I, Kathryn Simonson, hereby submit this original work as part of the requirements for the degree of:

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It is entitled:

Impact of Age of Implantation on Receptive and Expressive Language Outcomes of Children with Developmental Disabilities and Cochlear Implants

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This work and its defense approved by:

Committee Chair: Nancy Creaghead, PhD

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Impact of Age of Implantation on Receptive and Expressive Language Outcomes of Children with Developmental Disabilities and Cochlear Implants

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ABSTRACT

Previous research has suggested that early cochlear implantation before or during the critical language acquisition period leads to better language outcomes in children with typical development. This study asked the question, ‘Do children with developmental disabilities and a cochlear implant have better receptive and expressive language outcomes if they are implanted before 3 years of age than if they are implanted after 3 years of age?’ It was hypothesized that if children were implanted before 3 years of age, they would have better receptive and expressive language outcomes than children who were implanted after 3 years of age. Receptive and expressive language skills and developmental levels were assessed. The Wilcoxon Rank Sum Test was used to assess if a significant difference existed the language quotients between the groups. The results indicated that the children who were implanted before 3 years of age had significantly better receptive and expressive language scores than the children who were implanted after 3 years of age. From the data, there appeared to be a relationship between developmental quotients and language quotients. Limitations included differences in developmental levels, unequal numbers of children between the groups, and differences in age of identification. This study adds support that early cochlear implantation for children with developmental disabilities before the age of 3 years leads to better language outcomes.
ACKNOWLEDGEMENTS

My warmest thanks go to Dr. Grether, Dr. Creaghead, and Dr. Meinzen-Derr. Their insight and advice during this experience is invaluable to me. I also thank my friends, especially Jessica Gutzeit, and my classmate, Laura Twilling. Their support and humor leave a smile on my face. I thank my parents, Pam and Greg Simonson for teaching me the value of hard work, honesty, and perseverance. Finally, I thank my fiancé, Andy Vandiver, for his abundance of energy and goodness that motivates me to do my best every day.
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CHAPTER I:

INTRODUCTION AND REVIEW OF THE LITERATURE

Early exposure to auditory linguistic input has been thought to yield better language outcomes, both spoken and visual, for all individuals. However, children that are born with congenital, severe-profound hearing loss, are deprived of this early exposure crucial for developing normal spoken language. Many times, the cause of this congenital deafness may be related to additional disabilities as well, such as low intellectual functioning, sensory and/or motor impairments, learning disabilities, and communication disorders. It is estimated that 30-40% of children with congenital deafness also have additional disorders (Holden-Pitt & Diaz, 1998; Wiley, Meinzen-Derr, & Choo, 2004). Language acquisition is more challenging for these children than for those children with congenital deafness who do not have additional impairments.

Cochlear implants provide these individuals with the opportunity to experience auditory linguistic input, when hearing aids are of little or no benefit to them. Cochlear implants are an effective means of providing this auditory stimulation, thus counteracting the deleterious effects of deafness on language development. Currently, the earliest age for a candidate to receive a cochlear implant is 12 months, according to the United States Federal Drug Administration guidelines (American Speech-Language and Hearing Association, 2004). This has changed considerably since the inception of cochlear implants in the 1980’s. Even though cochlear implants provide many benefits to the child at this age, questions remain to be answered, including those concerning candidacy for cochlear implantation. At the present time, those individuals with additional disabilities and severe-profound hearing loss are included as possible
candidates (Edwards, Frost, & Witham, 2006). However, little is known about the language benefits they will receive from cochlear implants.

Thus far, research on the communication skills of children with developmental disabilities who receive cochlear implants has focused on speech perception, speech intelligibility, qualitative perceived benefits, and language outcomes. In general, there is not as much cochlear implant research with the population of individuals with developmental disabilities than with typical populations. Research that investigates prognostic factors for receptive and expressive language outcomes in this population is crucial for decision-making among parents and professionals. Age of implantation is one such decision that is critically important because of its known effects on language development, at least in typical populations. Age of implantation in those with developmental disabilities deserves more research attention. Without this information, a parent or professional may be making less informed decisions about when to implant a child with additional disabilities and hearing loss.

**Why Implant Early?**

Research suggests that early implantation provides an individual with two important long-term benefits. They include providing the individual with an earlier start in language learning and taking advantage critical language acquisition period (Tomblin, et al., 2005). Both of these factors are thought to lead to improved language outcomes for those who received a cochlear implant earlier versus those who were implanted at a later age. Current literature has investigated age of implantation in relationship to improved language outcomes in otherwise typical individuals (Sharma, et al., 2004; Baumgartner, et al., 2002; Nicholas & Geers, 2007).
Age-related Plasticity and the Critical Language Acquisition Period

Early implantation takes advantage of a time in mammalian development when the nervous system is most able to create and change neural pathways. These changes are in response to environmental stimulation, consequently changing behavior. In the case of a person receiving a cochlear implant, that environmental stimulation comes in the form of auditory input, which changes neural auditory pathways, eventually changing communication skills. It is thought that the ability to do this decreases as an individual ages. This concept, known as ‘age-related plasticity’ partially explains why there is a critical language acquisition period. It is suggested that children should receive their cochlear implants before or at least during this period to take advantage of the critical language acquisition period, a time of maximal brain plasticity (Tomblin, et al., 2005).

