

Early Maternal Word-Learning Cues to Children with and without Cochlear  
Implants

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To my husband, Steve, and son, Robert, for their love and support

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## CHAPTER I

### GENERAL INTRODUCTION

Lexical knowledge is critical to academic achievement. Children who develop large and robust vocabularies in preschool tend to have better language, reading, and cognitive outcomes than children with smaller and less robust vocabularies (e.g., Marchman & Fernald, 2008). Despite vast improvements in amplification technology, the vocabulary growth rates of children with cochlear implants lag behind those of typically developing children (for a review, see Ganek, McConkey-Robbins, & Niparko, 2012). A possible contributor to the lack of gains in lexical growth may be that mothers of children with cochlear implants provide auditory and visual linguistic input that differs from the input provided by mothers of children with normal hearing. Understanding the specific strategies mothers use to help children determine the meanings of new vocabulary words could allow investigators to optimize input provided to children with cochlear implants. This dissertation study compared the maternal word-learning input available to children with and without cochlear implants and evaluated the extent to which both groups of children take advantage of that input.

#### **Lexical Knowledge of Children with Cochlear Implants**

Over the last three decades, cochlear implants have improved the speech perception abilities of children with profound hearing loss. As a result, overall oral language outcomes have improved (Waltzman, Cohen, Green, & Rowland, 2002).



However, children with cochlear implants continue to demonstrate a delay in average vocabulary knowledge as compared to the mean for age-matched children with normal hearing (e.g., Ganek, McConkey-Robbins, & Niparko, 2012; Nott et al., 2009). In addition to having fewer total words in their lexicons, children with hearing loss, including children with cochlear implants, add words to their lexicons at a slower rate than children with normal hearing (Hayes et al., 2009; Nott et al., 2009). Thus, the vocabulary gap between children with and without cochlear implants widens across the preschool years. It is crucial to find ways to close this widening gap to interrupt the adverse consequences of limited vocabulary knowledge on reading and academic achievement.

### **Vocabulary Outcomes**

As a group, children with cochlear implants do not demonstrate equivalent vocabulary knowledge to age-matched peers with normal hearing. Svirsky and colleagues (2004) measured the vocabulary knowledge of children implanted between the ages of one year, four months and four years, zero months (N = 94) using the MacArthur-Bates Communicative Development Inventory (Fenson, Marchman, Thal, Dale, Reznick, & Bates, 2006). At age seven, the mean for children with cochlear implants on receptive as well as expressive vocabulary knowledge was more than one standard deviation below the mean expected of children with normal hearing. Similarly, Tomblin and colleagues (2005) considered the mean expressive language growth of children implanted between 11 months of age and three years, four months of age (N =

29). Children continued to perform below the range of normal two years post-implantation.

Many studies report that some children who receive cochlear implants early in life develop vocabularies within the range of normal as compared to children of their same chronological age. Connor and colleagues (2006) reviewed the receptive vocabulary standard scores of a group of children (N = 100) who received cochlear implants between the years 1981 to 2004. The mean score of children implanted earlier than age 30 months began to approach average vocabulary performance by the age of six. However, the mean scores of children implanted after 30 months did not approach average vocabulary performance by age six. Similarly, Geers and colleagues (2009) compared the receptive and expressive vocabulary performance of children with cochlear implants across a variety of educational settings (N = 153) to performance of the normative sample on a standardized test. Findings suggested that students in auditory-oral programs implanted before age 4;0 sometimes demonstrate expressive vocabulary knowledge in the range of normal by age seven. However, these studies did not use a typically developing, normal-hearing comparison group, but instead compared the performance of children with cochlear implants to test norms. Because these studies lacked a control group, it is difficult to interpret whether the normative sample from each test is comparable to the group of children with cochlear implants for any variable other than age (e.g., socioeconomic status). Nevertheless, these studies provide preliminary evidence that children implanted at an early age tend to learn words more quickly than children implanted at a later age.

Recent findings indicate that children with cochlear implants not only know fewer vocabulary words than peers matched for age, but that they also add words to their lexicons at a slower rate. Nott and colleagues (2009) evaluated the vocabulary growth of children with cochlear implants and children with normal hearing (N = 40) using parent-report diary methods. The children with cochlear implants took significantly more time to reach the first 50, first 100, and first word combinations from the onset of the first word as compared to the children with normal hearing. Hayes and colleagues (2009) assessed the receptive vocabulary growth of children with cochlear implants who were students at an auditory-oral school. The vocabulary level of children with cochlear implants was, on average at age 6;0, still significantly below the level expected for age-matched peers with normal hearing as compared to a normative sample (i.e., an estimate of the population mean). Perhaps more importantly, growth trajectories from hierarchical linear models predicted that children would not reach performance within the range of normal for their chronological age before their vocabulary growth tapered off. In sum, Hayes and colleagues (2009) and Nott and colleagues (2009) indicate that, over time, the gap in vocabulary knowledge between children with cochlear implants and children with normal hearing will widen.

### **Word-Learning Performance**

The ability to learn new words underlies the development of lexical knowledge. Moreover, the ability to learn new words rapidly given only a few exposures may account for the ability of young children to learn as many as ten new words in a day (Bloom, 2000). Children with cochlear implants, however, learn fewer novel words in

rapid word-learning tasks as compared to peers with normal hearing (Tomblin, Barker, & Hubbs, 2007). Deficits in rapid word learning may contribute to the low vocabulary knowledge of children with cochlear implants.

An initial step in adding new words to one's lexicon is rapidly connecting a novel word and its referent (i.e., disambiguation) using cues from the linguistic and nonlinguistic environment (Heibeck & Markman, 1987). To store the new word for later retrieval, a child must encode to his or her memory phonological and semantic properties associated with that word (Capone & McGregor, 2005). Typically developing children with normal hearing demonstrate the ability to rapidly learn words from a young age (Houston-Price, Plunkett, & Harris, 2005). For example, in the presence of a spoon, a fork, and a whisk, a young child who does not know the word "whisk" but knows "spoon" and "fork" will deduce that an adult is referring to the whisk with the novel label "whisk." If the child connects the word to the referent object, he or she should be able to identify "whisk" in a structured comprehension task immediately following the naming incident. This behavior is demonstrative of rapid word learning.

Rapid word-learning abilities are evident in children as young as thirteen months (Houston-Price, Plunkett, & Harris, 2005). Typically developing young children can learn a word with as few as three exposures to that new word (Woodward, Markman, & Fitzsimmons, 1994). Between the ages of 12 and 36 months, children's rapid word-learning abilities improve, perhaps as a result of cognitive development, experience learning new words, or both (Woodward et al., 1994). Improved word learning skills may account for some of the "vocabulary explosion" or rapid vocabulary growth occurring between one and three years of age (Woodward et al., 1994).

In rapid word-learning tasks, children with cochlear implants as a group perform more poorly than children of the same age with normal hearing. Tomblin, Barker and Hubbs (2007) found that children with cochlear implants (N = 14) between the ages of two and five years learned fewer words receptively and expressively in a rapid word-learning task than children with normal hearing. Houston and colleagues (2012) found that children implanted before age two (N = 25; age at test ranged from 22 to 40 months) did not learn as many words as children with normal hearing matched for chronological age. Researchers must explore the myriad of factors that may contribute to the poor rapid word-learning skills and impoverished lexical outcomes of most children with cochlear implants. Maternal input may represent one possible factor contributing to outcomes for children with cochlear implants.

### **Effects of Maternal Input on Word Learning**

Adult input to children can support the development of linguistic knowledge. Adults provide information to children in ways that facilitate language learning through child-directed speech and action. Research to date has focused primarily on adult input to single sensory modalities, (e.g., auditory motherese). However, linguistic input in a child's environment rarely is provided via only one sense. To understand the contributions of adult input to child language learning, it is imperative to consider a more ecologically valid model of multimodal (e.g., auditory and visual) input provision.

## **Unimodal Child-Directed Communication**

Child-directed speech, or “motherese,” differs from adult-directed speech in ways that may facilitate infant learning. Adults use higher pitch, shorter utterances, and longer pauses when addressing infants versus addressing adults (Fernald & Simon, 1984; Fernald & Mazzie, 1991). These prosodic features recruit child attention and convey meaning about language. The pitch changes of child-directed speech as compared to adult-directed speech, for example, elicit the listening preference of infants as early as four months of age (Fernald & Kuhl, 1987; Werker, Pegg & McLeod, 1994). By unintentionally directing a child’s attention to the contours of speech, parents are able to communicate various intentions (e.g., comfort, prohibition) via prosody rather than requiring children to rely on linguistic structure and content (Fernald, 1989).

Child-directed speech also promotes word recognition and subsequent learning. Infants between seven and eight months old are more likely to recognize words presented with high, elongated pitch contours than words presented in a more neutral pitch (Singh, Morgan & White, 2004). Importantly, children up to two years old are more likely to learn novel words presented with characteristics of child-directed speech as compared to adult-directed speech (Ma, Golinkoff, Houston, & Hirsh-Pasek, 2011).

Adults also use different motions and gestures to convey meaning about objects and object function to children than to adults. This phenomenon has been described as “motionese.” Child-directed actions are more repetitive, occur in closer proximity to the communicative partner, involve a wider range of motion and enthusiasm, and involve fewer steps per motion as compared to adult-directed actions (Brand, Baldwin & Ashburn, 2002). These differences also may direct child attention to structure within

action sequences. The adjustments parents make to their style of communication allow children to begin to learn about and build linguistic knowledge and communication proficiency.

### **Multimodal Child-Directed Communication**

In a child's environment, it is likely that child-directed speech and actions are provided simultaneously instead of in isolation. The provision of redundant information (as via both auditory and visual channels) clearly focuses the attention of even very young infants on salient characteristics of a learning incident (Gogate & Bahrick, 1998). Combinations of cues provided to children across multiple sensory channels may, in fact, recruit selective attention and facilitate early learning more so than provision of unimodal cues (e.g., only auditory or only visual). Bahrick, Lickliter and Flom's (2004) "Intersensory Redundancy Hypothesis" states that intersensory redundancy "promotes detection of salient information, causing the redundant stimulus to become foreground and [other stimuli to become] background," thereby facilitating selective attention (p. 100). If true, multimodal cues should recruit and hold the attention of children better than cues provided in isolation. As a result, children should be more likely to learn language from multimodal rather than unimodal learning opportunities.

The Intersensory Redundancy Hypothesis has implications for broad learning as well as linguistic learning in events where multimodal cues (auditory and visual) versus unimodal (auditory or visual) cues are available. When both auditory and visual information about an event are available, redundant cross-sensory cues should direct selective attention better than modality-specific cues (i.e., only visual or auditory cues).

For example, if a child sees a variety of toys and his or her mother picks one up (a visual cue) and provides an object label using prosody to highlight the specific label (an auditory cue), the child's attention should be drawn to that object paired with that label. Alternatively, if the mother only labels the object, the child should be less likely to pair the object with the label. However, when only auditory or only visual environment-level information about an event is available, unimodal cues should direct attention more so than multimodal cues. For example, if a chicken clucks outside of a child's line of vision, and the mother labels the auditory-only information as "clucking," this cue should be sufficient for pairing the event with the label. In fact, if the mother attempts to provide a visual cue when one is not available (i.e., when she cannot visually indicate the chicken), she may actually attenuate the child's attention to the target event.

To assess predictions for learning in infants suggested by the Intersensory Redundancy Hypothesis, Bahrick and Lickliter (2000) evaluated five-month-old infants' detection of changes in rhythms presented bimodally (auditory and visual) versus unimodally (auditory or visual). Infants perceived rhythm changes in the context of bimodal presentation, as evidenced by longer looking times at the event when the rhythm was changed. However, the authors did not find evidence of perception of rhythm change when the change was presented only through one modality. A follow-up study noted the same effect for three-month-old infants (Bahrick, Flom, & Lickliter, 2002). Thus, evidence suggests that even at the earliest ages, multimodal information about an event recruits and holds attention longer than unimodal information.

The Intersensory Redundancy Hypothesis has direct implications for language learning. If children can selectively attend to redundancy present in the context of



linguistic information, they likely will be able to begin the process of language learning. Gogate and Hollich (2010) proposed that word mapping, or the association of a label with an object, begins with perceiving patterns in redundant relationships of sound-object pairings. Children begin learning about basic, consistent sound-referent combinations (i.e., noticing that barking is always associated with dogs) and subsequently begin to pair more arbitrary sound sequences (i.e., words) with objects or actions. Redundancy in maternal cues about referents may direct a child's attention to important linguistic patterns.

### **Developmental Changes**

Child-directed speech and actions are available in a child's environment throughout infancy. Although child-directed speech is characterized broadly by differences in prosody as compared to adult speech, it changes in quality as children grow. Before an infant is four months old, mothers tend to use more high, bell-shaped, contoured pitch patterns with isolated words (i.e., one word utterances) than when a child is older. Mothers of children who are at least 14 months use more phrases than mothers of younger children, but emphasize target words by placing them at the end of a sentence (see Dominey & Dodane, 2004, for a review). Child-directed action, measured outside of linguistic contexts, also changes over time. Brand, Shallcross, Sabatos, and Massie (2007) assessed mothers' actions during demonstrations of toy-play to six- to eight-month-old children and 11- to 13-month-old children. Mothers of six- to eight- month-old children focused more eye gaze on their child throughout the interaction than did mothers of 11- to 13- month-old children. Mothers of younger

children participated in fewer object exchanges per minute with their children than mothers of older children.

Changes in multimodal child-directed communication have also been observed. When adults provide multimodal auditory and visual cues to children, those cues can occur temporally in a number of ways. Cues provided together temporally (within less than 150 milliseconds) to direct attention to the same object (e.g., shaking an object while labeling it) are considered synchronous, whereas cues provided at different times (more than 400 milliseconds apart; e.g., labeling an object and then shaking it) are considered asynchronous (and less useful as multimodal cues). Adults also provide cues by naming static objects (a unimodal cue) and objects that children are already holding (follow-in labels; a type of bimodal cue). During labeling events for new words, synchronous labeling events are thought to provide the most information (as compared to asynchronous, static, or follow-in labels) about the label's referent to the child (Gogate, Bahrick, & Watson, 2000; Matayaho & Gogate, 2008).

Gogate, Bahrick and Watson (2000) assessed the timing of mothers' auditory and visual cues during labeling events to children 5-8 months old, 9-17 months old, and 21-30 months old. Mothers were asked to explicitly teach novel nouns and verbs to their children. Gogate and colleagues found that regardless of child age, mothers overwhelmingly provided synchronous cues as compared to other cue types. However, mothers of the 9- to 17-month-old group and the 21- to 30-month-old group provided more asynchronous cues than mothers of the 5- to 8-month-old group ( $d = 1.33$ ). Further, mothers of the 21- to 30-month-old group provided more static labels and

follow-in labels than did mothers of the younger groups ( $d = 1.46$  and  $d = 1.77$ , respectively).

