looking time falls below a predefined criterion). Next, the testing phase consists of two types of trials, a same trial and a switch trial. During the same trials the infant is presented with

an object-word pair used in the habituation phase. During the switch trials, the word – object pairings from the habituation trials are switched; the word from one object is paired with the other object, thus creating a change from the pairing seen in the habituation phase. If the infants have learned the word-object associations in the habituation phase then the "switch" test trials present a violation to the learned connection, and infants should show increased looking time. Alternatively, if the infants have not noticed the associative link between the object-word pairings they will treat the two test trials as the same, showing no difference in looking time between the two trial types. The mean looking time to same and switch trials are compared to determine if learning has occurred. A longer look time to the switch trials would indicate learning.

Although the switch paradigm has been shown to successfully demonstrate word-object associations in young infants (Hay, Pelucchi, Graf Estes, & Saffran, 2011; Stager & Werker, 1997; Werker et al., 2002; Werker et al., 1998), it has been suggested that the memory demand level of the switch task may be too complex to test emerging skills (Yoshida, Fennell, Swingley, & Werker, 2009). For example, an unexpected finding using the switch design indicated that 17-month olds but not 14-month olds could associate novel words with minimal sound differences (Stager & Werker, 1997; Werker et al., 2002). This finding conflicted with studies indicating 14 month old infants discriminate known words from close approximations (Swingley, 2005; Swingley & Aslin, 2002). By using a different test procedure Yoshida et al. (2009) found that infants at 14 months of age were able to associate novel words with minimal sound differences whereas previous experiments using the Switch paradigm indicated otherwise. Yoshida et al., used a visual two-choice paradigm (similar to the LWL paradigm explained in detail in the following section of the manuscript) for the test phase. The study illustrates the limitations of the Switch paradigm with regard to testing younger infants on the more difficult task of minimal sounding word pair associations.

The intermodal preferential looking paradigm (IPLP; Golinkoff, Hirsh-Pasek, Cauley, and Gordon, 1987; Ma et al., 2011; Schafer & Plunkett, 1998) consists of a training phase in which objects are repeatedly paired with labels, each object-label pair in separate trials, followed by a test phase in which two objects from the training phase are presented simultaneously and one of the labels is presented. Two objects are presented on the screen and a camera underneath the monitor captures the infant's eye gaze to the objects. The duration of longest look to the target object and to the nontarget object is calculated for each trial. The mean longest look to the target is compared to the mean longest look to the nontarget to determine if an object-label association has been learned. The dependent measure commonly used with the design is the duration of longest look to the target over a 6 second (s) time window following speech stimulus offset. This method has been used effectively to study early word-object associations (Hollich et al., 2000; Houston et al., 2012; Ma et al., 2011) as well as syntactic knowledge (Meints, Plunkett, & Harris, 2002). However, Fernald and colleagues (Fernald et al., 2008) realized the dependent measure used in the IPLP design, a preference score based on total looking time to the target, was not sufficient to study how infant responses changed over development. For example, in the average looking time over a 6 s window, 24-month old infants were found to perform less well than 18-month olds; a finding not consistent with

the hypothesis that older infants should perform better than younger infants in a word recognition task. Fernald et al. modified the procedure by reducing the time widow used for analysis. With a shorter window, 2 s, the difference in looking time between 18- and 24-month olds agreed with the prediction that older infants would show an improvement in word recognition. Thus the older infants showed a shorter look time to the target then looked away, which the authors interpreted as a sign of rapid processing. Fernald and colleagues made changes to the IPLP design and the new paradigm has become known as the looking-while-listening procedure (LWL).

A major difference between the IPLP and the LWL procedures is the type of information obtained from the test trial. For example, the IPLP measures look time beginning after the offset of the target word, whereas the LWL measure begins at the onset of the target word to capture the beginning of eye movement shift to target. Additionally, the LWL procedure provides a reaction time (RT) measure as well as an accuracy measure. RT is a measurement of time taken to shift from nontarget to target image after onset of the target word. The RT measure allows study of processing and comprehension of linguistic information from critical points in the stimulus (e.g. in a sentence). In the LWL procedure the initial eye shift toward the target object can be measured. The LWL procedure also allows study of the developmental changes in processing. In a study of word recognition, Fernald and colleagues (Fernald, Pinto, Swingley, Weinberg, & McRoberts, 1998) measured RT in 15-, 18-, and 24- month olds. Their findings revealed that over the second year of life, during the period that infants typically go through a "vocabulary spurt", the speed and efficiency of verbal processing increased significantly. The 24-month olds shifted their gaze to the correct object before the end of the spoken word. The 15-month olds took longer to shift eye gaze to the target word after target word onset than the 18-month and 24-month olds, demonstrating the developmental changes in word processing. The ability to measure RT from the onset of eye shift at critical points in the stimulus and the two forced choice visual stimuli in the testing phase makes the LWL design a powerful tool for measuring word processing in young infants. The other measurement obtained from LWL, accuracy, is the mean proportion of looking time to the target picture at each time interval is measured from the target onset for each age group. It is calculated from the combined responses from both target- initial and nontarget-initial trials to show the mean time spent looking at the target picture as a proportion of total time spent on either the nontarget or the target, averaged over time. Thus, the accuracy measurement of the LWL procedure differs from the IPLP in that it is a proportion of total looking time to the target rather than a preference measurement of longest look to target.

Early Word Processing and Hearing Impairment

Two studies of word processing using a visual fixation experimental design have been done with infants with HI (Grieco-Calub et al., 2009; Houston et al., 2012). Grieco-Calub et al. measured processing speed for recognition of familiar words in infants 26 to 36 months. Houston et al. measured novel word-object associations in infants 21 to 40 months old. The findings of each study reveal that these experimental designs are useful

in assessing word processing abilities in infants with HI. The results of these studies are reviewed.

Using the LWL experimental design, Grieco-Calub et al. (2009) measured word processing (reaction time and accuracy) for recognition of familiar words in quiet and in the presence of competing speech in two groups of infants, those with cochlear implants (CI; n=26, age: 26 - 36 months) and an aged-matched control group of normal hearing infants (N=20, M = 29.6 months). The results revealed that the infants with CIs were slower to respond and less accurate at word recognition than infants with normal hearing. RT for both the CI group and the NH group showed faster average RTs in quiet (CI = 799 ms; NH = 598 ms) than in the presence of competing speech (presented at + 10 dB SNR; CI = 943 ms; NH = 872 ms). The CI group's average RT in quiet (799 ms) was significantly slower than the NH infants (difference = 201 ms); however, their RTs were not significantly different in the presence of competing speech. Accuracy, the proportion of looking time to the target word within 367-2000 ms after target word onset, was greater for both groups in the quiet condition (CI = 70%; NH = 85%) than in the presence of competing speech (CI = 58%; NH = 73%). While both groups showed similar patterns in RT and accuracy in quiet versus competing speech, the CI group was significantly less accurate at recognizing familiar words than the NH group.

In an effort to account for differences, listening experience (defined as the amount of experience since CI activation) was examined as a possible reason for group differences in processing time. The range of listening experience was 6-25 months and 26-36 months for the CI and NH groups, respectively. However, listening experience and RT were not significantly correlated for either group. In summary, this study was one of the first to use the LWL design on children with hearing loss. The study was one of the first to suggest the effect of hearing loss on early word recognition of familiar words may result in slower RT and reduced accuracy in word recognition when compared with children with normal hearing. This study did not, however, address novel word learning in infants with hearing impairment.

More recently, in a word learning study, Houston et al. (2012) examined the effect of early auditory experience on a novel object-label association task in infants with CIs using the IPLP design. They included infants with CIs (age range 21.7 to 40.1 months, n=25) and NH infants matched by chronological age. The task was to learn two novel object-word pairs spoken in infant directed speech. The dependent measure was the difference in the mean longest look to the target than to the nontarget on test trials. A significant difference between the longest look to the target and nontarget test trials indicated a learned association between object-word pairs. The test trials consisted of four test blocks with four trials per block. In the analysis they examined the effects of early auditory experience on the ability to learn the object-word associations. Using a multiple linear regression analysis (with age at CI implantation, aided hearing levels before CI implantation, and amount of CI experience as predictive factors on the success of learning the novel object-word association task) the results revealed a significant effect for aided hearing levels before implantation. These initial results suggested that some hearing experience before CI implantation facilitates word-learning performance.

Indeed, analysis of the data revealed 5 children had better pre-CI hearing levels than the rest of the group. Since only a small number of subjects may be influencing the effect of pre-CI hearing, these subjects were removed and the regression analysis was rerun. The results revealed that when the CI group had similar pre-CI hearing levels, the significant factor on word-learning performance was age at CI activation. Using the finding that age at CI was a significant factor in the word-learning task, the CI group, with the 5 subjects removed, was divided into two groups: early CI (<13.6 months, n = 12) and late CI (16 to 21.4 months, n = 8), and age-matched to a group of NH infants for further analysis. A comparison of the performance on the word learning task and age at CI (early CI and late CI) revealed the early implanted group's performance indicated word learning (mean longest look to target was greater than mean longest look to nontarget), but the late implanted group did not show evidence of word learning (no difference between longest look to target vs. nontarget). In contrast, both the NH age-matched controls revealed evidence of word-learning on the task.

The early implanted group performed similarly to their age-matched NH peers, whereas the late CI group was not similar to their age-matched peers. The authors' conclusion was that early auditory experience plays a significant role in word learning abilities for children with early onset hearing impairment. However, better pre-CI hearing thresholds predict better performance regardless of age at CI. The amount of listening experience (a range of 10.3 – 20.1 months) did not contribute to the variability in word-learning performance. The IPLP procedure used in this study did not include RT measures. Thus, a complete picture of word processing skills in infants with hearing loss could not be obtained in this study.

Infant Directed Speech

As discussed earlier, infant directed speech is thought to contribute to early language acquisition and word learning. When interacting with infants, adults often use a different style of speech than when interacting with other adults. The speech type used with infants has become known as infant-directed speech (IDS). The characteristics of IDS when compared to adult directed speech (ADS) include greater variation in fundamental frequency (F0), longer duration and hyper-articulation of vowels, slower tempo, simpler sentence structure (i.e. shorter utterances, more repetitions, restricted vocabulary), and higher amplitude (Cooper & Aslin, 1990; Fernald & Simon, 1984; McRoberts & Best, 1997; Stern et al., 1983). Researchers have found that the prosodic features of IDS maintain infants' attention longer than ADS (Cooper & Aslin, 1990; Fernald & Kuhl, 1987; Werker & McLeod, 1989), suggesting a preference for IDS over ADS.

The mechanisms in IDS responsible for the infant's preference appear to shift with the infant's age. A developmental, age-related preference for various properties of IDS appears to take place over the first two years, consistent with the ECM concept of word learning. This suggests that the reliance on specific cues shifts with development (i.e. perceptual cues become less salient within the second year of life). For example, the

most salient characteristic for young infants is the variation in pitch contours (Fernald & Kuhl, 1987), whereas 12-month olds prefer the linguistic structure of IDS (Hayashi, Tamekawa, & Kiritani, 2001), and 16-25 month olds do not show a preference for IDS over ADS (Robertson, von Hapsburg, & Hay, 2013). Reflecting this developmental preferential shift, as infants develop and begin using 2-word utterances their caregivers change their speech (i.e. lower mean F0) when interacting with them (Amano, Nakatani, & Kondo, 2006). In sum, IDS with younger infants serves to nurture and engage infants' attention to speech. As the infant matures in the communication process, IDS supports linguistic development, e.g. speech discrimination (Liu, Kuhl, & Tsao, 2003); syntax acquisition (Kemler Nelson et al., 1989); word segmentation (Thiessen et al., 2005), and word recognition (Singh et al., 2009).

Research has shown that IDS may play a role in listening experience and acquisition of early word learning (Ma et al., 2011). Ma et al. (2011) recently demonstrated that IDS assists in word learning and that its role in word learning is not necessarily driven by the age of the infant; rather, it is mediated by language abilities, (e.g. vocabulary size). In their study, word learning in IDS was compared to word learning in ADS with 21-month old infants (N = 48). The infants were divided into two groups; one group was exposed to IDS and the other to ADS. Using the IPLP paradigm in a novel word-object association task, the results showed that looks to the target word compared to the non-target were longer in the IDS condition but not in the ADS condition, suggesting word learning in the IDS condition only. Vocabulary was assessed using the McArthur-Bates Communicative Development Index (MCDI; Fenson, Marchman, Thal, Dale, Reznick, & Bates, 2006) to explore the impact of language development on word learning. A comparison of the performance on the word learning task to the infants' vocabulary score (the number of words produced according to parent report on the MCDI) revealed that infants with higher vocabularies performed better on the word learning task than infants with smaller vocabularies. A closer look revealed that infants with high vocabularies showed word learning in the second block of the test trials in the ADS condition. The authors suggested that learning in the second block of trials was due to additional time to learn the novel word-object associations.

Using the same experimental design and stimuli, 27-month olds were tested in the ADS condition to address the hypothesis that as children acquire more language they rely less on IDS in their language learning. The 27-month olds were able to learn the novel words in the ADS condition, regardless of their vocabulary size. The authors suggested that IDS facilitates word learning, especially for infants with smaller vocabularies. However, as infants develop more complex language skills they rely less on IDS for language learning. These findings support the ECM model of word learning that asserts that as infants age, there is a developmental shift in the salience of various cues used in word and language acquisition.

Given the importance of IDS in early language acquisition and the salient acoustic properties of IDS, researchers have explored the effect of hearing loss on infant preferences for IDS. Researchers have attempted to determine if the amplification devices worn by HI infants provide sufficient information to distinguish IDS from ADS,

as well as if infants with HI show similar preferences as infants with NH given the difference in early auditory experience (Bergeson, Miller, & McCune, 2006; ; Robertson et al., 2013; Segal & Kishon-Rabin, 2011). Bergeson et al. (2006) studied mothers' use of IDS when speaking to their infants with HI. Like mothers of typically developing infants, mothers of infants with HI use IDS when speaking with their infants. In their study, they recorded and acoustically analyzed the speech that mothers produce when speaking to their infants. Three groups of mothers participated, one group whose infants use CIs (age 10-37 months), and two groups of mothers with infants with NH, one group matched for listening experience of the CI group, and one matched for chronological age. Results showed that mothers adjusted their speech style to the infants with CIs according to listening experience of the infant rather than to the chronological age of the infant. Thus, measures of mean F0, pitch range, and duration produced by mothers of the infants with CIs more closely matched the measures obtained for the mothers of the younger, experience-matched normal hearing control infants. This study demonstrated that mothers of infants with HI adjust their language style to the perceived language level of the child.

Recently, Segal and Kishon-Rabin (2011) investigated listening preferences for IDS in infants (ages 14 to 33 months) with profound hearing loss who use CIs. In their study infants with NH and infants with HI wearing CIs were tested to determine whether a listening preference existed for IDS versus white noise and for IDS versus time reversed speech. Results from their study showed that children with CIs preferred listening to IDS over both white noise and time reversed speech. Thus, they concluded that the cochlear implant device allows children to develop listening preferences similar to infants with NH. In another study, Kishon-Rabin, Harel, Hildesheimer, and Segal (2010) examined the listening preferences of infants with HI for Hebrew versus English IDS, two languages that differ in their rhythmic patterns, with Hebrew having a predominantly weak-strong (iambic) stress pattern (Bat-El, 1993) and English having a predominantly strong-weak (trochaic) stress pattern (Cutler & Carter, 1987). The goal of the study was to determine whether infants who use CIs are able to develop a listening preference to IDS in their native language as compared to IDS of a non-native language. Results showed that both NH (N=19) and infants who use a CI (N=9) preferred listening to their native language (Hebrew) over the non-native language (English). The authors suggested that the CI must provide infants with sufficient access to the auditory signal to differentiate the iambic stress pattern of Hebrew from the trochaic stress pattern of English, even when both sets of stimuli are produced in an infant-directed register. A problem with this study was that they could not say unequivocally that the infants were using the rhythmic unit, as the phonemic detail of the stimuli also varied across the two languages. Thus, infants may have been responding to the phonemic differences between the two languages, and simply demonstrating a preference for listening to the familiar phonetic detail of their native language.