Cochlear implants offer a unique opportunity to explore critical periods of language acquisition and age-related plasticity of the auditory system because of the varied times in which individuals who are deaf can receive their cochlear implant. Speech and language skills are a result of complex, multi-component biological processes with differing trajectories of developmental maturity (Harrison, Gordon, & Mount, 2005). Studying the biological underpinnings of these neural changes in response to receiving a cochlear implant (CI) is complicated; nevertheless, researchers have found ways to explore these changes by studying latency potentials in the central auditory system.

If we assume that the central auditory system has age-related plasticity, then critical ages for cochlear implantation do exist. In a preliminary study by Sharma, Dorman, and Spahr (2002), P1 cortical auditory evoked potential latencies were used to assess the developmental/maturational status of auditory pathways to determine critical periods of brain plasticity. In this study, 104
congenitally deaf children were recruited for this study. They were all implanted between 1.3 years and 17.5 years. The duration of deafness varied. Researchers found that P1 latencies to speech were abnormal in those with the longest periods of auditory deprivation (7 or more years). These delayed latencies were thought to correspond to decreased synaptic efficiency and transmission of auditory signals. Those with the shortest periods of deprivation (approximately 3.5 years or less) had age-appropriate latency responses within 6 months after their cochlear implants were activated. It was determined that the P1 latency results indicated greater brain plasticity at earlier ages.

In addition to this evidence for age-related brain plasticity, early communicative behaviors, such as babbling, have been investigated with P1 latencies. Sharma, et al. (2004) found that development of pre-linguistic behaviors, such as babbling, is likely due to maturation of the central auditory pathway and is stimulated by auditory inputs from a CI. They studied the relationship between maturation of the central auditory pathways and development of babbling in babies with cochlear implants by comparing P1 latencies with vocalizations and found a strong correlation between the two. In this study, infants with deafness, who did not have cochlear implants did not reach the reduplicated or canonical babbling stage at the same time as infants with cochlear implants. Therefore, there is strong evidence to support the contention that babbling is positively influenced by changes in the central auditory pathway.

**Earlier Spoken Language Exposure**

**Auditory Listening Skills**

Auditory listening skills, in addition to improved language outcomes, have been shown to improve with cochlear implantation. Anderson, et al. (2004) found post-implantation improvement rates of auditory listening skills using the LiP, MAIS, MTP, and MUSS tests to
examine auditory perception in typically developing children with congenital hearing loss. Children who were implanted earlier achieved good core listening skills at younger ages than their counterparts who were implanted later. These core listening skills are needed for further personal, linguistic, and academic development. They concluded that early core listening skills would allow a child to develop language at an earlier age, due to the critical language acquisition period.

In another study, (Baumgartner, et al., 2002) children were implanted at different ages. They found that children under 3 years of age had increased speech perception performance compared to children who were implanted later than 3 years of age. The younger group with implants had increased levels of speech perception performance. A minimum of 18-24 months of CI experience was needed to make speech perception changes, likely attributed to maturity of auditory system and central processing.

In a study by Nicholas and Geers (2006) the relationship between duration of deafness and language skills was investigated. In general, early implantation and better pure tone average (PTA) scores before implantation were associated with better language scores in children implanted between 12 and 38 months of age, when examined at 3.5 years of age. The results indicated that earlier implantation/longer duration and decreased PTA’s resulted in higher language scores. In general, the longer a person goes without auditory stimulation, the more likely they will develop a language delay. By implanting earlier, individuals will decrease the duration of their deafness. Several studies have suggested that decreasing the duration of deafness will result in better language outcomes for the individual (Geers, 2004; Nicholas & Geers, 2006; Nicholas & Geers, 2007; Svirsky, et al., 2000).
Language Outcomes with Cochlear Implantation Age

The improved auditory listening skills that children acquire by receiving a cochlear implant are thought to improve language outcomes, and earlier implantation leads to these improved language outcomes. In a study by Nicholas and Geers (2007), children that were implanted before their second birthday achieved language skills comparable to their peers with normal hearing, compared to children who were implanted after their second birthday. The children that were implanted after their second birthday demonstrated more delayed language skills. This study evaluated the role of implantation age, duration of implant use, and aided pre-implant hearing in predicting language growth rate and overall language levels achieved. It was determined that age of implantation is more important than duration, especially if the child is implanted before 2 years.