### **Multimodal Communication and Lexical Learning**

If there is a reciprocal relationship between multimodal cue provision and child development, changes in multimodal child-directed communication over time may reflect changes in children's abilities to attend to and learn from those cues. For example, four- to five-month-old infants sustain attention to multimodal, child-directed input for a longer proportion of time than nine- to eleven-month-old infants (Werker, Pegg, & McLeod, 1994). Multimodal motherese may serve the purpose of scaffolding child attention in learning contexts, and consequently it may help children to learn to attend to relevant characteristics of events without as much support from the mother. Mothers of young infants, for example, tend to shake objects during labeling events, which in turn helps the infant to shift attention from the mother to the relevant object (Matayho & Gogate, 2008). Infants' ability to switch gaze from mother to object, in turn, predicts early label-to-referent mapping abilities (Gogate, Bolzani, & Betancourt, 2006). As children get better at mapping words, they may be able to attend to the task without their mother leading them through the steps (i.e., shaking the object to draw attention).

Among the earliest steps in language learning is the ability to pair arbitrary speech with an object. Gogate and Bahrack (1998) measured the effects of cue synchrony on the ability of seven-month-old infants to map vowel sounds to objects within a habituation task. They presented vowel sounds paired with objects in the following conditions: (a) while synchronously moving the target object, (b) while

asynchronously moving the target object (i.e., providing the sound and then later moving the object) and (c) while the target object remained still. The authors found evidence of sound-object mapping only in the synchronous condition, suggesting that infants as young as seven months can learn arbitrary relations and, perhaps more importantly, that this learning is facilitated by synchronous auditory and visual cue presentation.

As children begin to learn words, they must pair whole words with objects. Gogate, Bolzani, and Betancourt (2006) assessed associations between word learning and mothers' cue provision to pre-verbal children between six and eight months of age. Mothers taught two nouns to their children, and their teaching strategies were coded as synchronous, asynchronous, static, or follow-in. Child word learning was assessed in a preferential looking paradigm. Mothers who used more synchronous cues as opposed to asynchronous, static, or follow-in cues had children who were more likely to learn the novel words. These findings suggest a link between provision of multimodal auditory and visual cues to children and early word-mapping ability.

Changes in multimodal cue timing may reflect the ability of mothers to subconsciously alter their communication to suit their children's perceptual and consequent lexical development needs (Gogate, Walker-Andrews, & Bahrick, 2001). As children begin to benefit from temporally synchronous associative and then arbitrary auditory and visual information, mothers provide many overt multimodal cues. With time, as children establish the ability to initiate and sustain joint attention, mothers provide fewer temporally synchronous cues (Gogate, Bahrick, & Watson, 2000).

Over time, a child's ability to selectively attend to and interpret learning events changes. The Emergentist Coalition Model of Word Learning proposes that children differentially weight various word-learning cues across the course of development (Hollich et al., 2000). Although children presumably have many word-learning cues available to them at all times (e.g., attentional cues, linguistic cues, social cues, etc), children are not immediately able to process each of these cues with the same degree of efficiency to determine word referents. In fact, attentional cues are thought to be the core of a child's early ability to distinguish word referents. Consequently, if parents can direct their cues to increase the salience of a relevant object in word-learning contexts, they should be able to facilitate their child's language growth. Children in the earliest stages of language learning (i.e., five to eight months old) may benefit most from clear, synchronous cues that unambiguously direct their attention to the referent of a label. Children in later stages of language learning (i.e., 21 to 30 months), on the other hand, may be able to determine word referents using their knowledge of linguistic structure and regularities, without needing an adult to direct their attention. Further, children in the later stages of language learning may be better able to direct their mothers to provide labels by manipulating objects, and consequently mothers provide more follow-in labels.

### **Maternal Input to Children with Cochlear Implants**

Children with cochlear implants begin learning spoken language at a later age than their normal-hearing peers. Current FDA labeled indications do not support cochlear implantation under the age of 12 months. Prior to implantation, many children with cochlear implants exhibit age-appropriate nonverbal skills despite a lack of

linguistic knowledge (Geers, Nicholas & Sedey, 2003). Parents of a child who looks and acts like a three-year-old may find it difficult to use language and cues more appropriate for a typically developing, normal-hearing 12-month-old (i.e., potential linguistic level of recently implanted child). Thus, maternal input might be influenced more by a child's nonverbal capabilities than linguistic level. Auditory and visual cues, and the manner in which they are provided, may affect the rapid word-learning outcomes of children with cochlear implants. Research to date has focused primarily on auditory characteristics of maternal input to children with cochlear implants. The influence of visual referential cues remains unexplored.

### **Child-Directed Speech**

If child-directed speech facilitates word learning in children with normal hearing, it should play a crucial role for children with cochlear implants. Mothers of children with cochlear implants use characteristics of child-directed speech consistent with a child's listening experience as compared to his or her chronological age. Bergeson, Miller, and McCune (2006) analyzed maternal speech to children with cochlear implants with an average age of 25.2 months and children matched for age and listening experience (N = 27, *M* age = 9.4 months). Variables derived for maternal speech included mean frequency, frequency range, frequency standard deviation, pause duration, and speaking rate. Maternal speech to children with cochlear implants was similar to speech to children matched for listening experience (but not chronological age) for mean frequency, minimum frequency, pause duration, and speaking rate.

Kondaurova and Bergeson (2011) speculated that mothers of children with cochlear implants use child-directed speech based on a child's low language level, rather than listening experience alone. The authors analyzed acoustic characteristics of child-directed speech at clause boundaries for children with (n = 9) and without cochlear implants matched for age (n = 9) and listening experience (n = 9) at 2 points, age 16 and 22 months. Characteristics of child-directed speech (high pre-boundary pitch and long vowel durations) were present for children with and without cochlear implants. However, mothers of children with cochlear implants used characteristics of child-directed speech at both time points, longer than mothers of children with normal hearing from either group.

Additional work, however, suggests that factors other than language level (as measured by vocabulary knowledge) influence maternal use of child-directed speech. In a case-study, Lam and Kitamura (2010) evaluated maternal speech to a normal hearing child and his twin with a cochlear implant. Notably, the child with the cochlear implant had a higher vocabulary as estimated by a communicative development inventory than the child with normal hearing. Some acoustic characteristics of child-directed speech, including mean frequency, frequency range, vowel duration, were present in mother-child interactions with each individual twin. However, these characteristics of child-directed speech were more pronounced for the twin with cochlear implants than the twin with normal hearing (e.g., consonants were hyper-articulated for the twin with cochlear implants). Perhaps due to the presence of a hearing loss, the mother hyper-articulated consonant sounds for the twin with a cochlear implant. She did not appear to vary her presentation of child-directed speech to her children based on vocabulary level.

In summary, the extant literature indicates that mothers of children with cochlear implants adjust the acoustic characteristics of their speech, perhaps subconsciously, to optimize the child's opportunity to learn language. In a child's environment, however, referential cues are likely auditory as well as visual. To evaluate the nature of word-learning opportunities for children with cochlear implants, multimodal presentations of information must be considered.

### **Child-Directed Actions**

Child-directed actions are also a piece of maternal input to children with normal hearing. Child-directed actions are characterized by frequent repetition, occurrence in close physical proximity to the communicative partner, a wide range of motion and enthusiasm, and fewer steps per motion as compared to adult directed actions (Brand, Baldwin & Ashburn, 2002). These differences may also direct child attention to linguistic structure and salient features within action sequences.

Because most children with cochlear implants do not have impaired visual perception, their ability to make use of visual cues as compared to children with normal hearing, even pre-implantation, should not differ. Mothers of children with cochlear implants may be particularly sensitive to value of visual cues because visual cues can direct children's attention more easily than auditory cues. Unfortunately, the extant literature does not describe the provision of child-directed actions to children with cochlear implants as compared to children with normal hearing. However, some studies have described general use of visual communication strategies with children with cochlear implants.



Visual versus spoken communication to children with cochlear implants is highly variable. In a qualitative study, Preisler, Tvingstedt and Ahlstrom (2002) observed patterns of Swedish parent-child interactions for children with cochlear implants between the ages of two and six years. To be eligible for a cochlear implant in Sweden, children must have established manual communication with their family prior to surgery. The authors sought to evaluate use of visual (gesture and sign) and spoken communication in the home. They found, even post-implantation, that parents used more visual than spoken communication with their children. However, there was large variation in the proportion of visual and spoken communication provided to children, regardless of sign or speech proficiency. In addition, increased use of spoken communication over time was associated with fewer established bouts of eye gaze (i.e., an important visual cue) between the parent and child.

Visual cues direct the attention of children with and without hearing loss. Koester, Karkowski and Traci (1998) compared the tactile, visual and vocal cues used by deaf and hearing mothers to gain the attention of 9-month-old, pre-verbal infants with varying degrees of hearing loss. Visual strategies re-focused the attention of both hearing impaired and deaf infants most successfully. Hearing mothers, however, provided fewer visual cues to children than deaf mothers, regardless of hearing status. Follow-up work found the same pattern of performance in maternal interactions with hearing and deaf mothers of 18-month-old children with and without hearing loss (Koester, Brooks, & Karkowski, 1998). Further investigation of combined auditory and visual cues available to children with cochlear implants is warranted.

## Summary and Hypotheses

Maternal input in early word learning influences a normal-hearing child's word-learning performance (for a review, see Gogate, Walker-Andrews, & Bahrick, 2001). Thus, a central issue is whether lexical deficits of children with cochlear implants are partially attributable to differences in the word-learning environment for children with cochlear implants as compared to hearing children. The contribution of this dissertation study is the potential identification of environmental input differences between children with cochlear implants and children with normal hearing.

To determine how environmental converging and diverging cues impact the lexical development of children with cochlear implants, we sought to determine (a) if the input to children with cochlear implants in the early period of lexical development differs from the input to children with normal hearing at an equivalent age and children at an equivalent lexical level, and (b) if the children with cochlear implants and children with normal hearing learn from converging as well as diverging cues. Study 1 addressed issue (a) by measuring auditory and visual child directed cues in mother-child interactions. Study 2 addressed issue (b) via a controlled word-learning task.

Within the first study, the primary hypothesis was that mothers of children with cochlear implants would provide more auditory-only and converging auditory-visual word-learning cues than mothers of age-matched children with normal hearing. This hypothesis is based on the finding that mothers of children with cochlear implants provide child-directed speech cues consistent with a child's lexical level, rather than his or her chronological age (Bergeson, Miller & McCune, 2006; Koundarova & Bergeson, 2011). Because the children with cochlear implants in this study had low vocabulary

knowledge, parents were predicted to provide multimodal child-directed cues appropriate to a child's linguistic level rather than his or her chronological age.

Relevant to Study 2, we hypothesized that children with cochlear implants would learn fewer words in the context of asynchronous auditory and visual cues as compared to the context of synchronous auditory and visual cues. This hypothesis is supported by predictions made by the Intrasensory Redundancy model (Bahrick, Lickliter, & Flom, 2004). Further, we hypothesized that children with cochlear implants would learn fewer words than age-matched children in either context. This prediction is supported by extant knowledge base on rapid word-learning of children with hearing loss (Houston et al., 2012; Tomblin et al., 2005).

Characterization of the cues children receive in environmental word learning opportunities, and the extent to which children are able to use those cues, will lead to testable hypotheses as to the malleable factors that underlie the poor vocabulary growth of children with cochlear implants. Findings from this project will inform future investigations that seek to validate assessment as well as intervention for children with cochlear implants.

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## CHAPTER II

### STUDY 1: SYNCHRONY OF MATERNAL AUDITORY AND VISUAL CUES TO CHILDREN WITH AND WITHOUT COCHLEAR IMPLANTS

#### **Introduction**

Children with cochlear implants generally have smaller lexicons than their same-age peers with normal hearing (for a review, see Ganek, McConkey-Robbins, & Niparko, 2012). In addition to having fewer words in their lexicons, children with cochlear implants appear to add words to their lexicons at a slower rate than peers matched for language level (Ganek, McConkey-Robbins, & Niparko, 2012; Nott et al., 2009). To address the widening vocabulary gap between children with cochlear implants and children with normal hearing, professionals must consider possible differences in input provided to children with and without cochlear implants. The purpose of this study was to compare maternal auditory and visual cues about word referents available to children with cochlear implants and children with normal hearing matched for chronological age and matched for vocabulary level.

Vocabulary knowledge is critical to academic achievement. Vocabulary deficits can affect academic, cognitive and professional outcomes (Marchman & Fernald, 2008). Despite advances in amplification technology and overall language proficiency over the past three decades, children with hearing loss continue to exhibit low vocabulary knowledge (Waltzman, Cohen, Green, & Rowland, 2002). Deficits in rapid word-learning performance may contribute to deficits in vocabulary knowledge. Children with cochlear

implants learn fewer novel words in rapid word-learning tasks as compared to their peers with normal hearing (Tomblin, Barker, & Hubbs, 2007).

### **Rapid Word-Learning Performance in Children with Cochlear Implants**

To add a new word to one's lexicon, one must rapidly connect a novel word and its referent (i.e., disambiguation) using cues from the linguistic and nonlinguistic environment (Heibeck & Markman, 1987). Typical language learners are able to do this quickly and seamlessly. Rapid word-learning abilities are evident in children as young as thirteen months (Houston-Price, Plunkett, & Harris, 2005). Typically developing young children can learn a word (i.e., add it to the lexicon) with as few as three exposures to that new word (Woodward, Markman, & Fitzsimmons, 1994). Between the ages of 12 and 36 months, children's rapid word-learning abilities improve, perhaps as a result of cognitive development, experience learning new words, or both (Woodward et al., 1994). Improved word learning skills may account for some of the "vocabulary explosion" or rapid vocabulary growth observed between one and three years of age (Woodward et al., 1994).

In rapid word learning tasks, children with cochlear implants as a group perform more poorly than children of the same age with normal hearing. Tomblin, Barker and Hubbs (2007) found that children with cochlear implants ( $n = 14$ ) between the ages of two and five years learned fewer words receptively and expressively in a rapid word-learning task than children with normal hearing ( $n = 14$ ;  $d = .99$ ). Houston and colleagues (2012) found that even children implanted before age two ( $n = 25$ , age at test ranged from 22 to 40 months) did not learn as many words as children with normal

hearing matched for chronological age (n = 23; exact means not indicated in original paper). Poor word-learning performances could be attributed to characteristics of individual children (e.g., listening experience) as well as characteristics of environmental input. However, child-level factors affecting rapid word learning (e.g., age at implantation, speech perception) may be difficult or impossible to change. Because environmental factors are more amenable to manipulation, investigators must explore the role of input on the rapid word-learning performance of children with cochlear implants.