Although the above studies by Kishon-Rabin and colleagues established that infants prefer to listen to IDS, they did not address whether they prefer to listen to IDS relative to ADS. To that end Robertson et al. (2013) used a visual fixation experimental design to examine listening preference for IDS over ADS in a group of infants with HI

(8.9 to 32.2 months) whose listening age ranged from 5.1 to 11.5 months. Their performance was compared to two control groups of infants with NH, one group with a similar mean listening age (5.3 to 9.3 months) to the infants with HI, and one group with a similar mean chronological age (16.3 to 25.3 months). The results showed that the infants with HI looked longer when listening to IDS than to ADS, suggesting the infants with HI are provided with sufficient information by their devices to detect the differences between IDS and ADS and to show a preference for IDS. In addition, the results showed that the HI group and NH group matched for listening experience demonstrated a preference for IDS over ADS. Interestingly, the NH group matched for chronological age did not show a preference for IDS. Finally, the results also showed that in general, infants with hearing loss had shorter overall looking times to speech (IDS and ADS) compared to the NH control groups, suggesting possibly that infants with HI had reduced attention to speech.

In summary, relatively little is known about how infants with hearing loss process words. There are very few published studies that have examined how hearing loss affects word learning or word processing. In particular, no research has systematically examined how IDS facilitates word learning relative to ADS in infants with hearing loss. Although Houston et al. (2012) showed that early implanted infants were able to learn words spoken in IDS; they did not assess this relative to ADS. Additionally, because they used the IPLP, they were not able to obtain RT measures, and thus an incomplete picture of word processing was obtained. In general, their study suggests that pre-implant hearing ability and age of CI activation were factors that contribute to word learning in IDS. On the other hand, Ma et al. (2011) suggested that vocabulary size in NH infants predicts word learning in IDS but not ADS. This is not something that was investigated by Houston et al. (2012), thus it is unknown whether vocabulary size would have been a predictive factor for word learning performance in IDS for infants with HI. Additionally, Robertson et al. found older infants with normal hearing had a preference for ADS over IDS. Ma et al. tested whether older infants learned in ADS only; however they did not test if they could still learn in IDS at that age. Thus a true developmental picture of how and when infants use IDS and ADS could not be obtained. Additionally, Ma et al. also used the IPLP, and reaction time measures were not obtained, an important measure of word processing. Finally, Grieco-Caleb et al. (2009) used the LWL procedure to establish how hearing loss affects familiar word processing, but their study did not include ADS, or novel word learning.

The Present Experiment

The present study used the LWL procedure (Fernald et al., 2008) to investigate how children with hearing loss (CHL) compare to children with normal hearing (CNH) in word processing of familiar and novel word. Accuracy and RT measures were used to assess word processing. Children participated in two experiments, one designed to test word processing in IDS and the other designed to test word processing in ADS. The present study was designed to answer the following questions:

Question 1

Does speech type (IDS vs. ADS) affect word processing of familiar words in CHL and CNH?

Aim 1: Test the hypothesis that speech type will influence word processing in a familiar word recognition task in both CHL and CNH. Specifically RT (latency to orient to the target word from the nontarget) and accuracy (fixation proportion to target) in each of the speech type conditions (IDS and ADS) were measured in a familiar word recognition task.

Prediction: We predicted that both CNH and CHL would show facilitated word processing in the IDS condition, relative to the ADS condition. Specifically, the children would show decreased reaction time (latency to orient to the target word from the nontarget) and increased accuracy (fixation proportion to target) in the IDS condition when compared to the ADS condition. In addition, we predicted that CNH would show faster reaction time and increased accuracy when compared to the CHL.

Question 2

Does speech type (IDS vs. ADS) affect word processing of novel word-object associations in CHL and CNH?

Aim 2: Test the hypothesis that speech type will influence word processing in a novel word-object association task in both CHL and CNH. Specifically we measured reaction time (latency to orient to the target word from the nontarget) and accuracy (fixation proportion to target) in each of the speech type conditions (IDS and ADS) in a novel word-object association task.

Prediction: We predicted that both NH and HI groups would show facilitated word processing in the IDS condition, relative to the ADS condition. Specifically, results would show decreased reaction time (latency to orient to the target word from the nontarget) and increased accuracy (fixation proportion to target) in the IDS condition when compared to the ADS condition in a familiar word recognition task. In addition, we predicted that CNH would show faster reaction time and increased accuracy when compared to the CHL.

Question 3

Is there a relationship between word processing and vocabulary size for CHL versus CNH?

Aim 3: Test the hypothesis that productive vocabulary size as measured by the raw scores on the MacArthur-Bates Communicative Development Inventory (MCDI) is predictive of early word-processing skills (speed and accuracy to find the target in familiar and newly learned words) in both CHL and CNH using Pearson's Correlation. Correlations of RT and vocabulary size, and accuracy and vocabulary size were done for IDS and ADS conditions.

Prediction: We predicted that there would be a negative correlation between vocabulary size and RT in both Speech Type conditions; CHL and CNH with a larger vocabulary would find the target objects more quickly than infants with smaller vocabularies. In addition, we predicted that there would be a positive correlation between vocabulary size and accuracy, with the CHL and CNH with larger vocabularies showing greater accuracy.

CHAPTER 3.   METHODOLOGY

Participants

Two groups of children participated in this study: a group of CHL and a group of CNH. Each child participated in two experiments, one using IDS stimuli and the other using ADS stimuli. The two experiments were on separate days, about a week apart. The two groups of children were matched for gender, chronological age, and socioeconomic status (SES). The SES was determined by the educational level of the mother (Bornstein, Hahn, Suwalsky, & Haynes, 2003; Sininger, Grimes, & Christensen, 2010; Yoshinaga-Itano, Sedey, Coulter, & Mehl, 1998). The mothers' mean educational level for the CHL and the CNH were 14.8 years ($SD = 2.23$) and 15 years ($SD = 1.89$) respectively (see **Table 3-1**). The inclusion criteria for both groups included: 1) recognition of the four familiar words used in the experiment, which was determined by parent report (parents were asked if their child could identify the word in a storybook when named), 2) no severe motor delays, cognitive delays, or significant visual impairment, via parental report, and 3) English as the primary language in the children's homes, per parent report. All parents signed consent forms. This study was approved by the University of Tennessee Health Science Center's Institutional Review Board.

Children with Hearing Loss (CHL)

Eleven children (8 female, 3 male) with sensorineural hearing loss and a mean chronological age of 32.5 months (range = 23-42.1 months) participated in this study (see **Table 3-1**). CHL were recruited from the University of Tennessee's Child Hearing Services Clinic, through contacts with private otolaryngologists, audiologists, early interventionists, and through advertisements placed in local and regional association newsletters. The inclusion criteria for the HI group were: 1) bilateral, congenital, sensorineural hearing loss diagnosed with an auditory brainstem response test, 2) use of hearing aids and/or cochlear implants for at least 5 months, 3) no indication of auditory neuropathy spectrum disorder (defined as otoacoustic emissions present in combination with hearing loss greater than 40 dB and/or cochlear microphonic component recorded in combination with no obvious auditory brainstem response), and 4) if aided, an aided Speech Intelligibility Index (SII) score of > 20. This number is based on previous research indicating that an SII of 20 correlates with approximately 20% speech audibility (Amlani, Punch, & Ching, 2002; Stiles, Bentler, & McGregor, 2012). Since this study provided only an auditory presentation of the speech stimuli, an SII of 20 was included as a way to quantify sufficient access to the auditory signal.

Table 3-1 shows the hearing age, defined as the amount of time amplification had been used from the initial hearing aid/cochlear implant fitting until day of test (range = 6.3 – 34.9 months.; $M = 18.7$ months, $SD = 8.8$); the aided SII of each ear, and the type of devices worn by the children (3 used bilateral CIs, 8 used bilateral HAs).

Table 3-1. Demographic information for CHL and CNH pair-matched controls

				CHL Group									**CNH Controls**		
Sub	Gender	CA (mos)	Hearing Age (mos)	Device Type	Device Model	Bilateral Fit	SII (RE)	SII (LE)	SES	CDI	Sub	Age at Test	Gender	SES	CDI
2	F	40.6	20.5	HA	Phonak Cassia Micro	Yes	91	91	14	624	N20	40.9	F	18	671
3	F	42.1	27.4	HA	Oticon Safari 300P	Yes	87	81	12	675	N3	42.1	F	12	665
5	F	28.6	23.5	HA	Widex Baby BB4	Yes	NA	NA	16	634	N2	29.3	F	15	540
6	M	26.8	13.6	CI	Cochlear Nucleus 5	Yes	NA	NA	14	264	N11	26.8	M	14	531
7	F	38.8	7.6	HA	Oticon Safari 300P	Yes	88	94	14	598	N19	38.3	F	16	457
8	F	27.7	17.4	CI	MedEl Opus	Yes	NA	NA	18	578	N22	28.5	F	16	600
9	F	28.6	6.3	HA	Phonak Bolero	Yes	80	65	14	139	N1	29.3	F	15	564
10	M	35.7	26	HA	Phonak Maxx 311	Yes	78	49	16	107	N23	35	M	14	673
11	F	23	18.3	HA	Oticon Safari	Yes	72	72	11	98	N17	23.1	F	16	411
12	F	25.8	12	CI	Cochlear Nucleus 6	Yes	NA	NA	16	254	N25	26	F	16	620
14	M	39.6	34.9	HA	Oticon Safari 900	Yes	45	79	18	494	N26	39.1	M	16	411
Mean		**32.48**	**18.86**						**14.8**	**406**		**32.58**		**15.1**	**558.5**
SD		**6.9**	**8.8**						**2.23**	**233.4**		**6.7**		**1.6**	**98.8**

Notes: Sub, subject. CA, chronological age. mos, months. SII, Speech Intelligibility Index. RE, right ear. LE, left ear. SES, socioeconomic status defined as years of maternal education. CDI, vocabulary score on McArthur-Bates Communication Developmental Inventory. F, female. M, male. HA, hearing aid. CI, cochlear implant. NA, not available.

All children had bilateral, sensorineural hearing loss, ranging in severity from mild-to-profound. **Figure 3-1** shows the average thresholds and the threshold range of the 8 children fitted with hearing aids. Of the children wearing hearing aids, 3 children had a mild loss, 1 child had a mild to moderate loss, 1 child had a mild to moderately severe loss, 2 children had moderate to moderately-severe loss, and 1 child had an asymmetrical loss (mild to moderate in the right ear and severe in the left ear). Threshold information was unavailable for the 3 children who used cochlear implants. Communication mode for all the children was primarily aural/oral. All children participated in a therapy program 1 to 3 hours a week that emphasized an aural/oral approach. However, 4 children were also exposed sign language in another therapy program 2 times weekly. It was unclear how much sign language was used throughout the day with these children. Data from two additional CHL were excluded from the analysis because of: inattention (1) and not completing the experiment (1).

Children with Normal Hearing (CNH)

Each child with HI was matched for gender, maternal education level, and chronological age (M = 32.6 months, SD = 6.7; see **Table 3-1**) with a participant with NH. CNH were recruited through the University of Tennessee's Child Development Research Group database and from local daycare facilities. The inclusion criteria for the NH group were: 1) born after at least 36 weeks gestation, 2) had fewer than four prior ear infections, 3) had no history of hearing or vision impairments, 4) on the day of testing, passed a hearing screening using distortion product otoacoustic emissions [DPOAEs], and 5) scored > 20th percentile on the vocabulary measure (Fernald & Marchman, 2012). Six CNH were excluded from the analysis due to inattention (5) and experimenter error (1).

Vocabulary Measure

The McArthur-Bates Communicative Developmental Index (MCDI; Fenson et al., 2006) was used to measure vocabulary production for all children. The measure of vocabulary production was the number of words the child "understands and says" (i.e. productive or expressive vocabulary) according to the MCDI (Fenson et al., 2006). On their first visit to the laboratory, parents were given the appropriate version of the MCDI (Words and Gestures for children up to 17 months; Words and Sentences for 18 months and older) and instructed on how to complete the vocabulary questionnaire. The parents were asked to complete the questionnaire at home and return it at their next visit to the laboratory. The vocabulary scores for the HI and NH groups ranged from 98-675 (M = 406, SD = 233.4) and 411-671 (M =558.5, SD =98.5; see **Table 3-1**), respectively. The upper age range on which the MCDI Words and Sentences has normative data on is 30 months. Five subjects in the HI group and 5 subjects in the NH group were older than 30 months; however, none of the subjects reached the maximum number of words included
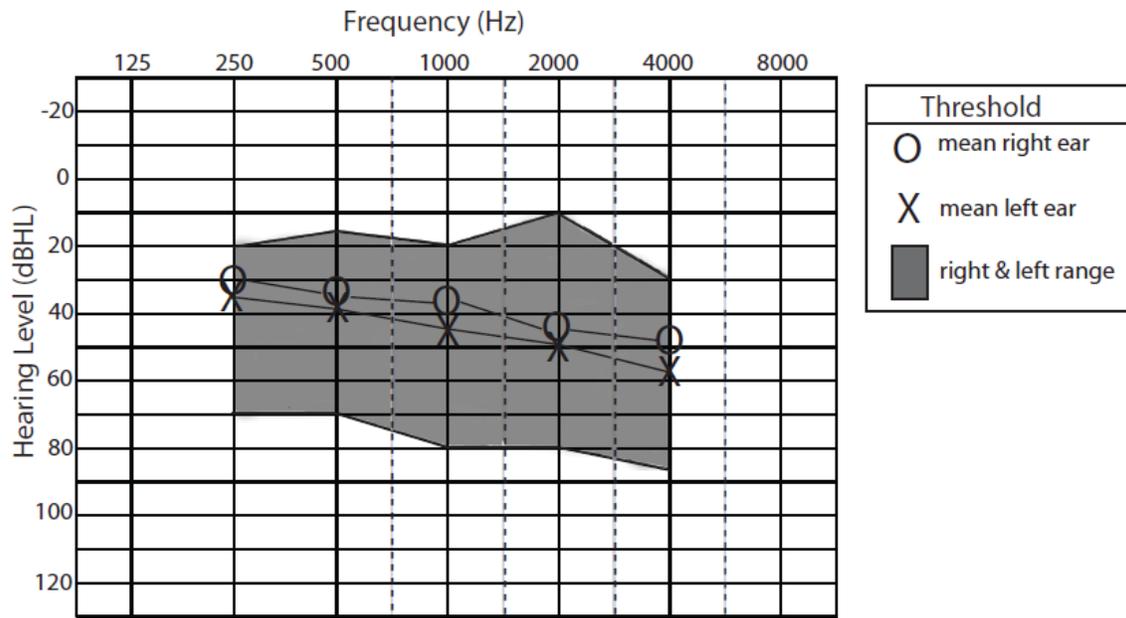
Figure 3-1.   Mean unaided thresholds of subjects using hearing aids

in the MCDI. Other studies have used the MCDI as a vocabulary measure with children older than the 30 months (Lew-Williams & Fernald, 2007).

Stimuli

Speech Stimuli

All speech stimuli were recorded by the same female talker. The stimuli were recorded in IDS and ADS. The recordings were made at a sampling rate of 44.1 KHz using a Sennheiser e-845s microphone and Maranz PMD 670 Professional Digital recorder. The female talker was a trained speech-language pathologist and mother of an infant. She was asked to imagine that she was talking to her infant (for IDS) and to an adult (for ADS); however, there was no baby present while the recordings were made.

