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The intelligibility of speech produced by young children with cochlear implants

Lana G. Colvard
University of Tennessee

To the Graduate Council:

I am submitting herewith a thesis written by Lana G. Colvard entitled "The intelligibility of speech produced by young children with cochlear implants." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Arts, with a major in Speech Pathology.

Peter Flipsen, Major Professor

We have read this thesis and recommend its acceptance:

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

To the Graduate Council:

I am submitting herewith a thesis by Lana Colvard entitled "The Intelligibility of Speech Produced by Young Children with Cochlear Implants." I have examined the final paper copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Arts, with a major in Speech Pathology.

Peter Flipsen, Major Professor

We have read this thesis and recommend its acceptance:

Patrick J. Carney

Kelly W. Harbuck

Accepted for the Council:

Vice Provost and Dean of Graduate Studies

THE INTELLIGIBILITY OF SPEECH PRODUCED BY YOUNG CHILDREN WITH COCHLEAR IMPLANTS

A Thesis Presented for the
Master of Arts
Degree
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Lana G. Colvard
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ABSTRACT

Objective: The purpose of the current study was to examine the intelligibility of speech produced by young children with cochlear implants. Specifically the questions posed was, does intelligibility vary across different sampling methods, by post-implantation age, and by listener familiarity?

Participants: Six preschool children participated in the study. These children were selected because they met the following criteria: 1) had pre-lingual deafness; 2) had severe to profound binaural hearing loss; 3) fitted with either a Clarion or Nucleus-24 multi-channel cochlear implant; 4) used verbal communication rather than signing during treatment; 5) had a receptive vocabulary within 2 standard deviations of the mean according to their age; 6) were implanted before age 4 years; and 7) had post-implantation age of at least 18 months.

Method: Data was gathered through a conversational speech sample, the Children's Speech Intelligibility Measure (CSIM), and rating scales. To assess percent intelligible in conversational speech, a thirty-minute language sample was collected and audio tape-recorded. Two experienced listeners, who were unfamiliar with the speakers, listened to each tape individually and orthographically transcribed the samples. The listeners then developed one final transcription per child through a consensus method. Percent intelligible in conversation was then determined using a procedure described by Shriberg (1986). The CSIM was used to obtain percent intelligible in single words. Each child imitated 50 words. Their utterances were audio taped and played back to a panel of 3 inexperienced listeners. There were 18 listeners (3 per sample) total. The listeners were asked to identify the word they thought the child said. In addition, rating scales were filled out by both parents and the primary clinician of each child. These individuals reported how much they understood and how much they believed others understood of the child's speech.

Data Analysis: Spearman Rank-Order Correlation Coefficients were used to determine relationships among the variables.

Results: The only factor to reach statistical significance was post-implantation age. The failure to find other statistically significant correlations may have been due to the small sample size used in the current study.

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LIST OF ABBREVIATIONS

ACE = Alternative Continuous Emission
BIT = Beginner's Intelligibility Test
CA = Chronological Age
CD = Compact Discs
CELF – P = Clinical Evaluation of Language Fundamentals – Preschool
CI = Cochlear Implant
CID = Central Institute for the Deaf
CIS = Continuous Interleaved Sampling
CSIM = Children's Speech Intelligibility Measure
CSL = Computerized Speech Lab
HA = Hearing Aid
IA = Implantation Age
ID = Identification
IRF = Improvement Rate Factor
MPEAK = Multi Peak
MP2 = Minimal Pairs Production Test
NTID = National Technical Institute for the Deaf
NU – 6 = Northwestern University – 6
PLS – 3 = Preschool Language Scale – Third Edition
PPVT – III = Peabody Picture Vocabulary Test – Third Edition
RTI = Research Triangle Institute
SEC = Scales of Early Communication in Hearing Impaired Children
SIR = Speech Intelligibility Rating
SNHL = Sensorineural Hearing Loss
SPEAK = Spectral Peak
SPINE = Picture Speech Intelligibility Evaluation
UCSF = University of California at San Francisco

CHAPTER 1

INTRODUCTION

The purpose of the current study was to examine the intelligibility of speech produced by young children with cochlear implants. While most research on this population has focused on speech perception, there has been limited research to date on speech production. The current study was intended to add to our knowledge in this area. Although the current question has been examined to a limited extent, the present study examined intelligibility across several measurement procedures. Specifically the question posed is, does intelligibility vary across different sampling methods, by post-implantation age, and/or by listener familiarity?

Normal Hearing

According to Loizou (1998), sound in the human ear undergoes many alterations as it moves through the auditory system to the brain. Acoustic pressure waves enter the outer ear and set the tympanic membrane (which separates the outer and middle ear) into vibration. The vibrations are transmitted through the middle ear via a small set of cartilages (called ossicles) in the middle ear. These mechanical vibrations then set up an acoustic pressure wave inside of the snail-shaped cochlea (the inner ear), which causes displacement of the basilar membrane of the cochlea. This displacement bends stereocilia on top of hair cells. These hair cells are attached to the basilar membrane and release an electro-chemical substance that causes nearby neurons to fire. These neurons collectively make up the auditory nerve and initiate the transmission of information about the acoustic signal to the brain.

The cochlea, which contains the basilar membrane, acts similar to a spectrum analyzer. The input signal or vibrations reach the inner ear and the basilar membrane. If the sound is made up of many different frequencies, as in the case of human speech, the displacement will occur at various sites along the membrane. Low frequency sounds will cause the most amplitude of displacement at the apex. It is within the apex of the cochlea that a cluster of nerve cell bodies are located, known as the spiral ganglion (Bess and Humes, 1995). High frequency signals will create the highest amplitude of displacement at the base of the basilar membrane (near the stapes). Damage to hair cells in particular regions of the basilar membrane is thought to account for hearing loss at the frequencies of sound associated with these membrane regions (Loizou, 1998).

Deafness

According to Loizou (1998), if the hair cells of the basilar membrane are damaged, the auditory system has no way to change acoustic pressure waves into neural impulses. Since the broken link does not allow the sound information to make it to the brain, a hearing impairment results. The hair cells may be damaged by any of several mechanisms including Meniere's disease, meningitis, congenital disorders, noise exposure, and certain drug usage. The greater the number of hair cells damaged, the more severe the hearing loss.

Cochlear Implants

Cochlear implants (CIs) are prosthetic devices that are surgically inserted into the inner ear in order to restore partial hearing and substitute for the damaged inner ear. If the auditory neurons are conserved, these devices offer a way to reduce the degeneration of spiral ganglion neurons that tends to occur over time in association with cochlear pathology (Leake, Snyder, Hradek, & Rebscher, 1995). These cochlear devices are based on the idea of "bypassing the normal hearing mechanism (outer, middle, and part of the inner ear including the hair cells) and electrically stimulating the remaining auditory neurons directly" (Loizou, 1998, p. 103). The site of stimulation is likely to be on the spiral ganglion cells or the first central node of Ranvier (Klinke & Hartman, 1997). By stimulating the neurons, the nerve fibers fire sending neural impulses to the brain, allowing for detection and interpretation of the sounds based on frequency and intensity as well as suprasegmental features (loudness and pitch). The amplitude of the signal current controls loudness of sound and pitch is related to the position in the cochlea that is being stimulated.

Several different implants are currently available. "All of the implant devices have the following features in common: (1) a microphone that picks up the sound; (2) a signal processor that converts the sound into electrical signals; (3) a transmission system that transmits the electrical signals to the implanted electrodes; and (4) an electrode or an electrode array (consisting of multiple electrodes) that is inserted into the cochlea by a surgeon" (Loizou, 1998, p. 104). According to Loizou, cochlear implants differ on four characteristics. Electrode design, which refers to electrode configuration and number of electrodes used, is the first characteristic. Multi-channel cochlear implants can stimulate different auditory nerve fibers at different places within the cochlea, while the single-channel implant can only stimulate one place. The use of four to six channels is sufficient to support high levels of speech reception in certain patients, (Brill et al., 1997; & Fishman, Shannon, & Slattery, 1997) yet increasing this number has not been found to increase speech perception test scores (Dorman, Loizou, Fitzke, & Tu, 1998; & Fu, 1997). Speech reception often depends on the etiology of deafness and the number of surviving auditory neurons available. Another way to increase the number of channels is to use bilateral implants. The use of two implants provides twice the number of electrodes as using one (Lawson, Wilson, Zerbi, & Finley, 1996) This technique also increases the number of stimulation sites as compared to unilateral implants.

The second characteristic that cochlear implants differ on is the type of stimulation, which can be either pulsatile or analog. Pulsatile stimulation occurs when the information is sent to the electrodes using a set of narrow pulsate-like vibrations. Analog stimulation refers to presenting an "electrical analog of the acoustic waveform itself" (Loizou, 1998, p. 106) to the electrode. This latter type of stimulation is continuously changing depending on the auditory input.

Cochlear implants also differ on the transmission link, which may be transcutaneous or percutaneous. Using a transcutaneous system, stimuli are transmitted through a radio frequency link. A percutaneous system sends the stimuli directly through plug connections to the electrodes. Unlike the transcutaneous system, this link does not require any implanted electronics (except the electrodes).

Finally cochlear implants may differ on the type of signal processing, using either feature extraction or waveform representation. These two processing "strategies differ in the way information is extracted from the speech signal and presented to the electrodes" (Loizou, 1998, p. 111). The feature extraction strategy, involves presentation of a type of spectral feature, such as formants, using feature extraction algorithms. When using the waveform strategy, a type of waveform is derived by dividing the speech signal into various frequency bands.

Available Implant Types

The Nucleus Spectra 22, Clarion, and MED-EL Combi 40 + are the three cochlear implants in the United States that are currently approved by the Food and Drug Administration (FDA). According to Loizou (1998), the Nucleus Spectra 22, made by Cochlear, incorporates previous speech processors and also uses new circuitry from the spectral peak (SPEAK) speech approach. According to Cochlear (2001a), the speech processor acts as a microcomputer that converts sound into electrical information. The information is then sent to the implant, which stimulates the auditory nerve. The SPEAK strategy "conveys sound information by stimulating many different sites along the cochlea" depending on the pitch of the sound (p. 1). This speech strategy is designed to improve speech comprehension, and it provides more information than the older strategies due to the following: (1) it may stimulate 10 electrodes in one cycle; (2) it uses up to 20 filters to provide a wider frequency range; and (3) it is able to preserve spectral and temporal information by using an adaptive stimulation rate.

The National Institute of Health (1995) states that the majority of individuals using the latest speech strategies (SPEAK) will score above 80 percent correct on high context sentence perception tests. A new cochlear implant system known as Nucleus 24, also made by Cochlear is currently undergoing clinical trials in the United States. This system offers the widest choice of speech coding strategies: Spectral peak (SPEAK), continuous interleaved sampling (CIS), and alternative continuous emission (ACE). The CIS strategy allows the speech signal to be quickly delivered in a sequential pulsatile mode. The ACE coding strategy works similarly to the SPEAK strategy except that it varies the rate of stimulation of the electrodes allowing a faster stimulation rate. Either the Sprint or ESPrit speech processors, as well as the three coding strategies, may be used with the Nucleus - 24 implant (Cochlear, 2001b). Use of the CIS and SPEAK strategies has resulted in large improvements in speech reception performance when compared with older strategies (Skinner et al., 1994; Wilson et al., 1991).

According to Skinner et al. (1994), a comparison of the SPEAK and multi-peak (MPEAK, a feature extraction design) strategies, which may both be used with the Nucleus 22, found that the patients using the SPEAK method performed better on vowel, consonant, monosyllabic word and sentence recognition. This was due to the fact that the MPEAK strategy is susceptible to errors when used in noisy environments.