### **Environmental Input and Word Learning**

Adult input to children can support the development of linguistic knowledge. Adults instinctively provide information to children in ways that facilitate language learning through child-directed speech and action. Parents tend to provide auditory and visual cues simultaneously. This “multimodal motherese” plays a role in recruiting and directing infant attention. The provision of redundant information (as via both auditory and visual channels) clearly focuses the attention of even very young infants on salient characteristics of a learning incident (Gogate & Bahrick, 1998). Combinations of cues provided to children across multiple sensory channels may, in fact, recruit selective attention and facilitate early learning more so than provision of unimodal cues (e.g., only auditory or only visual).

Bahrick, Lickliter and Flom’s (2004) “Intersensory Redundancy Hypothesis” states that intersensory redundancy “promotes detection of salient information, causing the redundant stimulus to become foreground and [other stimuli] background,” thus

facilitating selective attention (p. 100). If true, multimodal cues should recruit and hold the attention of children better than cues provided in isolation. As a result, children are more likely to attend to multimodal rather than unimodal input (Bahrick, Lickliter, 2000; Bahrick, Flom, & Lickliter, 2002).

If children can selectively attend to redundancy present across linguistic patterns, they likely will be able to begin the process of language learning. Gogate and Hollich (2010) proposed that word mapping, or the association of a label with an object, begins with perceiving patterns in redundant relationships of sound-object pairings. Children begin learning about basic, consistent sound-referent combinations (i.e., noticing that barking is always associated dogs) and subsequently begin to pair more arbitrary sound sequences (i.e., words) with objects or actions. Redundancy in maternal cues about referents may direct a child's attention to important linguistic patterns.

If there is a reciprocal relationship between multimodal cue provision and child development, changes in multimodal child-directed communication over time may reflect changes in children's abilities to attend to and learn from those cues. Multimodal motherese may serve the purpose of scaffolding child attention in learning contexts, and consequently help children learn to attend to relevant characteristics of events without as much support from the mother. Mothers of young infants, for example, tend to shake objects during labeling events, which in turn helps the infant to shift attention from the mother to the relevant object (Matayho & Gogate, 2008). Infants' abilities to switch gaze from mother to object, in turn, predicts early label-to-referent mapping abilities (Gogate, Bolzani, & Betancourt, 2006). As children get better at mapping words, they may be

able to attend to the task without their mother leading them through the steps (i.e., shaking the object to draw attention).

When adults provide auditory and visual cues to children, those cues can occur in a number of ways (see Table 1). Cues provided together temporally (within less than 150 milliseconds) to direct attention to the same object (e.g., shaking an object while labeling it) are considered synchronous, whereas cues provided at different times (more than 400 milliseconds apart; e.g., labeling and object and then shaking it) are considered asynchronous (and less useful as multimodal cues; Gogate, Bahrick & Watson, 2000). Adults also provide cues by naming static objects (a unimodal cue) and objects that infants are already holding (follow-in labels; a type of bimodal cue). In some cases, adults also provide auditory and visual cues that indicate different referents (e.g., talking about one object while holding another). Thus, children can receive auditory and visual information that converges to indicate a single referent (converging cues), auditory information that diverges to indicate different referents (diverging cues) and information via only one sense (auditory-only cues).

Table 1. Types of Auditory and Visual Cues Provided to Children about Referents

Cue category	Cue type	Example
Moving synchronous	Converging	Shakes one object while labeling
Follow-in labeling	Converging	Labels object child is looking at
Moving asynchronous	Diverging	Labels object then indicates after 400+ milliseconds
Indicating different objects	Diverging	Holds one object while labeling another
Still-object labeling	Auditory-only	Labels an object within view without indicating
Labeling objects not present	Auditory-only	Labels object not in child's view

Multimodal child-directed communication changes as children develop. Gogate, Bahrnick and Watson (2000) assessed the timing of mothers' auditory and visual cues during labeling events to children 5-8 months old, 9-17 months old, and 21-30 months old. Mothers were asked to explicitly teach novel nouns and verbs to their children. Gogate and colleagues found that regardless of child age, mothers overwhelmingly provided synchronous cues as compared to other cue types. However, mothers of the 9- to 17-month-old group and the 21- to 30-month-old group provided a higher proportion asynchronous cues than mothers of the 5- to 8-month-old group ( $d = 1.33$ ). Further, mothers of the 21- to 30-month-old group provided a higher proportion of static labels and follow-in labels than did mothers of the younger groups ( $d = 1.46$  and  $d = 1.77$ , respectively).

Mothers may subconsciously match their communication to suit their child's perceptual and consequent lexical development needs (Gogate, Walker-Andrews, & Bahrnick, 2001). As children begin to benefit from temporally synchronous associative and then arbitrary auditory and visual information, mothers provide many overt multimodal cues. As children establish the ability to initiate and sustain joint attention, mothers provide fewer temporally synchronous cues (Gogate, Bahrnick, & Watson, 2000).

### **Maternal Input to Children with Cochlear Implants**

Children with cochlear implants begin learning spoken language at a later age than their normal-hearing peers. Current FDA labeled indications do not support cochlear implantation under the age of 12 months. Prior to implantation, many children

with cochlear implants exhibit age-appropriate nonverbal skills despite a lack of linguistic knowledge (Geers, Nicholas & Sedey, 2003). Parents of a child who looks and acts like a three-year-old may find it difficult to use language and cues more appropriate for a typically developing, normal-hearing 12-month-old (i.e., potential linguistic level of newly implanted child). If so, maternal input might be influenced more by nonverbal capabilities than linguistic level. Auditory and visual cues, and the manner in which they are provided, may affect the rapid word-learning outcomes of children with cochlear implants.

Mothers of children with cochlear implants tend to provide auditory cues consistent with child-directed speech (e.g., high pitch, short utterances, and long pauses) to their children (Bergeson, Miller, & McCune, 2006; Kondaurova & Bergeson, 2011). Unfortunately, literature to date does not describe the provision of child-directed motions to children with cochlear implants. To consider characteristics of child-directed actions as possible sources of information to influence rapid word learning, other studies of children with hearing loss must be conducted.

Visual cues are important for directing the attention of children with hearing loss. Koester, Karkowski and Traci (1998) compared the tactile, visual and vocal cues used by deaf and hearing mothers to gain the attention of 9-month-old, pre-verbal infants with varying degrees of hearing loss. Visual strategies re-focused the attention of both hearing and deaf infants most successfully. Hearing mothers, however, provided fewer visual cues to children than deaf mothers, regardless of hearing status. Follow-up work found the same pattern of performance in maternal interactions with a different group of 18-month-old children with and without hearing loss (Koester, Brooks, & Karkowski,



1998). The majority of children with hearing loss are born to parents who have normal hearing (Mitchell & Karchmer, 2004). Further investigation of the timing of combined auditory and visual cues available to children with cochlear implants, particularly those born to parents with normal hearing, is warranted.

The current study sought to identify environmental input differences between children with and without cochlear implants. Specifically, this study examined maternal auditory and visual cues about word referents available to children with cochlear implants as compared to those available to children with normal hearing matched for chronological age and children matched for vocabulary level. If mothers can direct their auditory and visual cues to increase the salience of a relevant object in word-learning contexts, they should be able to facilitate their children's language growth. Infants in the earliest stages of language learning (i.e., children with fewer than 50 vocabulary words) may benefit most from clear, converging cues that unambiguously direct their attention to the referent of a label. Infants in later stages of language learning, on the other hand, may be able to determine word referents using their knowledge of linguistic structure and regularities, with less need for an adult to direct their attention. Thus, identification of differences in input to children with and without cochlear implants represent a first step towards determining if deficits of children with cochlear implants are partially attributable to differences in the word-learning environment.

The following research questions were addressed: (a) Do mothers of children with cochlear implants provide a higher proportion of converging cues to children with cochlear implants than parents of children with normal hearing matched for age level, but not different from parents of children matched for vocabulary level? (b) Do mothers

of children with cochlear implants provide a lower proportion of diverging cues to children with cochlear implants than parents of children with normal hearing matched for age level, but not different from parents of children matched for vocabulary level? and (c) Do mothers of children with cochlear implants provide a lower proportion of auditory-only cues to children with cochlear implants than parents of children with normal hearing matched for age level, but not different from parents of children matched for vocabulary level?

## Method

### Participants

Participants included 30 mother-child dyads divided into three groups: a cochlear implant group (n = 10), an age-matched group (n = 10), and a vocabulary-matched group (n = 10). All participants came from English-speaking families committed to developing listening and spoken language skills (not sign language). Maternal education level varied freely across the participant pool and was used as a covariate in analysis. See Table 2 for a description of group characteristics.

Table 2. Group Characteristics

Group	Child Age	Years Maternal Education	Number of Siblings
Cochlear Implant (n = 10)	23.00 (9.40)	15.95 (2.03)	1.20 (1.03)
Age Match (n = 10)	24.10 (9.49)	17.45 (3.59)	1.10 (0.87)
Vocabulary Match (n = 10)	13.50 (4.01)	18.20 (2.30)	.80 (.78)

Dyads in the cochlear implant group were recruited from the National Center for Childhood Deafness and Family Communication (NCCD) at Vanderbilt University Medical Center. All dyads included a child with at least one cochlear implant device. All children had a diagnosis of severe to profound, bilateral hearing loss as measured by auditory brainstem response as well as behavioral audiometry. Parents of all children reported that children had no useable access to sound before receiving a cochlear implant. Functional aided hearing demonstrated aided sound field thresholds of at least 30 dB HL for 500 through 4000 Hz. Children did not have additional diagnoses known to affect cognitive and/or language development (e.g., Down syndrome) or significant visual impairment. The mean age of children in the cochlear implant group was 23 months ( $SD = 9.40$  months). Average duration of time using a cochlear implant was 5.5 months ( $SD = 3.21$  months). All children received regular speech-language therapy services. To identify environmental input differences between children with and without cochlear implants within a developmental period when auditory-visual cue combinations matter most, this study focused on very early word learning. Children in the cochlear implant group were eligible to participate in this study if they had an expressive vocabulary of less than 50 words ( $M = 14.50$  words;  $SD = 23.24$  words) as measured by the MacArthur Bates Communicative Development Inventory - Words and Sentences (CDI; Fenson et al., 2006). Parents also completed the LittlEars Auditory Questionnaire to describe their child's auditory function (Kühn-Inacker, Weichbold, Tsiakpini, Coninx, & D'Haese, 2004). This questionnaire requires parents to answer 35 "yes/no" questions about their child's responses to environmental sounds. See Table 3 for child-specific information.

Table 3. Characteristics of Individual Child Participants in Cochlear Implant Group

Participant	Chronological age	Degree of Hearing Loss	Age at Identification	Amount of time with CI	Bilateral implants?	Little Ears Score
1	14 months	Severe to Profound	Birth	2 months	Yes	12
2	15 months	Severe to Profound	Birth	7 months	Yes	25
3	15 months	Severe to Profound	Birth	4 months	No	13
4	18 months	Severe to Profound	Birth	5 months	Yes	23
5	19 months	Profound	Birth	10 months	Yes	30
6	21 months	Severe to Profound	10 months	6 months	Yes	19
7	22 months	Severe to Profound	2 months	11 months	Yes	34
8	29 months	Severe to Profound	Birth	6 months	Yes	25
9	35 months	Profound	29 months	2 months	Yes	2
10	42 months	Severe to Profound	Birth	2 months	No	8

*Note.* CI = cochlear implant; Little Ears = Little Ears Auditory Questionnaire score out of 35 possible points (Kühn-Inacker et al., 2004).

Dyads in the age-matched and vocabulary-matched groups were recruited via advertisement, research recruitment networks, local area preschools, and local area music programs. All mothers and children who participated in this study spoke only English in the home. Participants in these groups demonstrated normal hearing per parent report. Children in the age-matched group were within three months of age of a child in the cochlear implant group (M = 24.10 months; SD = 9.49 months). Children in the vocabulary-matched group had an expressive vocabulary of less than 50 words (M = 10.40 words; SD = 9.15 words). Average child age was 13.5 months (SD = 4.01 months). Mothers of children with normal hearing completed the Ages and Stages Questionnaire to confirm their child's status as a typical language learner (Squires & Bricker, 2009). Every participant in the age and vocabulary matched groups performed above the referral cutoff in the Communication Skills and Problem Solving sections.

Mothers in all three groups completed the MacArthur Bates Communicative Development Inventory - Words and Sentences (CDI; Fenson et al., 2006) and the Parent Stress Index (Abidin, 2012). These measures are descriptive and not included as variables within this study. See Table 4 for group results.

Table 4. Descriptive Measures (Means and Standard Deviations) by Group

Group	MCDI Receptive Score	MCDI Expressive Score	PSI Percentile Score
Cochlear Implant	53.00 (70.41)	13.10 (20.15)	35.67 (20.10)
Age-Matched	308.00 (79.67)	175.70 (139.68)	59.50 (18.68)
Vocabulary-Matched	91.20 (74.25)	10.40 (9.16)	47.44 (15.94)

*Note.* MCDI = MacArthur Bates Communicative Development Inventory (Fenson et al., 2006); PSI = Parent Stress Index (Abidin, 2012). Within the Parent Stress Index results, scores are not included for mothers who scored significantly below the defensiveness cut-off as outlined by the test manual (n = 4 for age-matched group, n = 4 for cochlear implant group, n = 1 for vocabulary matched group).

## Procedures

One objective of this study was to observe ecologically-valid mother-child interactions. Mealtime routines were selected for data collection because they provide equal opportunity for structured mother-child interactions across groups of participants. Children with cochlear implants do not always wear amplification during other opportunities for mother-child interactions (e.g., getting dressed, bath time, riding in the car). In addition, families of low socioeconomic status do not always have experience playing directly with their children during set-aside play times (Brice-Heath, 1996). Thus, mealtime provides opportunity for familiar interaction regardless of socioeconomic status and in which children with cochlear implants are likely to wear their devices.

Mother-child dyads were video-recorded during two mealtime interactions on two separate days within a 14-day period. Two cameras captured the interaction: one following the mother's face and torso and an additional stationary video camera capturing the face and torso of the child. Children were seated in a highchair or booster seat throughout the interaction, and mothers were free to move around as necessary. Each mealtime interaction was recorded from the time the mother began feeding the child to the natural end of the meal (usually indicated by mothers asking children if they were finished). Mothers were asked to interact with their child as they typically would. The observer did not actively participate in the interactions.