Different phrases were used for the training phase and the test trials. The training phase consisted of short phrases (Look at the [target]! It's a [target]! [Target]!), used to associate the novel word label with the visual object. The test trials consisted of a short question followed by a repetition of the target word (Where's the [target]? [Target]!). Several samples of each phrase were recorded. Two of the primary researchers listened to the phrases and chose the phrases to be used based on their subjective impressions of IDS and ADS. The phrases were then verified with acoustic analysis. To ensure that the IDS stimuli had IDS characteristics [e.g., a higher fundamental frequency (F0), a wider frequency range, and a longer duration than the ADS (Fernald, 1993; Jacobson, Boerman, Fields, & Olson, 1983; Garnica, 1977)], an acoustic analysis was done on all the target phrases (training and test) using Pratt (Boersma & Weenink, 1996, see **Table 3-2**). In addition, an acoustic analysis of the duration of the target words in IDS and ADS was done to determine the difference in duration between IDS and ADS (see **Table 3-3**).A comparison of the acoustic values for all the stimuli in each phase revealed similar values for mean F0 and F0 range for IDS and ADS. The pitch analysis revealed greater overall variability in F0 range and higher mean average F0 in the IDS than in the ADS. These values are consistent with values presented in previous research (Fernald, 1989; Ma et al., 2011; Thiessen et al., 2005). The duration of the IDS sentences (training and test phases) was longer than the ADS sentences. In order to equalize the duration of the trials, longer pauses were inserted between sentences in the ADS condition. Thus, both the training and test trials were 6.5 s long. The stimuli were adjusted in Adobe Audition to have the same root-mean-square power (-20 dB) and were presented at 65 dB SPL (A-weighted scale). Calibration of the soundfield was checked periodically using a Larson Davis System 824 sound level meter. In addition to training and test trials, filler phrases were used to reduce repetitiveness. The filler phrases were recorded in IDS and used in the IDS and ADS conditions (e.g. Good job! Here's another picture!).

Four novel words (dax, nila, blick, modi) and four familiar words (baby, doggie, shoe, ball) were used in the experiment. The novel words were composed of phonotactically legal phoneme sequences for English (i. e. they contained sound

Table 3-2.   **Acoustic analysis of the stimuli used in the experiment**

Measure	IDS			ADS		
	Training	**Test**	**Combined**	**Training**	**Test**	**Combined**
F0 range	132-628	125-619	125-627	111-334	119-304	111-334
Mean F0	347	364	356	207	189	198
SD	28.76	16.22	24.17	23.15	12.11	20.05

Notes: F0 = fundamental frequency. SD = standard deviation.

Table 3-3.   **Duration of targets in IDS and ADS**

Target	IDS	ADS	Difference
nila	514	471	43
dax	652	591	61
blick	414	357	57
modi	619	523	96
shoe	623	481	142
baby	533	452	81
doggie	604	505	99
ball	495	376	119

Note: Difference = IDS – ADS.

sequences that occur in English) and balanced for the phonotactic probability of phoneme occurrence in English (see **Table 3-4**). Phonotactic probability was provided by an online calculator (Vitevitch & Luce, 2004). The probability of occurrence was based on an adult-corpus of 20,000 words (Vitevitch & Luce, 2004). The novel words were used in pairs (dax-nila and blick-modi), one pair in each experiment. Although young word learners are typically successful at distinguishing known words with similar phonetic content (Swingley, 2005; Swingley & Aslin, 2002), previous research suggest that phonological encoding of similar sounding novel words is difficult for early word learners (Pater et al., 2004; Yoshida et al., 2009). Therefore, to encourage word learning, the novel word pairs were dissimilar in number of syllables and no repetition in phonemes (blɪk - moʊdi; dæks - nɪlə).

Visual Stimuli

Visual stimuli consisted of digitized photographs of colorful objects. All images (novel, familiar, and filler) were matched in size (11.5 in. x 8 in.) and brightness. The images of the novel objects are shown in **Table 3-5** with their associated novel word label. The two novel objects paired together in the test phase were perceptually different in color and shape to encourage learning. Several different visual images were used for the familiar words (ball, shoe, baby, doggie) to help sustain attention throughout the experiment. The visual stimuli for each of these familiar objects were matched for visual salience. Filler trials consisted of more complex and colorful pictures than the experimental stimuli and were used in the test phase to maintain children's interest. In addition to the visual stimuli used during the trials themselves, an attention getter movie was used between training trials. The movie consisted of a colorful animated scene in which animals slowly move across the screen accompanied by music.

During the training trials the novel objects, presented in isolation, moved across the screen in various patterns while the object was being labeled. The motion was not tied to the timing of the speech stimuli. The image appeared on the screen for 500 ms before the onset of the carrier phrase and for 1 s after the speech stimuli ended. An attention-getter movie, with music, appeared between training trials. The purpose of the attention-getter was to regain the child's attention to the monitor before the onset of the next trial.

The test trials started with presentation of visual stimuli. During the test phase, two stationary objects (in yoked pairs, either familiar or novel) appeared on the left and right sides of the screen, 14 in. apart (see **Figure 3-2**).

The familiar objects were yoked based on their animacy (e.g. baby-doggie, ball-shoe). Each object served as target and nontarget on an equal number of trials. For the test trials the images appeared on the screen 1 s before the onset of the carrier phrase. The longer presentation of the visual stimuli (1 s versus 500 ms) in the test trials was to ensure the child had enough time to see both images before the onset of the speech. The

Table 3-4. **Phonotactic probability of target words**

Target Word	Probability for Phonemes					Probabilities for Biphones			
	1st	2nd	3rd	4th	5th	1st	2nd	3rd	4th
ball (bɔl)	.0512	.0165	.0737			.0008	.0035		
shoe (ʃu)	.0097	.0221				.0002			
baby (beɪbi)	.0512	.0292	.0350	.0179	.0404	.0017	.0000	.0006	.0008
doggie (dɑgi)	.0518	.0605	.0179	.0432		.0023	.0007	.0005	
blick (blɪk)	.0512	.0447	.0350	.0422		.0050	.0044	.0035	
modi (moʊdi)	.0572	.0493	.0036	.0403	.0404	.0042	.0000	.0001	.0023
dax (dæks)	.0518	.0000	.0535	.0501		.0000	.0000	.0049	
nila (nɪlə)	.0238	.0962	.0737	.0798		.0019	.0090	.0084	

Table 3-5.   Novel object-label associations

Novel Word Label	Object
dax	
nila	
blick	
modi	
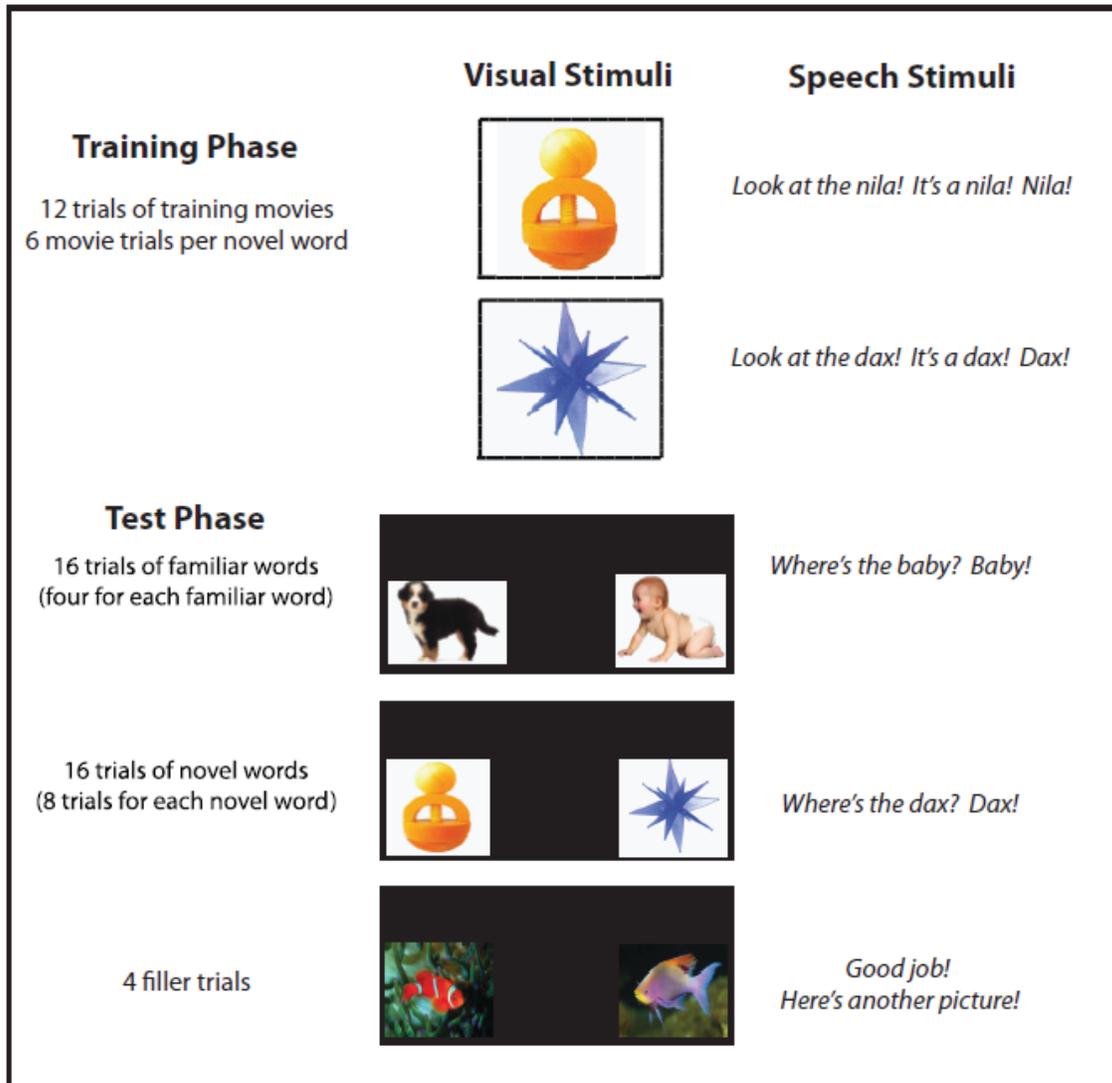
Figure 3-2.   An example of visual and auditory stimuli used in the experiment
The training phase associated one object-word pair per trial; the test phase paired two
objects, either familiar or novel. The filler trials provided colorful pictures and
encouraging phrases to maintain interest.

target word was presented at 2.5 s into the trial. The target word was repeated 2 s after the onset of the initial target word. The image continued to be displayed for 1 s after the speech stimuli ended. **Figure 3-3** shows the time line for a test trial.

Apparatus

The LWL procedure was conducted in a sound-attenuated booth. Images were presented on a 43" Samsung 450 LCD/LED television screen located 37 inches from the child's face. The testing booth had dark curtains covering each wall. An overhead low-level light was used during testing to avoid complete darkness, thus ensuring that the television display provided the most interesting visual for the child. The auditory stimuli were presented through a loudspeaker (JBL Creature II) placed below the television monitor. A hidden video camera (Security Labs SLC-160C) below the television monitor recorded the child's looking behavior at 30 frames per second. A zoom allowed the camera to be adjusted to focus on the child's face only, thus allowing a clear visual of the child's eye gaze and shifts of fixation.

The experiment was run using WISP, a custom-made software program for MatLab, developed internally at the Infant Learning Lab at the University of Wisconsin. WISP output the stimuli to the television monitor in the testing room. Simultaneously it presented an information slide on the PC computer screen with information about the experiment (subject code number, speech type condition, and the training/test phase trial number). A Horita TG 50 timestamp generator delivered a timestamp to the video from the hidden camera in the test booth. A second video camera (Security Labs SLC-160C) was in the experimenter's room and recorded the information slide from the PC monitor. It was routed through a picture-in-picture (PIP) digital quad splitter (Clover QC900) to the video from the hidden camera in the test booth. The video of the child's eye gaze (with the PIP of the information slide and a timestamp) was routed to the software program iMovies on a Macintosh computer in the experimenter's room. The experimenter monitored the child's looking behavior on the Macintosh monitor during the experiment. Only a visual presentation was available to the experimenter (i.e. no audio feed) during the experiment. However, a third video camera (Panasonic SDR H80P) capable of audio recording was hidden behind a black curtain in the back of the test booth. The Panasonic camera recorded the visual presentation of the television screen in addition to the sounds in the booth. This video allowed monitoring post experiment, to ensure the auditory and visual stimuli were presented correctly and with accurate timing.

In order to synchronize the visual recording from the camera under the television screen with the audio recording from the Panasonic camera, a clapperboard was used. Prior to bringing the participant into the booth, both cameras were started. The clapperboard was used to capture the visual display of the clapperboard on the camera beneath the television screen and the audio of the clapperboard on the Panasonic camera.
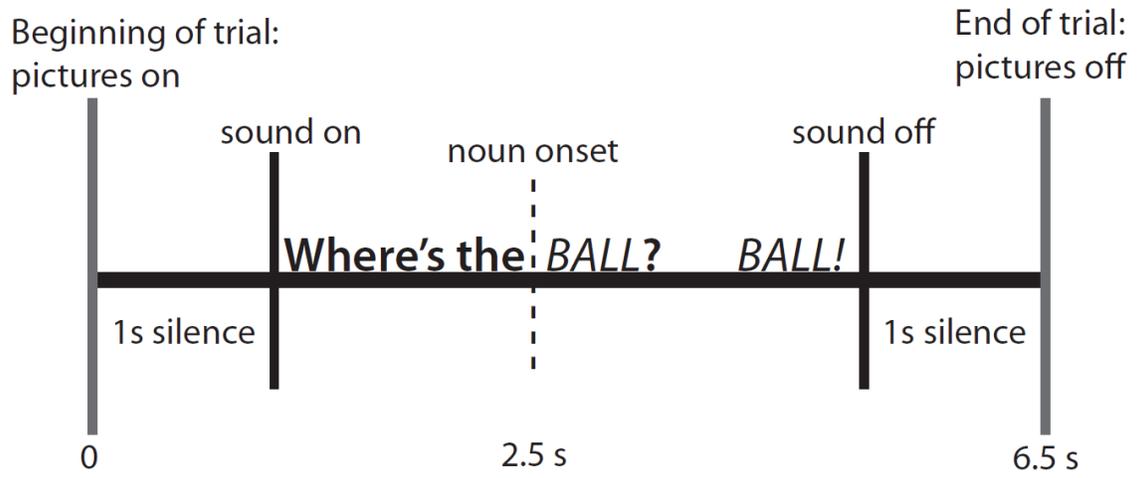
Figure 3-3. **Schematic timeline for the test trials**

The recorded segment of the clapperboard from each video was used offline with video editing software (Adobe Premiere Pro) to synchronize the looking behavior of the child (from the hidden camera) with the sounds in the booth (from the Panasonic camera). A new video was made that combined the visuals from the hidden camera with the audio from the Panasonic camera. This new video was used in the analysis for prescreening to exclude any trials due to extraneous noise during target word presentation and for coding eye gaze.

Procedure

All infants participated in two experiments, approximately one week apart. Each experimental session tested a different speech condition, IDS or ADS. Two novel label-object pairs were used in each speech type condition and counterbalanced across subjects. To control for label-object bias, half the subjects were presented with dax-nila in the IDS condition, and blick-modi in the ADS condition. The other subjects were presented the novel words in the reversed condition (i.e. blick-modi in the IDS condition, and dax-nila in the ADS condition). The following description applies to both (IDS and ADS) test sessions.

Prior to entering the test booth, the experimenter asked the parent to keep the child seated on his/her lap facing the TV monitor and to not provide instructions or interact with their child during the course of the experiment. The parents were also instructed to wave their hands in front of the camera if they wanted to stop the experiment. The caregiver wore headphones and listened to music during the experiment to reduce the potential for bias. The experimenter, located outside the booth, controlled the experiment. Each experiment consisted of two phases, a training phase and a test phase. **Figure 3-2** shows an example of the visual and linguistic stimuli used in the experiment. The training phase consisted of 12 training trials (6 trials per novel target, randomized by presentation order) of the novel word-object pairs. Each novel label-object pair was presented in isolation. An attention-getter movie was presented between each training trial to reengage the child's attention to the screen. The next trial was presented when the child was engaged in the attention-getter movie. The testing phase consisted of 36 trials, 8 per novel word, 4 for each familiar word, and 4 filler trials used to maintain the child's attention. There were 2 pseudo-randomized testing orders; no label was presented twice in succession; each object was presented on the left and right sides an equal number of times; and the target object did not appear on the same side more than 3 trials in a row. The entire experiment lasted 5-6 minutes.