The Clarion cochlear implant system was developed as a cooperative effort by the Research Triangle Institute (RTI), University of California at San Francisco (UCSF), and the Advanced Bionics Corporation. The CIS speech processing strategy may be used with this device (Miyamoto, Kirk, Svirsky, & Sehgal, 1999). This non-simultaneous strategy only allows a single electrode to deliver stimulation to the auditory nerve (Advanced Bionics Corporation, 2000). In this device, "the stimulation mode can be either monopolor or bipolar" (Loizou, 1998, p. 120). According to Advanced Bionics Corporation, the bipolar "configuration allows for a more localized site of stimulation, depending on the spatial separation of the two electrodes" (p. 13). The electrical current will be more controlled if the bipolar pair is close together. A monopolar stimulation allows for a wide current spread and stimulation of a larger number of remaining neurons. In a study by Loeb and Kessler (1995), 46 patients equipped with the Clarion prosthesis were tested before implantation and 3, 6, and 12 months post-implantation. Speech perception was tested using the open-set CID sentences and the open-set

Northwestern University-6 (NU-6). Fifty-seven percent of the subjects achieved moderate or excellent CID results with 3 months post-implantation. Thirty percent only achieved to a poor level within 12 months and the remaining thirteen percent improved gradually over time. Results of the NU-6 suggested that the "majority of patients with either excellent or poor results achieved most of their ultimate performance almost immediately after fitting" of the Clarion device (p. 292). According to Waltzman (2000) previous studies have revealed marked postoperative improvements within adult subjects on open-set stimuli when CIS replaced simultaneous analog. These studies suggest that the dynamic technological developments in this implant design and processing influence the interactions and correlations among the variables that affect outcome with a cochlear implant.

The Combi 40 + cochlear implant system was developed by MED-EL (MED-EL, 2000). This device is the thinnest implant package available and is designed for atraumatic insertion. Its features include a soft electrode for maximum protection of the cochlear structures, deep electrode placement to enhance low pitch sounds, and special implant versions for cases of ossification or cochlear malformation. Specifically, a standard electrode array is available to reach deep into the cochlea to stimulate as many auditory nerve endings as possible. A short array has been designed for insertion into an ossified or malformed cochlea. Also, persons with significant cochlear ossification may use the split electrode array. The manufacturing company, MED-EL, suggests implementation of the CIS strategy for optimum results with this device. This is a relatively new device and there do not appear to be any published outcome studies to date.

Candidacy

Not every person with a hearing loss is a candidate to receive a cochlear implant. Individuals inquiring about possible cochlear implantation must meet specific qualifications that are determined through preoperative evaluations which are completed to determine if the patient is medically and audiologically suitable for the cochlear implant. First, the person must be found to have a severe or profound bilateral hearing loss. Profound deafness is classified as a loss of 90 dB or higher. The individual must also achieve a sentence recognition score of 30% correct or less under the best-aided conditions (Loizou, 1998). Individuals 12 months or older who meet the above criteria are considered viable candidates (Cochlear, 2002). The information on preoperative status may be used to evaluate device efficacy and progress for patients who are implanted (Zwolan, 2000).

Cochlear Implant Outcomes

According to Loizou (1998), “there is great variability in the speech recognition performance of cochlear implant patients” (p. 21). Performance in this case refers to the child’s ability to detect, identify, discriminate, or recognize speech. There are four factors that have been found to affect auditory performance. The first factor is duration of deafness. An individual with a shorter duration of deafness will tend to exhibit better auditory performance than an individual with a longer duration of deafness. As the duration of deafness lengthens progressive degeneration of spiral ganglion neurons may be expected (Leake, Snyder, Hradek, & Rebscher, 1995). The second factor is the age at onset of deafness. Whether the child acquired deafness before (prelingual) or after (postlingual) learning speech and language plays a major role in the success of a cochlear implant. It has been established that those with postlingual deafness perform better than those who are prelingually deaf. According to Loizou, a child is defined as being prelingually deaf if he or she has lost their hearing before or during the development of speech and language. Postlingual deafness on the other hand is when hearing has been lost after the development of speech and language. Eisenberg (1982) explained that individuals with prelingual deafness have a decreased tolerance for sound and often respond differently than people that are postlingually deaf. The individuals that have received cochlear implants who have prelingual deafness may first respond to the sensation as a vibration rather than as sound. According to Loizou, the third factor is age of implantation. Different levels of auditory performance may be achieved depending on the age of implantation. It appears that individuals who receive their cochlear implant at an early age function better than those implanted in adulthood. The final factor that affects auditory performance is the duration of cochlear implant use. Loizou stated there is a strong positive relationship between duration of use and auditory functioning. Speech perception and production have also been found to improve within four years following implantation (Loizou).

Intelligibility

In order to facilitate communication it is important that the listener understand the message sent by the speaker. According to Kent, Miolo, and Bloedel (1994), "intelligibility is the functional common denominator of verbal behavior" (p. 81). There is little agreement on how it should be measured, however, because the method of evaluating intelligibility is loaded with procedural and interpretative problems. For example, it is unclear what the judgments should be based on (e.g., general impressions vs. transcription). It is also still unclear who the judges should be (e.g., unfamiliar non-professionals vs. family members vs. experienced clinicians).

The Current Study

Several studies (Allen, Nikopolous, & O'Donoghue, 1998; Chin, Finnegan, & Chung, 2001; Dawson et al. 1995; Doyle, 1987; Miyamoto, Kirk, Robbins, Todd, & Riley, 1996; Miyamoto, et al., 1999; Mondain et al., 1997; Moog & Geers, 1999; Osberger, Robbins, Todd, Riley, & Miyamoto, 1994) have examined the development of intelligible speech in children fitted with cochlear implants. Only one study to date appears to have looked at this topic with more than a single measure. Chin et al. (2001) tested the intelligibility of 20 early school-aged children, who wore a cochlear implant, at the single-word and sentence level. When deciding on a successful method of assessment, it is important "to know which of the factors are most important to clinical intelligibility assessment and how efficiently they can be addressed" (Kent et al., 1994). The intelligibility issues being addressed in the current study are sample format (single words versus conversation), test format (ratings versus transcription versus closed set multiple choice) and listener familiarity (parent versus clinician). In addition, intelligibility will be examined relative to the effect of experience with the implant (i.e., post-implantation age) along with possible differences relating to listener familiarity.

Research Questions

1. Does intelligibility differ across different sampling methods?
2. Does intelligibility vary by post-implantation age?
3. Does intelligibility vary according to listener familiarity?

CHAPTER 2

REVIEW OF LITERATURE

Intelligibility

Intelligibility of speech has been examined in a number of different populations. For the present purposes the following discussion will focus primarily on the speech of the hearing impaired.

"Above all, intelligibility is a joint product of a speaker and a listener" (Kent et al., 1994, p. 81). In two studies completed by Weston and Shriberg (1992), it was found that articulatory variables alone did not account completely for communication failure. Factors that may affect intelligibility include the language competency of the speaker, the listener's familiarity with the speaker, the clarity of the acoustic and visual signals of speech, and contextual cues. Since intelligibility is rooted in a speaker-listener dyad, it is probable that "a particular talker has a range of intelligibility potentials, depending on listener familiarity, nature of the linguistic message, physical setting, motivation, effort level, and so on" (Kent et al., p. 82).

A study completed by Allen et al. (1998) found that speech intelligibility develops progressively over time. One hundred and eighteen children who were deafened before the age of 3 years and implanted before the age of 7 years were assessed pre-implantation and up to 5 years post-implantation. Using the Speech Intelligibility Rating (SIR), before implantation the mean rating was 1 for the children (connected speech unintelligible). One year post-implantation the mean rating was 2 (connected speech unintelligible and intelligible speech developing in single words) and by the third year post-implantation the mean rating was 3 (connected speech intelligible to listener who concentrates). After 4 years of implantation the average rating was 4 (connected speech intelligible to listeners with little experience) and at 5 years post-implantation the average rating was 5 (connected speech intelligible to all listeners). The increases noted up to the fourth year were statistically significant.

Intelligibility should not be confused with severity of involvement of the speech, voice, or other problem. These two tend to be highly correlated, but in certain instances may be distinct and separate. For example, a child may have a severe voice quality or prosody disorder and still be quite intelligible. A listener might rate the child as having a severe speech impairment yet be able to understand the content of the message (Kent, 1992).

Factors Affecting Intelligibility in Deaf Speech

Intelligibility is determined by the listener's perception of the speaker's speech. One factor that may affect the listener's judgment is the context in which the speech occurs. Porter and Bradley (1985) suggest there is linguistic basis to intelligibility. The amount of the message understood may be influenced by word familiarity, vocabulary, grammatical features, and linguistic probability of word incidence. When completing oral reading exercises, Levitt (1980) stated, "if the reading material is at a linguistic and cognitive complexity level above the student's level of functioning, the student's intelligibility may be negatively affected in a reading task and may be higher during spontaneous speech" (as cited in Porter & Bradley, 1985, p. 515). Allen, et al. (1998) also suggest that the child needs to have competent language skills to complete the language sample. In either reading or spontaneous speech, if the child does not recognize the word or does not have an adequate vocabulary, then intelligibility will be affected.

Segmental Factors

Speech sound accuracy may or may not affect the intelligibility of a child. Williams (2000) has suggested that a child's intelligibility may be reduced when the contrastive function of sounds are absent. This lack of contrast or phoneme collapse results in homonymy of the words. This indicates that the child has developed a compensatory strategy to makeup for their limited sound system.

Although the effects of different individual error types on intelligibility is not yet fully understood, "there is a high negative correlation between the frequency of segmental errors and intelligibility, i.e., the higher the incidence of segmental errors, the poorer the intelligibility of the speech, on average" (Levitt, 1977; as cited in Parkhurst & Levitt, 1978, p. 249).

Kent (1992) stated that it is possible for the results of articulation and phonological tests to be highly correlated with independent views of intelligibility, but these evaluations are not assessments of intelligibility. Kent et al. (1994) noted that a person might have a continuing articulation disorder, such as lisping, and still be highly intelligible to others. Also a person with a phonological disorder may be intelligible to individuals that are familiar with the phonological pattern (Flipsen, 1995). Smith (1975) stated that research on speech production in children has been directed toward examination of phonologic properties. This may be partially due to the previously noted high correlation between phonologic characteristics and speech intelligibility.

The speech of deaf individuals is characterized by a number of segment-level problems that might affect intelligibility. Markides (1970) for example examined voicing of 83 hard-of hearing and deaf children using 24 monosyllabic words presented pictorially. The children frequently used voiceless stops when the voiced stops were needed. Mangan (1961) also noted that while reading a list of phonetically balanced words, 21 deaf and 9 hard-of-hearing children devoiced the final voiced consonants. Nober (1967) interpreted these and other findings to suggest that voiced sounds are harder to produce for hard-of-hearing and deaf individuals. Hudgins and Numbers (1942) examined the effect of omissions of sounds on word intelligibility in hard-of-hearing and deaf individuals ranging in age from 8 to 19 years old. Correlation of .56 between initial position omissions and .16 between final position omissions and intelligibility were found. This suggests that an error in the initial part of a word will reduce intelligibility to a larger extent than an error in the final position. However through additional research, Nober stated that errors within the speech of deaf individuals appear more frequently in the final position and decrease in frequency from the medial to initial positions of words. It is apparent that additional research is needed concerning this factor. Hudgins and Numbers also examined the use of consonant blends. In that study, teachers of the participants listened to audiotapes of the children reading sentences. The examiners reported, "the frequency of errors in consonant blends had an important effect on the listener's ability to understand the child" (p. 401). These children added /ə/ between the two consonants, thus changing the rhythm of each utterance. Place of articulation is also thought to affect intelligibility of deaf speech. Within Nober's study consonant production in isolated words was examined. It was found "that as the place of consonant production moved further back in the mouth, the chances of it being produced correctly decreased with the exception of glottal sounds" (p. 402). The percentage of consonants produced correctly were as follows: bilabials, 59%; labiodentals, 48%; glottal, 34%;

linguadentals, 32%; lingua-alveolars, 23%; linguapalatals, 18%; and linguavelars, 12%. Vowel errors are also made by deaf individuals. Smith (1972; as cited in Gold, 1980) stated that in this population there is a high incidence of tense/lax vowel confusion. Back vowels, as a rule, are more likely to be produced correctly than front vowels and vowels with low tongue position are correctly produced more often than those with middle or high tongue position (Mangan, 1961 & Nober, 1967). "Consonant errors are generally believed to be more directly correlated with overall intelligibility than vowel errors are" (Gold, p. 404). Hudgins and Numbers stated that consonant articulation and rhythm are more essential than vowel articulation to overall intelligibility.