In each mealtime interaction, the observer provided the same six novel items for mothers to include in the interaction. These items were unfamiliar to the children (as confirmed by the parent prior to beginning the mealtime interaction). The observer named each item for the mother, and the name of the item was written on the item

(novel names included “blicket,” “dax,” “arge,” “chi,” “runker” and “gow”). The same objects were used in each interaction. These items were included to ensure that a set of novel words was used in the interaction in the event that mothers did not discuss other objects unknown to the child. Inclusion of the novel objects may have prompted mothers to label these objects more than they would label other novel objects. Follow-up analyses addressed mothers’ converging referential cues to only the novel objects to determine if response patterns differed for references to novel objects versus all nouns in the interaction. Mothers were given the following information and instructions: “One of the things I am interested in seeing is how children respond to new objects. I want you to use these things in your mealtime. The names of these things are written on the items. They are called blicket, dax, arge, chi, runker, and gow.” Mothers were not given other instructions regarding the items. Number of exposures to each item was not controlled.

## **Data Preparation**

Maternal utterances for each interaction were orthographically transcribed using Systematic Analysis of Language Transcripts conventions (SALT; Miller & Iglesias, 2010). For each dyad, one transcript file included both interaction transcripts. All nouns within the transcript, including proper nouns (e.g., dad’s name), object names (e.g., spoon) and abstract nouns (e.g., dream) were identified and coded by the author. See Appendix I for noun coding rules. The SALT program then generated an alphabetical listing of all transcript nouns. Within two days of the second interaction, the author presented the list of nouns to the mother and asked her to identify the nouns she

believed her child understood. Having identified all unknown nouns in the mealtime interactions, the author viewed videos to code referential cues for each noun token (e.g., for converging cue mother points to labeled object; see Appendix I for coding manual). Only those unknown nouns presented in utterances considered child-directed (i.e., not those included in utterances to the examiner or to other people present at any time in the video) were coded. The author generated a coding manual for this study based on coding procedures used in similar studies of children with normal hearing (e.g., Gogate, Bahrick & Watson, 2000). All referential cues for unknown nouns were coded as converging, diverging, auditory-only or other (for a review, see Table 1).

## **Analysis**

Using the SALT program, the first author calculated the frequency of converging, diverging, auditory-only and other cues provided to children within each transcript. From the frequency data, the proportion of each type of cue and the proportion of cues provided relative to only the novel objects used in the interaction was calculated. The proportion of three cue types (converging, diverging, and auditory-only) across groups was compared using an analysis of variance. “Other” cues were coded infrequently (an average of less than one time per participant) and not compared between groups. Proportion, however, was calculated including “other” cues in the denominator. Group membership (cochlear implant, age-matched or vocabulary-matched) represented the between-subjects independent variable and proportion of auditory-only, converging, and diverging cues represented dependent variables. Within this analysis, maternal



education level was applied as a covariate. Main effects between groups were analyzed with follow-up linear contrasts.

## **Reliability**

To collect reliability data, the first author trained a lab assistant (undergraduate linguistics and psychology major) to code naming events using the coding manual. Data was collected from six additional dyads to provide training practice for the reliability coder (data from these dyads were not included in the final study). The author and lab assistant coded two transcripts together and four additional transcripts separately. Following coding of each transcript, reliability was calculated for the identification of nouns, identification of child-directed utterances, and for converging, diverging, auditory-only and other codes. The author and lab assistant discussed patterns of coding discrepancy between each transcript. Reliability above 90% was obtained for each of the final two training transcripts.

The lab assistant coded 33% of the study samples using video and transcripts from each group and point-by-point coding agreement was calculated. Table 5 displays reliability data. Reliability percentages were sufficiently high to indicate that the author had accurately captured the children's responses. The author's scoring was used for analysis.

Table 5. Point-by-Point Percent Agreement Calculated Based on 33% of Samples within each Participant Group

	Group		
	Cochlear Implant	Age-Matched	Vocabulary-Matched
Nouns Codes	99.36%	98.99%	98.98%
Child-Directed Utterance Codes	98.35%	96.29%	100.00%
Converging Cue Codes	95.31%	95.07%	99.50%
Diverging Cue Codes	91.89%	97.78%	98.96%
Auditory-Only Cue Codes	91.67%	92.31%	87.11%

## Results

This study compared proportions of auditory-visual cue types about word referents provided to children with cochlear implants, children with normal hearing matched for chronological age, and children with normal hearing matched for vocabulary size. Mother-child interactions were video-recorded during mealtime. Each dyad participated in two mealtime observations. Maternal utterances were transcribed and coded for (a) nouns produced, (b) child-directed utterances, (c) nouns novel to children and (d) auditory and visual cues provided about referents.

Table 6 provides information about the transcripts obtained for each group, including average number of total utterances, average number of child-directed utterances, mean percent novel nouns produced in child-directed utterances, mean length of child-directed utterances and mean number of different words produced by mothers in child-directed utterances. Average number of total utterances and average

number of child-directed utterances did not differ significantly between groups. However, mothers of children in the age-matched group used fewer novel words as a proportion of total nouns produced than the cochlear implant or vocabulary-matched group ( $t(18) = 5.11, p < .01$ ;  $t(18) = 5.38, p < .01$ ;  $d = 2.28$ ) presumably because age-matched children had higher receptive lexical knowledge. Consistent with Bergeson and colleagues (2006), mothers of children with cochlear implants had a shorter mean length of utterance than mothers of age-matched children ( $t(18) = 3.87, p < .01$ ;  $d = 1.73$ ), but a mean length of utterance not statistically different than that of mothers of vocabulary-matched children ( $t(18) = 1.43, p = .17$ ). Mothers of children in the cochlear implant group produced a lower number of different words than mothers of age-matched children ( $t(18) = 3.13, p < .01$ ;  $d = 1.40$ ) but not vocabulary-matched children ( $t(18) = .40, p = .69$ ).

The first research question addressed whether mothers of children with cochlear implants provided a different proportion of converging auditory and visual cues about novel nouns than mothers of children matched for chronological age or mothers of children matched for vocabulary size. Proportion of converging cues was entered into an analysis of variance with group membership (cochlear implant, age-matched or vocabulary-matched) as the between-subjects variable. Based on evidence that maternal education is associated with child vocabulary development (e.g., Dollaghan et al., 1999), years of maternal education was entered as a covariate. Years of maternal education correlated significantly with proportion of converging cues ( $r(28) = .42, p = .02$ ). The homogeneity of slopes assumptions was not violated as the covariate did not

Table 6. Group Means and Standard Deviations on Transcript Variables

Group	Average Number Total Maternal Utterances	Average Number Child-Directed Utterances	Average Proportion of Novel Nouns Used by Mothers	Average MLU of Mothers	Average NDW of Mothers
Cochlear Implant	387.30 (253.55)	297.20 (257.35)	65.66 (20.44)	3.27 (.78)	213.80 (98.48)
Age-Matched	455.40 (245.98)	328.00 (148.69)	24.90 (14.76)	4.37 (.44)	355.80 (104.21)
Vocabulary-Matched	390.70 (127.02)	368.50 (114.27)	68.14 (20.69)	3.72 (.61)	228.70 (62.03)

*Note.* MLU = Mean Length of Utterance in words; NDW = Number of Different Words

interact significantly with group membership (independent variable). The overall ANCOVA indicated a main effect of group on proportion of converging cues ( $F(2, 26) = 8.22, p = .001$ ). A follow-up linear contrast using adjusted means indicated that mothers of children with cochlear implants provided a lower proportion of converging cues ( $M = 68.89$ , unadjusted  $SD = 13.59$ ) than mothers of vocabulary-matched children ( $M = 83.14$ , unadjusted  $SD = 11.72$ ;  $F(1, 26) = 5.54, p = 0.03, d = 1.12$ ). Mothers of children with cochlear implants provided a nonsignificantly different proportion of converging cues as mothers of age-matched children ( $M = 60.66$ , unadjusted  $SD = 12.08$ ;  $F(1, 26) = 1.85, p = .19, d = .64$ ).

The second research question asked whether mothers of children with cochlear implants provided a different proportion of diverging auditory and visual cues than mothers of children matched for chronological age and mothers of children matched for vocabulary size. An analysis of variance was calculated with proportions of diverging cues as the dependent variable and group membership (cochlear implant, age-matched or vocabulary-matched) as the between-subjects independent variable. Years of maternal education was included as a covariate. Years of maternal education correlated significantly with proportion of converging cues ( $r(28) = .34, p = .04$ ). The homogeneity of slopes assumptions was not violated as the covariate did not interact significantly with group membership (independent variable). The ANCOVA yielded a main effect of group ( $F(2, 26) = 5.97, p = .003$ ). Follow-up linear contrasts using adjusted means revealed that mothers of children with cochlear implants provided a higher proportion of

diverging cues ( $M = 24.55$ , unadjusted  $SD = 10.90$ ) than mothers of vocabulary-matched children ( $M = 10.44$ ,  $SD = 11.13$ ;  $F(1, 26) = 8.53$ ,  $p = 0.007$ ;  $d = 1.28$ ), but nonsignificantly different from mothers of age-matched children ( $M = 24.57$ ,  $SD = 15.15$ ;  $F(1, 26) = .00001$ ,  $p = .99$ ,  $d = .002$ ).

The third research question compared proportions of auditory-only cues provided by mothers of children with cochlear implants to mothers of children with normal hearing matched for age and matched for vocabulary size. Years of maternal education did not correlate significantly with proportion of auditory-only cues ( $r(28) = .30$ ,  $p = .11$ ). An analysis of variance with auditory-only cues as the dependent variable and group membership as a between subjects variable yielded no main effect of group ( $F(2, 26) = 1.81$ ,  $p = .17$ ). The overall pattern of results for all cue types is displayed in Figure 1.

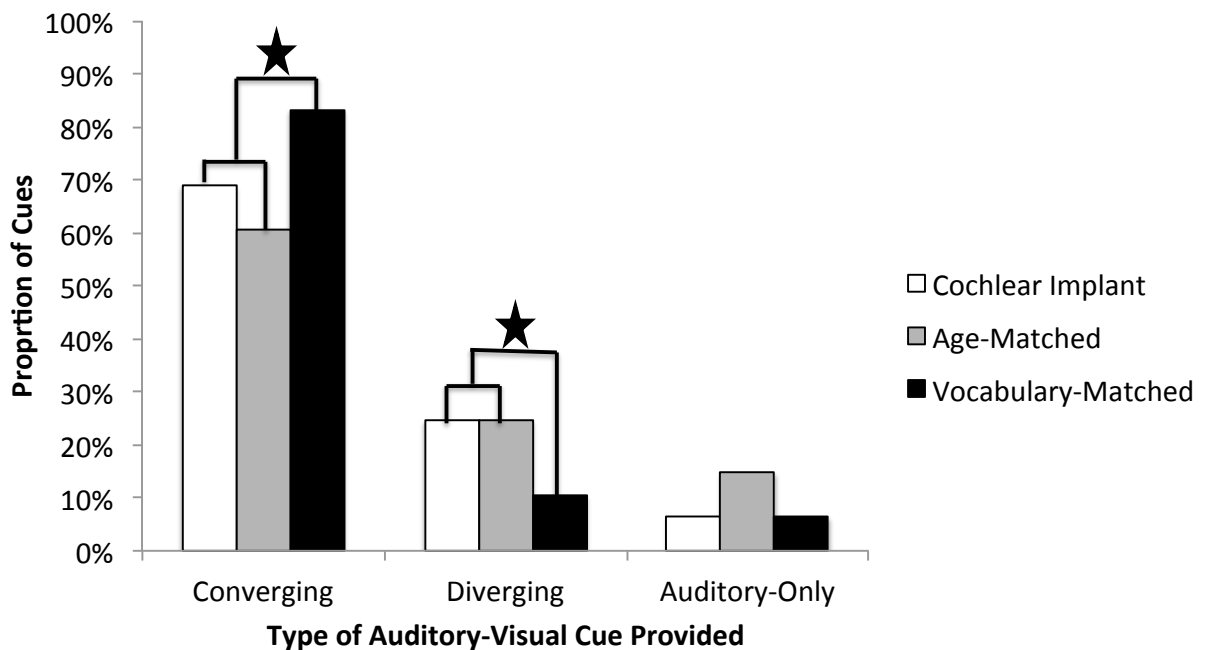


Figure 1. Proportion of Auditory-Visual Cues about Word Referents

## Further Analyses

Additional analyses were undertaken to explore other potential patterns of maternal input. The primary research questions for this study compared proportions of cues provided to participants to control for the number of unknown noun tokens presented by mothers. Using a proportion variable ensures that group differences are not solely based on the higher vocabulary knowledge of the age-matched group (i.e., mothers of age-matched children use fewer novel noun tokens because these children understand more words than children in other groups). This analysis is consistent with other studies of multimodal cues presented to children with normal hearing (e.g., Gogate, Bahrick & Watson, 2000; Matayaho & Gogate, 2008). However, it is possible mothers of children with hearing loss and mothers of children with normal hearing (both age-matched and vocabulary-matched) present similar total numbers of converging auditory-visual cues. To assess this possibility, analyses of cues provided in reference to the six novel objects (dax, blicket, arge, gow, chi and runker) were undertaken. Only cues for these objects were analyzed to control for the amount of information (novel object labels) that children did not know. Because converging cues are thought to provide the most information to children, only converging cues were analyzed.

Numbers of converging cues produced in reference to the novel objects were entered into an analysis of variance with group membership (cochlear implant, age-matched or vocabulary-matched) as the between-subjects variable and years of maternal education as a covariate. Years of maternal education

correlated significantly with number of converging cues ( $r(28) = .45, p = .01$ ). The homogeneity of slopes assumptions was not violated as the covariate did not interact significantly with group membership (independent variable). An overall ANCOVA indicated a main effect of group on number of converging cues ( $F(2, 26) = 3.09, p = .045$ ). Additional linear contrasts using adjusted means indicated that mothers of children with cochlear implants provided a lower number of converging cues ( $M = 26.90$ , unadjusted  $SD = 24.19$ ) than mothers of vocabulary-matched children ( $M = 46.70$ , unadjusted  $SD = 24.05$ ;  $F(1, 26) = 2.86, p = 0.04, d = .82$ ). Mothers of children with cochlear implants provided a number of converging cues that was not significantly different from mothers of age-matched children ( $M = 28.10, SD = 34.74$ ;  $F(1, 26) = .08, p = .93, d = .04$ ). Figure 2 displays this pattern of results.