Coding Eye Movements

Editing the Video Recordings

In order to appropriately code for eye movements in reference to the stimuli presented, two video recordings (the video of the child's eye gaze recorded in iMovie and the audio/video recording from Panasonic camera) were used. The two video recordings were exported and subsequently screened and edited in Adobe Premiere Pro. The audio/video from the Panasonic camera was viewed to ensure the correct speech stimuli were presented through the loudspeaker and the correct visual stimuli were presented on the screen. After viewing the video from the Panasonic camera, the video of the child's eye gaze and the audio from the Panasonic video were synchronized, using the clapperboard information previously recorded on the two videos. A single new video was created with audio and the child's eye gaze. The new movie was trimmed to when the experiment started and contained the child's eye gaze, the timestamp, the PIP information slide, and the audio captured from the booth during the experiment. The new video was used for analysis to code the eye movements.

Training the Coders

The custom software iCoder, developed in Anne Fernald's laboratory at Stanford University (Fernald et al., 2008), was used to code the eye movements from the videos made during the experiment. The primary researcher for the study, who was trained at the Stanford University laboratory, trained and supervised two research assistants to code eye movements using the iCoder software. After several weeks of training and practice, the research assistants, unaware of the study's hypotheses, assisted in coding the data for the study. Each coder was required to judge whether the child was looking at the left picture, the right picture, or off of either picture, i.e., when the child is shifting gazing between the two pictures or looking elsewhere in the room. The coder indicates the eye gaze position frame-by-frame.

Pre-Screening for Codeable Trials

The videos were prescreened using the iCoder to flag any trials that were deemed non-useable due to factors unrelated to the auditory and visual stimuli (e.g. extraneous noise or inattentive behavior). The reason for elimination was noted in iCoder. Two coders, blind to the side of the target presentation, independently watched each testing session in real time with the sound on. Trials were eliminated for the following reasons: 1) the child did not look at either picture before target onset; 2) the parent or the child was talking during target presentation; 3) the child was fussy or inattentive; 4) the child's eyes were not visible after sound onset; 5) equipment malfunctioned during the trial; or 6) the trial was aborted because the experiment ended before all the trials were presented.

If the pre-screeners did not agree on all useable and non-useable trials, the primary researcher viewed the video to determine if the trial should be coded.

Coding Eye Movements

The iCoder software was used for coding child eye movements. The coding was done without sound, by the coders, blind to trial type (novel versus familiar) and side of target presentation. An information slide shows the condition (IDS or ADS), the subject's code number, the phase (training or trial), and the trial number. For each test trial, coders analyzed the child's eye gaze and indicated when a change in eye gaze response occurred. The position of the child's eyes was indicated, i.e., oriented to the left picture, the right picture, or off from either picture. The coded information, i.e. the trial number, trial status (on/off), eye gaze response (right, left, or off), and the timecode associated with each entry is displayed in iCoder.

When the coding was completed for the entire study, the iCoder data was compiled using the custom software Datawiz, which was developed in the same laboratory as the iCoder. The iCoder data was combined in Datawiz with test order files, which contained other relevant information about the trials (e.g. onsets and offsets of the target words, identity of target type and side of presentation for each trial). The output generated by Datawiz, referred to as the iChart, was used for analysis.

Reliability Coding

Reliability coding was done to ensure coding was consistent across coders. The reliability criteria used in the present study was similar to previous studies using this method of coding (Fernald et al., 2008; Grieco-Calub et al., 2009). To assess inter-coder reliability, 25% of the data were coded by a second coder and their results were compared. Two scores were obtained for each comparison: 1) an entire-trial agreement score and 2) a shift-specific agreement score. An entire-trial agreement score, based on the percentage of time in which both coders agree on the same event occurring on the same frame or differing by no more than a single frame, was set at 95%. In the present study 98.8% of entire-trial agreement was obtained. Because this score includes a majority of consecutive frames where the child is likely fixated on one event, there is a likelihood of high agreement between coders. A shift-specific reliability score, which gives a more rigorous reliability check than the entire trial reliability, was done as well. This score is a percentage of frames from shift start to finish on trials with 3 or more shifts, differing by only one frame. The reliability for this measure was set at 90%. In the present study 96.7% of shift-specific reliability was obtained. The primary researcher examined the coding data and made the final decision about the gaze patterns when discrepancies between coders indicated a score below the set criteria. The coders were re-trained for judging eye gaze patterns when the scores were below the standards set.

Dependent Measures

Children's looking behavior in response to speech stimuli under various conditions was assessed using measures of accuracy and latency to orient to a matching picture following the spoken target word. On each trial, at the onset of the target word, the children were looking at the nontarget picture (nontarget-initial trials) about half the time, whereas about half the time they were looking at the target picture (target-initial trials). For a correct response on nontarget-initial trials, the children would shift eye gaze to the target picture upon hearing the target word. The correct response on target-initial trials was to continue fixation on the target picture with no shifts of eye gaze. The time window used to measure responses to the spoken stimuli was 300 – 1800 ms following the onset of the target word for all nontarget- and target-initial trials. This time window was chosen based on the age of the subjects (Fernald, Perfors, & Marchman, 2006; Fernald et al., 2008; Fernald et al., 1998) and the complexity of the task. Previous research indicates shifts occurring before 300 ms would not be in response to hearing the target word because the children would not have time to process the spoken word and have time to make adjustments of their eye gaze (Fernald et al., 2008). The end of the time window (1800 ms) was chosen based on an analysis of the reaction time of the initial shift of eye gaze, as has been done in previous studies (Fernald et al., 2008; Fernald et al., 2006), from the HI group's ADS condition. A histogram of data from the current study (see **Figure 3-4**) revealed that responses after 1800 ms were considered to be outliers, thus, less clearly a response to the target word.

Accuracy

Accuracy represents how reliably children looked at the correct picture, based on the mean time spent looking at the target picture, as a proportion of the total time spent on either the target or the nontarget picture (i.e., [looking time to target]/[total looking time to target + nontarget]), within the 300-1800 ms time window. The accuracy measure includes both target- and nontarget-initial trials. Included in nontarget-initial trials are trials in which the child was not looking at either picture at target word onset (i.e., 'away' events). These events were counted as nontarget-initial trails. Thus, regardless of the child's eye gaze at target word onset, all useable trials were included in the accuracy analysis. Mean accuracy measures were computed for each participant on each trial type as the mean proportion of time looking to the target divided by the mean proportion of time looking to the target or to the nontarget [i.e. (looking time to target) / (total looking time to target + nontarget)].

Reaction Time

Reaction time (RT) represents the latency to orient to the target word from the nontarget between word onset and first eye movement to target within the 300-1800 ms time window. Because the RT measure can only be calculated when the child is looking
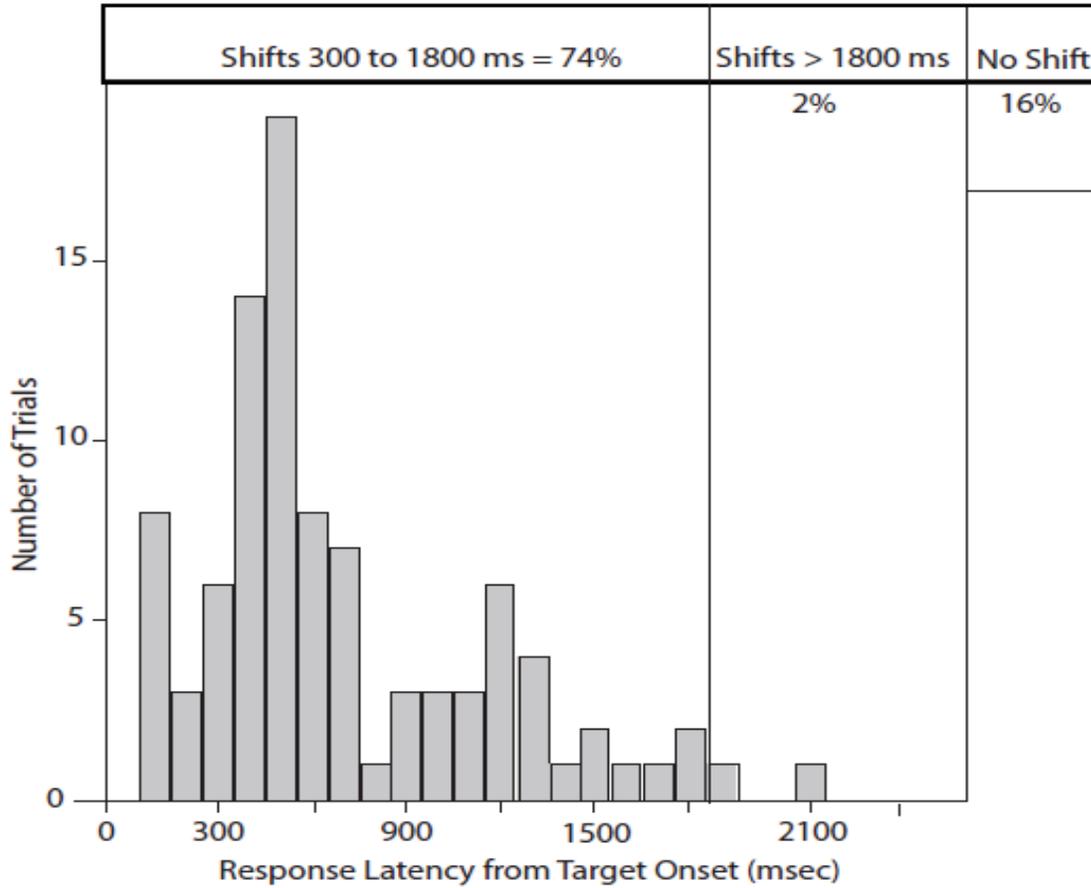
Figure 3-4. **Distribution of reaction times of first shifts from nontarget to target**
The measurement for reaction time from word onset to the first shift from the nontarget to the target picture for the HI group in the ADS condition is shown.

at the nontarget picture at target word onset, target-initial trials and trials when the child is looking at neither picture (away-initial trials) are not used in the RT analysis.

CHAPTER 4. RESULTS

Familiar Words

Accuracy

As a reminder, mean accuracy measures were computed for each participant on each trial type as the mean proportion of time looking to the target divided by the mean proportion of time looking to the target or to the nontarget [i.e. (looking time to target) / (total looking time to target + nontarget)]. Results showed mean accuracy for the CHL in IDS was 78% (SD = 10%) and in ADS was 66% (SD = 16%); mean accuracy for the CNH in IDS was 78% (SD = 12%) and in ADS was 81% (SD = 10%).   A one-sample t-test revealed a significant difference from chance level (.05) for each group in each condition, indicating that each group recognized the target word above chance levels; CHL: [IDS ($t(10)$ = 9.16, p < .001, d = 2.76) and ADS ($t(10)$ = 3.343, p < .001, d = 1.01], CNH: [IDS: ($t(10)$ = 7.905, p < .001, d = 2.38); ADS: ($t(10)$ = 10.811, p < .001, d = 3.26)]. **Figure 4-1** shows an overview of the mean change in fixation to the target object at each frame (33 ms interval) by the CHL and CNH for each speech type condition.

A two-way mixed design ANOVA was used to test for differences in accuracy of word recognition for each speech type (IDS and ADS, repeated measures) between the two groups (CHL and CNH). No main effect for group was found, F(1, 20) = 3.538, p = .075, partial eta-squared = .15. No main effect for speech type was found, F(1, 20) = 1.769, p = .198, partial eta-squared = .81. A significant interaction of speech type by group was found, F(1, 20) = 5.957, p = .024, partial eta-squared = .229, indicating group differences depend on speech condition. To better understand the speech type by group interaction, independent t-tests were performed for each speech type. A significant difference between groups was found in the ADS condition, (independent $t(20)$ = -2.739, p = .013, d = -1.1679), indicating the CNH had higher accuracy (M = .8124, SD = .0958) than the CHL (M = .6596, SD = .1583). as shown in **Figure 4-2**. In addition, paired t-tests were performed to compare speech type for each group. For CHL a significant difference between speech types was found (paired $t(10)$ = 2.232, p = .050, d = .67), indicating the CHL had higher accuracy in IDS (M = .7769, SD = .1003) than in ADS (M = .6596, SD = .1583). No significant difference was found between speech types for the CNH.

Reaction Time

A two-way mixed design ANOVA was used to test for differences in speed of word recognition (RT) for each speech type (IDS and ADS, repeated measures) between the two groups (CHL and CNH). A marginal main effect for group was found, F(1, 18) = 3.725, p = .07, partial eta-squared = .171. No main effect for speech type was found, F(1,
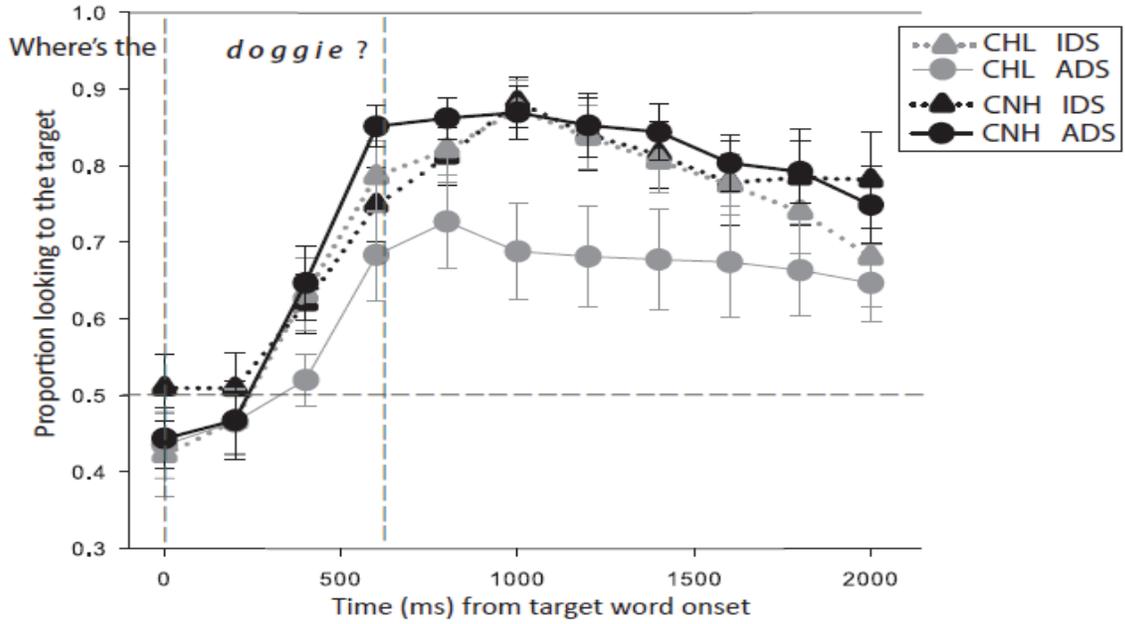
Figure 4-1.   Profile plot for familiar words
Gray symbols represent the CHL group responses and black symbols represent the CNH group responses. Triangles represent responses to IDS and circles represent responses to ADS. The dashed horizontal line represents the 50% chance level. The dashed vertical lines represent the beginning and ending of the target word. Error bars represent standard error over participants.
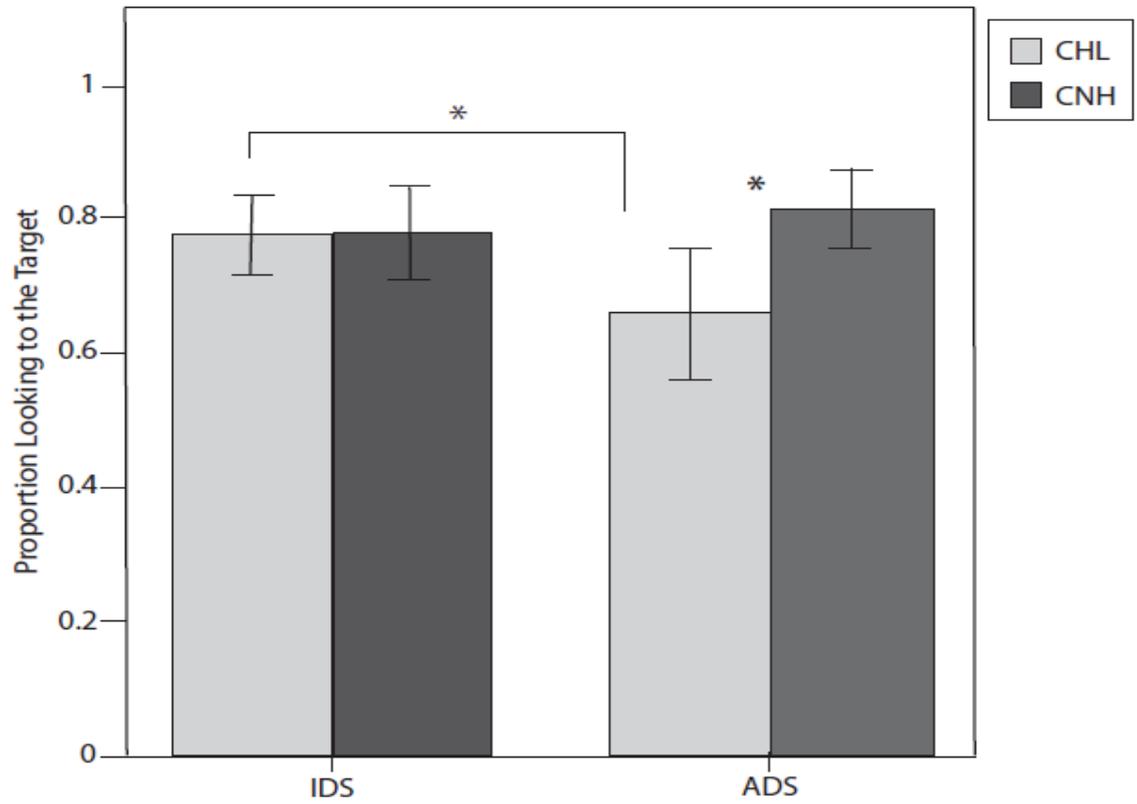
Figure 4-2. **Comparison of familiar word mean accuracy for IDS and ADS**
Error bars represent $\pm\, 2$ standard errors. Asterisk (*) represents significant difference ($p \leq .05$).