Non-segmental Factors

Suprasegmental factors such as timing, duration of phonemes, transitioning, and pauses are also thought to affect intelligibility of deaf speech. According to Gold (1980) these suprasegmental deficiencies contribute as much as segmental deficiencies to the poor intelligibility of deaf speech. The timing of speech for deaf individuals is much slower than normal speakers. Voelker (1938) compared the reading rate of 98 deaf children to 13 normal-hearing children in grades 1 to 3. He discovered that the quickest deaf reader was somewhat slower than the average normal reader. Similar results were also reported by Boone (1966). Boone stated that although the speech rate of deaf speakers increases with maturation it remains noticeably slower than that of normal hearing individuals. Differences in rate may reflect differences in either segment duration or pause duration. Hood (1966; as cited in Gold, 1980) suggested that training of duration of segments could improve the intelligibility of deaf speech if articulation is also intact. Levitt (1971) found that deaf individuals tend to inject extra sounds between consonants as they transition their articulators from one position to the next (as cited in Gold). Hudgins (1946) suggested there are increases in within- and between-phrase pauses that give rise to the overall rate difficulties and therefore to decreased intelligibility. However, Parkhurst and Levitt (1978) noted that pauses might aid to indirectly increase intelligibility. They suggested that prolonged pauses give the listener extra time to process the unclear speech of the deaf individual.

Vocal quality may also affect intelligibility of deaf speakers. One of the most frequently noted aspects of deaf speech is abnormal nasality. Stevens, Nickerson, Boothroyd, and Rollins (1976) used an accelerometer attached to the nose of deaf individuals to monitor velopharyngeal opening during vowel production. The results showed that 76% of the subjects had excessive nasalization of the vowel produced. Another quality problem is that of pitch. Willemain and Lee (1971) noted that in addition to higher pitch, a wider pitch range characterizes deaf speech. The pitch of these individuals also usually increases as the complexity of the message increases.

Measurement Issues

There are a variety of ways to measure intelligibility. Unfortunately there is little agreement on how to measure intelligibility correctly and completely. According to Kent et al. (1994) intelligibility measures in the past have been made using rating scales or impressionistic statements. In recent years, more quantitative and analytic methods for assessment for persons with hearing impairment have been developed.

Ideally, intelligibility should be measured using reliable and precise methods. Impressionistic statements allow rapid evaluations, but often lack both intraobserver and interobserver reliability. Analytic assessments, which may be more appropriate, involve "examining a complex structure or process in terms of its elements and their relationship. Intelligible speech is a complex product of language formulation, phonological organization, and motor execution" (Kent et al., 1994, p. 82).

Words versus Conversation

Intelligibility in spontaneous conversation has been shown to differ from single words. According to O'Neill (1975), speech intelligibility may increase with word familiarity and predictability, thus words heard in context will be easier to understand than isolated words (as cited in Gulian & Hinds, 1981). Thomas (1964, as cited in Gold, 1980) noted that from the perception of experienced listeners, the intelligibility of deaf children is 15% better for sentences (25%) than words (10%). Kirk and Hill-Brown (1985) suggest otherwise. The various segmental problems that individuals with hearing loss often exhibit may combine to contribute to their inability to smoothly produce the phonemes in connected speech.

Chin et al. (2001) examined the intelligibility of 20 children age 4.8 to 7.8 years fitted with a cochlear implant. The Minimal Pairs Production Test (MP2), and 10-sentences from the Beginner's Intelligibility Test (BIT) were given. Sixty adult inexperienced listeners participated by generating an intelligibility score for both the MP2 and BIT tests. Results indicate that sentence intelligibility was significantly correlated with single-word intelligibility ($r = .77$).

Use of Rating Scales

Rating scales are often used to provide a general indication of how intelligible a person's speech may be. This type of intelligibility measure is appealing since it may be easily and quickly administered. Doyle (1987) examined inter-rater reliability when using two intelligibility scales as well as when using untrained listener-raters. The five-point scale developed by the National Technical Institute for the Deaf (NTID) and a percentage intelligibility scale were used. Oral reading samples were gathered from 20 hearing-impaired children and audio taped for the 20 listeners to review. The listeners were audiologists (familiar listeners) that were untrained in the proper use of rating scales. The results revealed that mean ratings for each scale occurred toward the end points (either higher or low; no scores in the middle). Also, variability in the ratings was large for some samples. The fact that variability is often a problem with rating scales confirms the need to use multiple listeners. Kendall's coefficient of Concordance was calculated to reveal inter-rater reliability. The NTID scale value was .81 and the percent intelligible value was .88. Both of these scores were statistically significant. Intra-rater reliability was evaluated by repeating two samples for each listening session. This reliability was high for both scales. The NTID scale value was .96 while the percent intelligible scale was .92. Doyle concluded that the use of untrained listeners to rate the speech of hearing-impaired children may provide reliable results. Also, a relatively small number of listeners are sufficient to provide the necessary ratings. These findings support the use of small groups of unfamiliar listeners for the current study.

<u>Listener Familiarity</u>

Intelligibility may vary depending on the listener's familiarity with the speaker's population. Gulian and Hinds (1981) examined the perception of deaf speech by experienced and naive listeners. They assessed 14 children ages 5 to 11 that had prelingual profound hearing loss. Each child identified familiar objects or actions presented on stimulus cards. The children's own teachers were used as experienced listeners along with three naive listeners (adults that had no contact with deaf speakers in general). The listeners were asked to write down what they heard. The results indicated that although the teachers made more correct responses the difference was not statistically significant ($p > .05$). Gulian and Hinds concluded that familiarity with deaf speakers did not grant a substantial advantage in intelligibility judgments in general. However, although each group of listeners identified the overall same number of errors, the recognition of error type (i.e., correct, errors, and omissions) differed significantly for each group. Experienced listeners misidentified substitution errors and the vowel and/or word presented, while the naive listeners made more errors recognizing omissions. The authors state that these results are "contrary to the general findings in this area that intelligibility scores obtained by naive listeners are lower than those obtained by experienced listeners" (p. 169). McGarr (1983) compared the amount understood by experienced versus inexperienced listeners. These listeners heard words produced in sentences, in isolation, and as segmented words. Relative word intelligibility, context, position of the target word in the sentence, and overall sentence length were factors originally thought to account for differences among the groups. The experienced listeners scored consistently higher than the inexperienced individuals in identification of target words in sentences by 20.5%, in isolated words by 14.6%, and in segmented words by 5.03%. "Because the overall pattern of scores was similar for both groups, there was no statistical significant interaction between listening experience and predicted word intelligibility" (p. 454). For sentence context, the experienced listeners scored higher but no significant interaction was found. As for position of the test word within the sentence, no statistically significant interaction between listener experience was found. McGarr concluded that regardless of the listener's previous experience, the two groups correctly identified the target words with similar accuracy. Similar overall results were found in a study of listener experience on two measures of intelligibility by Ellis & Fucci, (1992). In this study, 10 experienced listeners and 10 inexperienced listeners judged 9 audiotaped speech samples. They completed a magnitude-estimation scaling task and a word-identification task. Results indicated that there was no significant trend based on experience on either task. Like Gulian and Hinds' study, familiarity did not assist in identification of correct words or rating when the context of the samples were not available. These three studies suggest that experienced listeners have no great advantage in the understanding of deaf speech.

Intelligibility and Cochlear Implants

Studies that have examined intelligibility in children with cochlear implants are summarized in Table 1.

Intelligibility and Age of Implantation

According to Zwolan (2000), there is a growing trend to decrease the age at which children may receive a cochlear implant. Investigators have argued that doing so will supply children with better access to auditory information, which is essential for the development of speech and language (Hoffman, 1997; Osberger, 1997). Moog and Geers (1999) assessed the intelligibility of 22 prelingually deaf children ages ranging from 6:4 to 10:10 who had used cochlear implants from 1 to 7 years. These children had been implanted between the ages of 2:4 to 9:4. The Picture Speech Intelligibility Evaluation (SPINE) was given to assess speech production. Scores from the SPINE indicated that all

TABLE 1

Studies of intelligibility in children with cochlear implants.

Method	Participants					Intelligibility Findings
Authors	Number	Age	Hearing Loss	Control Group	Listeners	
Doyle (1987)	20	mean 11.54 years I. A. < 6 years	Pre-lingual bilateral SNHL		20 adult familiar listeners without training	Mean ratings for NTID and % intell. scales occurred toward end points; It was concluded that few children had speech intell. in middle range.
Osberger, et al. (1994)	29	mean I. A. 5.7 years	Pre-lingual deafness Deaf onset .9 years	Hearing aid users I – 90-100 II – 101-110 III - > 110 dBHL	3 adult inexp. listeners	Largest change in speech intell. after 2 + years of CI use; Mean intell. for CI group higher than HA groups I and II after 3.5 – 4.0 years of use; CI group remained below intell. scores of HA group I.
Dawson, et al. (1995)	12	I.A. 8 + years	Profound hearing loss Deaf onset < 5 yrs		12 adult familiar listeners	Mean group performance for post-op assessment was significantly higher than pre-op assessments (p. < 0.01); Pre-op intelligibility scores ranged from 0% to 36% while post-op scores ranged from 19% to 81% (procedures by McGarr, 1983); Most subjects showed significant improvements on high context intelligibility sentences than on low context sentences.
Miyamoto, Kirk Robbins, Todd, & Riley (1996)	50	I. A. 5 yrs	Pre-lingual deafness Deaf onset 0.8 yrs	Hearing aid users I – 90-100 II – 101-110 III – >110 dBHL	3 adult unfamiliar listeners	Gradual improvement overtime was noted in speech intelligibility for CI subjects (especially after 6 mo.); After 1.5 – 2 years the CI group had surpassed HA group II; Average intelligibility of CI group after 3.5 - 4 years implanted doubled the speech intelligibility of HA group II (according to the BIT and Monsen Sentence Test).
Mondain, et al. (1997)	16	mean I.A. 3.11 years	Pre-lingual deafness		50 adult listeners	Speech sample transcriptions used to judge speech intelligibility; After 1 year CI use the children were 4.2%, 2 years were 30.7%, 3 years were 55.2%, and 4 years were 74.2% intelligible.

TABLE 1

Continued.

Method	Participants					Intelligibility Findings
Authors	Number	Age	Hearing Loss	Control Group	Listeners	
Allen, Nikolopoulos, & O'Donoghue (1998)	84	I.A. < 7 years	Congenital deafness or deaf onset < 3 yrs		84 adult familiar listeners	Intelligibility continued to develop after 5 years post-implantation according to the SIR.
Miyamoto, Kirk, Svirsky, & Sehgal (1999)	31	4-5 years I. A.	Pre-lingual deafness			Children implanted before 3 years had higher mean speech intelligibility scores (20%) than those implanted after 3 years (8.5 – 9%).
Moog & Geers (1999)	22	C. A. 6;4 - 10;10 years	Profound hearing loss		Listeners participated; Details not given	Nineteen children were 90% intelligible while the remaining three were 74%, 76%, and 85% intelligible; Significant improvements on SPINE compared to standardized sample of profound deaf children (not aided – 74%).
Chin, Finnegan, & Chung (2001)	20	C. A. 4;8 - 7;8 yrs I. A. < 6;0	Profound bilateral hearing loss Deaf onset < 3;0		60 adult listeners without experience	Sentence intelligibility (BIT) was significantly and positively correlated MP2 (speech production).

Note: IRF = Improvement Rate Factor (Loeb & Kessler, 1995); SIR = Speech Intelligibility Rating; NTID = National Technical Institute for the Deaf; BIT = Beginner's Intelligibility Test; MP2 = Minimal Pairs Production Test; SPINE = Picture Speech Intelligibility Evaluation; SNHL = sensorineural hearing loss; IA = implant age; CI = cochlear implant; HA = hearing aid; HL = hearing loss; Prof. = profound; Chron. = chronological; C. A. = chronological age; Imp = implantation; op = operative; intell. = intelligibility.

but three of the children were 90% intelligible. These remaining three subjects were 74%, 76%, and 85% intelligible. The children who were implanted before 4.5 years of age achieved the best auditory skills, which in turn developed language skills that equated the performance of typically developing age matched peers. Miyamoto et al. (1999) investigated the influence of age at implantation on speech performance. Thirty-one children using either a Nucleus (SPEAK) or Clarion (CIS) cochlear implant were divided into three groups based on age at implantation (Group 1 – < 3;0, Group 2 – 3;0 to 3;11, Group 3 – 4;0 to 5;3). Speech intelligibility was measured one time at pre-implantation and at 6-month intervals thereafter. Each child repeated 10 simple sentences from the BIT. These sentences were audiotape recorded and randomly played back to a panel of three inexperienced listeners. The mean percentage of words correctly identified for each of the three groups were computed. The children implanted before the age of 3 years (Group 1) had a mean intelligibility score of 20% while the children implanted after that age scored only 8.5 to 9%. The relationship between speech intelligibility and age at implantation in this study was not statistically significant.