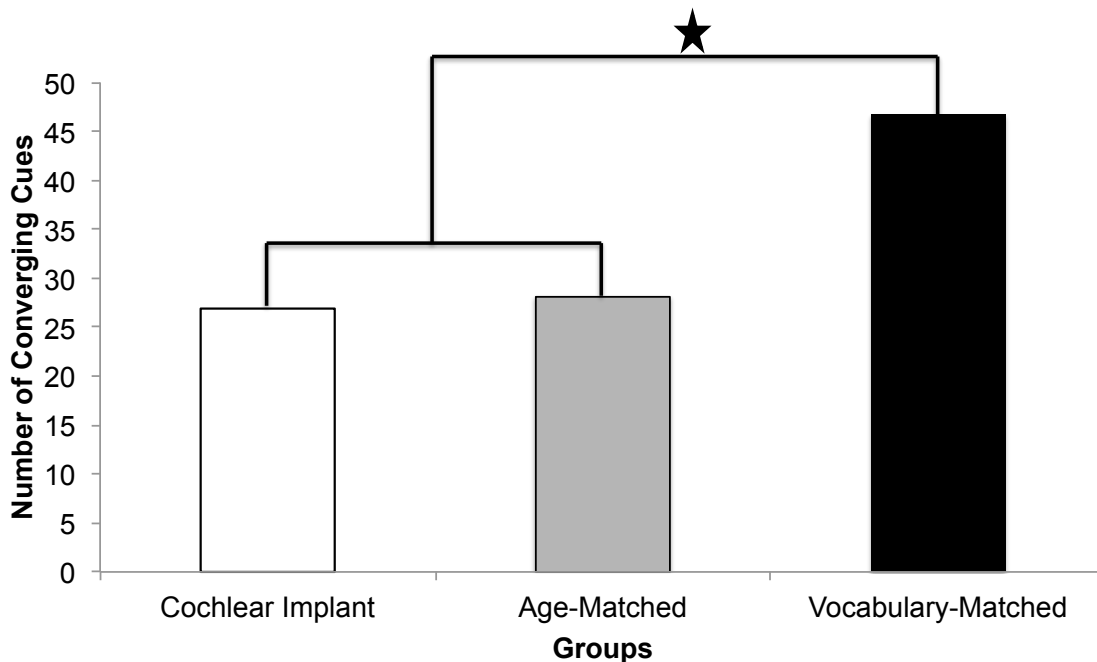


Figure 2. Number of Converging Cues Provided in Reference to Novel Objects



## Discussion

The purpose of this study was to compare types of maternal auditory-visual input about word referents available to children with cochlear implants, children with normal hearing matched for age, and children with normal hearing matched for vocabulary size. Although other works have considered the acoustic qualities of maternal input provided to children with cochlear implants, this study is the first to consider auditory-visual maternal input provided to children with cochlear implants. The results of this investigation indicate that mothers provide auditory-visual input to children with cochlear implants in way that did not significantly differ from the way that mothers provide auditory-visual input to children matched for chronological age, and not to children matched for vocabulary size.

Auditory and visual cues about word referents are presented to children in a variety of ways. Recall that these cues can be converging to indicate the same referent at the same time, diverging to indicate different referents or auditory-only (no visual cue provided; see Appendix for greater detail). Studies of children with normal hearing indicate that converging auditory-visual cues best facilitate learning new words (Gogate, Walker-Andrews, & Bahrick, 2001). However, as children develop the ability to make use of increasing lexical and syntactic knowledge, they likely rely less on auditory and visual cues to determine the meanings of novel words. As children develop, parents shift their provision of primarily converging auditory-visual cues to provide increasing numbers of diverging and auditory-only cues (Gogate, Bahrick, & Watson, 2000).

Children with cochlear implants present a paradox to parents: they often look and act similar to children of their same chronological age, but they have the lexical knowledge of much younger children (Geers, Nicholas, & Sedey, 2003). Consequently, parents may provide auditory-visual cues about word referents according to a child's chronological age or according to his or her lexical level. This study indicates that mothers of children with cochlear implants provide proportions of converging and diverging cues that are similar to the proportions of mothers of children matched for chronological age. Mothers of children matched for vocabulary size, on the other hand, provide a higher proportion of converging auditory-visual cues and lower proportion of diverging cues than mothers of children with cochlear implants.

The finding that mothers of children with cochlear implants provide auditory-visual cues ("multimodal motherese") consistent with a child's chronological age and not vocabulary size stands in contrast to findings from studies of unimodal motherese (child-directed speech only). Bergeson and colleagues (2006) found that mothers provide child-directed acoustic cues to children with cochlear implants in the same way as mothers of children matched for language level. Similarly, this study found that mothers of children with cochlear implants use shorter utterances than mothers of children matched for chronological age, similar to mothers of children matched for vocabulary size.

Two factors may have contributed to mothers' provisions of referential cues consistent with child-directed speech but not child-directed actions to children with cochlear implants. The first is a child's developmental level. Mothers

of children with cochlear implants may be sensitive to the overall development and not the lexical level of a child with a cochlear implant when providing visual cues. Studies of children with delayed overall development and delayed lexical development (e.g., children with Down's syndrome) may provide insight into child-level characteristics that affect maternal provision of visual cues. Iverson and colleagues (2006) found that mothers provided more deictic gestures to children with Down's syndrome than typically developing children matched for vocabulary size. This finding supports the hypothesis that mothers may provide visual cues according to a child's overall developmental level.

The second factor that may affect mothers' provisions of visual cues is the responsiveness of the child. Mothers of children with language delays not associated with hearing loss (i.e., language-impaired children) provide less linguistic input to children who are less vocally responsive than children who are more vocally responsive (Giralometto, Weitzman, & Weigs, 1999; Paul & Elwood, 1991). It is possible that children with cochlear implants do not solicit visual referential cues from their mothers in the same way that some children with language delays do not solicit linguistic input. Children with normal hearing, on the other hand, may subconsciously solicit visual cues about word referents when they have a low vocabulary level. Further research should explore the possibility that a child's responsiveness affects the referential cues he or she receives about word referents.

Given that children with cochlear implants demonstrate slower rates of lexical growth than children with normal hearing, the findings of this study may be

the first step in the identification of environmental factors that affect lexical outcomes for this population. If mothers can provide auditory and visual cues to increase the salience of a relevant object in word-learning contexts, they may be able to facilitate their child's language growth. Further, if children with low lexical knowledge (i.e., who have less than 50 words in their vocabulary) rely on converging auditory-visual cues to learn words from their environment, access to large numbers of converging cues becomes increasingly important.

The present study represents the first step toward identification of environmental differences between children with cochlear implants and children with normal hearing that may affect lexical learning outcomes. Future child-level and environment-level research is warranted. At the level of children, further studies should evaluate the extent to which children with cochlear implants make use of converging and diverging cues during word-learning opportunities. This information will help professionals determine the importance of auditory-visual cue provision to lexical growth in children with cochlear implants. At the level of the environment, future works may consider the development and implementation of parent training. If increasing the number of converging cues presented to children with cochlear implants may improve their vocabulary knowledge, mothers could learn to increase their provision of converging cues during word-learning opportunities. Future studies should evaluate the development and efficacy of parent trainings related to auditory-visual cue provision.

Strengths and weaknesses of this study should be considered in the interpretation of these results. This study is among the first to consider visual as

well as auditory input provided to children with cochlear implants during daily routines. The author chose to use a routine, mealtime, that is generally structured similarly across families. A structured measurement scenario may be more representative of the generalized tendency to provide referential cues to children than a less structured scenario, such as free play. Additionally, the author chose to analyze data from two observations, as opposed to only one. Using data from more than one observation is likely to result in a more stable estimate of mothers' referential behaviors than a single observation (Yoder & Symons, 2010).

However, analyzing data from only mealtimes represents a potential weakness. If maternal referential cues to children vary based on activity, the results of this study are only representative of information provided to children during mealtimes. In addition, the etiologies of children with hearing loss are widely varied. The stringent inclusionary criteria for this study do not allow the author to draw conclusions about the general population of children with hearing loss or children who have used cochlear implants for a longer period of time.

Further investigation may also address limitations to the present study. Although sample size for this study was large enough to capture group differences in cue provision, the group of children with cochlear implants was not completely representative of all children with hearing loss. More work should be done to determine if this finding holds for children with varying degrees of auditory experience (e.g., children who have used cochlear implants for a longer period of time, children who use hearing aids). In addition, this study only considered one word-learning scenario present in a child's day. It is possible that

maternal cue provision differs during various daily activities. Further exploration of cue provision throughout a child's day would better indicate the extent to which this environmental difference may contribute to a child's lexical development.

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## CHAPTER III

### STUDY 2: WORD-LEARNING PERFORMANCE OF CHILDREN WITH AND WITHOUT COCHLEAR IMPLANTS GIVEN SYNCHRONOUS AND ASYNCHRONOUS CUES

#### **Introduction**

The ability to learn new words underlies the development of lexical knowledge. Moreover, the ability to rapidly learn new words given only a few exposures may account for the ability of young children to learn as many as ten new words in a day (Bloom, 2000). Children with cochlear implants, however, learn fewer novel words in rapid word-learning tasks as compared to their peers with normal hearing (Tomblin, Barker, & Hubbs, 2007). Differences in rapid word-learning performance may account for differences in vocabulary knowledge: children with cochlear implants display lower levels of vocabulary knowledge than their peers with normal hearing (Connor, Craig, Raudenbush, Heavner, & Zwolan, 2006; Ganek, McConkey-Robbins, & Niparko, 2012; Nott, Cowan, Brown, & Wigglesworth, 2009). To date, studies of rapid word learning in children with cochlear implants have focused primarily on child-level factors that affect individual differences in word-learning performance, such as age of implantation (Houston, Stewart, Moberly, Hollich, & Miyamoto, 2012; Tomblin, Barker & Hubbs, 2007). The purpose of the present study is to investigate how a task-level factor, temporal synchrony of auditory and visual information about word

referents, affects word learning in preschool children with cochlear implants as compared to preschool children with normal hearing.

### **Rapid Word Learning**

An initial step in adding new words to one's lexicon is rapidly connecting a novel word and its referent (i.e., disambiguation) using cues from the linguistic and nonlinguistic environment (Heibeck & Markman, 1987). To store the new word for later retrieval, a child must encode phonological and semantic properties associated with that word to his or her memory (Capone & McGregor, 2005). Typically developing children with normal hearing demonstrate the ability to rapidly learn words from a young age (Houston-Price, Plunkett, & Harris, 2005). For example, in the presence of a spoon, a fork, and a whisk, a young child who does not know the word "whisk" but knows "spoon" and "fork" can deduce that an adult is referring to the whisk with the novel label "whisk". If the child connects the word to the referent object, he or she should be able to identify "whisk" in a structured comprehension task immediately following the naming incident. This behavior is demonstrative of rapid word learning. Once a child has initially added a word to his or her lexicon in this way, he or she should be able to begin learning more about that word (e.g., learning about contexts in which the word can be used).

In rapid word learning tasks, children with cochlear implants as a group perform more poorly than children of the same age with normal hearing. Tomblin, Barker and Hubbs (2007) found that children with cochlear implants (n = 14)

between the ages of two and five years (implanted between ages one and four years) learned fewer words receptively and expressively in a rapid word-learning task than children of the same age with normal hearing. Houston and colleagues (2012) determined that children implanted before age two ( $n = 25$ ) did not learn as many words at 22 to 40 months as children with normal hearing matched for chronological age. Walker and McGregor (2013) similarly found that children with cochlear implants ( $n = 24$ , mean age = 4.86 years, mean age of implant = 1.68 years) comprehended fewer words in rapid learning tasks as compared to age-matched children. In addition, the children with hearing loss retained fewer of the words that they do learn in these tasks. These studies indicate that children with cochlear implants, even those implanted relatively early, learn and retain fewer words receptively and expressively than children with normal hearing matched for age. However, investigators still do not know how task-level factors, such as types of information presented to children about new words, affect the word learning of children with cochlear implants.

A myriad of child-level factors affect the rapid word-learning performance of children with cochlear implants: speech perception and integration, auditory working memory, and listening experience (Bergeson, Houston, & Miyamoto, 2010; Wilstedt-Svenson et al., 2004; Houston et al., 2012). However, often these characteristics of children with cochlear implants cannot be manipulated to mirror or more closely approximate children with normal hearing (e.g., speech perception skills). Thus, investigators must begin to consider how environmental, or task-level factors affect word-learning performance in this population. Task-

level factors may represent malleable factors that can alter the word-learning outcomes for children with cochlear implants. Understanding how the characteristics of a word-learning task affect a child's ability to rapidly learn new words may provide professionals with insight about ways a child's environment may be manipulated to encourage lexical growth.

### **Auditory and Visual Cues about Word Referents**

Adults instinctively provide information to children in ways that facilitate language learning through child-directed speech and actions. Child-directed speech and actions are frequently provided simultaneously in a child's environment. For example, parents often point to or hold a new toy when introducing it to a child. A growing body of research in children with normal hearing illustrates that this visual and auditory input plays a role in recruiting and directing child attention. The provision of redundant information (as via both auditory and visual channels) clearly focuses the attention of even very young children on salient characteristics of a learning incident (Gogate & Bahrick, 1998). Combinations of cues provided to normal hearing children across multiple sensory channels may, in fact, recruit selective attention and facilitate early learning more so than provision of unimodal cues (e.g., only auditory or only visual). Bahrick, Lickliter and Flom's (2004) "Intersensory Redundancy Hypothesis" states intersensory redundancy "promotes detection of salient information, causing the redundant stimulus to become foreground and [other stimuli] background," thus facilitating selective attention (p. 100). If true,

multimodal (i.e., auditory plus visual) cues should recruit and hold the attention of children better than cues provided in isolation. As a result, children with normal hearing should be more likely to learn language from multimodal rather than unimodal learning opportunities.

Auditory and visual cues about word referents can occur temporally in many situations. Cues provided together temporally (within less than 150 milliseconds) to direct attention to the same object (e.g., shaking an object while labeling it) are considered synchronous, whereas cues provided at different times (more than 400 milliseconds apart; e.g., labeling an object and then shaking it) are considered asynchronous (and less useful as multimodal cues). During labeling events for new words, synchronous labeling events are thought to provide the most information about a label's referent as compared to asynchronous cues (Gogate, Bahrick, & Watson, 2000; Matayaho & Gogate, 2008).

Among the earliest steps in language learning is the ability to pair arbitrary speech with an object. Gogate and Bahrick (1998) measured the effects of cue synchrony on the performance of seven-month-old infants mapping vowel sounds to objects within a habituation task. They presented vowel sounds paired with objects in three conditions: (a) while synchronously moving the target object, (b) while asynchronously moving the target object (i.e., providing the sound and then later moving the object) and (c) while the target object remained still. The authors only found evidence of sound-object mapping only in the synchronous condition, suggesting that infants as young as seven months can learn arbitrary



relations. Perhaps more importantly, sound-object mapping is facilitated by synchronous auditory and visual cue presentation, as opposed to asynchronous or unimodal auditory presentation.