In general, earlier implantation leads to better receptive and expressive language outcomes. This concept has been examined through numerous studies with children with severe-profound hearing loss, who received cochlear implants at various ages. Not only do these children have better language outcomes overall, but they also have increased language acquisition rates (Svirsky, et al., 2000; Tomblin, et al., 2005). Svirsky and colleagues (2000) found an increased rate of English language acquisition for those with cochlear implants compared to those without implants. Tomblin, et al. (2005) looked at growth of expressive language skills in infants and toddlers who were implanted at different ages using repeated language measures between 10 and 40 months of age. They found language growth was more rapid in children implanted as infants versus those who were implanted as toddlers. Age at initial stimulation accounted for 14.6% of variance of individual differences in expressive language growth rates (age at initial cochlear implant stimulation). Growth rate curve analysis revealed
more rapid language growth rates in children who were implanted earlier versus later due to their earlier exposure to auditory linguistic input.

**Benefits of Cochlear Implantation for Children with Additional Disabilities**

Success of a cochlear implant is measured by several factors including improved speech perception, auditory listening skills, awareness to environmental sounds, satisfaction with relationships, academic gains, and language outcomes. Several studies have indicated that these qualities often improve with cochlear implantation in children with additional disabilities. Although children with developmental disabilities are not routinely excluded as candidates for cochlear implants (Edwards, et al., 2006), their additional disabilities has raised questions as to whether they could benefit. The following studies have investigated the benefits of implanting children with developmental disabilities with cochlear implants.

In a study by Wiley, Jahnke, Meinzen-Derr, & Choo (2005), perceptual qualitative benefits per parent report were studied. They found that families reported many qualitative benefits of CI. Perceived benefits included: awareness to environmental sounds, communication progress, and greater attention and interest to the world around them. In particular, families whose children were implanted at greater than 2 years of age perceived greater benefits than children implanted before 2 years.

Berretini, et al. (2008) investigated objective post-implant outcomes and perceived benefits in daily life in children with an additional disability and congenital hearing loss with a cochlear implant. Parents reported positive benefits following implantation, with an overall consensus of improved quality of life. The reported benefits included a growing awareness of environmental sounds; more attentive/interested at home and at school; better ability to communicate their wants and needs; and better ability to communicate in general. Of the children with both
additional disabilities and cochlear implants that were studied, most improved their communication skills, even though only 35% achieved an exclusively oral mode of communication. In other words, even if the children did not achieve an oral mode of communication, their non-verbal communication improved.

**Communication Skills in Children with Additional Disabilities and Cochlear Implants**

The current study will investigate how age of implantation affects language outcomes for children with developmental disabilities. The population of interest in this study, children with developmental disabilities who received cochlear implants has added challenges to language-learning in addition to their hearing loss before implantation. According to Pisoni (2000), cognition is thought to play a key role in a person’s ability to learn language, aside from age at onset of deafness, length of deprivation, and age of implantation. This is due to learning, memory, attention, and language processing skills that are unique to each individual who receives an implant. Geers, Nicholas, & Sedey (2003) sought to investigate what factors impact language outcomes in children implanted before 5 years of age. They found that non-verbal IQ was one of the strongest predictors for language outcomes. The current study will investigate how age of implantation affects language outcomes for children with developmental disabilities, many of whom have cognitive deficits.

Research that investigates communication skills of children with special needs who receive cochlear implants is scarce. However, the research that is available indicates that these children can learn to communicate, even if the rate of progress is slow (Wiley, et al., 2005). Holt and Kirk (2005) found that children with mild cognitive deficits who had cochlear implants demonstrated an improved ability to perceive speech, improved reception of language, and improved use of
language. Children with mild mental retardation benefited from cochlear implantation with improved ability to perceive speech, understand language, and use language.

Speech perception testing on children with additional disabilities and cochlear implants, using measures such as the EARS test battery indicates that many children demonstrate the following gains after implantation: the possibility of learning to hear; better reaction to dangerous situations; hearing the voices of parents; and strengthening emotional relationships, even though they have less significant language gains than typically developing children with cochlear implants (Hamzavi, et al., 2000). These children have also been reported to recognize words from a closed set without lip-reading and improve on open-set perception with the aid of lip-reading (Pyman, et al., 2000). Both are important skills for developing language.

Speech production has been researched in children with additional disabilities who are deaf with cochlear implants. Nikolopolous, Archbold, Wever, and Lloyd (2008) used the Speech Intelligibility Rating (SIR) scale to test long-term speech intelligibility, in children with additional disabilities and cochlear implants, versus age-equivalent children with just cochlear implants. All subjects were implanted before 5 years of age. The findings revealed that 70% of children in the group with a developmental disability and a cochlear implant developed connected intelligible speech. Ninety-six percent of the children in the group with only a cochlear implant developed connected, intelligible speech. Of the children with both a cochlear implant and a developmental disability, 16% of them achieved the two higher categories of speech intelligibility (speech that is intelligible to all people, or to people with little experience with the individual). Researchers found that the total number of developmental disabilities was strongly associated with speech intelligibility outcomes, where a higher number of disabilities was related to lower speech intelligibility. Language and communication disorders were the most
important contributing factors to speech intelligibility outcomes. In general, most children with additional disabilities improved in speech production, with the majority of children improving their speech intelligibility. This gain would likely be considered significant enough to change the child’s quality of life, even though only those familiar with the child would be able to understand them. Age of implantation did contribute a small amount (< 2%) to variability in speech intelligibility scores between the two groups.