Intelligibility and Sampling Methods

The majority of studies examining speech intelligibility use only one sampling method. The only study to date, which appears to have assessed speech intelligibility using more than one sampling measure was the previously mentioned study by Chin et al. (2001) Recall that they reported that sentence intelligibility was significantly correlated with single-word intelligibility (r = .77).

Intelligibility and Post-implantation Age

Intelligibility in children with cochlear implants is influenced by additional factors, especially experience with the implant. Tobey, et al. (1998) stated that generally, "the greater the experience with an implant, the higher the overall speech intelligibility" (p. 28). Both postlingually and prelingually deafened children will benefit from their cochlear implant, but it has been found that children with prelingual and congenital deafness make improvements in speech production at a slower rate than the postlingually deaf children (Tong, Busby, & Clark, 1988).

In a longitudinal study by Osberger et al. (1994), the intelligibility of 29 prelingually deafened children who had received Nucleus multichannel cochlear implants (CI) was examined. The children's mean age of onset of deafness was 0.9 years and the mean age of implantation was 5.7 years. The speech of these subjects was compared to that of hearing aid (HA) users. These HA subjects were divided into three groups based on their unaided thresholds at 500, 1000, and 2000 Hz. The Gold users demonstrated thresholds between 90 to 100dBHL, the Silver users had hearing levels of 101 to 110dBHL, and the Bronze group illustrated thresholds greater than 110dBHL. Each subject repeated 10 sentences that were modeled by an examiner. The repeated sentences were tape recorded and randomly played to a panel of inexperienced listeners. The listeners wrote down what they thought each subject had said. Intelligibility was computed as the mean percentage of words accurately understood. Results indicated that the largest changes in speech intelligibility were not observed until the subjects had used their cochlear implant for 2 or more years. In addition, the mean speech intelligibility of the implanted subjects was higher than the hearing aid subjects within the Bronze and

Silver groups after 3.5 – 4 years of device use. The CI user's mean intelligibility scores, however remained below those of the Gold HA group by 30%.

Dawson et al. (1995) completed a study intended to measure articulation and speech intelligibility. This was completed over a 12-month period with a group of 21 individuals who received their cochlear implant at the age of 8 years or over. The participants were both pre- and postlingually deaf. Speech intelligibility was assessed using the procedure of McGarr (1983) in which the patients were asked to read a total of 36 sentences that varied by length and contextual cues. Intelligibility was measured from "the number of key monosyllabic words in the sentences correctly identified by normally hearing listeners" (p. 554). The average postoperative speech intelligibility was significantly higher than the preoperative measurements. There was also a significant increase of articulation accuracy over time as measured by the Fisher-Logemann Test of Articulation Competence (Fisher & Logemann, 1971). This was attributed to a considerable improvement of consonant and consonant blend accuracy.

Miyamoto et al. (1996), completed a longitudinal study on the influence of cochlear implantation on speech production. They examined 50 children with prelingual deafness that had received a cochlear implant. Their mean age of implantation was 5 years of age. Fifty-nine children using hearing aids were also included. Speech production intelligibility was measured through the use of either the Beginner's Intelligibility Test (BIT) or the Monsen Sentence Test depending on the age of the subjects. Each subject's responses were audio recorded and then played back for a panel of 3 listeners with no prior experience with individuals having a hearing loss. Speech production intelligibility scores revealed that the CI subjects gradually improved over time. The average speech intelligibility prior to implantation was 0%. After 3.5 years of use performance improved to 40%. This score exceeded the intelligibility of 39 of the 59 of the hearing aid users.

Mondain et al. (1997) tested production intelligibility in 16 children with prelingual deafness that used multi-channel cochlear implants. The children in the study received their implants at a mean age of 3 years and 11 months. Speech production intelligibility was measured by fifty listeners who identified target words and/or sentences from recorded speech samples. Results showed that the children with 1 year of implant use were 4.2% intelligible. The children with 2 years experience were 30.7% intelligible, those with 3 years experience were 55.2% intelligible, and those at 4 years post implantation were 74.2% intelligible.

Intelligibility and Listener Familiarity

There does not appear to have been any studies conducted concerning how listener familiarity affects judgment of speech intelligibility in cases of children or adults with cochlear implants.

Justification for the Present Study

As mentioned previously, the purpose of the current study was to examine the intelligibility of speech produced by young children with cochlear implants. Although studies that examine speech production intelligibility in this population are accessible (as indicated previously), it is apparent that more research in the area is needed to add to the collection of information available.

A question that is likely to be in the mind of the parents or family of the children who receive cochlear implants is "When will my child be able to communicate intelligibly?" or in other words "When will I be able to understand more of my child's speech?" The current study will help to answer questions such as these. Another important justification for the completion of the current study is that this is one of the only studies to date that has looked at the topic of intelligibility with more than a single measure. By examining speech intelligibility across two measures (single words and conversation), by post – implantation age, and according to listener familiarity, a more complete view of the intricate phenomenon of intelligibility can be obtained. The three additional analyses completed between intelligibility include receptive vocabulary chronological age, and age of identification. These analyses also add to the information available concerning which factors may affect the development of speech intelligibility.

CHAPTER 3

METHOD

Participants

Six preschool children participated in the current study (See Table 2). The children were chosen based on the following: (1) prelingually deaf (defined as loss of hearing before 3 years of age); (2) severe to profound binaural hearing loss (90 + dB HL); (3) used either Clarion or Nucleus multi-channel cochlear implants; (4) used spoken communication rather than signing during treatment; (5) receptive vocabulary as measured by the Peabody Picture Vocabulary Test – 3rd Edition (PPVT-III; Dunn & Dunn, 1997) within 2 standard deviations of the mean for their age (Standard Score 70+); (6) implanted before age 4 years; and (7) post-implant age (experience with the implant) of at least 18 months to increase the likelihood that the children would be producing multi-word utterances. Prior to participation in the study, each parent or guardian gave informed consent for his or her child's participation. A sample consent form is shown in Appendix A.

All six participants differed somewhat by chronological age, age of implantation, and age of identification. The range of ages can be seen within Table 2. The average chronological age for the six participants was 5 years (S. D. = 10 months), average age at implantation was 2 years, 4 months (S. D. = 6 months), and age at identification was 8 months (S. D. = 6 months).

Parents of the children were paid $10.00 for having their child participate (see Appendix C). It should be noted that the children who participated in the current study

TABLE 2
Summary of Participant Data for the Current Study.

#	Etiology	C.A.	Age at Implantation	Gender	Age of ID	Aided Prior to Implantation	Implant Type	Tested Post Implant Age	PPVT - III * Scores
1	unknown	4;5	2;6	Female	0;0	Binaural aids	Nucleus-24	1;11	99
2	Partial cochlear agenesis	3;9	1;8	Male	0;11	Binaural aids	Nucleus-24	2;2	76
3	unknown	5;2	2;7	Female	1;3	Unilateral aid	Clarion	2;6**	81
4	unknown	5;3	2;4	Female	0;8	Binaural aids	Clarion	2;10	89
5	unknown	6;2	3;0	Female	1;0	Binaural aids	Clarion	3;2	72
6	unknown	5;6	2;0	Female	0;3	Binaural aids	Nucleus-24	3;6	77

* Peabody Picture Vocabulary Test – Third Edition
** Data from the second testing session.

were part of a longitudinal study of speech development in children with cochlear implants. Data for five of the six children were obtained at initial testing. Data for one child were obtained at Time 2, which occurred 3 months after initial testing, in order to generate a "spread" of post-implant ages for the current study.

The PPVT-III was administered as the index of receptive vocabulary of each participant at the time of the study. This score may also indirectly represent the child's speech perception abilities. The subject's scores ranged from 72 to 99 (see Table 2). Thus all of the children met the criteria of scoring within two standard deviations of their age group mean.

Test Protocol

The following procedures were used to gather data for the current study: (1) a conversational speech sample; (2) an intelligibility rating scale; and (3) the Children's Speech Intelligibility Measure (CSIM; Wilcox & Morris, 1999). Both the conversational speech sample and the CSIM productions were recorded on digital audiotape using a Sony PCM-M1 tape recorder and a Sony TCM-150 microphone mounted on the tabletop. All samples were recorded at a sampling rate of 48 KHz. In addition to the examiner, a parent/guardian of each child, the supervising clinician working with each child in Child Hearing Services, and speech pathology students with no prior experience with the children assisted with generating judgment data for the study.

The total time for each participant to complete all tests was approximately 45 – 60 minutes. The individual tests and the approximate completion times for each are as follows: (1) Peabody Picture Vocabulary Test – III, 15 minutes; (2) Conversational speech sample, 15-30 minutes; and (3) Children's Speech Intelligibility Measure (CSIM), 15 minutes. The rating scale was completed by the parent and clinician while each child was being tested.

Intelligibility Measures

(1) Conversational Speech Sample

A conversational sample of each child was elicited, audio tape-recorded, and eventually stored onto compact discs (CD). The samples were elicited using a variety of topics (i.e. favorite movies or cartoons) and materials such as pictures from the Bracken Concept Development Program (Bracken, 1998). A sample size target of at least 90 different words was selected because by gathering at least 90 different words it is more likely that the child will have produced all of the phonemes in the English language (Shriberg, 1986). The number of different words in the samples ranged from 26 to 127. Only one sample (Participant 2) produced a sample with fewer than 58 different words. The average sample included 85 different words. To avoid fatigue effects on other aspects of the protocol (the conversational samples were always evoked first), the conversations were terminated after 25-30 minutes.

Two speech-language clinicians (who did not normally work with hearing-impaired children) with more than 10 years of clinical experience and who were not present at the time of the taping orthographically transcribed each sample using a consensus approach. Two unfamiliar listeners were chosen for this task to avoid listener bias that might skew the results. Each clinician first sat alone and transcribed the sample. The two clinicians then met and compared their transcriptions in order to draft one final transcription. This resulted in 6 transcriptions (1 per child). Through these transcriptions, percentage of words understood was determined. The calculation of percentage of words understood involved an estimation procedures described in Shriberg (1986). Although by definition the number of words cannot be truly known in unintelligible speech, listeners can reliably count the number of syllables heard (as peaks of relative loudness). The transcribers were advised to indicate each syllable heard in unintelligible sections of the transcript (see Transcriber Instructions, Appendix D). The number of unintelligible syllables in each transcript was then counted. The number of words was estimated by knowing that preschool speech typically includes approximately 70% monosyllabic words, 20% disyllabic words, and 10% of words containing 3 or more syllables. Thus words in preschool speech would contain on average 1.4 syllables. The number of unintelligible syllables divided by 1.4 yields an estimate of the number of unintelligible words. Transcribers were paid $100.00 for their word (see Appendix C).

(2) Rating Scale

A parent or guardian of each child and the supervising speech-language pathologist or audiologist from the Child Hearing Services who works with each child both completed the intelligibility rating scale. They were asked to base their remarks on the child's day-to-day speech. (See Appendix B). Form A is intended for the parent and Form B is intended for the clinician. The clinician scale was not completed for the one child not attending CHS. Since there are no commonly used rating scales, those used in this study were generated specifically for this purpose.

(3) Children's Speech Intelligibility Measure (CSIM)

Prior to administering this test, the examiner randomly chose a word from the 50 lists of 12 similar sounding words provided by the test makers. Different sets of words were chosen for each participant. Each child imitated the 50 words spoken by the examiner. These words were audiotape recorded. Owing to some technical difficulties (e.g., noise or over-talk, production in a phrase rather than in isolation) the actual samples ranged in size from 45 to 50 words. The CSIM samples were then prepared using Computerized Speech Lab Model 4400 (CSL). Each word produced by the child was isolated and stored in a separate digital file. Each file was presented to the listeners using Windows Media player on a Dell PP01L laptop computer with an Altec Lansing ATP3 speaker system. Eighteen unfamiliar listeners (all female) judged the tapes to avoid the listeners becoming familiar with the word lists. Specifically, three different individuals, two undergraduates and one graduate student, listened to each child's recordings. Mean age of the listeners was 21.6 years (range = 19 to 23). Specific listener instructions were given to each student to read prior to initiation of the task (see Appendix E). Although the CSIM manual suggests presenting each word one time only, in the current study each file was presented two times (consecutively) to aid listener selection. It was thought that under normal listening conditions it would be reasonable to ask a speaker to repeat what they said at least once. Listening occurred inside a single-wall sound-treated booth. Listeners were seated three feet from the computer speakers. Listeners were each given the lists of words the child might have said and were asked to circle the words they thought the child said (one of 12 per item). The percentage correctly identified was then calculated for each listener and averaged across the three listeners for each child. Listeners were paid $15.00 each for their time (see Appendix C).