As infants begin to learn words, they must pair whole words with objects. Gogate, Bolzani, and Betancourt (2006) assessed associations between word learning and mother's cue provision to pre-verbal infants between 6 and 8 months of age. Mothers were asked to teach two nouns to their infants, and their teaching strategies were coded as synchronous or asynchronous. Infant word learning then was assessed in a preferential looking paradigm. Mothers who used more synchronous cues than asynchronous cues had infants who were more likely to learn the novel words. These findings support the hypothesis that provision of synchronous multimodal auditory and visual cues relates to greater early word learning than asynchronous cues.

The auditory deprivation experienced by children with hearing loss prior to receiving a cochlear implant may affect the way children with cochlear implants perceive and process auditory and visual information. A large body of literature has focused on the effects of auditory and visual stimuli on speech perception in children and adults with cochlear implants (see Houston, Beer, Bergeson, Chin, Pisoni, & Miyamoto, 2012 for a review). Landry and colleagues (2012) determined that some groups of adults using cochlear implants are "unable to segregate incongruent auditory and visual information adequately" (p. 26). In children, age of implantation as well as duration of implant use affect a child's integration of auditory and visual information about speech (Bergeson, Houston

& Miyamoto, 2010; Houston et al., 2012). Children with cochlear implants do not show a preference for audio-visual speech presentation until at least one year post-implant, whereas children with normal hearing began to establish this preference by six months of age (Bergeson et al., 2010). Data exploring the effects of auditory-visual presentations of speech on the speech perception skills of children with cochlear implants support the idea that auditory-visual presentations of other lexical learning cues may also affect children with cochlear implants.

The purpose of this study was to investigate how temporal synchrony of auditory and visual information about word referents affects rapid word-learning performance in children with cochlear implants as compared to children with normal hearing. Four research questions were addressed: (a) Do children with cochlear implants and children with normal hearing learn more words when presented with synchronous auditory-visual cues than when presented with asynchronous auditory-visual cue? (b) Do children with cochlear implants learn fewer words than children with normal hearing when presented with synchronous auditory-visual cues? (c) Do children with cochlear implants learn fewer words than children with normal hearing when presented with asynchronous auditory-visual cues? and (d) Does chronological age or duration of implant use correlate with word-learning performance for children with cochlear implants in the synchronous or asynchronous condition?

## Method

### Participants

Participants included 20 children divided into two groups: a cochlear implant group ( $n = 10$ ) and an age-matched group ( $n = 10$ ) of children with normal hearing. Participants in the cochlear implant group had a mean age of 23 months ( $SD = 9.40$  months, range 14 – 42 months) and participants in the age-matched group had a mean age of 24.1 ( $SD = 9.49$  months, range 15 – 43 months; each child in the age-matched group was within three months of age of a participant in the cochlear implant group). All participants came from English-speaking families; the families of children with cochlear implants were committed to developing listening and spoken language skills (not sign language). Maternal education level varied freely across the participant pool (cochlear implant group  $M = 15.95$  years,  $SD = 2.03$ ; age-matched group  $M = 17.45$  years,  $SD = 3.49$ ). Years of maternal education did not differ significantly between groups ( $p = .20$ ) and did not significantly correlate with performance on the experimental task ( $p = .43$ ).

**Cochlear implant group.** Children in the cochlear implant group were recruited from the National Center for Childhood Deafness and Family Communication (NCCD) at Vanderbilt University Medical Center. Participants had at least one cochlear implant device and a diagnosis of severe to profound, bilateral hearing loss as measured by brainstem response as well as behavioral

audiometry. Each parent reported that his or her child had no useable access to sound before receiving a cochlear implant. Functional aided hearing demonstrated aided sound field thresholds of at least 30 dB HL for 500 through 4000 Hz. Children did not have additional diagnoses known to affect cognitive and/or language development (e.g., Down syndrome) or significant visual impairment. Average duration of time using a cochlear implant was 5.5 months (SD = 3.21 months, range = 2 – 11 months). To identify environmental input differences between children with and without cochlear implants within a developmental period when auditory-visual cue combinations matter most, this study focused on very early word learning. To be eligible to participate in this study, children in the cochlear implant group had to have an expressive vocabulary of less than 50 words as measured by the MacArthur Bates Communicative Development Inventory - Words and Sentences (CDI; Fenson et al., 2006). Parents also completed the LittleEars Auditory Questionnaire to describe their child's auditory function (Kühn-Inacker et al., 2004). All children received regular speech-language therapy services and one child received occupational therapy services. Review Table 3 for child-specific information.

**Age-matched group.** Children in the age-matched group were recruited via advertisement, research recruitment networks, local area preschools, and local area music programs. Participants in this group demonstrated normal hearing per parent report. Mothers of children with normal hearing completed the Ages and Stages Questionnaire to confirm their child's status as a typical

language learner (Squires & Bricker, 2009). Every participant with normal hearing performed above the test manual referral cutoff in the Communication Skills and Problem Solving sections.

## **Procedures**

All participants completed the experimental task in a one-on-one setting with the author. Children were seated at a table directly facing the examiner. Each child completed 20 word-learning trials, each trial consisting of the introduction of two novel objects, a short wait period where the objects were removed from sight, and a receptive assessment. In each trial, the examiner introduced the two novel objects using either synchronous auditory-visual cue pairings or asynchronous auditory-visual cue pairings. Each child participated in ten synchronous trials and ten asynchronous trials.

For synchronous trials, the examiner introduced each of the two novel objects by shaking each individual object while simultaneously labeling it three times with a nonsense word. For example, the examiner picked up each object, one at a time, and said “Look, a *yan!* I see the *yan!* Look at that *yan!* Look, a *bape!* I see the *bape!* Look at that *bape!*” Following the introduction of the two novel objects, they were removed from the child’s field of vision and replaced with a piece of paper and a sticker. The child put the sticker on the paper and the paper and sticker were removed. Next, the two novel objects were again placed side-by-side in front of the child on the table. The examiner then asked for one of the novel objects, saying “Where is the *yan?*” for example. Each child response

was recorded as correct (touching or indicating the correct object), incorrect (touching or indicating the other object or both objects), or no response (not indicating or touching either object).

For asynchronous trials, the examiner also introduced two novel objects. However, the examiner only made physical contact with the object only after more than 400 milliseconds but less than 2 seconds (average 1.4 seconds) had passed after she labeled the object. (Exact timing of contact with the object was measured from video recordings). For example, the examiner put two objects on the table, removed her hands from the objects, paused, and said “Look, a *mobe*! I see the *mobe*! Look at that *mobe*! Look, a *bape*! I see the *bape*! Look at that *bape*!” Next, the examiner picked one object up, shook it, and put it back on the table. Following the introduction of the two objects, they were removed from the child’s field of vision and replaced with a piece of paper and a sticker. The child put the sticker on the paper, and the paper and sticker were removed. Next, the two novel objects were again placed side-by-side in front of the child on the table. The examiner then asked for one of the novel objects, saying for example “Where is the *mobe*?” Each child’s response was recorded as correct, incorrect or no response (see above).

Synchronous and asynchronous cue presentations were counterbalanced across and within groups (two possible orders of presentation synchrony). In addition, nonsense names and objects were paired differently for each child in a pre-planned, random order and the object requested within each trial was

counterbalanced within groups. All cue presentations and child responses were video-recorded to ensure reliable recording of child responses.

### **Stimulus Selection**

To develop this experimental task, the examiner collected fifty novel objects. These objects included tools (e.g., a plate hanger), kitchen items (e.g., a drain cover) and other items (e.g., a head scratcher) not likely to be familiar to a child, and thus, not likely to have a label within a child's lexicon. For each child participant, the examiner presented the objects to the child's mother, away from the child, and asked if the child had experience with or a name for any of the objects. Objects that the mother identified as familiar to the child were eliminated from the set. Of the remaining objects, 40 were selected to use in the experimental task. Seventeen of the participants used the same set of novel objects; three participants had one object replaced due to the mother's report (two in age-matched group, one in the cochlear implant group).

A corpus of 40 names was formulated based on the nonsense word corpus created by Storkel (2013). Each name followed a consonant-vowel-consonant sequence. Twenty names were assigned randomly to the synchronous trials, and the other 20 to asynchronous trials. The set of names used in the synchronous trials had the same average phonotactic probability as the set of names in the asynchronous trials. Further, each name contained only those consonants identified as the "early eight" or consonants produced earliest

by children with normal hearing. Those consonants included /m/, /b/, /n/, /w/, /j/, /h/, /p/, and /d/.

## **Analysis**

Number of objects correctly selected in synchronous trials and in asynchronous trials was calculated for each participant. Performance by trial type (asynchronous versus synchronous) across groups was compared using an analysis of variance. Group membership (cochlear implant or age-matched) represented the between-subjects independent variable and trial type (asynchronous or synchronous) represented a within-subjects independent variable. Main effects were analyzed with follow-up linear contrasts. The final research question was addressed with correlational analyses.

To train for a lab assistant (undergraduate linguistics and psychology major) to collect reliability data, the author described the following response the three response categories, correct, incorrect, or no response, by describing each response category. The assistant scored responses for 33% of the participants from each group using the video recordings. Reliability was calculated and determined to be greater than 98% for each group. Reliability percentages were sufficiently high to indicate that the first author had accurately captured the children's responses. Thus, the first author's scoring was used for analysis.



## Results

This study compared the word-learning performance of children with cochlear implants and children with normal hearing when children are provided with synchronous and asynchronous auditory and visual temporal cues about word referents. All children were included in the analysis because all children demonstrated understanding of the task by selecting at least one object (i.e., no child was scored “no response” for every trial question). Number of correct objects identified was entered as the dependent variable into an analysis of variance. Figure 3 displays the overall pattern of results. The analysis yielded a main effect of group membership ( $F(1, 35) = 3.13, p = .02$ ) but not an effect of trial type ( $F(1, 35) = .002, p = .096$ ) or an interaction effect ( $F(1, 35) = 16.9, p = .06$ ).

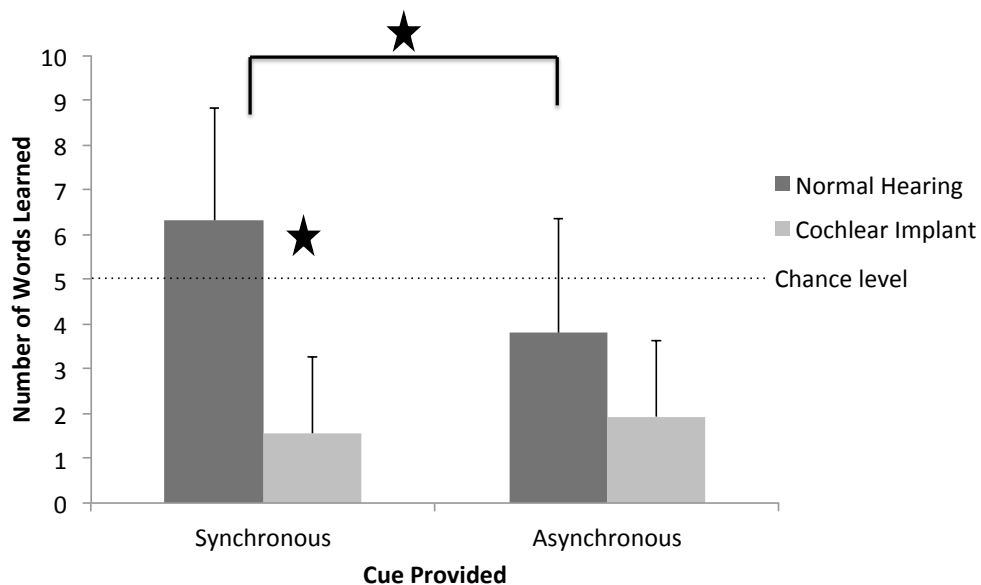


Figure 3. Number of Words Learned by Group and Cue Type Provided

The first research question addressed whether learning in the synchronous condition was more evident than in the asynchronous condition. The overall ANOVA revealed no main effect of condition but an interaction effect that approached significance ( $p = .06$ ). A follow-up contrast indicated that children with normal hearing learned more words in the synchronous condition than the asynchronous condition ( $F(1, 17) = 2.05, p = .049, d = .92$ ). Children with cochlear implants, on the other hand, did not learn different numbers of words across conditions ( $F(1, 17) = .13, p = .90, d = .06$ ).

The second research question compared the performance of children with cochlear implants with children with normal hearing given synchronous auditory and visual information. A linear contrast confirmed that children with cochlear implants ( $M = 2.10$  words,  $SD = 1.60$ ) learned fewer words in the synchronous condition than did children with normal hearing ( $M = 6.3, SD = 2.54; F(1, 17) = 4.43, p < .001, d = 1.98$ ).

The third research question compared the performance of children with cochlear implants with children with normal hearing given asynchronous auditory and visual information. In this condition, children with cochlear implants did not learn fewer words ( $M = 2.2, SD = 1.93$ ) than did children with normal hearing ( $M = 3.8, SD = 2.90; F(1, 17) = 1.45, p = .17, d = .64$ ).

The final research question addressed whether chronological age or amount of time with a cochlear implant correlated with performance in either the synchronous or asynchronous condition. A Spearman correlation revealed that for children with normal hearing, chronological age was related to performance in

the asynchronous condition ( $r_s(8) = .80, p = .001$ ) but not the synchronous condition ( $r_s(8) = .20, p = .58$ ). Spearman's correlation was used because performance in the synchronous or asynchronous condition was not normally distributed. Performance of children with cochlear implants in the synchronous condition was significantly correlated with duration of implant use ( $r_s(8) = .65, p = .04$ ) but not chronological age ( $r_s(8) = .03, p = .92$ ). Performance of children with cochlear implants in the asynchronous condition was not correlated with either duration of implant use ( $r_s(8) = .40, p = .25$ ) or chronological age ( $r_s(8) = .59, p = .07$ ). Figures 4 and 5 display this pattern of results.