Therefore, it can be concluded that even though children with developmental disabilities are less likely to achieve language skills equal to their peers without such disabilities, they do receive a host of other benefits that lead to a greater quality of life. Improved language outcomes following cochlear implantation are worth investigating for these children. The age at which they are implanted is a critical decision for their parents to make.

**Purpose**

The present study seeks to investigate whether the age of cochlear implantation affects language outcomes for children with developmental disabilities. The research question is: Do children with developmental disabilities and a cochlear implant have better receptive and expressive language outcomes if they are implanted before the age of 3 years than if they are implanted after 3 years of age? It is hypothesized that if children were implanted before 3 years of age, they would have better receptive and expressive language outcomes than children who were implanted after 3 years of age. This study aims to describe, compare, and contrast the language outcomes of children with developmental disabilities who were implanted before 3 years of age versus after 3 years of age.
CHAPTER II:

METHODS

This research study was conducted as a part of a larger study that investigates outcomes of deaf children with developmental disabilities who are deaf and receive cochlear implants. It was conducted at a large urban pediatric hospital. Eligible participants for the study were recruited through the hospital’s Division of Developmental and Behavioral Pediatrics via letters mailed to their homes, as well as by word-of-mouth recruitment from a developmental pediatrician.

In this study, receptive and expressive language quotients and developmental quotients were collected for participants who were deaf with additional disabilities and cochlear implants. The two groups of children were divided based on age. One group consisted of children with cochlear implants with an additional disability who were implanted before the age of 3 years, 0 months. The other group consisted of those with an additional disability with cochlear implants who were implanted after 3 years, 0 months. The aim of this study was to compare the receptive and expressive language outcomes of the two groups to determine if the age of implantation resulted in a significant difference in the receptive and expressive language outcomes. The Wilcoxon Rank Sum Test was used to compare the receptive and expressive language quotients between the group that was implanted before 3 years of age and the group that was implanted after 3 years of age.

Participants

Eligibility criteria for children who participated in this study included children who received cochlear implantation prior to the age of 6 at the time of this study. All participants were diagnosed with one or more additional disabilities. The children were divided into two
groups based on age. Three years of age was chosen because previous studies have indicated that this age is during or before, the critical period for optimal language learning for children receiving an implant (Anderson, et al., 2004; Baumgartner, et al., 2002; Nicholas & Geers, 2006; Sharma, et al., 2004; Sharma, et al., 2002). Tables 1 and 2 provide demographic information about the two groups that includes gender, etiology of hearing loss, age at hearing loss identification (in months), age at hearing loss, and age at cochlear implantation (in months).

Table 1 describes the group that was implanted before 3 years of age. This group included 14 children, 8 females and 6 males, who were implanted between the ages of 13.5 months and 30.3 months. Ages of identification in this group ranged from 0 months of age to 15.4 months of age. Their developmental disabilities included mild cognitive delay, cognitive delay, motor delay, CHARGE syndrome, motor apraxis, cerebral palsy (CP), and ataxic cerebral palsy. Etiologies of hearing losses included auditory neuropathy (AN), prematurity, congenital cytomegalovirus (CMV), CHARGE, autosomal dominant hereditary enlarged vestibular aqueduct (EVA), viral encephalitis, and meningitis.

Table 2 describes the group that was implanted after 3 years of age. This group consisted of 7 individuals, 1 female and 6 males, who were implanted between the ages of 36.4 months and 54.1 months. In this group, ages of identification of hearing loss ranged from 0 months of age to 25.4 months of age. Developmental disabilities included CHARGE, severe global cerebral palsy, autism spectrum disorder, mild spastic diplegia/mild cognitive delay, cognitive quadra CP, mild cognitive delay, severe cognitive delay, and deaf/blind. Etiologies for hearing loss included CHARGE, EVA, Connexin, prematurity, Group B Streptococcal Meningitis, congenital CMV, and infantile refsum.
Table 1: Participant Demographic Information – Age of Implantation <3 years