18) = .257, *p* = .619, partial eta-squared = .014. A significant speech by group interaction was revealed, F(1, 18) = 5.488, *p* = .031, partial eta-squared = .234. To better understand how CHL compared to CNH, independent t-tests comparing group differences were performed for each speech type. Significant differences between groups were found in the ADS condition (independent *t*(19) = 3.107, *p* = .009, *d* = 1.33), indicating CNH showed faster RT (*M* = 440 ms, *SD* = 82.31) than CHL (*M* = 703 ms, *SD* = 266.66), as shown in **Figure 4-3**. RT did not differ between groups for IDS (independent *t*(19) = .279, *p* = .078).

In addition, planned comparisons were done to better understand the difference in performance between speech types for each group. For CNH a paired t-test comparing IDS RT and ADS RT revealed a significant difference between speech types (paired t(9) = 3.793, p = .004, d = 1.2, indicating the CNH had a faster RT in ADS (440 ms, SD = 82.31) than in IDS (577 ms, SD = 129.43). No significant difference between speech types was found for the CHL (paired t(9) = -.991, p = .348).

Correlations Between Accuracy and RT in Familiar Word Processing

To examine how accuracy and RT were correlated within speech type, Pearson's correlations were performed. Accuracy in IDS was not significantly correlated with RT in IDS for CHL (*p* = 0.1) nor for CNH (*p* = .15). Accuracy in ADS was not significantly correlated with RT in ADS for CHL (*p* = .09) nor for CNH (*p* = .15). To examine whether word processing in IDS is correlated with word processing in ADS, Pearson's correlations were performed. No significant correlations were found for either CHL or CNH.

Novel Words

To ensure against object bias in the novel condition, a comparison of the novel objects used in the counterbalanced conditions was made to determine if there were any preferences for any of the test objects.   An object bias was defined as a preference for one particular object over its matched pair if, before target word onset, it was looked at more than 75% of the time across all trials (Graf Estes, Edwards, & Saffran, 2011). No object bias was found for the CHL and CNH by examining the children' looking behavior before the onset of the target word on all novel object test trials (see **Table 4-1**).

Accuracy

As a reminder, mean accuracy measures were computed for each participant on each trial type as the mean proportion of time looking to the target divided by the mean proportion of time looking to the target or to the nontarget [i.e. (looking time to target) / (total looking time to target + nontarget)]. Results showed mean accuracy for the CHL in IDS was 66% (*SD* = 10%) and in ADS was 57% (*SD* = 8%); mean accuracy for the CNH
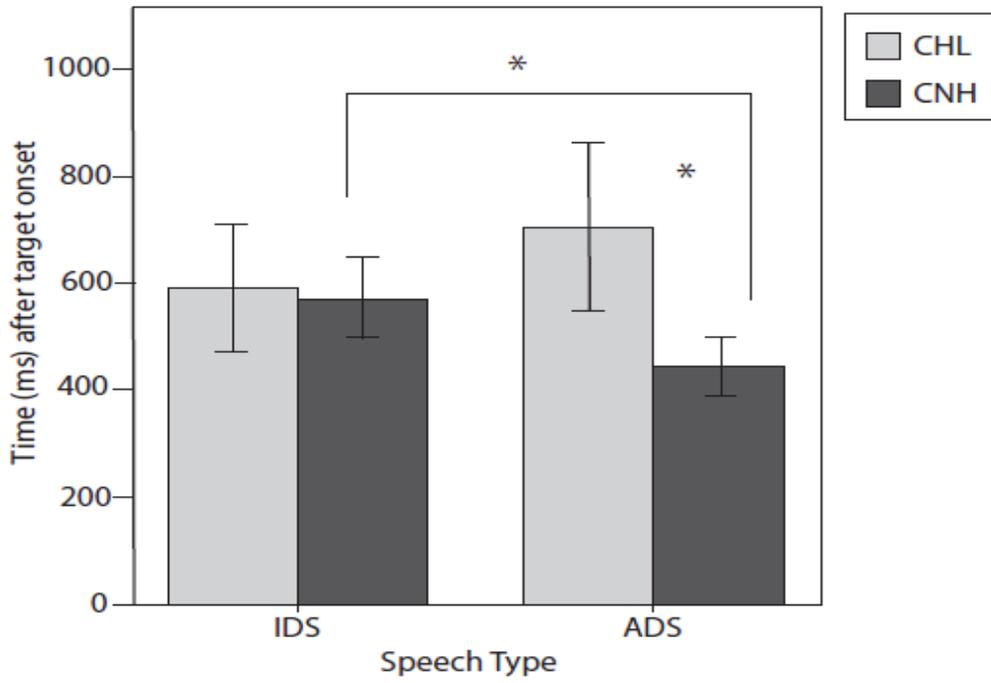
Figure 4-3. **Mean RT in IDS and ADS for familiar words**
Error bars represent ± 2 standard error. Asterisk (*) represents significant difference ($p <$ .05).

Table 4-1.   **Object preference analysis**

Condition	CHL Group		CNH Group	
	IDS	ADS	IDS	ADS
Test Condition 1				
modi	39.95%	41.27%	34.51%	41.43%
blick	41.71%	42.91%	41.46%	37.52%
off	18.33%	15.82%	24.03%	21.05%
Test Condition 2				
dax	43.40%	39.53%	39.28%	33.91%
nila	38.67%	41.00%	42.05%	35.98%
off	17.94%	19.47%	18.67%	30.11%

Note: The percentage of look time for each object and off look times represent the look time from picture onset to target word onset.

was 65% (*SD* = 16%) and in ADS was 69% (*SD* = 16%). A one sample t-test revealed that response accuracy was significantly higher than chance level (.05) for each group in each condition, indicating that both groups learned the word-object association for the novel words; CHL: [IDS (*t*(9) = 3.6593, *p* = .005, *r* = 0.77) and in ADS (*t*(10) = 2.9914, *p* = .01, *r* =0.69)], CNH: [IDS: (*t*(10) = 2.232, *p* = .05, *r* = 0.58); ADS: (*t*(10) = 3.9372, *p* = .003, *r* = 0.78)]. **Figure 4-4** illustrates above chance responses and shows the time course of looking to the target as the speech stimuli was spoken for the two groups, with separate curves for IDS and ADS.

Mean accuracy for the CHL in IDS was 66% (SD = 14%) and in ADS was 57% (SD = 8%); mean accuracy for the CNH in IDS was 65% (SD = 16%) and in ADS was 69% (SD = 16%), as shown in **Figure 4-5**. A two-way mixed design ANOVA was used to test for differences in accuracy of novel word recognition for each speech type (IDS and ADS, repeated measures) between groups (CHL and CNH). No significant main effects were found for group, F(1, 19) = 1.291, *p* = .270, partial eta-squared = .064, or for speech type, F(1, 19) = .417, *p* = .526, partial eta-squared = .021. No significant speech type by group interaction was found, F(1,19) = 2.619, *p* = .122, partial eta-squared = .121

Reaction Time

Measures of RT included only trials in which the child was looking at the nontarget picture at the onset of the target word. In addition, each participant needed to contribute 3 trials to be included in the analysis. Thus, the total number of participants included were CHL (*n* = 6) and CNH (*n* = 5). A two-way mixed design ANOVA was used to test for differences in speed of novel word recognition (RT) for each speech type (IDS and ADS, repeated measures) between the two groups (CHL and CNH). A main effect for group was found, F(1, 9) = 5.381, *p* = .046, partial eta-squared = .374. No main effect for speech type was found, F(1, 9) = .016, *p* = .903, partial eta-squared = .002. No speech by group interaction was found, F(1, 9) = .001, *p* = .972, partial eta-squared = <.01. To explore the differences between groups, a t-test comparing the mean RT (collapsed across speech types) for the two groups was performed, *t*(31) = 2.322, p = .027. A significant difference between groups was revealed, as shown in **Figure 4-6**, suggesting the CNH had faster RT (*M* = 629 ms, *SD* = 233.2) than the CHL (*M* = 819 ms, *SD* = 238.634).

Correlations Between Accuracy and RT of Novel Words

To examine the correlation between the two word processing measures, accuracy and RT, Pearson correlations were performed for each group in each speech type. For CNH a significant correlation was found between IDS accuracy and IDS RT measures (*r* = -.856, *p* = .014) and between ADS accuracy and ADS RT measures (*r* = -.797, *p* = .010). For CHL no significant correlations were found in IDS accuracy and IDS RT measures (*p* = .982) or in ADS accuracy and ADS RT measures (*p* = .249).
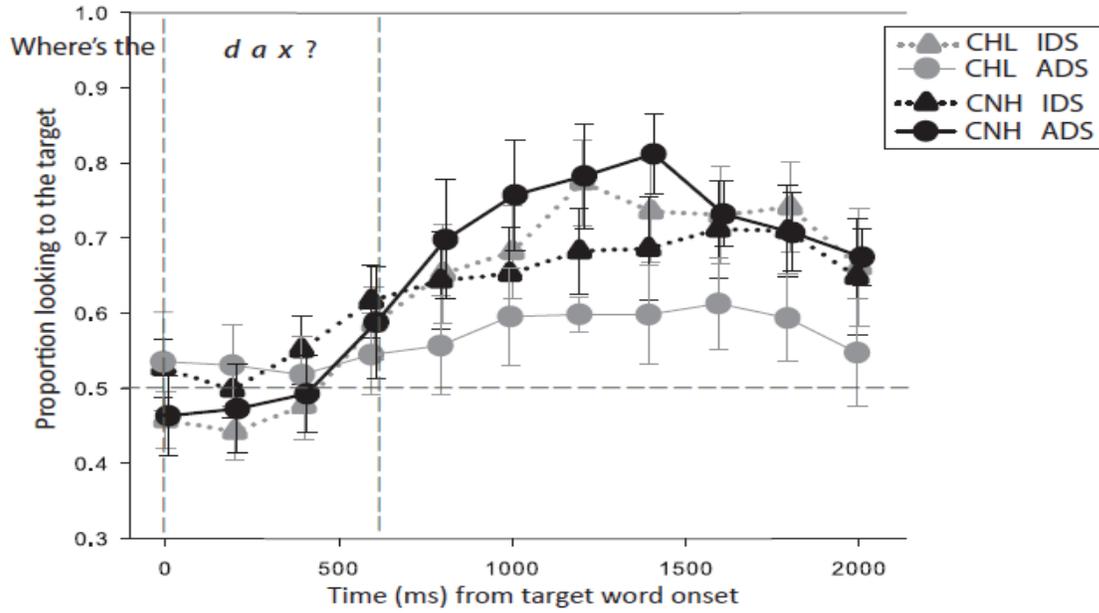
Figure 4-4.   Profile plot for novel words
Gray symbols represent the CHL group responses and black symbols represent the CNH group responses. Triangles represent responses to IDS and circles represent responses to ADS. The dashed horizontal line represents the 50% chance level. The dashed vertical lines represent the beginning and ending of the target word. Error bars represent standard error over participants.
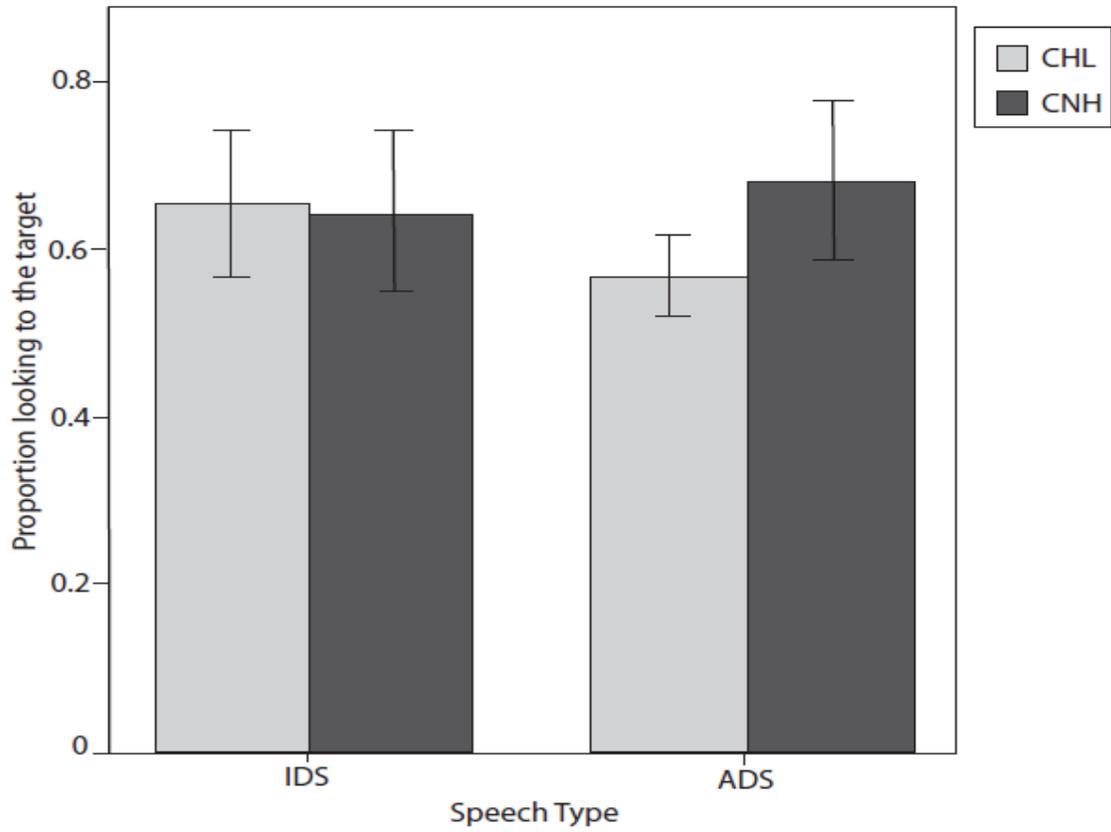
Figure 4-5.   Mean accuracy in IDS and ADS for novel words
Error bars represent $\pm$ 2 standard errors.
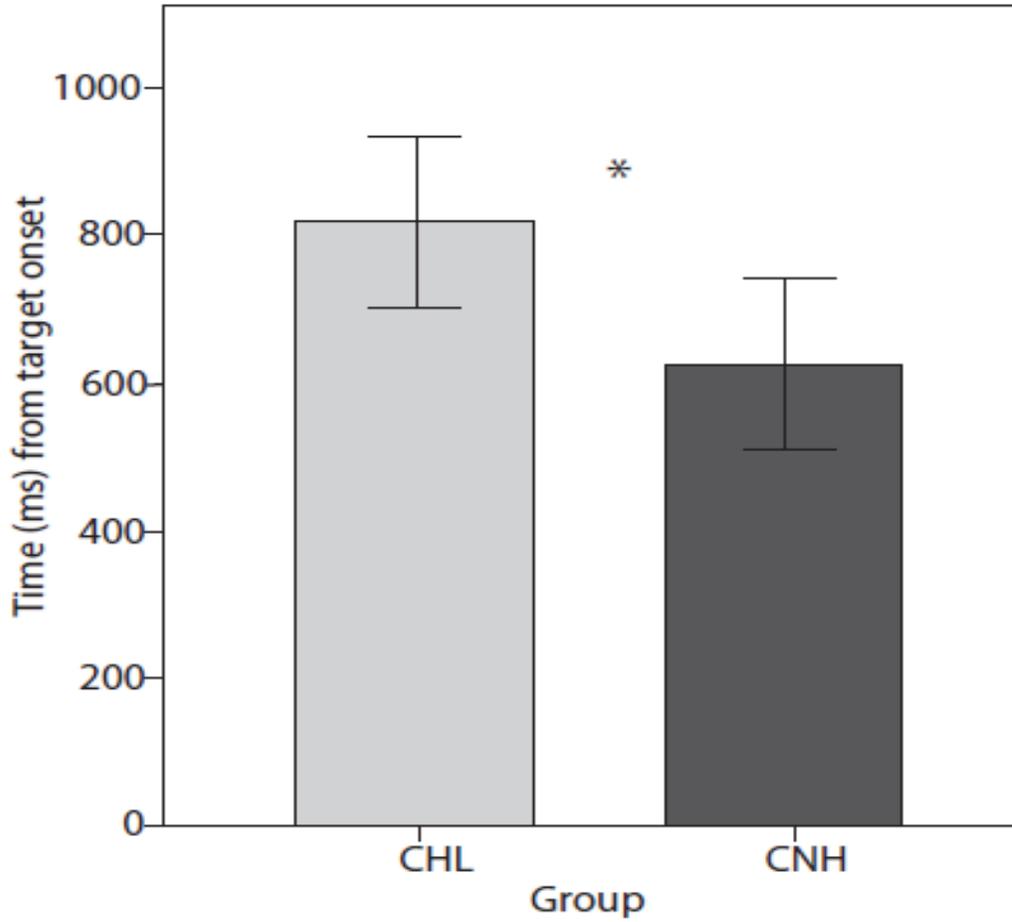
Figure 4-6.   Mean RT for novel words for CHL and CNH
Error bars represent ± 2 standard errors. Asterisk (*) represents significant difference (*p* < .05).