Data Analysis

The relationship among the variables addressed in the study was examined using Spearman Rank-Order Correlation Coefficients (Rho). In addition the relationships among intelligibility across age of implantation was examined graphically and by correlating intelligibility with post-implantation age, length of time in treatment, PPVT – III score, and parental and clinician ratings.

For analysis purposes, items on the rating scales (see Appendix B) were converted to number values from 0 to 4. A rating of "very little or none" became 0, a rating of "some (but less than half)" became 1, a rating of "about half " became 2, a rating of "most (more than half)" became 3, and a rating of "everything (or almost everything" became 4.

Reliability Testing

Four of the inexperienced listeners (two undergraduate and graduate students) were randomly chosen to listen to the same child's single word sample for a second time, one month after initial testing, to verify intra-rater reliability. Each of the four students listened to four different samples, individually. The procedure was the same as the initial listening sessions of the single word samples. From Time 1 to Time 2, the differences ranged from 4 – 9% with all scores increasing from Time 1 to Time 2. This increase may be due to a learning effect. In another words, the listeners are more adjusted to the task and the child's speech since they have completed this previously. Although the scores are different from one session to the other, it is considered a normal occurrence within the retesting situation (Wilcox & Morris, 1999). The intra-rater reliability correlation (Spearman rho) for this task was .949, which suggests that the data from this procedure are quite reliable.

Inter-rater reliability for the CSIM was examined by looking at the spread of scores across judges for each of the six participants. The scores across the judges ranged from 46.6% to 51%, 21.7% to 30.4%, 43.7% to 54.2%, 51% to 61.2%, 44% to 50%, 54% to 56% for participants 1-6 respectively. On average there was a 7.3% spread across the judges.

Reliability testing was not carried out for the consensus transcription. It was felt that the approach itself (independent transcription followed by resolving of differences) was sufficient to control for any judgment differences between the two transcribers.

CHAPTER 4

RESULTS

The results for the current study are listed within Table 3. The scores for the six participants in single words ranged from 26.8% to 55.7%. Percent intelligible during conversational speech ranged from 26% to 91%. Intelligibility ratings completed by each mother of how much she understands of her child's speech ranged from 3 (Most or more than half) to 4 (Everything or almost everything) and how much the mothers believed others understand ranged from 1 (Some but less than half) to 3 (Most or more than half). Father's completed rating scores ranged from 2 (About half) to 4 (Everything or almost everything) on how much they understand their child and when judging how much others understand, the values ranged from 1 (Some but less than half) to 3 (Most or more than half). Clinician ratings on how much they understand of the child's speech ranged from 2 (About half) to 4 (Everything or almost everything), while their ratings of how much others understand ranged from 1 (Some but less than half) to 3 (Most or more than half). A comprehensive list of all correlations obtained can be found in Appendix F.

Intelligibility and Sampling Methods

As show in Table 3, in four of six cases (participants 1, 3, 5, 6), intelligibility was better in conversation than single words. In one case (participant 4) single words were more accurately understood and in one case (participant 2) there appeared to be no difference between the two sampling methods. The relationship between intelligibility in single words and conversation may be seen in Figure 1. The correlation between the two sampling methods was not significant (rho = .314, $p > .05$). Intelligibility in single words did not appear to be directly related to intelligibility in conversation.

TABLE 3

Intelligibility Data for the Six Participants in the Current Study

Participant	Percentage Intelligible: Single Words	Percentage Intelligible: Conversation	Intelligibility Ratings***: Mother* self	Mother* others	Father* self	Father* others	Clinician** self	Clinician** others
1	48.8	91.0	-	-	4	3	4	3
2	26.8	26.0	4	3	4	3	-	-
3	47.9	68.0	4	3	4	3	3	2
4	55.7	45.0	3	1	4	3	2	1
5	47.3	75.0	4	2	2	1	3	1
6	54.0	80.0	4	3	4	3	2	1

* Parent rating form in Appendix B (Rating Form A)
** Clinician rating form in Appendix B (Rating Form B)
*** Rating Scale:

Self = How much of what he/she says do you usually understand?
Others = How much of what the child says do you think other people usually understand?

4 = Everything (or almost everything)
3 = Most (more than half)
2 = About half
1 = Some (but less than half)
0 = Very little or none

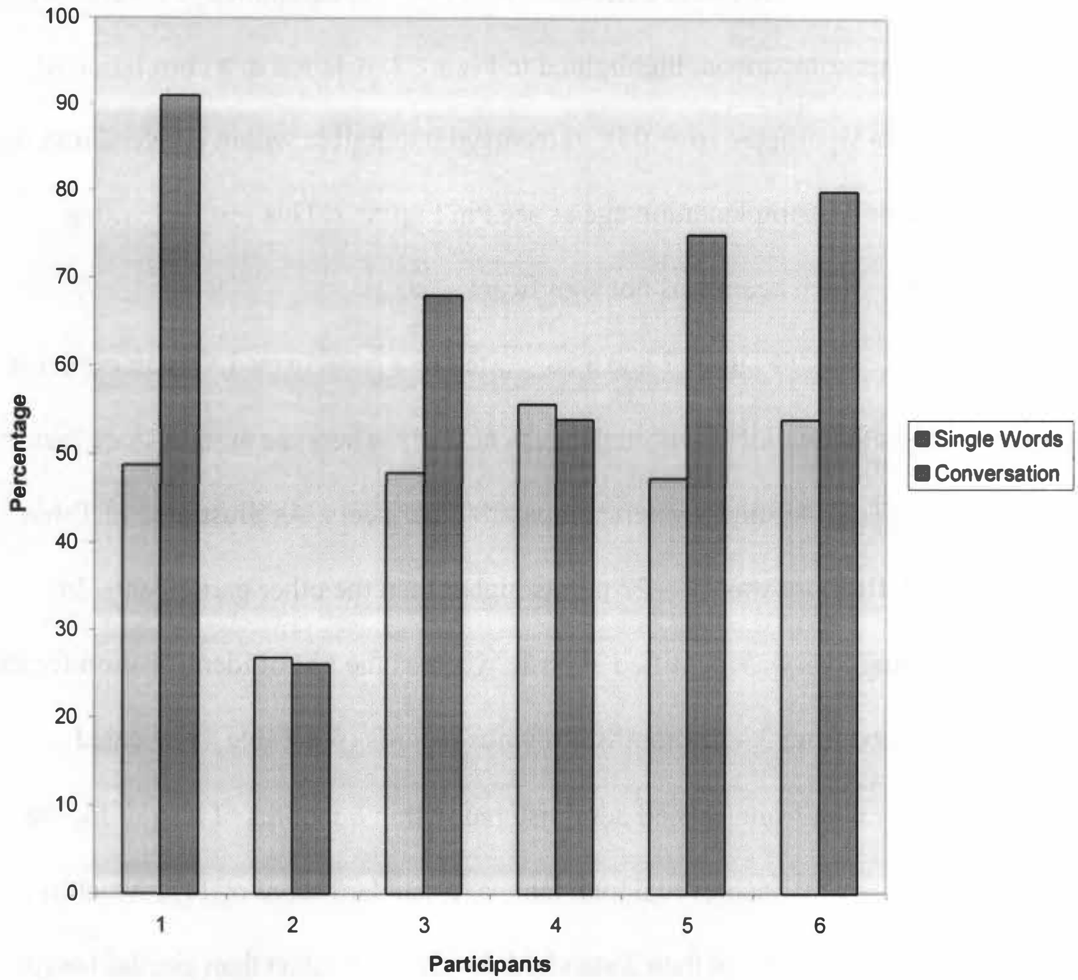

Figure 1: Comparison of Single Word Scores and Percent Intelligible in Conversation

Intelligibility and Post-implantation Age

The single word scores were correlated with post-implantation age for each of the six participants. This comparison, highlighted in Figure 2, resulted in a correlation of .314, which was not significant ($p > .05$). Percentage intelligible within conversation was then correlated with post-implantation age as seen in Figure 3. This resulted with a correlation of .086, which again was not significant.

An examination of Figures 2 and 3 suggested that participant 1 was an outlier in comparison to the other children within the current study. There are at least three factors that make this child extraordinary when compared to her peers. As illustrated in Table 2, this child's PPVT-III score was 10 – 27 points higher than the other participants. In addition, her hearing loss was identified at birth, whereas the age of identification for the other children ranged from 3 - 15 months. Previous records (see Table 4) revealed additional language data from tests all administered within 6 months of testing for the current study. Participant 1 achieved a total language standard score of 115, which is at least 35 points higher (i.e., more than 2 standard deviations higher) than similar language test scores of the other participants in the study.

The analyses were then repeated excluding this participant. The relationship between single word intelligibility and post-implantation age for the remaining five participants, as seen in Figure 4, revealed a Spearman rho correlation of .500. Although not significant, this is a relatively high correlation, which suggests that a strong relationship between single word intelligibility and post-implantation age may have been found with a larger sample size. According to Welkowitz, Ewen, and Cohen (1987;

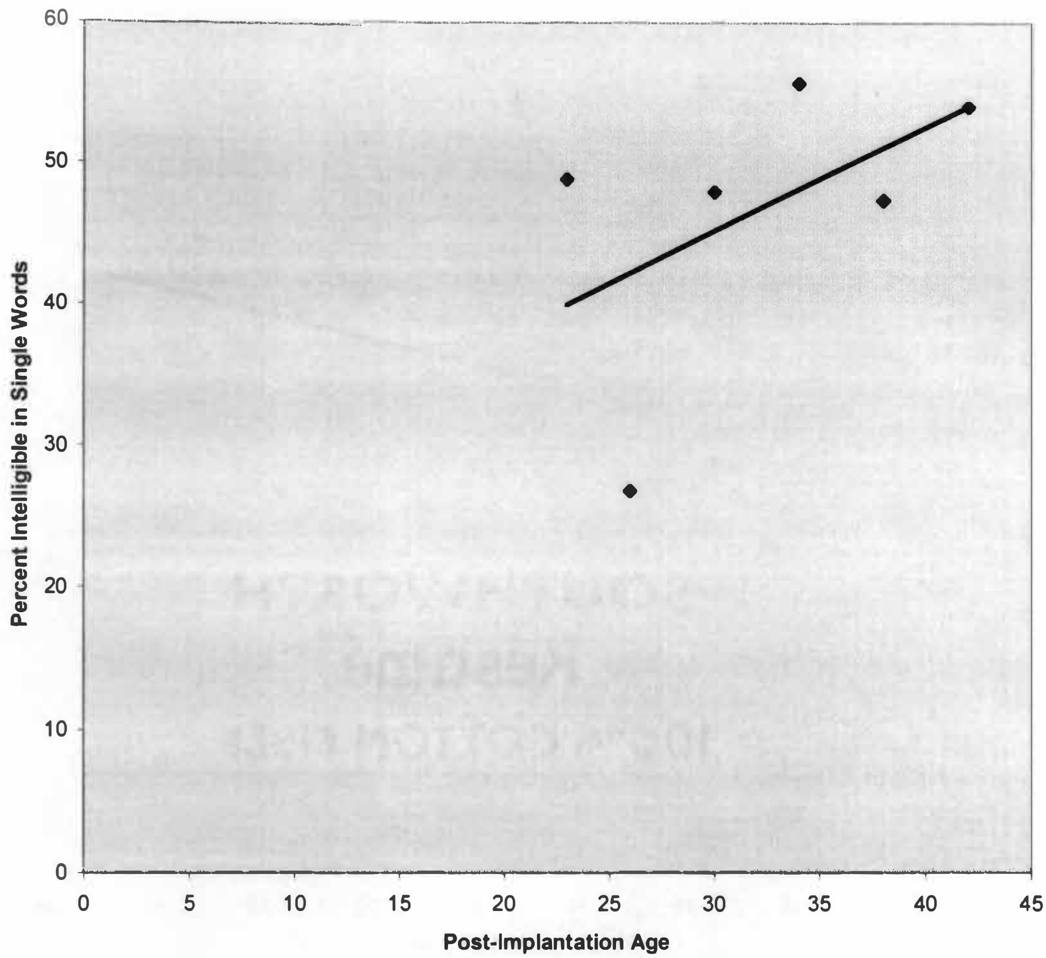

Figure 2: Comparison of Percentage Intelligibility in Single Words and Post-Implantation Age