<table>
<thead>
<tr>
<th>Child</th>
<th>Gender</th>
<th>Developmental Disability</th>
<th>Etiology of Hearing Loss</th>
<th>Age at Hearing Loss Identification (in months)</th>
<th>Age of Cochlear Implantation (in months)</th>
<th>Duration Since Cochlear Implantation (in months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M</td>
<td>Mild cognitive delay</td>
<td>Auditory Neuropathy (AN), premature</td>
<td>6.8</td>
<td>24.3</td>
<td>20.1</td>
</tr>
<tr>
<td>2</td>
<td>M</td>
<td>Cognitive delay</td>
<td>Congenital Cytomegalovirus (CMV)</td>
<td>15.4</td>
<td>20.9</td>
<td>28.7</td>
</tr>
<tr>
<td>3</td>
<td>M</td>
<td>Motor delay</td>
<td>--</td>
<td>--</td>
<td>23.4</td>
<td>28.8</td>
</tr>
<tr>
<td>4</td>
<td>M</td>
<td>Motor delay</td>
<td>--</td>
<td>--</td>
<td>23.4</td>
<td>28.8</td>
</tr>
<tr>
<td>5</td>
<td>F</td>
<td>CHARGE</td>
<td>CHARGE</td>
<td>0</td>
<td>16.6</td>
<td>18.6</td>
</tr>
<tr>
<td>6</td>
<td>F</td>
<td>Motor apraxis</td>
<td>AN</td>
<td>1.0</td>
<td>16.6</td>
<td>29.0</td>
</tr>
<tr>
<td>7</td>
<td>F</td>
<td>CHARGE</td>
<td>CHARGE</td>
<td>0</td>
<td>15.0</td>
<td>13.1</td>
</tr>
<tr>
<td>8</td>
<td>M</td>
<td>Mild cognitive delay</td>
<td>Autosomal dominant hereditary, EVA</td>
<td>3.9</td>
<td>30.3</td>
<td>26.6</td>
</tr>
<tr>
<td>9</td>
<td>F</td>
<td>CP</td>
<td>Congenital CMV</td>
<td>1.0</td>
<td>13.9</td>
<td>38.5</td>
</tr>
<tr>
<td>10</td>
<td>F</td>
<td>CP</td>
<td>Congenital CMV</td>
<td>1.0</td>
<td>13.8</td>
<td>24.7</td>
</tr>
<tr>
<td>11</td>
<td>M</td>
<td>Cognitive</td>
<td>Congenital CMV</td>
<td>15.1</td>
<td>29.3</td>
<td>51.6</td>
</tr>
<tr>
<td>12</td>
<td>F</td>
<td>Ataxic Cerebral Palsy</td>
<td>Viral Encephalitis</td>
<td>11.1</td>
<td>17.3</td>
<td>52.1</td>
</tr>
<tr>
<td>13</td>
<td>F</td>
<td>CHARGE</td>
<td>CHARGE</td>
<td>4.6</td>
<td>18.3</td>
<td>53.2</td>
</tr>
<tr>
<td>14</td>
<td>F</td>
<td>CP</td>
<td>Meningitis</td>
<td>2.7</td>
<td>13.5</td>
<td>68.1</td>
</tr>
</tbody>
</table>
Table 2: Participant Demographic Information – Age of Implantation >3 years

<table>
<thead>
<tr>
<th>Child</th>
<th>Gender</th>
<th>Developmental Disability</th>
<th>Etiology of Hearing Loss</th>
<th>Age at Hearing Loss Identification (in months)</th>
<th>Age of Cochlear Implantation (in months)</th>
<th>Duration Since Cochlear Implantation (in months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M</td>
<td>CHARGE</td>
<td>CHARGE</td>
<td>0</td>
<td>51.4</td>
<td>17.7</td>
</tr>
<tr>
<td>2</td>
<td>M</td>
<td>Severe Global Cerebral Palsy (CP)</td>
<td>Enlarged Vestibular Aqueduct (EVA)</td>
<td>15.7</td>
<td>48.9</td>
<td>31.8</td>
</tr>
<tr>
<td>3</td>
<td>M</td>
<td>Autism Spectrum Disorder</td>
<td>Connexin</td>
<td>25.4</td>
<td>36.4</td>
<td>34.9</td>
</tr>
<tr>
<td>4</td>
<td>M</td>
<td>Mild spastic diplegia, mild cognitive delay</td>
<td>Premature</td>
<td>3.0</td>
<td>36.6</td>
<td>9.9</td>
</tr>
<tr>
<td>5</td>
<td>M</td>
<td>Cognitive quadra CP</td>
<td>Group B Streptococcal Meningitis</td>
<td>6.8</td>
<td>40.7</td>
<td>17.1</td>
</tr>
<tr>
<td>6</td>
<td>M</td>
<td>Mild cognitive delay</td>
<td>Congenital CMV</td>
<td>3.3</td>
<td>38.1</td>
<td>17.7</td>
</tr>
<tr>
<td>7</td>
<td>F</td>
<td>Severe Cognitive Delay, deaf/blind</td>
<td>Infantile refsums</td>
<td>0</td>
<td>54.1</td>
<td>20.3</td>
</tr>
</tbody>
</table>

Materials and Procedures

As part of the larger study, parents/caregivers were asked to complete a questionnaire to collect demographic information and list other services and therapies. Information collected in this questionnaire include subject characteristics, educational programs the child had been involved in, types, intensity and attendance at therapies, educational level and other related information regarding the parents/caregivers.