To examine whether word processing measures in familiar word processing were related to novel word processing Pearson correlations were performed for each speech type. No significant correlations were found for either group

Correlations Between Word Processing and Vocabulary

The CNH had marginally significantly higher vocabulary scores ($M = 558.5$, $SD = 98.5$) than the CHL ($M = 406$, $SD = 233.4$), [$t(20)= -1.996$, $p =.06$, $d =.8511$]. Individual scores are shown in **Figure 4-7**. To test the hypothesis that vocabulary size is correlated with word processing, Pearson correlations were performed for each group separately. Specifically, the MCDI expressive vocabulary raw scores for each group were correlated with reaction time and accuracy measures for novel and familiar words in each of the speech types. The results are shown in **Table 4-2**.

Children with Hearing Loss (CHL)

Vocabulary scores were significantly correlated with RT for familiar words in IDS but not novel words (see **Figure 4-8**); $r(10) = - .736$, $p = .015$, suggesting that children with larger vocabularies had faster RT for speech processing of familiar words in IDS than children with smaller vocabularies. A marginally significant correlation was found with RT for familiar words in ADS (see **Figure 4-9**; $r(11) = - .578$, $p = .062$), suggesting a larger vocabulary may provide an advantage in familiar word processing in the ADS condition. There were no significant correlations between vocabulary size and novel word processing for IDS or ADS.

Children with Normal Hearing (CNH)

Vocabulary scores were marginally correlated with accuracy for novel words in ADS (see **Figure 4-10**); $r(11) = .591$, $p = .055$, suggesting that children with larger vocabularies had higher accuracy for speech processing of novel words in ADS than did children with smaller vocabularies. A marginal significant correlation was found with RT for novel words in ADS (see **Figure 4-11**; $r(9) = - .619$, $p = .075$), suggesting a larger vocabulary may provide an advantage in novel-word processing in the ADS condition. There were no significant correlations between vocabulary size and familiar word processing for either IDS or ADS.

Because the sample size in each group is rather small the data were pooled across groups and the correlations re-examined. The results of that analysis are shown in graphical form **Table 4-3**, and suggest that when the data are pooled only two correlations emerge as being significant. Specifically, only Familiar RT for IDS and ADS emerge as significant. It is likely that these correlations are reflecting the results for the HI group.
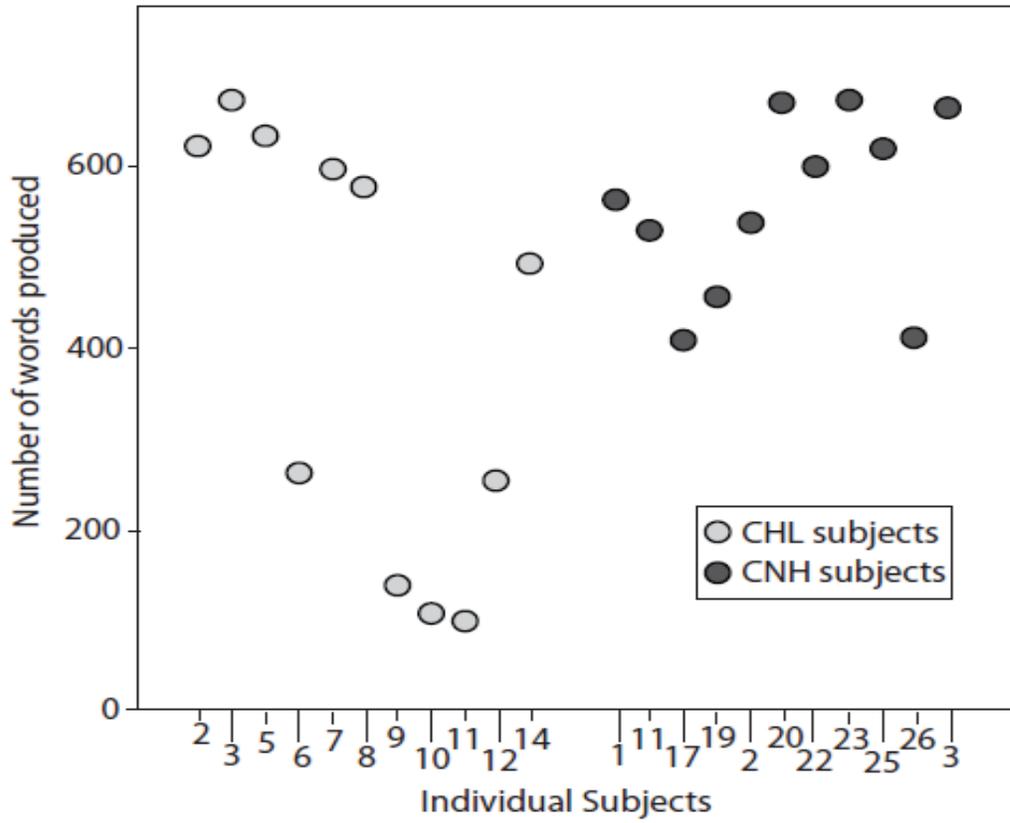
Figure 4-7. **Vocabulary scores for the CHL and CNH**

Table 4-2. Individual group correlations with vocabulary

Variable	CHL Group		CNH Group	
	r	*p*	*r*	*p*
IDS				
Familiar Accuracy	0.336 (11)	.312	.141 (11)	.679
Familiar RT	-0.736 (10)	.015*	-.077 (11)	.822
Novel Accuracy	-.017 (10)	.963	-.048 (11)	.888
Novel RT	-.393 (9)	.296	.165 (7)	.724
ADS				
Familiar Accuracy	.188 (11)	.579	.191 (11)	.574
Familiar RT	-.578 (11)	.062	.153 (10)	.673
Novel Accuracy	-.170 (11)	.617	.591 (11)	.055
Novel RT	-.032 (8)	.940	-.619 (9)	.075

Notes: The number of subjects used in the correlation is in parentheses. * denotes significance at the .05 level (2-talied).
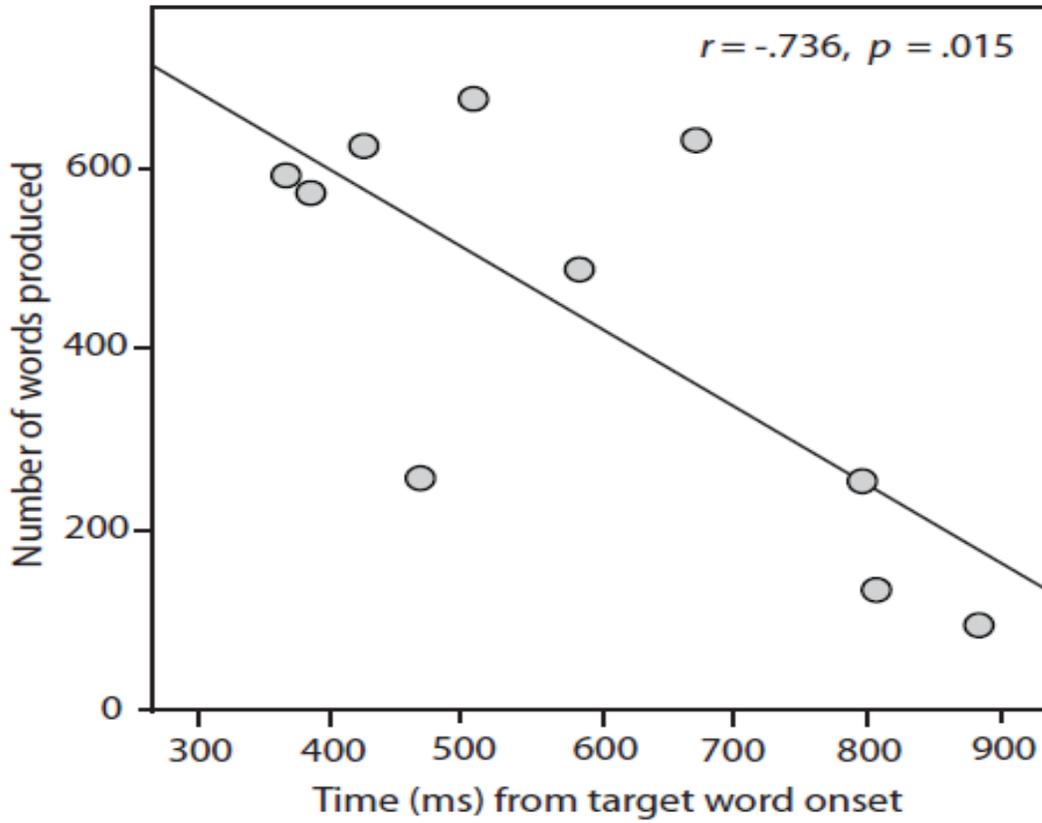
Figure 4-8.   **Correlation between vocabulary size and RT for CHL in IDS familiar words**
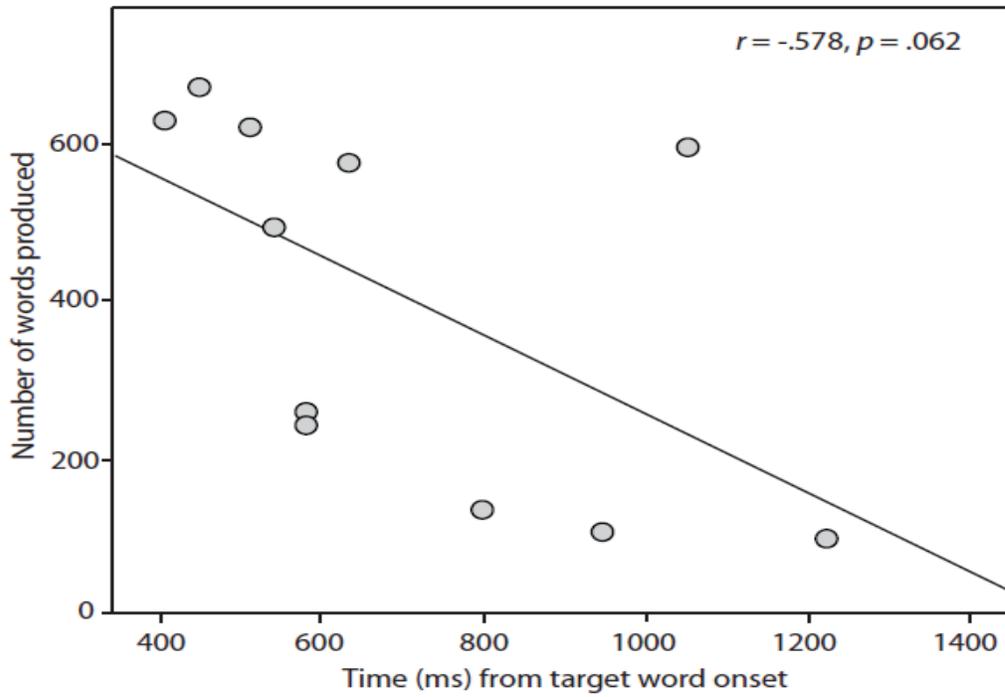
Figure 4-9. **Correlation between vocabulary and RT for CHL in ADS familiar words**
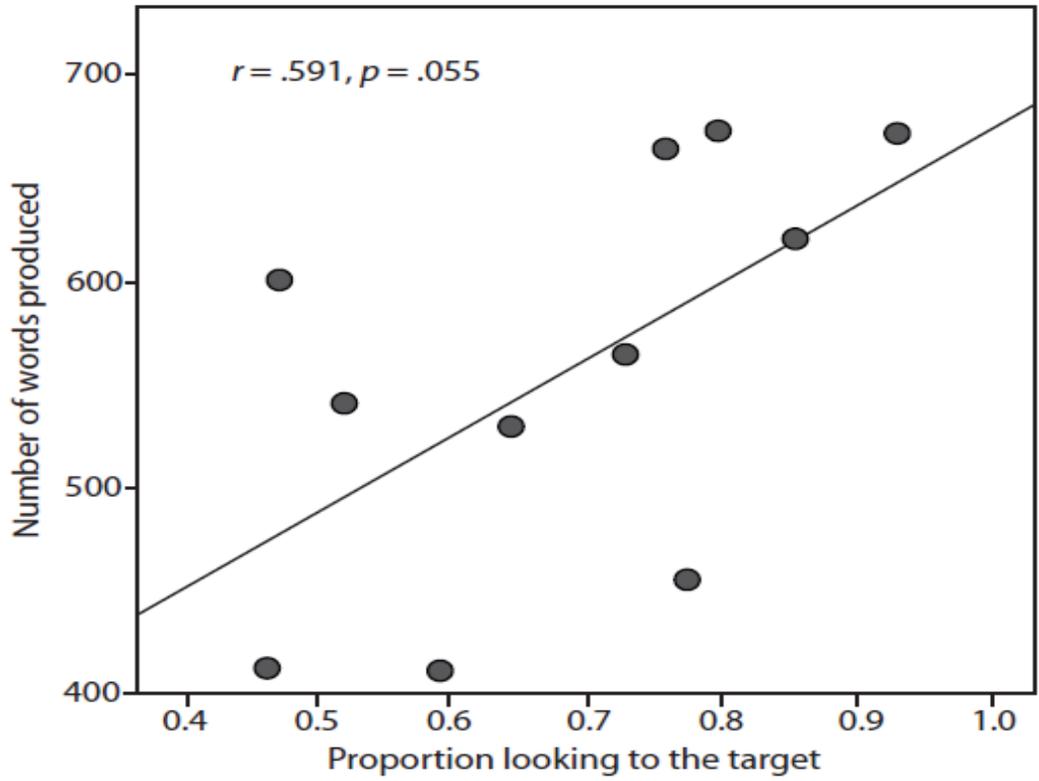
Figure 4-10. Correlation between vocabulary and accuracy for the CNH in ADS novel words
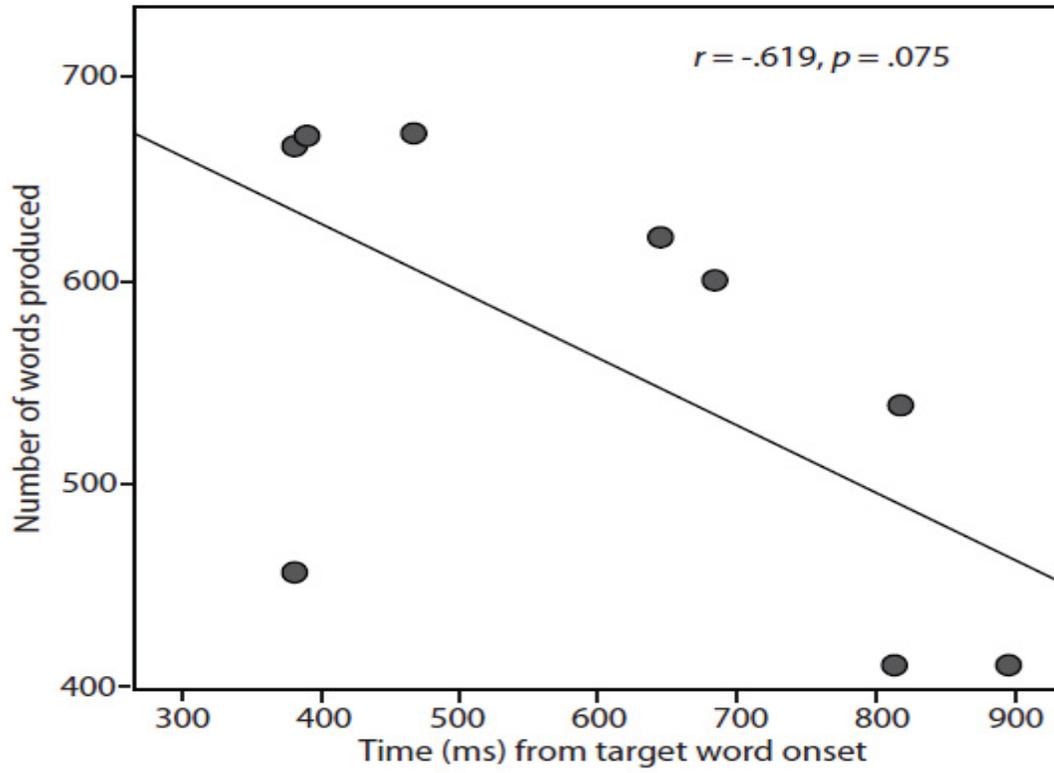
Figure 4-11. **Correlation between vocabulary and RT for the CNH in ADS novel words**