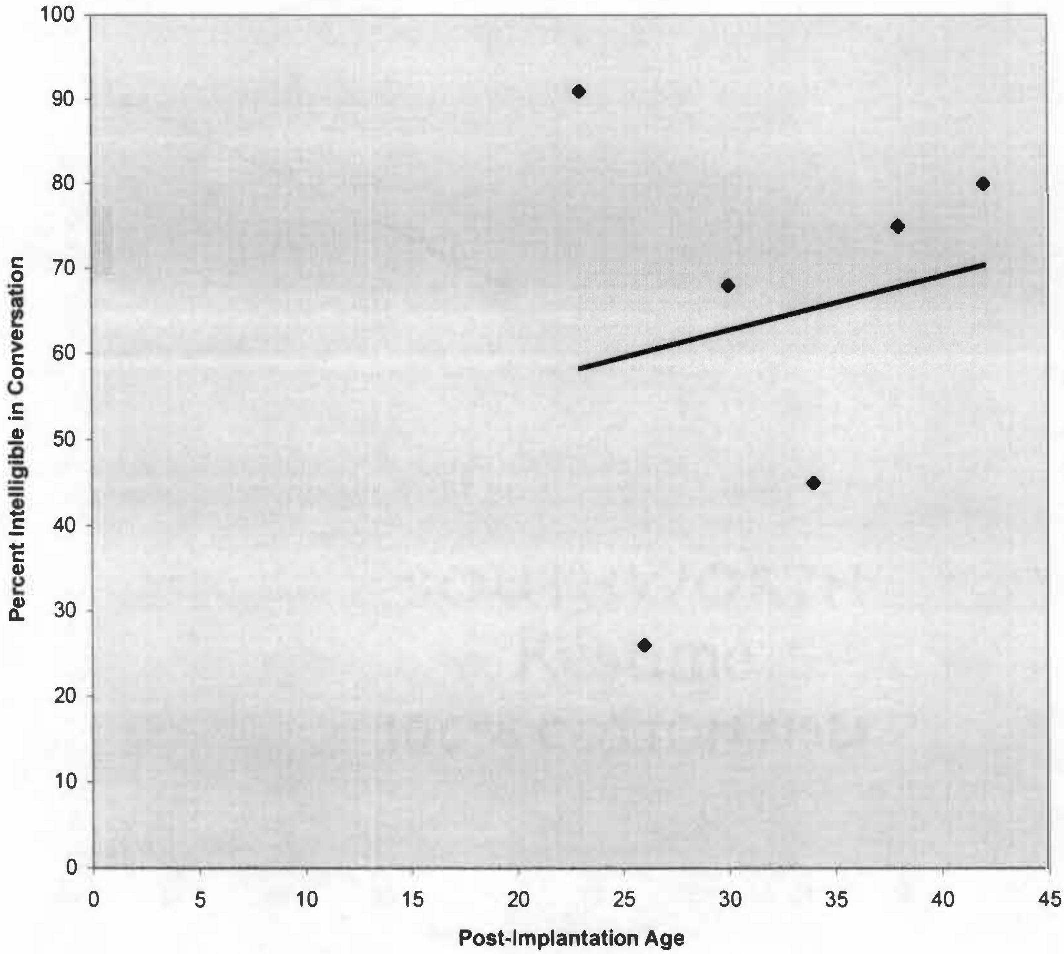

Figure 3: Comparison of Percentage Intelligible in Conversational Speech and Post-Implantation Age

TABLE 4
Language Assessment Data for the Six Participants in the Current Study

Participant	Language Test	Standard Score	Age at Administration
1	PLS – 3	115	4;10
2	SEC	Rec. A – 67.5 Rec. B – 65.9 Exp. A – 72.3 Exp. B – 75.0	3;11
3	CELF-P	70	5;2
4	CELF-P	81	4;10
5	CELF-P	70	6;2
6	PLS-3	71	5;8

Note: PLS – 3 = Preschool Language Scale –3; SEC = Scales of Early Communication in Hearing Impaired Children; CELF – P = Clinical Evaluation of Language Fundamentals – Preschool

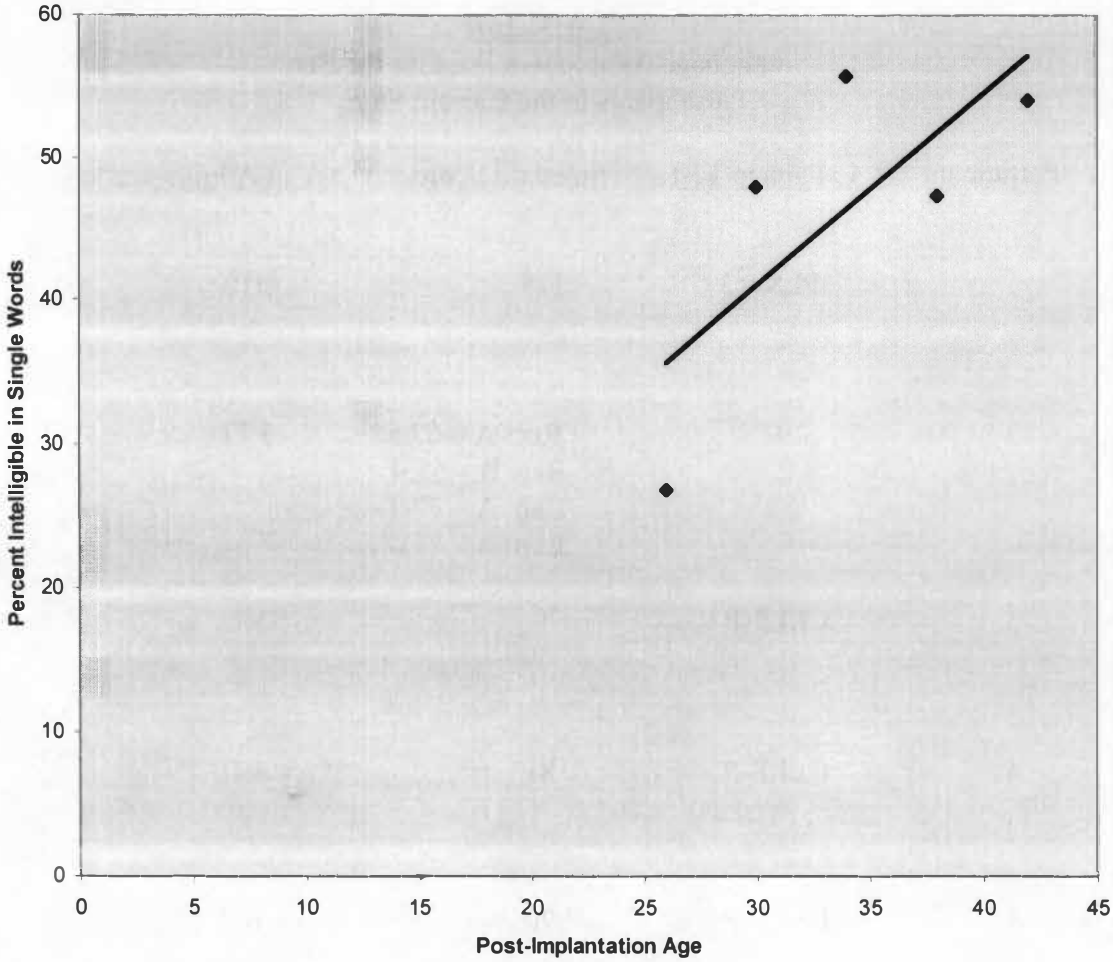

Figure 4: Comparison of Percent Intelligible in Single Words and Post-Implantation Age with Five Participants

p. 353) the sample would have had to include 17 participants in order for this correlation to reach a statistically significant level. When percent intelligible in conversation was correlated with post-implantation age for the five participants, a correlation of .900 was obtained (see Figure 5). This represents a statistically significant relationship between the two variables ($p < .05$). This suggests that intelligibility in conversational speech is related to the child's post-implantation age or experience with the cochlear implant.

Summary

Overall, intelligibility in conversational speech was significantly correlated with post-implantation age. This relationship was only true when the outlier participant was removed from the analysis. In no case were single word scores significantly correlated with post-implantation age.

Intelligibility and Listener Familiarity

Intelligibility ratings completed by parents and clinicians are listed in Figure 6, 7, and 8. Figure 6 illustrates the rating values of each child's mother, Figure 7 represents the ratings for the fathers for the participants, and Figure 8 shows the ratings from the child's primary clinicians.

Examination of the three figures indicates that the mother, father, and clinician each judge themselves as being able to understand more of the child's speech than they believed other, less familiar listeners could understand. This seems reasonable since the familiar listeners have advantages such as exposure to the child's speech, knowledge of their areas of interest and usual topics of conversation, etc. (Flipsen, 1995). In comparing

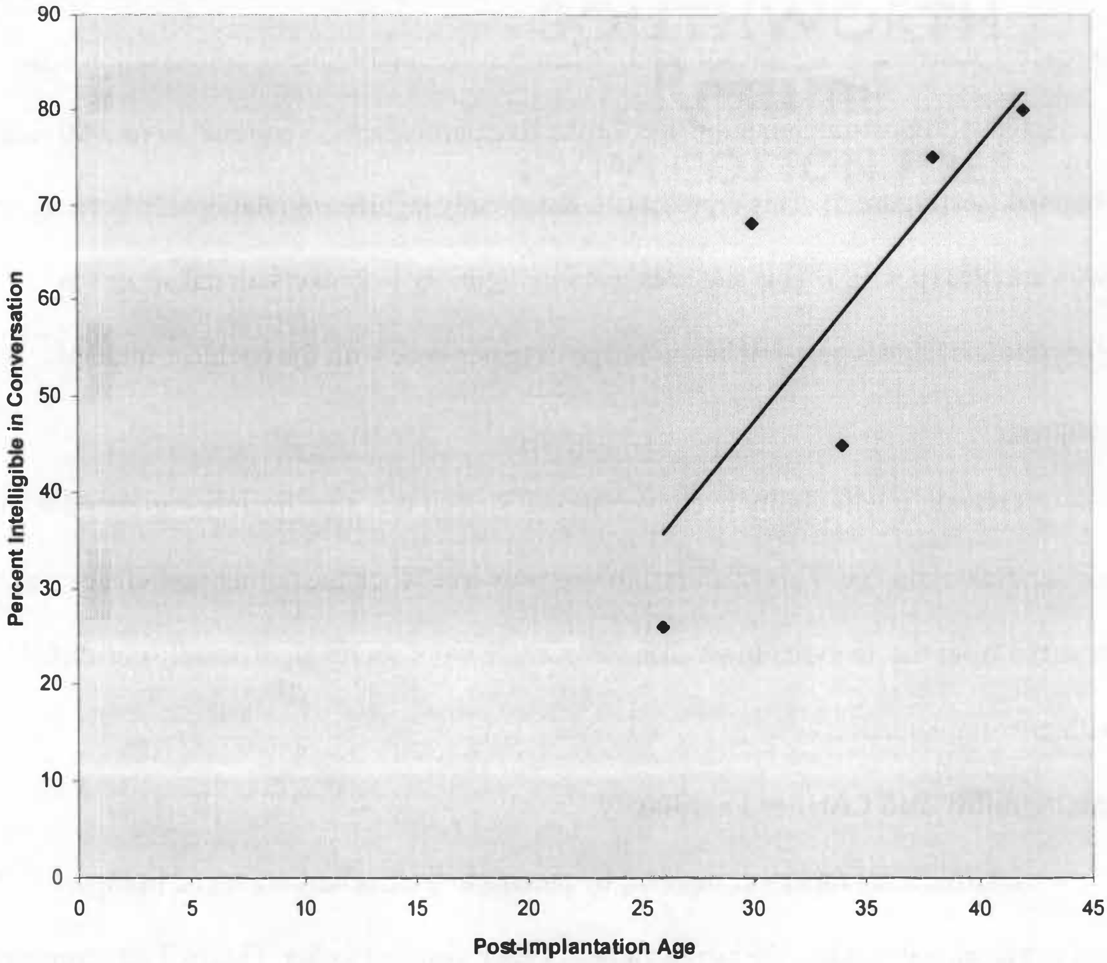

Figure 5: Comparison of Percentage Intelligible in Conversation and Post-Implantation Age with Five Participants