The children were administered the Preschool Language Scale – 4th edition (PLS – 4) (Zimmerman, Steiner, & Pond, 2004), a standardized language assessment designed to test
receptive and expressive language skills of children from ages birth to 6 years, 11 months. The receptive language portion, the Auditory Comprehension subscale, includes an assessment of the child’s basic receptive vocabulary, an understanding of concepts, grammatical markers, complex sentences, comparisons, and inferences. The Expressive Language subscale assesses the child’s ability to name objects, use concepts of description, express quantity, use grammatical markers, and produce multi-word utterances. This particular assessment allows for parent participation for input on a variety of questions, (i.e. “Does your child do …?”). Parent/caregiver input can be used for some items on this evaluation.

If the child used sign language to communicate alone or in combination with verbal communication, a sign language interpreter was provided. If this was the case, two language scores were reported, one with test items presented verbally and the other with verbal and sign language (total communication). Test items were first presented verbally by the evaluator. If he/she responded correctly, that response was noted. If he/she did not respond correctly, then the sign language interpreter presented the item in sign. Some questions were unable to be translated into sign language, such as labeling body parts, as the signs provide the answer. Even though the total communication score was recorded, only those presented verbally were counted in this data set. Because the lowest possible score on the PLS-4 is 50, this study used receptive and expressive language quotients. These were found by dividing the child’s test age by their chronological age and multiplying it by 100. Language quotients close to 100 indicated that the child’s language level were age-appropriate, while quotients below 80 indicated that a child’s language levels were significantly delayed.

The information gained during the evaluation was compared to information obtained through chart review and the results of the Revised Gesell Developmental Schedules (Ball, 1977)
assessed by the developmental pediatrician. The areas evaluated were adaptive functioning, gross and fine motor functioning, language functioning, and personal-social functioning. The Revised Gesell Developmental Schedules were administered previous to the child receiving the cochlear implant, and thus provided a brief indication of the cognitive level at which the child was functioning prior to receiving the cochlear implant.

To statistically compare the receptive and expressive language outcomes and developmental quotients between the two groups, the Wilcoxon Sum Rank Test was applied using the median receptive and expressive language quotients and median values for developmental quotients in the two groups. Mean, median, minimum, and maximum values were reported for language quotients. Statistical analysis focused on median values with the Wilcoxon rank sum test because the data was highly skewed within the groups.
CHAPTER III: RESULTS

For each child in this study age of implantation (in months), developmental quotients, receptive language quotients, and expressive language quotients were collected and separated into tables for each group. Table 3 describes the children that were implanted before 3 years of age and Table 4 describes the children that were implanted after 3 years of age.

Table 3: Age of Implantation and Language Quotients - Age of Implantation < 3 Years

<table>
<thead>
<tr>
<th>Child</th>
<th>Age of Implantation (in months)</th>
<th>Developmental Quotient</th>
<th>Receptive Language Quotient</th>
<th>Expressive Language Quotient</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>24.3</td>
<td>75</td>
<td>0.636</td>
<td>0.636</td>
</tr>
<tr>
<td>2</td>
<td>20.9</td>
<td>70</td>
<td>0.163</td>
<td>0.184</td>
</tr>
<tr>
<td>3</td>
<td>23.4</td>
<td>83</td>
<td>0.423</td>
<td>0.442</td>
</tr>
<tr>
<td>4</td>
<td>23.4</td>
<td>89</td>
<td>0.403</td>
<td>0.423</td>
</tr>
<tr>
<td>5</td>
<td>16.6</td>
<td>30</td>
<td>0.171</td>
<td>0.229</td>
</tr>
<tr>
<td>6</td>
<td>16.6</td>
<td>92</td>
<td>1.177</td>
<td>1.089</td>
</tr>
<tr>
<td>7</td>
<td>15</td>
<td>50</td>
<td>0.357</td>
<td>0.286</td>
</tr>
<tr>
<td>8</td>
<td>30.3</td>
<td>46</td>
<td>0.179</td>
<td>0.214</td>
</tr>
<tr>
<td>9</td>
<td>13.9</td>
<td>50</td>
<td>0.192</td>
<td>0.173</td>
</tr>
<tr>
<td>10</td>
<td>13.8</td>
<td>83</td>
<td>0.342</td>
<td>0.605</td>
</tr>
<tr>
<td>11</td>
<td>29.3</td>
<td>64</td>
<td>0.163</td>
<td>0.2</td>
</tr>
<tr>
<td>12</td>
<td>17.3</td>
<td>115</td>
<td>1.13</td>
<td>1.203</td>
</tr>
<tr>
<td>13</td>
<td>18.3</td>
<td>50</td>
<td>0.07</td>
<td>0.085</td>
</tr>
<tr>
<td>14</td>
<td>13.5</td>
<td>33</td>
<td>0.062</td>
<td>0.111</td>
</tr>
</tbody>
</table>
Table 4: Age of Implantation and Language Quotients - Age of Implantation > 3 Years