Table 4-3.   **Combined group correlations with vocabulary**

Variable	N	Pearson Correlation	*p* value
IDS			
Familiar Accuracy	22	.224	.316
Familiar RT	21	-0.552	.010*
Novel Accuracy	21	.063	.788
Novel RT	16	-.313	.238
ADS			
Familiar Accuracy	22	.358	.101
Familiar RT	21	-.596	.004**
Novel Accuracy	22	.288	.194
Novel RT	17	-.433	.082

Notes: * Correlation is significant at the .05 level (2-tailed). ** Correlation is significant at the .01 level (2-tailed).

Correlations Between Other Variables Related to Hearing Impairment

Aided speech intelligibility index (SII) measures were used to assess audibility. Aided SII measures were available for 7 children who used hearing aids. Novel word accuracy in IDS and familiar word RT in IDS were significantly correlated with SII (r =.825, p = .043; r = -0.943, p = .005, respectively), and familiar word accuracy in IDS was marginally correlated with SII (r = .742, p = .056). The results indicated that children with higher SII measures had higher accuracy and faster RTs than children with lower SII measures.

Amplification device did not correlate with accuracy or RT in IDS or ADS, perhaps due to the small sample size of CI users (n = 3). However, a comparison of performance of the CI group with the HA group revealed the HA group's mean RT in the novel IDS and familiar ADS conditions were 2 standard deviations slower than the RT of the CI group. In addition, the HA group showed 2 standard deviations poorer accuracy for familiar words in ADS.

A comparison of hearing age differences revealed no significant correlations accuracy or RT in IDS or ADS. An analysis of the relationship between hearing age and expressive vocabulary in the CHL revealed no significant correlation (r = .288, p > .05).

CHAPTER 5.   DISCUSSION

Relatively little is known about how young children with hearing loss process words. The Emergentist Coalition Model (ECM) of early word learning proposes that a multi-source, coalition of cues (e.g. perceptual, social, and linguistic) are used by early word learners, and that the emphasis on various cues changes across development. Because hearing loss influences speech perception, different word learning patterns may emerge in CHL relative to CNH. One perceptual cue used by young children to bolster word learning is infant-directed speech (IDS). In CNH, 21-month-olds can learn words in IDS but not in ADS; however, by 27 months children can also learn words in ADS (Ma et al., 2011). Currently, it is unknown how CHL process words in IDS and ADS. This study examined how children process words in IDS and ADS. A LWL paradigm was used (Fernald et al., 2008). Two components of word processing (accuracy and RT) were measured in familiar word recognition and novel word processing in a group of CHL and CNH matched for age, gender, and SES. The predictions were: 1) CNH would show faster reaction time (RT) and higher accuracy than CHL, 2) word processing may show different patterns for familiar versus novel words, and 3) vocabulary size would be correlated with word processing skills. Start text or a 1st Level Head on this line.

Familiar Word Processing

Familiar word processing was tested because we wanted to determine how speech type affected word processing when processing demands were minimal. Based on previous research with CHL and CNH in a familiar word recognition task in IDS (Grieco-Calub et al., 2009), we predicted that hearing loss would affect word processing, thus, the CNH would show higher accuracy and faster reaction time. In addition, we expected that the CNH would be able to process familiar words in ADS, based on Ma et al.'s findings (2011) that CNH at 27 months could learn novel words in ADS. Since no previous research has investigated word recognition in ADS with CHL, it was difficult to predict their ability to process words in ADS. The ECM theory suggests that as children acquire more experience with language they become less reliant on perceptual cues such as the exaggerated prosody cues present in IDS; however, how much language experience is needed before a difference is seen is unknown. Compared to their NH peers, CHL typically have smaller vocabularies (Geers, Moog, Biedenstein, Brenner, & Hayes, 2009; Hayes, Geers, Treiman, & Moog, 2009; Johnson & Goswami, 2010) and show slower rates of vocabulary growth (Blamey et al., 2001). Thus, the CHL may continue to rely on IDS to provide cues in word processing.

Results of the present study suggest that the CNH were more efficient at word processing than the CHL; however, this finding was dependent on speech type. In the IDS condition children in the CHL were highly accurate (78%, $SD = 10$%) and showed a similar pattern as the CNH (78%, $SD = 12$%). Reaction times were similar as well for the two groups, (CHL: $M = 590$ ms, $SD = 189$; CNH: $M = 571$ ms, $SD = 124$). These findings are consistent with previous results showing that when listening to IDS, CHL

and CNH (ages 24-31 months) achieve 75–85% accuracy in familiar word recognition (Grieco-Calub et al., 2009; Zangl, Klarman, Thal, Fernald, & Bates, 2005). Grieco-Calub et al. (2009) used the same LWL procedure and the same familiar words (ball, shoe, baby, and doggie) to test familiar word recognition in IDS. Their study examined word processing in a group of CHL who used cochlear implants ($M = 31.3$ months) and an age-matched NH group. The HI group in their study had a very similar accuracy score (70%, $SD = 13\%$) compared to the HI group in our study (78%, $SD = 10\%$). A comparison of RT measures between the two studies could not be done due to different response time windows used for the two studies. Grieco-Calub et al. used a response time window of 367-2000 ms, whereas the time window used in the present study was 300-1800 ms.

In the ADS condition, a different pattern emerged in a comparison of the HI and NH groups on accuracy and RT measures. As predicted by our hypothesis, accuracy was poorer in the HI group (66%, $SD = 16\%$) compared to the NH group (81%, $SD = 10\%$), and RT was slower for the HI group ($M = 703$ ms, $SD = 267$) than the NH group ($M = 440$ ms, $SD = 82$). The accuracy and RT measures suggest that word processing in ADS is likely to be negatively affected for CHL compared to their NH peers. It is noteworthy that the HI group, on average, recognized the familiar words in the ADS condition significantly above chance ($p < .01$), thus demonstrating their ability to process familiar words without the reliance on the exaggerated perceptual cues present in the IDS condition. This finding suggests that the CHL may be on their way to developing a similar pattern of word processing as their NH peers. For the CHL at this stage of development, the exaggerated perceptual cues present in IDS are salient and thus enhance word processing; however, the CNH appear to have more facilitated word processing in the ADS condition.

The ECM theory posits that as children experience more language, the early attentional and auditory perceptual cues are not as dominant, and children begin to focus on social and linguistic cues. In our study the CHL had a mean hearing age of 18.86 months ($SD = 8.8$), thus differing from their NH peers on the amount of experience listening to language. The results support the ECM theory; the CNH who have more language experience are able to use ADS to facilitate word processing. Additionally, the finding that the CHL were able to process words in ADS above chance levels demonstrate that children use multiple cues in word processing and can shift their reliance on cues present in speech.

Novel Word Processing

Novel word processing was tested because we wanted to determine how speech type affected word processing in a new learning situation as opposed to recognition of familiar words. Based on previous research (Ma et al., 2011), we expected the CNH in our study to show novel word learning in IDS and ADS, however, we were unable to predict the outcome for the CHL. Ma et al. studied novel word learning using IDS and ADS in CNH. They used the IPLP procedure, which is a similar to the LWL procedure; however, the measurement used to determine learning in the IPLP procedure was

different from the measurement used in the present study. In the IPLP study, performance was measured by the single longest look to one of two objects in each trial following the onset of the target word. The means between the longest look to target and longest look to nontarget objects were compared to determine word learning.   In addition, there were reminder trials in the test phase of the experiment to reinforce the word-object associations presented during the training phase. Children at 21 months of age looked longer at the target word in IDS than in ADS. In the same study, 27-month olds were presented with the same novel word learning task in ADS. They showed word learning in ADS. Consistent with Ma et al.'s study, the CNH in our study demonstrated novel word learning in ADS as measured by the proportion of looking time to the target in relation to the total looking time in each trial.

Previous studies have shown that CHL demonstrate novel word learning in word-object association tasks, however, in some instances they show poorer outcomes than age-matched CNH (Houston et al., 2012; Walker & McGregor, 2013). Houston et al. (2012) studied novel word learning in a group of CHL who used CIs (age range 21.7 to 40.1 months). Their experimental design was identical to the procedure and analysis methods used by Ma et al. (2011), with the exception that they only used IDS. Their results revealed that children who received their CIs by 14 months of age, or children who had more residual hearing before cochlear implantation, looked longer at the target object than the nontarget, indicating novel word learning. Children who received their CIs later than 14 months did not look longer to the target object, indicating they were unable to learn the novel word-object associations. Compared to CNH, the early implanted CI group showed novel word learning and did not differ from the CNH, while the later implanted CI group did not demonstrate learning, unlike the CNH. The results indicate that performance for the CI group is dependent on when they received their CIs or how much residual hearing they had before implantation.

In the present study CHL using HAs and/or CIs ($M = 32.4$ months) demonstrated novel word learning in IDS. It is noteworthy that in this study children demonstrated novel word learning without the use of retention trials during the test phase. In addition, the CHL demonstrated novel word learning in the ADS condition as well.

Walker and McGregor (2013) demonstrated that children with CIs learn novel words as well as their vocabulary-matched NH peers. In their study (Walker & McGregor; 2013) word learning was examined in children with CIs (2-6 years of age) using real-time exchanges between the child and the experimenter. Real objects were manipulated by the adult and child throughout the experimental session. Although speech type was not mentioned in the procedures for the experiment, it can be assumed that the experimenter talked in a manner appropriate for children rather than in a speech type meant for adult conversations. In a training session, novel objects were first presented with familiar objects and both, novel and familiar objects were named. Next the novel objects were presented with another novel object and the initial novel object was labeled 3 times using sentential stimuli. After the children were trained on 4 novel word-object pairs, the testing procedure began. The test consisted of the presentation of 2 examples each of 3 novel objects. The children were asked to give the named object to

the experimenter. Three groups of children were tested: children using CIs, age-matched NH peers, and vocabulary-matched NH peers. The results showed that the CI group scored significantly above chance levels, indicating they were able to learn the word-object associations; however, the CI group's performance was marginally poorer than their age-matched NH peers. No difference was seen in performance between the CI group and their vocabulary-matched NH peers. Consistent with Walker and McGregor (2013), the CHL in the present study demonstrated novel word learning; however, no difference between novel word accuracy was shown between their performance and the CNH, even when ADS was used.

While Houston et al. (2012) and Walker and McGregor (2013) used different methods and measurements to assess novel word learning; they both demonstrated novel word learning using IDS in CHL similar in age to the children in the present study. Current results are consistent with the results of these studies showing that CHL demonstrate novel word learning significantly above chance in word-object association tasks. The present study extends the literature, demonstrating that novel word learning is possible in ADS as well as in IDS. However, since word processing was assessed using different measures, we are unable to compare the results to these studies specifically on accuracy and RT measures. In the present study, there were no differences observed on the accuracy measures between speech types or between the CHL and the CNH, indicating CHL were as accurate as CNH at identifying novel words in IDS and ADS. The RT measures revealed the CNH had an overall faster RT than the CHL ($M = 629$ ms, $\pm$ 233 and $M = 819$ ms, $\pm$ 239, respectfully); however, this was not specific to either IDS or ADS. The results of the RT measures suggest the CNH have an advantage in novel word processing compared to the CHL but it is not specific to IDS or ADS. The accuracy and RT measures should be interpreted with caution due to the small sample size; however, the finding that the CHL were able to learn the novel words above chance levels in ADS, as did CNH, was remarkable and extends the literature regarding how CHL compare to CNH in novel word learning tasks.

In summary, in the novel word condition, both the CHL and CNH showed novel word learning in IDS and ADS. For accuracy measures, the two groups appear to use IDS and ADS in similar ways for word processing, regardless of speech type. However, the NH group showed an overall advantage in speed of processing when compared to the HI group, regardless of speech type. These findings are consistent with previous studies that indicate some aspects of novel word processing may be negatively affected by hearing loss (Houston et al., 2012; Walker & McGregor, 2013).