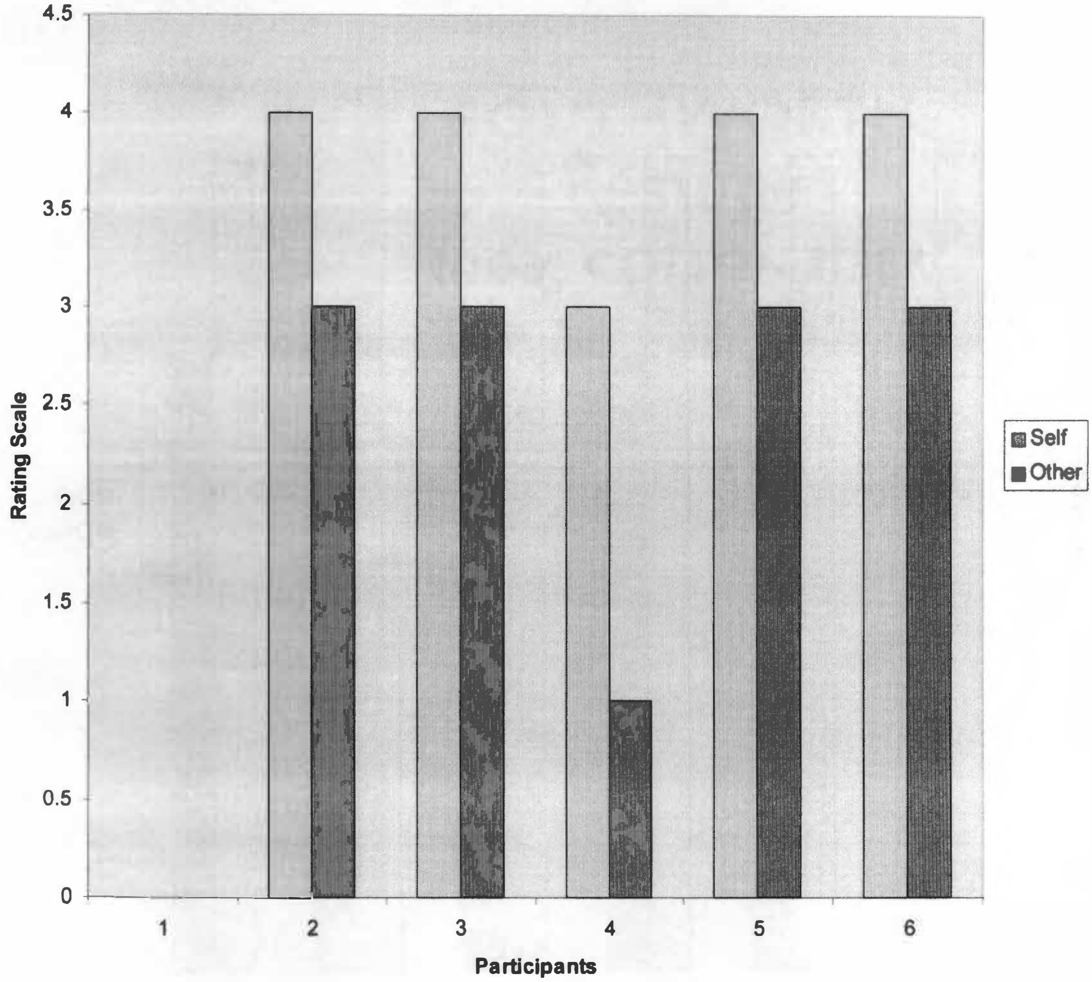

Figure 6: Mother Intelligibility Rating Values

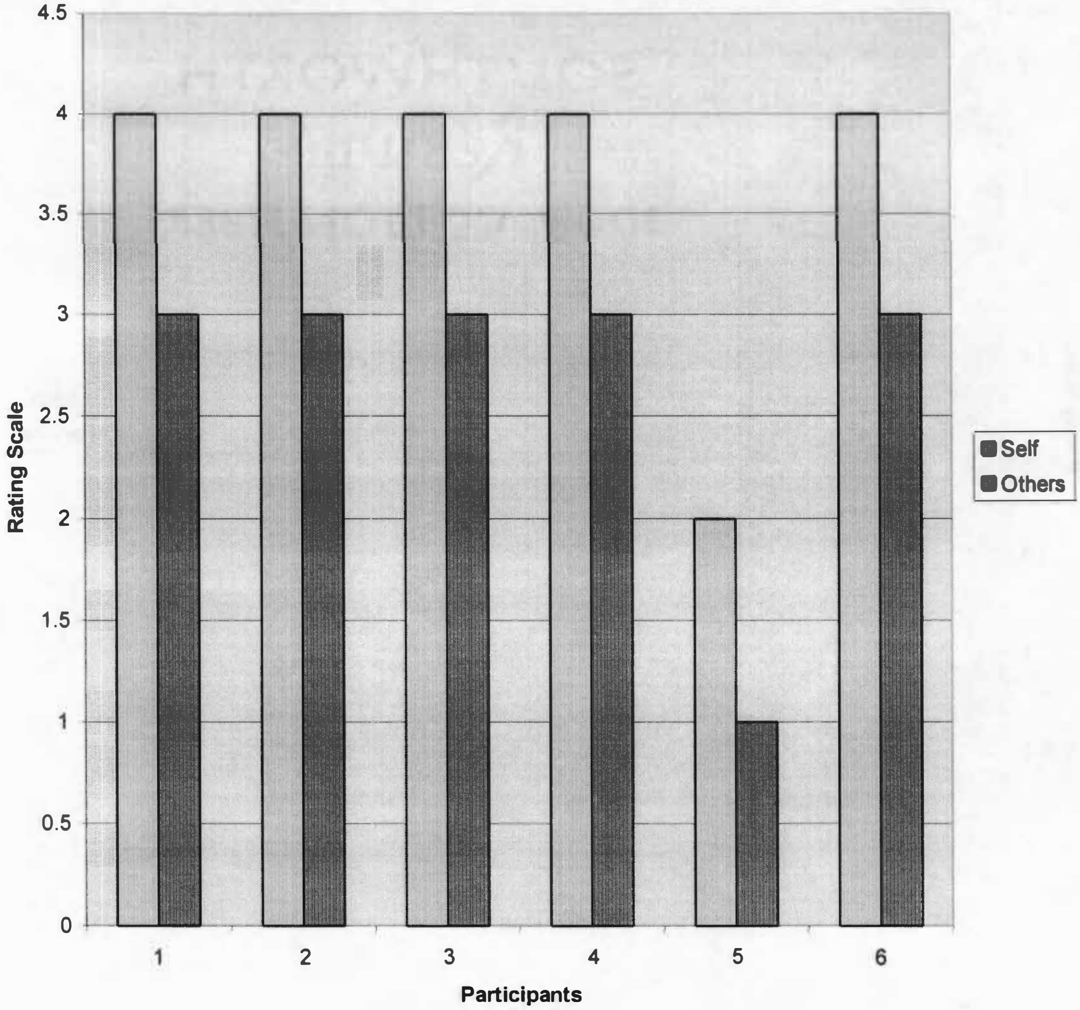

Figure 7: Father Intelligibility Rating Values

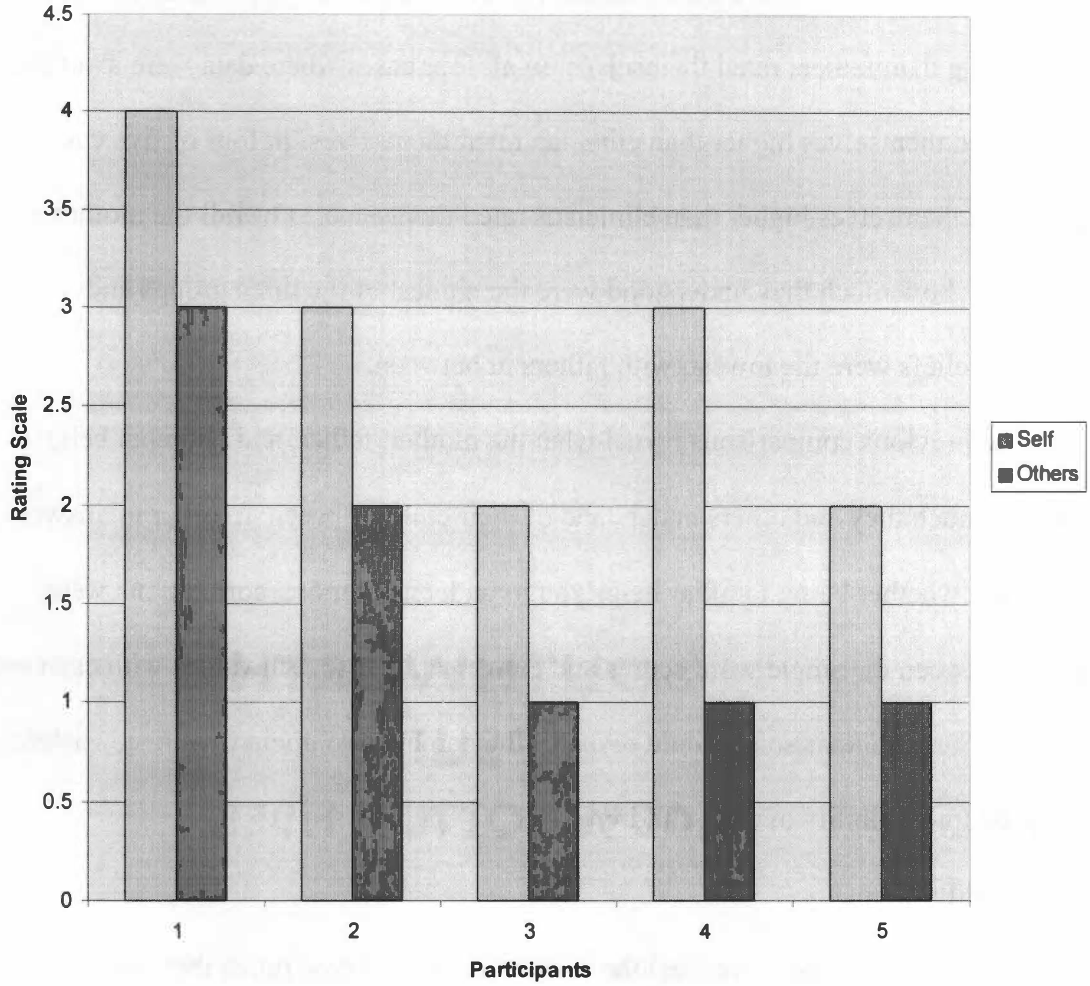

Figure 8: Primary Clinician Intelligibility Rating Values

the three judges, in four of five cases, mothers rated themselves higher in terms of understanding than fathers rated themselves. In all four cases where data were available, mothers rated themselves higher than clinician rated themselves. In four of five cases, fathers rated themselves higher than clinicians rated themselves. Overall the mother's beliefs about how much they understood were the highest of the three groups and clinician's beliefs were the lowest, with fathers in between.

The previous comparisons reveal what the mother, father, and clinician believe about how much they and others understand of their child's speech. In order to answer the question whether being familiar helps you to understand more, correlations were obtained between the single word scores and conversational speech values with each set of ratings. These comparisons should reveal if the parents or clinicians were consistent in judging the intelligibility of their children.

Six Original Participants

When single word scores and the mother's rating of how much they understand of their child were compared, a value of -.707 was revealed. This same correlation would have been statistically significant if there had been 8 participants rather than 6 within the current study (Welkowitz et al., 1987, p. 353). Single word values compared to mother's rating of how much they believed others understand revealed a correlation of -.497. Neither of these values was statistically significant. A correlation of .393 was obtained when the relationship between single word intelligibility and the father's ratings of self-understanding were compared. An identical correlation of .393 was found when single word intelligibility data were compared to how much the fathers thought others understand of their child's speech. Again, neither of these correlations were significant.