<table>
<thead>
<tr>
<th>Child</th>
<th>Age of Implantation (in months)</th>
<th>Developmental Quotient</th>
<th>Receptive Language Quotient</th>
<th>Expressive Language Quotient</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>51.4</td>
<td>75</td>
<td>0.609</td>
<td>0.478</td>
</tr>
<tr>
<td>2</td>
<td>48.9</td>
<td>33</td>
<td>0.063</td>
<td>0.1</td>
</tr>
<tr>
<td>3</td>
<td>36.4</td>
<td>80</td>
<td>0.085</td>
<td>0.169</td>
</tr>
<tr>
<td>4</td>
<td>36.6</td>
<td>70</td>
<td>0.457</td>
<td>0.348</td>
</tr>
<tr>
<td>5</td>
<td>40.7</td>
<td>50</td>
<td>0.388</td>
<td>0.185</td>
</tr>
<tr>
<td>6</td>
<td>38.1</td>
<td>42</td>
<td>0.091</td>
<td>0.2</td>
</tr>
<tr>
<td>7</td>
<td>54.1</td>
<td>27</td>
<td>0.095</td>
<td>0.176</td>
</tr>
</tbody>
</table>

Table 5 illustrates the comparison of language quotients between children that were implanted before 3 years of age and those that were implanted after 3 years of age. Statistical analysis focused on the median values because the data was highly skewed with large ranges for receptive language, expressive language, and developmental quotients. Children who received their cochlear implant before 3 years of age had significantly higher receptive language quotients than the group that was implanted after 3 years of age (0.35 versus 0.09, p = 0.048, respectively). In addition, the children who received their implant before 3 years of age also had significantly higher expressive language quotients (0.32 versus 0.18, p = 0.04, respectively). It is important to note, however, that the developmental quotients between the two groups were also significantly different (70 versus 42, p = 0.06, respectively), indicating the potential for this factor to confound the final results.
Table 5: Comparison of Receptive Language, Expressive Language, and Developmental Quotients between Study Groups

<table>
<thead>
<tr>
<th></th>
<th>Children Implanted &lt; 3 years</th>
<th>Children Implanted &gt; 3 years</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Receptive Language Quotients</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>0.42</td>
<td>0.20</td>
<td>0.048*</td>
</tr>
<tr>
<td>Median</td>
<td>0.35</td>
<td>0.09</td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>0.07-1.18</td>
<td>0.06-0.61</td>
<td></td>
</tr>
<tr>
<td><strong>Expressive Language Quotients</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>0.44</td>
<td>0.20</td>
<td>0.04*</td>
</tr>
<tr>
<td>Median</td>
<td>0.32</td>
<td>0.18</td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>0.09-1.2</td>
<td>0.10-0.48</td>
<td></td>
</tr>
<tr>
<td><strong>Developmental Quotients</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>69</td>
<td>49</td>
<td>0.06*</td>
</tr>
<tr>
<td>Median</td>
<td>70</td>
<td>42</td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>30-115</td>
<td>27-80</td>
<td></td>
</tr>
</tbody>
</table>

* p-value significant at 0.05 level
CHAPTER IV: DISCUSSION

This study examined if there were receptive and expressive language differences in children with developmental disabilities and cochlear implants that are implanted at different ages. It was hypothesized that children who were implanted before their third birthday would have better receptive and expressive language scores than children who were implanted after their third birthday. Through the analysis of data using the Wilcoxon Sum Rank Test, it was found that children who were implanted before the age of 3 had better receptive and expressive language scores than those who were implanted later. Based on this finding, it seems that there is a relationship between age of implantation and receptive and expressive language scores in the population of children with developmental disabilities, where children who are implanted earlier may develop better receptive and expressive language skills than if they are implanted later. However, these results should be interpreted with caution due to differences between the groups, such as significant differences in median developmental levels, differing ages of hearing loss identification, and varied durations of deafness.

Early Implantation and Language Outcomes

It is clear from previous studies that investigated age of implantation in typical populations that earlier implantation is associated to greater language outcomes (Nicholas & Geers, 2007; Tomblin, et al., 2005; Sharma, et al., 2002). This study is one of few that focused on age of implantation in the population of children with developmental disabilities. The finding of better receptive and expressive language outcomes for the group that was implanted before the age of 3 could be explained by their decreased duration of deafness and better median developmental quotients, compared to the group that was implanted after 3 years of age. It may also be due to differences in intervention types and frequencies of intervention.
**Duration of Deafness**

In the present study, implantation before 3 years of age was related to higher receptive and expressive language outcomes for the population of children with developmental disabilities. One possible reason for this is the decreased duration of deafness for the group that was implanted younger. As mentioned before, duration of deafness is known to impact language development, where a longer duration has more deleterious effects on language development. This result reflects the findings in previous research on duration of deafness, where a longer duration is correlated with a greater language delay (Nicholas & Geers, 2006). This finding supports that earlier implantation (and decreased duration) is better for language outcomes in all individuals, including those with developmental disabilities.