Correlations Between Speech Processing Efficiency and Vocabulary

The ECM theory suggests that young children shift their word processing strategies from attentional cues, such as the exaggerated prosody cues in IDS, to linguistic cues as they gain more experience learning words. Thus, we wanted to explore the relationship between vocabulary size and word processing of IDS and ADS to see if the relationship between word processing and vocabulary development was influenced by

speech type. Based on previous study results we predicted that vocabulary size and familiar word processing may be correlated. However, the results of previous studies did not allow us to predict whether there is any correlation between vocabulary size and novel word processing. To examine the effect of vocabulary size on word processing, we analyzed each group separately.

Familiar Words

Previous studies using looking-time measures have shown a link between early vocabulary growth and spoken word recognition with familiar words (Fernald, Perfors, & Marchman, 2006; Grieco-Calub et al., 2009). Fernald et al. (2006) used a LWL experimental design to study the link between processing efficiency and vocabulary growth in typically developing children from 12 months to 25 months of age. They measured speed and accuracy comprehension of familiar words at 15, 18, and 25 months of age, and measured vocabulary using the MCDI at 12, 15, 18, and 25 months. They found that speed and accuracy measures at 25 months were highly correlated with vocabulary measures from 12 to 25 months, indicating that children who were faster and more accurate in word recognition at 25 months were those children who showed faster and more accelerated vocabulary growth from 12 to 25 months.

Consistent with the Fernald et al. (2006) study, in the present study there was a significant correlation between vocabulary and RT of familiar words in the IDS condition with CHL (r =-0.736, p = .02) and a marginal correlation between vocabulary and familiar word RT in ADS (r =-0.578, p = .06). The relationship between vocabulary size and RT suggests that larger vocabularies were related to faster word recognition in CHL for IDS. In addition, 3 CHL (subjects 9, 10, and 11) had vocabularies below 200 words (below the 20th percentile for their age on the MCDI and more than 1 SD from the mean of the other 8 CHL in the study). Their mean RT measures in ADS in the familiar word condition (M = 990 ms) were more than 2 SD below the mean of the CHL who had higher vocabularies (M = 594 ms). These findings suggest that as young children develop larger vocabularies their word processing becomes more efficient. However, expressive vocabularies did not correlate with accuracy scores for familiar words in IDS or ADS, as has been found in previous research.

Using the same LWL procedures and vocabulary measures as Fernald et al. (2008) and the present study, Grieco-Calub et al. (2009) examined the relationship between familiar word processing and vocabulary measures in a group of children using CIs (M = 31.3 months). Consistent with Fernald et al.'s (2006) results, they found a significant but moderate correlation between vocabulary size and accuracy measures for the children using CIs (r = .489); however, unlike Fernald et al.'s findings, they did not find a correlation between RT and vocabulary measures. The inconsistency in results from the present study and the Grieco-Calub et al. (2009) study may be related to the differences in populations studied and/or the time windows used in the analyses. Even though the mean age was similar between the two studies, (in the present study the mean age was 32.5 months and the Grieco-Calub study was 31.3 months); the mean hearing

age in the present study was 6-39 months compared to 6-25 months in Grieco-Calub et al.'s study. Additionally, the Grieco-Calub et al. study only tested children with CIs. In the present study we had 8 children who used hearing aids and 3 who used CIs. The range of RT measures for in the Grieco-Calub et al. study (500–1200 ms) was greater than the range in the current study (366-805 ms). The time window in the Grieco-Calub et al. study was 367-2000 ms, whereas in the present study the time window was 300-1800 ms. The results of the present study are consistent with the evidence that there is a relationship between word processing and vocabulary; however, with regard to CHL the results from the present study and Grieco-Calub et al. (2009) are inconsistent with whether RT measures or accuracy measures show the best correlation.

In the present study the NH group showed no significant correlations between vocabulary size and familiar word processing for either IDS or ADS. These results are not consistent with the findings from the Fernald et al. (2006) study; however, there are differences in the age range of children between the two studies. In the present study the age range for the NH group was 23–42 months; in Fernald et al. (2006) the age range was 12–25 months. In addition the range of vocabulary scores for the NH group (411-673) in the present study was more restricted than the mean range reported in the Fernald et al. study (9.6–391.7).

Novel Words

Correlation findings for the CHL in the novel condition revealed no correlation between vocabulary and novel word accuracy scores in IDS or ADS. These results are consistent with the results from Ma et al. (2011). Using a similar on-line looking while listening procedure, Ma et al. compared novel word processing with concurrent expressive vocabulary size (measured using the MCDI) in NH 21-month and 27-month olds. For the 21-month-old group the word learning task was either in IDS or ADS. Their results revealed a high correlation between vocabulary size and performance on the word learning task, regardless of speech type, suggesting that 21-month-olds with larger vocabularies were more efficient at the word learning task than children with smaller vocabularies. This is consistent with the relationship shown between vocabulary size and familiar word processing (Fernald et al., 2006). However, at 27 months, there was no correlation between vocabulary size and novel word learning in ADS, indicating vocabulary size was not related to the word learning task performance.

In the present study, the NH group showed a marginal correlation between vocabulary and novel word accuracy in ADS ($r = .591$, $p = .055$). These results are consistent with results from Bion, Borovsky, and Fernald (2013). They studied the relationship between vocabulary development (MCDI) and accuracy on novel word learning using a LWL experimental design in CNH 18-, 24-, and 30-months old. They reported accuracy measures on word processing (in child-directed speech) and expressive vocabulary measures from the MCDI. No correlation between accuracy and vocabulary was seen when all children were included in the analysis. However, when each age

group was analyzed separately the 30-month group showed a significant correlation between vocabulary and accuracy; the other two groups did not.

Unlike Ma et al. (2011) and Bion et al. (2013), in the present study the relationship between vocabulary and novel word RT measures were analyzed. The HI group did not show a correlation between RT and vocabulary in IDS or ADS; however, the NH group showed a marginal correlation between vocabulary and novel word RT in ADS (r = -0.619, p = .075), suggesting that children with larger vocabularies had faster RTs in ADS.

Taken together, the results from these studies show a relationship between vocabulary and word processing measures in novel word processing tasks in some conditions but not other conditions; however, age or possibly the range of vocabulary scores vary too much between studies to accurately make comparisons between the studies. In the present study, the vocabulary range for the NH group was not very large (411-673), thus creating a restriction in the range of scores. In addition, for the HI group 6 children had a range of 494-678 words, while 5 children had a range of 98-264 words, thus there was not an even spread of scores across the group. In general, the current study findings suggest that CNH with larger vocabularies may show more efficient novel word processing.

Other Variables Related to Hearing Impairment

Other factors may contribute to word processing for the HI group, such as the type of amplification device used, hearing age, communication mode, audibility, and degree of hearing loss. In our study, type of amplification device, hearing age, and communication mode did not correlate with word processing proficiency; however, audibility did show a significant correlation. Aided speech intelligibility index (SII) measures were used to assess audibility. Aided SII was available for 7 children who used hearing aids. Novel word accuracy in IDS and familiar word RT in IDS were significantly correlated with SII, indicating that children with higher SII measures had higher accuracy and faster RTs than children with lower SII measures.

Even though amplification device did not correlate with word processing proficiency, perhaps due to the small sample size of CI users, the HA group's mean RT in the novel IDS and familiar ADS conditions were slower than the RT of the CI group. In addition, the HA group showed 2 standard deviations poorer accuracy on familiar words in ADS. Since this is such a small sample size caution is advised in interpreting the results that CIs provide more efficient word processing. However, it should be noted that the CI group had a younger mean chronological age (26.7 months) compared to the HA group (M = 34.6 months) and a shorter mean hearing age (14.3 months) compared to the HA group (M =20.6 months).

A comparison of hearing age differences revealed no significant correlations with word processing measures of accuracy or RT in IDS or ADS, consistent with Grieco-

Calub et al. (2009). However, in the present study, CHL with less than 18 months hearing age (n = 6) performed more than 1 standard deviation slower on RT measures for the familiar words in ADS compared to the children with more hearing age experience, consistent with studies indicating younger children have slower RT than older children (Fernald et al., 2006). An analysis of the relationship between hearing age and expressive vocabulary in the CHL revealed vocabulary and hearing age were not correlated ($r = .288$, $p > .05$). However, Grieco-Calub et al. found a moderate correlation between vocabulary and hearing age in their cohort ($r = .607$, $p = .001$). Two factors make the comparison of findings from these two studies difficult. One, the MCDI measurement tools used in the studies were different. Grieco-Calub et al. used the MCDI Words and Gestures form for the expressive vocabulary inventory, which has a maximum of 396 words. In the present study, expressive vocabulary was measured using the MCDI Words and Sentences, which has a maximum of 680 words. Secondly, the Grieco-Calub et al. study included only CHL using CIs, which show a more significant change in access to speech from pre-CI to CI activation than do the access to speech before intervention with hearing aids in the present study of hearing aid users.

The analysis of other factors associated with hearing loss in this study should be considered with caution due to the small sample of children used for the comparisons. This study was not designed to specifically assess other factors which may play a role in word processing; however, these findings do support other studies indicating multiple factors should be considered when evaluating CHL for risk of delayed language development (Eisenberg, Johnson, Ambrose, & Martinez, 2012; Lederberg, Schick, & Spencer, 2013; Moeller, Tomblin, Yoshinaga-Itano, Connor, & Jerger, 2007).

Other factors related to word processing in young children, including the quantity of speech directed to young children, have been studied as well (Bergeson et al., 2006; Kondaurova, Bergeson, & Xu, 2013; VanDam, Ambrose, & Moeller, 2012; Weisleder & Fernald, 2013). Weisleder and Fernald (2013) studied how quantity of speech input and word processing efficiency at 19 months influences vocabulary development at 24 months for CNH. Their results revealed that the amount of speech input at 19 months is a predictor of vocabulary size at 24 months, and that word processing efficiency at 19 months influences this outcome. In addition, they found the type of speech the children were exposed to matters. Child-directed speech was a significant predictor for vocabulary size, whereas overheard speech directed to another adult was not. These results suggest speech directed to young children influences language development more so than overheard speech. VanDam et al. (2012) utilized full-day audio recordings of children's listening environments to examine whether CHL (24-36 months) received similar amounts of speech input from their caregivers as NH peers. In addition to quantity of speech input (number of adult words), they examined the number of conversational turns between the adult and the child, child language abilities in relationship to maternal input, and limitations in auditory experience due to characteristics of hearing loss than might influence listening experience, including unaided pure tone average thresholds (PTA) and aided SII auditory measures. Their findings revealed the amount of speech and the number of conversational turns were the same for CHL as their NH peers; however, PTA and SII were associated with the amount

of parental speech directed towards them, indicating that children with milder degrees of hearing loss were exposed to more parental speech and conversational turns than children with more severe hearing loss. Finally, Bergeson et al. (2006) and Kondaurova et al. (2013) showed that mothers of young children who receive CIs are sensitive to their infants' listening experience, rather than their age, and modify their speech accordingly. The findings from these studies are supportive of the benefit of IDS versus ADS, and mothers' sensitivity to their child's need for IDS. When caregivers talk to infants and young children they tend to use IDS with younger children and child-directed speech with older children, rather than adult directed speech.

Regarding findings (Weisleder & Fernald, 2013) that indicate the amount of speech input at 19 months is a predictor of vocabulary size at 24 months, and that word processing efficiency at 19 months influences this outcome, CHL are at increased risk due to the amount of time they go without their amplification (Moeller, Hoover, Peterson, & Stelmachowicz, 2009). Caregivers of CHL may be sensitive to listening situations and choose to not attempt verbal communication with their child when listening conditions are less than ideal. For example, while traveling in a car young children ride in the backseat. Communication in this situation with CHL may be more difficult for the caregiver who is driving. Road noise and lack of visual cues would degrade the listening situation for the CHL. In addition, hearing aids are frequently not used when riding in the car to prevent the young child from taking the hearing aid out of their ear and putting it in their mouth, thus contributing to less than ideal situations for communication. Another example of altered communication opportunities is bath time. Bath time typically provides an opportunity for parent-child interaction. However, for CHL it is less than ideal because hearing devices are not worn at bath time, thus creating a degraded listening situation for communication. Caregivers may choose to wait until the listening situation is more conducive for conversation with their children. In addition, CHL show reduced word processing when background noise is present compared to their NH peers (Grieco-Calub et al., 2009), thus leading to less opportunity for communication.

In summary, the complex interplay of factors such as communication mode, audibility, and amount of maternal speech input are not static. Despite these complex interactions, early identification and intervention can maximize the negative consequences of early auditory deprivation on vocabulary and language development by examining the individual differences seen in CHL. Evidence is building that suggests that young children use multiple cues present in speech for word processing, that speech type affects word processing in early development, and that hearing impairment appears to affect the speed of spoken word processing. Taken together, the research studies on young children with and without hearing loss demonstrate the importance of the type and amount of maternal speech directed toward infants and toddlers. In addition to vocabulary size, the type and amount of speech directed to young children appears to affect word processing. Children with hearing impairment are at a disadvantage, possibly due to several factors affecting word processing and word learning, including degraded listening situations and the amount of speech directed toward them. Our study provides additional information in how hearing loss may affect early word processing. Results

suggest that IDS may facilitate familiar word processing in young children with hearing impairment, especially those who have small vocabularies.

These findings add to the knowledge base of professionals who work with young children with hearing impairment and their parents, thus providing more information to develop strategies to improve communication and support language growth. In more difficult listening situations when speech processing requires more complex processing, such as when novel information is being presented, CHL may benefit from IDS. The benefit of IDS cues may allow for faster RT and higher accuracy in overall comprehension of the conversation topic, thus providing more processing time to focus on other aspects of the verbal exchange, such as more time to process novel words and complex language structures. Clinical implications from this study include the finding that IDS plays an important role in word processing in young children. In particular, IDS facilitates processing of familiar words, and thus, may provide a more efficient means for novel word processing. In addition, children with smaller vocabularies will more than likely benefit from the use of IDS. Thus, early interventionists have evidence to support the value of educating parents and caregivers on the role IDS plays in early language learning.

Future studies are needed to determine what factors are most important in early word processing in CHL. It could be that the rate of speech has more of an impact than other characteristics of IDS once children acquire a certain level of language understanding. Additionally, the amount of speech directed toward young CHL and the quality of the speech signal needs to be investigated. If speech directed toward CHL is reduced, then strategies for increased parent-child conversational turns can be addressed.

Limitations

A limitation to this study is the structured nature of the experimental design. This experiment did not simulate natural listening situations children are exposed to in daily living. This experimental design excludes social cues such as eye contact, facial expressions, and natural gestures which contribute to word processing in natural settings. Thus, in a more natural setting, social cues would likely to impact the communication process.

Another limitation of the present study is the range of productive vocabulary scores. The MCDI Words and Sentences production vocabulary section contains 680 words. The mean vocabulary size of the CHL was 406 words (out of a possible score of 680 on the MCDI). Five of the 11 CHL scored in the 75th percentile on the vocabulary assessment. According to the ECM we would expect children with smaller vocabularies to rely on the enhanced perceptual cues present in IDS, and thus show an advantage in word processing using IDS. A larger cohort of children who are more evenly distributed across the vocabulary range may provide a better picture of how speech type affects word processing.

Additionally, the design of the study limited the novel word-object association learning to the familiarization (training) phase only. Some studies (Houston et al., 2012; Ma et al., 2011) used reminder (retention) trials during the test phase to reinforce the novel word-object associations throughout the test phase. The reminder trials may help with retention of the word-object association over the course of the experiment, which may provide more trials for the analysis. This may be very helpful for assessing RT since a large number of trials are needed for RT measures.

Future studies that include a larger number of participants could possibly provide enough information on other variables which may interact with hearing loss in word processing, such as amount of hearing, the impact of hearing aid fitting strategies, and the amount of listening experience. In addition, it may be advantageous to collect data comparing IDS and ADS in the presence of noise, thus providing a more ecologically relevant picture of the role of IDS in word processing for young children.

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