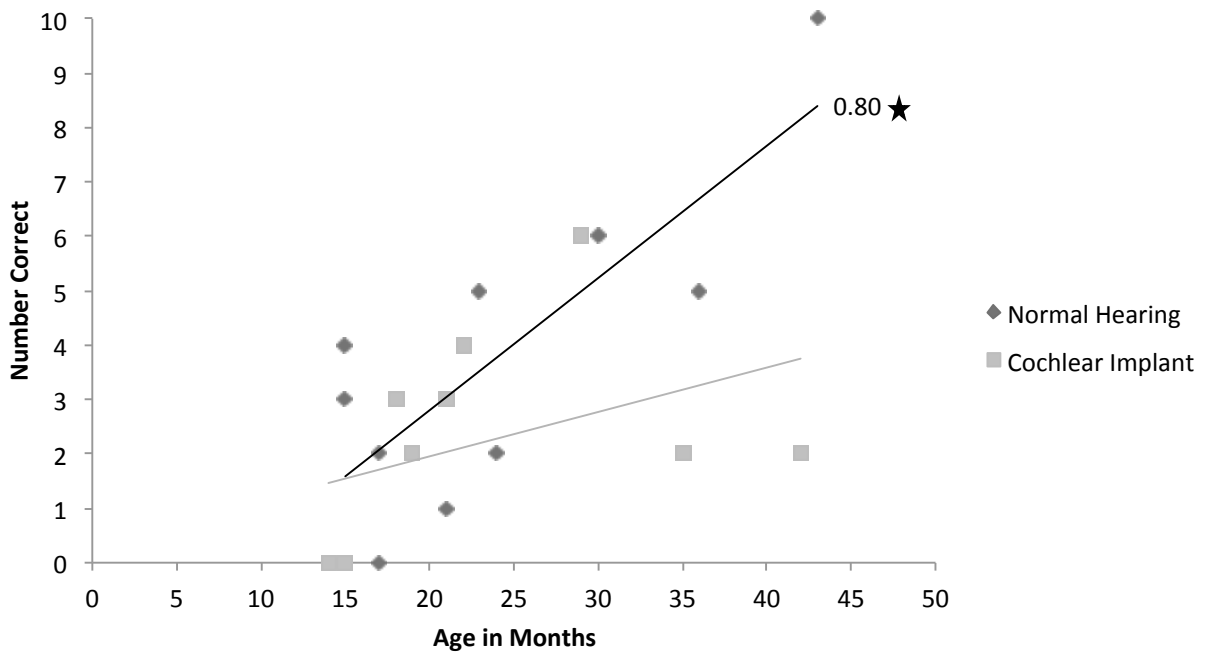


Figure 4. Relationship of Chronological Age to Number Correct Selections in Asynchronous Condition

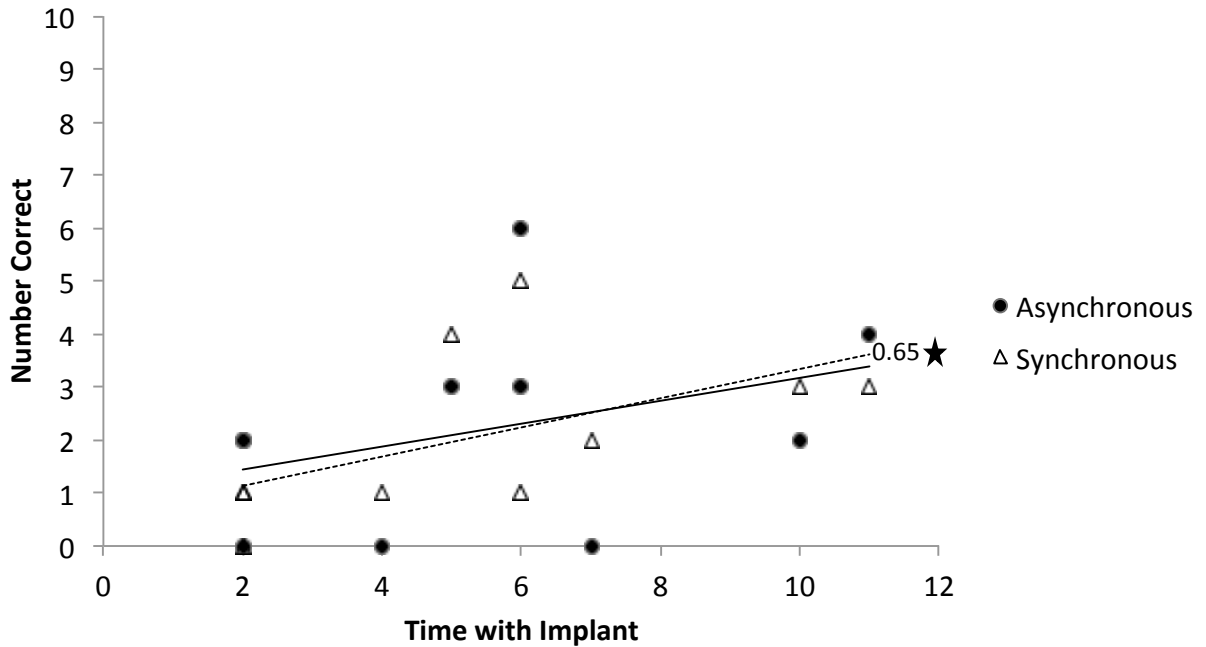


Figure 5. Relationship of Duration of Cochlear Implant Use with Number Correct Selections for Cochlear Implant Group

### Discussion

The goal of this study was to determine how temporal synchrony of auditory and visual information about word referents affects rapid word-learning performance of children with cochlear implants as compared to children with normal hearing. The pattern of rapid word-learning performance of children with cochlear implants differed from children with normal hearing. Children who have worn cochlear implants for less than one year did not benefit from temporal synchrony of auditory and visual cues in the same way as age-matched children with normal hearing.

Children with cochlear implants learned fewer words than children with normal hearing matched for chronological age when auditory and visual cues were presented synchronously. Children with normal hearing were able to

receptively identify more words than predicted by chance levels (50%) whereas children with cochlear implants performed well below chance. However, the groups did not significantly differ on number of words receptively identified when cues were presented asynchronously. In this condition, both groups performed below chance levels. This finding is consistent with other studies that indicate that synchronous auditory and visual cues about word referents facilitate word learning in children with normal hearing (Gogate & Bahrick, 1998; Gogate, Bolzani, & Betancourt, 2006). Further, this result replicates findings of other investigations that children with cochlear implants learn fewer words in word-learning tasks than children with normal hearing (Houston et al., 2012; Tomblin, Barker, & Hubbs, 2007; Walker & McGregor, 2013).

Within-group differences revealed different patterns of responding for children with cochlear implants and children with normal hearing. Children with normal hearing learned more words in the synchronous cue condition than in the asynchronous cue condition, whereas children with cochlear implants did not. In other words, children who had worn cochlear implants for less than one year were unable to make use of synchronous cues about word referents to the same extent as children with normal hearing in a rapid word-learning task.

The lack of a relationship between temporal synchrony and word learning in the group of children with cochlear implants may reflect difficulty learning words at a number of levels. Because children in this study had used cochlear implants for less than one year, it is possible that they would not have been able to rapidly learn words regardless of the amount or type of input they received

from the examiner. Although children with normal hearing show evidence of rapid word learning before they are one year old, children with cochlear implants may need more time to develop this linguistic skill (Gogate, Bolzani, & Betancourt, 2006). Alternatively, the chance-level performance of children with cochlear implants may reflect a need for more input to rapidly learn words. Because children with cochlear implants demonstrate difficulty with speech perception and working memory, they may need more input (beyond temporal synchrony; e.g., increased repetition, slowed rate of input) to achieve success in word-learning tasks (Bergeson, Houston, & Miyamoto, 2010; Wilstedt-Svenson et al., 2004). An additional explanation may be that children with cochlear implants do not integrate auditory and visual information in the same way as children with normal hearing. The auditory-visual integration differences between children with cochlear implants and children with normal hearing in speech perception tasks may extend to other lexical learning tasks (i.e., pairing a novel word and its referent; Bergeson, Houston & Miyamoto, 2010).

Because age and duration of implant use can affect rapid word-learning performance (Houston et al., 2012; Tomblin, Barker & Hubbs, 2007), the relationship between these variables and word-learning performance in both groups of children was explored. Chronological age was strongly correlated with performance of children with normal hearing in the asynchronous condition, but not the synchronous condition. This finding supports the hypothesis that asynchronous cues about word referents become more accessible to children with normal hearing as they develop (Gogate, Bahrick, & Watson, 2000). In the

group of children with cochlear implants, chronological age was not correlated with performance in either condition. However, duration of implant use was correlated with performance in the synchronous condition (but not the asynchronous condition). Thus, synchronous cues may become more accessible to children with cochlear implants as they use the implants over time. If duration of implant use predicts word-learning performance in the synchronous condition, this finding would suggest that auditory experience (possibly as a proxy for receptive lexical level) and not developmental level drives lexical learning.

The overarching findings of this study indicate that temporal cues are not sufficient to help children who have used cochlear implants for less than one year learn words as well as their same-age peers with normal hearing within the age group studied. Further investigation is needed to explore when temporal synchrony begins to affect word-learning performance in children with cochlear implants. Building on the documented relation between duration of implant use and word-learning performance under the condition of synchronous cues, investigators should continue to consider the impact of child-level factors. In addition to duration of implantation, age of implantation, communication mode, and pre-implant residual hearing can be explored. Knowledge of the interaction between child-level factors and word-learning performance could inform future interventions. For example, if children benefit from synchronous cues most from one to two years post-implantation, altering maternal cue synchrony might be an appropriate intervention for families with children in that age range. In addition, investigations of word learning in children with cochlear implants should consider

how other environment-level factors (e.g., number of word presentations, amount of additional information included) relate to performance. Because environment-level factors are likely more malleable than child-level factors, investigators must understand the impact of the environment on word learning to begin developing interventions.

Additional research may also address limitations of the present study. A larger, more varied group of cochlear implant users would allow investigators to consider how temporal synchrony affects word learning across the population of children who use cochlear implants (e.g., children with progressive hearing loss, children with additional disabilities, samples of children from families with low socioeconomic status). Lowering the chance level on the receptive learning task from 50% could also reveal differences between groups of children with normal hearing and children with cochlear implants. Finally, presenting the task in a more ecologically valid scenario (e.g., as a teacher would present new vocabulary words) could further demonstrate how word learning occurs for children with cochlear implants on a daily basis.



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## CHAPTER IV

### GENERAL DISCUSSION

The pair of studies reported in this dissertation compared multimodal cues about word referents available to and used by children with cochlear implants and children with normal hearing. The first study quantified the proportion of converging and diverging auditory-visual cues present in maternal speech to children with cochlear implants as compared to children with normal hearing matched for chronological age and children matched for vocabulary size. Mothers provided auditory-visual input to children with cochlear implants in a way that was different from the way that mothers provide input to children matched for vocabulary size. However, input provided to children with cochlear implants was not significantly different from the input provided to children matched for chronological age. The second study evaluated the effects of synchronous (a converging cue) and asynchronous (a diverging cue) auditory-visual cues on the word-learning performance of children with cochlear implants and children with normal hearing matched for chronological age. Children with cochlear implants did not learn words in either condition; their performance was not above chance level responding. In contrast, children with normal hearing made use of synchronous cues to learn words. These findings represent a first step toward determining how environment-level factors influence the lexical outcomes of children with cochlear implants. In these two studies, the focus was on very early

word learning, as children with cochlear implants had lexicons of less than 50 words.

### **Maternal Auditory-Visual Cues about Word Referents**

Study 1 results indicated that mothers of children with cochlear implants used approximately 68% converging cues when discussing unknown nouns with their children. The ratio of converging and diverging cues used by mothers of children with cochlear implants was not significantly different from that used by mothers of children with normal hearing matched for chronological age. However, mothers of children with normal hearing matched for vocabulary size (i.e., younger children) used a larger proportion of converging cues than either of the other groups. A follow-up analysis of the actual number of converging and diverging cues provided by mothers about a pre-determined set of unfamiliar objects with nonsense names revealed a similar pattern of results. Mothers of children with cochlear implants appear to use multimodal cues according to a child's age and not lexical level. Thus, if these mealtime interactions index maternal input across the day, children with cochlear implants have fewer converging cues about unknown words available to them in naturalistic word-learning contexts than do children with normal hearing with the same vocabulary size.

The finding that mothers of children with cochlear implants provide auditory-visual cues (multimodal motherese) consistent with a child's chronological age and not vocabulary size stands in contrast to findings from

studies of unimodal motherese (auditory cues only). Bergeson and colleagues (2006) found that mothers provide child-directed acoustic cues to children with cochlear implants in the same way as mothers of children matched for language level. Similarly, this study found that mothers of children with cochlear implants use shorter utterances than mothers of children matched for chronological age. However, to fully understand the nature of word-learning cues available to children with cochlear implants at the early stage of word learning investigators must examine maternal input from a multimodal perspective. Combinations of auditory and visual cues are particularly critical at this early word learning point, when child learning may be reliant on multimodal cues to a far greater extent than unimodal cues.

A child's developmental level as well as child responsiveness may contribute to mothers' provisions of referential cues consistent with child-directed speech but not child-directed actions to children with cochlear implants. Mothers of children with cochlear implants may be sensitive to the overall development and not the lexical level of a child with a cochlear implant when providing visual cues. Studies of children with delayed overall development and delayed lexical development (e.g., children with Down's syndrome) may provide insight into child-level characteristics that affect maternal provision of visual cues. Iverson and colleagues (2006) found that mothers provided more deictic gestures to children with Down's syndrome than typically developing children matched for vocabulary size.

Mothers of children with language delays not caused by hearing loss provide less linguistic input to children who are less vocally responsive than children who are more vocally responsive (Giralometto, Weitzman, & Weigs, 1999; Paul & Elwood, 1991). It is possible that children with cochlear implants do not solicit visual referential cues from their mothers in the same way that some children with language delays do not solicit linguistic input. Children with normal hearing, on the other hand, may subconsciously solicit visual cues about word referents when they are early word learners. Further research should explore the possibility that a child's responsiveness affects the referential cues he or she receives about word referents. It is possible, for example, that a child's pointing behaviors, combined with vocalization, solicit synchronous auditory and visual cue information from adults. If responsiveness drives referential cue provision, it is possible intervention could change the responsiveness of children with hearing loss.

There are many other possible reasons that mothers of children with cochlear implants provide auditory-visual cues consistent with those provided to age-matched peers with normal hearing. Mothers may provide auditory motherese-type cues to children because they are hyper-aware of their child's hearing loss. Sensitivity to a lack of auditory input may affect speech cues provided to children but not gestural cues. That is, mothers may attribute a need for reduced complexity in speech input to the child's hearing difficulties. But, that need to simply speech input may not carry over to other types of input (namely visual) that facilitate early word learning. Finally, current therapy techniques may



encourage mothers to avoid giving visual input to children with cochlear implants. For example, parents participating in auditory-based speech and language therapy often are encouraged to present information using the “audition first” strategy (Fitzpatrick & Doucet, 2013). In other words, parents are asked to present information through speech alone before adding visual cues. Participation in therapy that employs these types of strategies may influence a parent’s provision of visual cues at home, thus increasing the number of diverging cues provided to children.