**Developmental Levels**

Another explanation for the difference in receptive and expressive language scores between the two groups is the difference in developmental quotients, which included cognition. Learning, memory, attention, and language processing have all been described as important factors in successful language outcomes for individuals with developmental disabilities who use cochlear implants (Pisoni, 2000). Although there was a large range in developmental quotients in the later group with implants (27-80), the median developmental levels were lower than in the younger group. It is assumed that learning, memory, and attention, all cognitive aspects of development, were weaker in the later group. Thus, their poorer language outcomes after a CI would be expected.

In a study by Holt and Kirk (2005), the speech and language of children with mild cognitive delays and children without such delays with cochlear implants were examined in a retrospective study. It was found that children with mild cognitive delays made language improvements, even though their language outcomes were not as high as the group without
implants. Given this finding, it would be expected that the later implanted group in the current study, with cognitive delays, would not have made as much language progress as the earlier implanted group with implants.

Cognition was found to influence language outcomes in a study that investigated language in children with cochlear implants and developmental disabilities (Meinzen-Derr, Wiley, Grether, & Choo, 2010). This study investigated how different variables impact language outcomes in this population. In this study, 20 children were recruited with developmental disabilities and CIs. Researchers looked at how variables such as age at hearing loss diagnosis, implant duration, number of different therapies, age at implantation, income, and number of siblings. Of these factors, it was found that non-verbal cognitive quotients (NVCQ), age at hearing loss diagnosis, implant duration, and the number of different therapies attended were significant factors in language performance, while age at implantation was not. Therefore, the NVCQ was more important than age at implantation for determining language learning success in this population.

**Age of Hearing Loss Identification**

With universal newborn hearing screenings, more children are being identified with hearing loss at younger ages. This has led to better language outcomes for children with congenital hearing loss through early intervention services aimed at providing aural rehabilitation and language therapy (Vohr, et al., 2010; Wolff, et al., 2010). Age of hearing loss identification was collected as part of the demographic information in Tables 1 and 2 for each child in this study. Many of the children in both groups were identified as having hearing loss at birth, presumably through universal newborn hearing screenings. Although this study did not statistically analyze this variable, a relationship between hearing loss identification and language outcomes may
exist. In Table 2, Child 3 had the latest identification at 25.4 months of age with a developmental disability diagnosis of Autism Spectrum Disorder. His/her receptive and expressive language quotients were also very low (receptive language 0.085, expressive language 0.169) compared to the median language quotients (receptive 0.09, expressive 0.18) in this group. This child’s developmental disability and the symptoms of this disorder, such as inattention to others and decreased interest in social interactions, may have masked any concern of potential hearing loss, thus prolonging any treatment and recommendations. For other children in this study, their additional disabilities may have masked concerns for hearing loss as well. This is an important factor to consider when interpreting the results of this study.

Limitations

The limitations of this study included the unequal sample sizes between the two groups of children with twice as many participants in the group that was implanted before 3 years of age than the other group. Developmental quotients were not controlled for in this study, which may have impacted receptive and expressive language results. Also, the variability in when the children were identified and their differences in the durations of deafness were not taken into account in the design of this study.

Conclusions

This study supports early implantation of children with developmental disabilities and congenital sensorineural hearing loss. In the current study and in previous studies, lower developmental quotients and overall severity of additional disabilities have been related to decreased language performance (Holt & Kirk, et al., 2005; Edwards, et al., 2006; Meinzen-Derr, et al., 2010). Therefore, when professionals and families consider cochlear implantation for a child with a developmental disability, they must regard the child’s developmental level, when
predicting receptive and expressive language gains. In spite of the emotional obstacles, medical issues, and financial investment, most parents are satisfied with the benefits their child receives after a CI (Wiley, et al., 2005).

**Future Research**

Ultimately, the decision to implant a child and choosing the right time to do it is a difficult one. When these decisions are guided by research that is specific to the population with developmental disabilities, more accurate outcomes can be expected and parents may find decisions about cochlear implants to be easier. Future research that focuses on longitudinal data on this population is very important when one considers language gains over time. Such research could investigate issues related to language such as academic performance, social skills, vocabulary growth, and syntax development. Parent and community attitudes towards implanting a child with a developmental disability could also be researched. Such research would be valuable especially for professionals in understanding different parent perspectives on cochlear implantation.
REFERENCES