Whatever the cause, children with cochlear implants appear to have fewer converging cues about word referents available to them in a naturalistic word-learning context than do children with normal hearing with their same vocabulary size. Thus, maternal input represents a possible factor contributing to the slow lexical growth of children with cochlear implants. If converging cues best facilitate word learning, children with cochlear implants likely need increased access to these cues during language learning opportunities, especially at this earliest point of word learning. If mothers can provide auditory and visual cues to increase the salience of a relevant object in word-learning contexts, they may be able to facilitate their children’s language growth.

### **Temporal Synchrony of Cues and Word-Learning Performance**

Study 2 results indicated that children with cochlear implants who have fewer than 50 expressive words did not learn words in rapid word-learning contexts, regardless of the temporal synchrony of auditory-visual cues provided.

Children with normal hearing matched for chronological age, on the other hand, learned words when presented with synchronous (i.e., converging) auditory-visual cues about word referents. Recall that the mean expressive MCDI score for children with cochlear implants was 53 words, whereas the mean expressive score for age-matched children with normal hearing was 308 words. Neither group learned words when presented with asynchronous (i.e., diverging) auditory-visual cues about words. This finding is consistent with other studies that indicate that synchronous auditory and visual cues about word referents facilitate word learning in children with normal hearing (Gogate & Bahrack, 1998; Gogate, Bolzani, & Betancourt, 2006). Further, this result supports the conclusion of other investigations that children with cochlear implants learn fewer words in word-learning tasks than same-age children with normal hearing (Houston et al., 2012; Tomblin, Barker, & Hubbs, 2007; Walker & McGregor, 2013). Further analysis indicated that the performance of children with normal hearing was related to a child's chronological age, whereas performance of children with cochlear implants was related to duration of implant use.

The lack of a relationship between temporal synchrony and word learning in this group of children with cochlear implants may reflect difficulty learning words at a number of levels. Because children in this study had used cochlear implants for less than one year, it is possible that they would not have been able to rapidly learn words regardless of the amount of input they received from the examiner. Although children with normal hearing show evidence of rapid word learning before they are one year old, children with cochlear implants may need

more time to develop this linguistic skill (Gogate, Bolzani, & Betancourt, 2006; Houston et al., 2012). Alternatively, the poor performance of children with cochlear implants may reflect a need for more input to rapidly learn words regardless of length of time since implantation. Because children with cochlear implants demonstrate difficulty with speech perception and working memory, they may need more input (beyond temporal synchrony) to be successful at word-learning tasks (Bergeson, Houston, & Miyamoto, 2010; Wilstedt-Svenson et al., 2004). This need may be true only at this early point of word learning, or it may be true across the course of language acquisition. An additional explanation for this result may be that children with cochlear implants do not integrate auditory and visual information at the same rate as children with normal hearing. The auditory-visual integration differences between children with cochlear implants and children with normal hearing in speech perception tasks may extend to other lexical learning tasks (i.e., pairing a novel word and its referent; Bergeson, Houston & Miyamoto, 2010).

### **Implications**

To understand how auditory-visual cues about word referents affect lexical outcomes of children with cochlear implants, investigators must understand (a) what cues are available to children in word-learning contexts and (b) how (and if) children use those cues to learn words. This study indicates that, during mealtime, children with cochlear implants have access to fewer converging auditory and visual cues than do children with the same expressive vocabulary

size. However, in a word-learning task, children with cochlear implants did not use auditory-visual cues to successfully learn new words. More work is needed to further interpret the effects of environmental word-learning cues on lexical outcomes.

The finding that children did not use synchronous (converging) or asynchronous (diverging) cues to learn words may reflect the limited duration of implant use for children in this study. As children learn to process the information they receive from the cochlear implant, it is possible that they will be able to use auditory and visual cues as a child with normal hearing would. Future work should expand the group of children with cochlear implants to include children with more listening experience, and those children who develop their expressive lexicon at a rate faster than participants in this study. Longitudinal observation of children with cochlear implants and their abilities to integrate auditory and visual information are vital to understanding the gap in vocabulary knowledge between children with and without hearing loss. It is possible that children with hearing loss need altered auditory and visual input throughout their day to account for differences in their ability to learn words from their environment.

Despite the lack of receptive word learning during Study 2, auditory and visual cues about word referents may still be an important environmental factor contributing to lexical knowledge of children with cochlear implants. Mothers may still be able to alter their presentations of auditory and visual cues to ensure that children with cochlear implants receive information that facilitates their ability to learn words. Future work should also explore other environmental factors that

contribute to word learning. For example, perhaps children with cochlear implants need more repetitions of words, in combination with synchronous cues, to complete rapid word-learning tasks. In addition, future investigations may consider the characteristics of input from other adults, including teachers, to children with hearing loss.

### **Limitations**

As expected, there are several limitations in this dissertation study to address. First, the small sample size and nature of participants does not allow the authors to draw conclusions about the general population of children with cochlear implants. For example, children who used another language (e.g., American Sign Language, Spanish) were excluded from this study. Most of the children in this study received a cochlear implant at a relatively young age, and consequently are not representative of later implant recipients. To expand the findings of this work to other groups of children with cochlear implants, a larger and more varied participant pool will need to be included.

A second set of limitations existed in the procedures for Study 2. The level of chance responding was high in the word-learning task (50%) and thus the sensitivity of the receptive task may not have allowed for the capture of slight differences in the word learning in children with cochlear implants versus children with normal hearing. In addition, the procedures for Study 2 were too difficult for children in the vocabulary-matched group of children with normal hearing to complete. An alternate method (e.g., eye gaze, preferential looking) may better

assess the word learning in this younger group. A better understanding of the word learning performance of children at this lexical level (i.e., less than 50 expressive words) would add more information to the findings of this study.

### **Conclusion**

Maternal auditory and visual cues about word referents represent a possible environmental factor contributing to lexical outcomes of children with cochlear implants. Mothers of children with cochlear implants provide auditory and visual cues comparable to those provided to children with normal hearing matched for chronological age. Mothers of children with normal hearing matched for vocabulary size, however, provide larger numbers of converging auditory and visual cues than do mothers of children with cochlear implants. Preliminary data suggest that children who have used a cochlear implant for less than one year cannot take advantage of converging cues to the same extent as children with normal hearing. Nevertheless, with continued implant use, children may be better able to access auditory and visual information to rapidly learn new words. Continued investigation in this line of inquiry may lead to knowledge of the best ways to alter a child's environment to facilitate language learning.

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## APPENDIX I

### CODING MANUAL

#### **Transcription and Coding Manual**

#### **Early Maternal Word-Learning Cues to Children with Cochlear Implants**

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This manual will provide guidelines for coding interactions for the study “Early Maternal Word-Learning Cues to Children with Cochlear Implants” (IRB # 120688). The purpose of coding these interactions is to identify the types of word-learning cues provided to children during mother-child interactions.

This work was informed by coding procedures described in: Bahrnick, Lickliter & Flom, 2004; Gogate, Bahrnick, & Watson, 2000; Gogate, Bolzani, & Betancourt, 2006; Matayho & Gogate, 2008; Gogate & Bahrnick, 2008.

To prepare interaction data for coding, (a) video files of each interaction must be transcribed, (b) naming events must be marked in transcriptions and (c) codes must be applied to transcription files. Procedures and definitions for completing these steps are described below.

## Transcription

Transcription procedures for this study will follow those procedures outlined in *Transcription and Basic Coding Manual* (Schuele, 2009).

To prepare to transcribe interactions, read Schuele (2009) pages 1-15. The procedures described should be used to transcribe language samples, with the following changes:

- Transcribe only parent utterances.
- Use M to designate the mother.

## Maternal Cues about Referent Coding

Some language and coding procedures for this study are based on those procedures outlined in *Transcription and Basic Coding Manual* (Schuele, 2009).

### Typing Conventions

1. Square brackets should be used to mark codes (e.g., [sync]).
2. Codes should occur directly after an object has been named, with one space between the code and the object. All coding should occur prior to sentence-final punctuation marks. For example:

M I will get your spoon [async].

### Data Preparation

Prior to coding, all novel nouns in the transcript must be identified. To do this, the coder should go through the transcript and mark all nouns with the code [noun].

The following should not be included in the list of novel nouns: pronouns (I, he, that, those), animal sounds, ambiguous nouns (e.g., things, stuff).

Do include abstract nouns, such as “dream” and “wish.” (Make sure these are used in noun form, as in, “I had a dream” or “I made a wish”). Do not include nouns describing time (today, tomorrow, morning, etc). In addition, do not include nouns that are part of rote phrases (e.g., what’s the matter?, good job).

Once all novel nouns have been identified, nouns should be compiled into a list on an Excel spreadsheet. Label the spreadsheet with the childcode and date of data collection (e.g., LVERN\_120112). Each noun identified should have its own cell in the list. If a noun is used more than once, it should only appear one time in the excel list (but be coded every time in the transcript).

Following generation of this list, all words in the excel file should be randomized and presented to the parent via phone call. The parent should be asked whether or not she believes that the child understands the words listed. If she answers “yes,” probe further to find out how the mother has determined that her child knows this word.

Once the mother has confirmed that a word on the list is novel, this should be marked on the excel sheet. If the mother confirms that her child knows a word, this should also be indicated.

Following completion of the excel sheet, the coder should return to the transcript. For every confirmed novel noun (i.e., noun the child does not know), the noun should be marked with [nov].

## Maternal Cue Coding

Possible codes for novel noun cues can take the following forms:

### **Converging Cues:**

Synchronous Labeling: [sync]

Synchronous Labeling using eye gaze: [gaze]

Follow-in Labeling: [fin]

### **Diverging Cues:**

Asynchronous Labeling: [async]

Asynchronous Follow-In Labeling: [afin]

Conflicting Labeling: [conf]

### **Auditory-Only Cues:**

Static Object Labeling: [stat]

Absent Object Labeling: [absent]

### **Other Cues:**

Abstract Noun Labeling: [abstract]

Other [other]

1. **Synchronous Labeling:** Synchronous labeling occurs when an adult labels an object while simultaneously moving, indicating (as in pointing at), or holding out the object. Simultaneous means that the action occurs within 400 milliseconds of the label. When deciding if an event is synchronous labeling, take the child's point of view- if the child can see the parent moving the object, that is synchronous labeling. If a mother has an object in her hand but has in no way indicated that is the object she might be discussing, that is not synchronous labeling (i.e., object is not moving at all). Synchronous codes can be used even if an adult is only manipulating part of the labeled item (e.g., lunch) or if two objects are being manipulated together (e.g., labeling yogurt while moving yogurt and a spoon).

Example: Shaking a spoon while saying "I've got your spoon!"

M I've got your spoon [sync]!

One way of indicating an object is for an adult to use his or her eye gaze. This way of labeling an object is not quite as informative as other means of indicating a referent; in instances where only adult gaze is used, code [gaze]. This code should only be used when gaze is prominently used to indicate an object during a labeling event.

Example: Looking at a spoon while saying “Oh, there’s your spoon.”

M {Oh} there’s your spoon [gaze].

**2. Follow-in Labeling:** Follow-in labeling occurs when an adult labels an object that a child is already looking at or playing with (within 400 milliseconds of the child’s action). If a child is playing with an object, then puts it down and it is labeled after 400 milliseconds, this does not constitute follow-in labeling.

Example: Saying “you want more milk?” while the child is looking at his or her milk.

M You want more milk [fin]?

**3. Asynchronous Labeling:** Asynchronous labeling occurs when an adult labels an object and then, after 400 milliseconds, manipulates or indicates the object. Asynchronous labeling also occurs if an adult manipulates an object and then, after 400 milliseconds or more, labels that object.

Example: Saying “let’s find your plate” and then going to get the plate out of the cabinet.

M Let’s find your plate [async].

**4. Asynchronous Follow-In Labeling:** Asynchronous follow-in labeling occurs when a child manipulates an object, puts it down, and then after 400 milliseconds have passed, the adult labels the object.

Example: Saying “Eat your peas” after the child picks up, examines, then sets down a pea.

M Eat your peas [afin].

**5. Conflicting Labeling:** Conflicting labeling occurs when an adult labels one object but manipulates or indicates (sometimes subconsciously), a different object.

Example: Saying “We need to get some milk!” while holding a spoon.

M We need to get some milk [conf]!

**6. Static Object Labeling:** Static object labeling occurs when an adult labels an item in the child's field of vision, but does not indicate that object in any way. In this case, the adult may be holding the object but not have moved it for several seconds.

Example: Saying "Eat your carrots" without looking at or indicating the carrots in any way.

M Eat your carrots [stat].

**7. Absent Object Labeling:** Absent labeling occurs when an adult uses a noun to refer to something that is not present in the room.

Example: Saying "I hear the firetruck!" when a siren is audible outside of the house.

M I hear the firetruck [absent]!

**8. Abstract Noun Labeling:** Abstract noun labeling occurs when an adult uses a noun that is not an object.

Example: Saying "Take two more bites" or "I have no idea."

M I have no idea [abstract].

**9. Other:** Any other action combined with a labeling event that cannot be included in any of the other codes here. This category can also encompass instances where it is unclear what the mother is doing because she is off camera.

### **Decisions about Codes**

In some cases, a parent may use overlapping cue types to indicate a referent, and the coder will have to judge which code to assign to a naming event. The following list indicates the order in which codes should be assigned:

#### For Converging Cue Types

- 1) Synchronous
- 2) Follow-In
- 3) Gaze

Example: If a parent picks up an object a child is looking at, and then shakes and labels that object, it should be coded as [sync].

If a child is looking at a different object than the one the parent is shaking, judgment should be used to determine which object is most saliently labeled by

the parent. For example, if a parent is peeling a banana while gazing at and labeling a spoon that the child is looking at, this should be labeled [fin] because both gaze and follow-in labeling indicated the spoon, even though the adult is peeling the banana.

#### For Diverging Cue Types

- 1) Conflicting
- 2) Asynchronous follow-in
- 3) Asynchronous

Example: If a parent holds and moves one object while labeling another, and then picks up the labeled object, the event should be coded as [conf].

#### Other Conflicts

If diverging cues and auditory-only cues are used in one event, the diverging cue should be coded per predictions made by the Intracensory Redundancy Hypothesis (Bahrack, Lickliter & Flom, 2004).

Example: If a parent labels a static object, then later picks it up, the event is labeled [async].

If follow-in labeling is used in conjunction with conflicting or asynchronous labeling, the follow-in cue should be coded.

If synchronous adult eye gaze is used in conjunction with conflicting or asynchronous labeling, the diverging cue should be coded.

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