The clinician's rating of how much they understood of the child's speech and the single word scores were compared, which revealed a non-significant correlation of -.632. Although this value was not significant, it is a relatively high negative correlation. In a sample of 10 participants this value would be statistically significant. The clinician's ratings of how much they thought others understand were then compared to single word scores to reveal a non-significant value of -.224.

Comparison of percent intelligible in conversation with mother's rating of how much they understand and how much mothers believed other's understand revealed two non-significant values of .354 and .112. When percent intelligible in conversation was compared to how much the fathers felt they understand, a correlation of -.131 was obtained. A value of -.131 was also obtained when percent intelligible in conversation was compared to how much the fathers believed that others understand. Both figures were not significant. The clinician's ratings of self-understanding of the child's speech were compared to single word scores. This revealed a non-significant correlation of .527. In a sample size of 17 this correlation would have been significant. The clinician's ratings of how much they believed others understand were compared percent intelligible in conversation. The correlation of .447 that was obtained was not significant.

Overall these findings suggest no significant relationship between the formal measure of intelligibility (single word and conversational speech) obtained from unfamiliar listeners and ratings obtained from very familiar listeners.

Without Outlier

The same comparisons were completed excluding participant 1. A non-significant correlation of -.707 was found when single word scores and mother's ratings of self-understanding were compared. Although this finding was not significant, the value is relatively high. If the sample size had included 8 participants rather than 5, then the value would be statistically significant. When single word intelligibility scores were compared with mother's ratings of how much they believed others understand a non-significant correlation of -.447 was found. The correlation between single word scores and both father's ratings of how much they understand and father's rating of how much they believed others understand were both .354, which is a non-significant finding. When determining the relationship between single word scores and clinician's ratings of self-understanding a correlation of -.894 was determined. Although this correlation is negative it remains a high value. This value would have been considered significant if there had been at least one more participant. A correlation of -.258 was obtained between single word scores and the clinician's ratings how much they believed others understand. This correlation was again non-significant.

Percent intelligible in conversation was compared to mother's ratings of self-understanding to reveal a non-significant correlation of .354. When percent intelligible in conversation was compared to mother's ratings of how much they believed others to understand, a non-significant correlation of .112 was found. The father's ratings of self-understanding were correlated with percent intelligible in conversation to reveal a non-significant value of -.354. This same non-significant value was also found between percent intelligible in conversation and the father's ratings of how much they believed others understand of the child's speech. The clinician's ratings of how much they understand were compared to percent intelligible in conversation. This revealed a non-significant correlation of .000. A non-significant correlation of -.258 was also found when percent intelligible in conversation was compared to clinician's ratings on how much they believed others to understand.

Again overall with the outlier excluded from the analysis there were no significant correlations between the formal measures of intelligibility obtained from unfamiliar listeners and ratings obtained from very familiar listeners.

Summary

Familiar listeners (mothers, fathers, clinicians) consistently rated themselves as understanding more of the child's speech than they believed others understood. And mothers consistently rated themselves at a higher level of understanding than fathers rated themselves, who then also rated themselves at a higher level than the child's primary clinician. Results from the formal measure of intelligibility (obtained using unfamiliar listeners) were not significantly correlated with any of the intelligibility ratings obtained from the familiar listeners.

Additional Analyses

Given the small number of significant findings obtained additional analyses were completed to determine any further relationships between various factors within the study and speech intelligibility in single words and conversational speech. PPVT-III scores were chosen as one of the four additional factors to examine since this measure of receptive vocabulary may also be considered an indicator of speech perception ability. This is important since it is currently discussed whether speech perception precedes the development of speech production. Chronological age (CA) was chosen as another factor since communication develops overtime or as children get older (Van Riper & Emerick, 1990). It is known that the presence of a hearing loss often changes typical communication development. CA was examined in the current study to determine if this aspect affected intelligibility. Age at identification was also chosen since this value would determine how long the child was without any type of hearing assistance or without receiving auditory information.

Intelligibility and Receptive Vocabulary

Six Original Participants

Receptive vocabulary scores were considered a factor that might affect intelligibility since receptive vocabulary may be considered an indirect measure of speech perception. Values from the PPVT-III compared to single word intelligibility, which revealed a correlation of .657, ($p > .05$). Although this is not a significant value, it is a relatively high correlation. The sample would have needed to have 9 participants in it for this value to be considered statistically significant (Welkowitz et al., 1987, p. 353). When comparing percent intelligible in conversation to PPVT-III scores, the correlation was .314. There was no significant relationship overall between intelligibility scores and receptive language (or speech perception).

Without Outlier

The analyses of single word scores and intelligibility in conversational speech were computed again without Participant 1. The relationship between single word intelligibility and PPVT-III scores revealed a correlation of .800, which was not statistically significant ($p > .05$). Since this is a high correlation, the value would have been considered if the sample size had been larger. According to Welkowitz et al. (1987) there needed to be 6 participants (one more) included in this comparison in order for this value to be statistically significant (p. 353). A non-significant correlation of .300 was obtained when percent intelligible in conversation and PPVT-III scores were compared ($p > .05$).

Summary

It appears that intelligibility is not related to receptive vocabulary.

Intelligibility and Chronological Age

Six Original Participants

Chronological age was compared to single word scores, which revealed a correlation of .314. This value was not significant. Chronological age was also compared to percent intelligible in conversation. This again resulted with a correlation of .314.

Without Outlier

These same analyses were also completed without the participant outlier. The correlation between single word scores and chronological age for the five participants was .00. A correlation of .700 was obtained when percent intelligible in conversational speech and chronological age were compared. This is a relatively high value. If their had been 8 participants in the sample, this value would have reached a statistically significant level (Welkowitz et al., 1987, p. 353).

Summary

Intelligibility did not appear to be related to chronological age.

Intelligibility and Age of Identification

Six Original Participants

Age of identification of hearing loss was compared to both single word scores and intelligibility at the conversational level. The correlation between age of identification and intelligibility at the single-word level was -.543. This value was not significant.

Age of identification and intelligibility at the conversational level were compared. This also revealed a correlation of -.543, which was not significant. Although both values were negative, they were relatively high correlations. If these values were obtained with a sample size of 14 participants, then the correlation would have reached statistical significance.

Without Outlier

Comparisons between age of identification of hearing loss and single word scores were made for the five participants (excluding the outlier). A value of -.500 was revealed. Although this negative correlation did not reach statistical significance, it is relatively high. The same value would have been statistically significant if there had been 16 participants instead of 5. Age of identification and percent intelligible in conversational speech were also compared. The correlation of -.200 was computed, which again was not significant.

Summary

Intelligibility did not appear to be related to age of identification.

CHAPTER 5

DISCUSSION

Intelligibility is thought to be a complex interaction of a number of factors related to the listener, speaker, listening environment, and speaking context (Kent et al., 1994). However, of the factors examined in the present study, few revealed statistically significant relationships with intelligibility as judged in single words or in conversational speech.

The first question asked in this study was whether intelligibility differs across sampling methods. It was found that percent intelligibility did differ from single words to conversation for five of six participants. Four of the participant's speech intelligibility scores were better in conversation than single words, while one participant's scores were worse in conversation and for one participant there was no difference. In their review of previous research, Gulian and Hinds (1981) suggest "words heard in context are easier to understand than isolated words" (p. 165). A similar statement was made by Thomas (1964; as cited in Gold, 1980). From his research it was suggested that intelligibility scores will be better for sentences than words. Despite the trend, the correlation between the two sampling methods was not statistically significant in the current study (rho = .314, $p > .05$). This suggests that the two assessment methods are not directly related to each other. In other words, speakers with high intelligibility in single words would not necessarily be highly intelligible in conversation.

The current study is one of a kind, because it appears to be the only study of children with cochlear implants where intelligibility was assessed in conversation. As well, only one other study appears to have examined intelligibility using more than a single method. Chin et al. (2001) examined intelligibility of 20 children fitted with a cochlear implant with measures of single word and sentence intelligibility. These authors found that intelligibility in single words and sentences were significantly correlated ($r = .77$, $p < .0001$). This is not consistent with the findings in the current study. Differences between the two studies might account for this. Both the sentences from Chin et al. and the conversational speech samples from the current study involve the speaker having the ability to smoothly connect single phonemes and words to form sentences (Kirk & Hill-Brown, 1985). But sentences and conversation are two different levels of communication and the sentences in Chin et al. were produced by imitation. In the conversations in the current study the children needed competent enough language skills to formulate each sentence (Allen et al., 1998). It is also possible that the non-significant correlation in the current study could have been affected by the smaller sample size.

It is interesting that the four participants whose conversation scores were higher than their single word scores had the highest overall intelligibility in conversation. The two other participants had the lowest intelligibility scores in conversation, but had similar or higher single word scores. This pattern appears similar to results in Yorkston and Beukelman (1978) who found there was an interaction between severity and intelligibility scores as judged in sentences and in words. In their study of intelligibility in adult dysarthric speakers, the most intelligible participants scored higher on sentence tasks rather than on single words and the least intelligible participants attained higher scores on single words. They concluded, "sentence context seemed to increase the understandability of the most intelligible speakers but decrease the understandability of the least intelligible speakers" (p. 504). The findings of Yorkston and Beukelman's

(1978) study can be explained by examining contextual cues available within sentences. Those individuals who were less involved likely had fewer speech sound production errors and those who were more likely involved had more speech sound production errors in comparison. Remember that speech sound production has the largest impact on intelligibility. The persons in the less involved group were more likely to be able to completely produce most words within each sentence. With few speech sound errors, the listener would be able to guess the intent of the message given the contextual support remaining within the sentence. While the persons in the second group, who were more involved, produced few of the words within the sentence correctly due to the larger number of speech sound errors, leaving less contextual support for the listener. This would explain why sentence context increased the understandability of intelligible speakers, yet decreased the understandability in lesser intelligible speakers. A similar pattern may have occurred in the conversational speech samples in the current study.

The second question examined in the current study was whether intelligibility differs by post-implantation age. When all six participants were included the correlations between intelligibility and both single word and conversational speech were not significant. However, when participant 1, who was deemed an outlier primarily because of her superior language performance, was excluded the correlations between percent intelligible in conversation and post-implantation age increased to a significant .900. Osberger et al. (1994) and Tobey et al. (1998) supports these findings overall. In the study completed by Osberger et al. the largest change in speech intelligibility was obtained after 2 or more years of cochlear implant use (see Table 1). Tobey et al. state, "the greater the experience with an implant, the higher the overall speech intelligibility"

(p. 28). This finding suggests that experience with a cochlear implant is a determining factor in speech intelligibility in conversation. The fact that this was only significant in conversation may be because of the limited range of scores on the CSIM (26.8% to 55.7% versus 26% to 91% in conversation).

Some of the studies in Table 1 also examined the topic of intelligibility versus post-implantation age. Osberger, et al. (1994) assessed speech intelligibility in sentences over time in 29 children fitted with cochlear implants. Their results indicate that the largest change in intelligibility was noted after two or more years of cochlear implant experience. After 3.5 to 4 years of use, the mean intelligibility of the children's speech was 40%. Similar results were found by Miyamoto et al. (1996). In their study, gradual improvements occurred over time in sentence speech intelligibility of 50 children with cochlear implants. Changes were noted to begin at 6 months post-implantation. At each successive testing interval, the intelligibility scores were significantly greater than the preceding testing interval. Mondain et al. (1997) judged single word speech intelligibility of 16 children with cochlear implants over a four year period. Speech intelligibility at one year post-implantation was 4.2%, two years post-implantation was 30.7%, three years post-implantation was 55.2%, and four years post-implantation was 74.2% intelligible. These studies support the notion that experience with the cochlear implant influences the overall speech intelligibility (the finding in the current study).

Comparing the specific intelligibility findings of the current study with the previous studies is only possible for the study of Mondain et al. (1997) who used single words. Both Osberger et al. (1994) and Miyamoto et al. (1996) used sentence stimuli. Although Chin et al. (2001) examined intelligibility in single words and conversation, a comparison cannot be made since the authors do not provide the data from the single words task. Average data from Mondain et al. and the data from the current study are shown together in Figure 9. Examination of this figure shows that the data from the current study are very similar to those found by Mondain et al. Since Mondain et al. found a significant correlation this suggests that the small sample size and limited range of the sample word data in the current study may have led to the non-significant findings for the intelligibility in single words and post-implantation age. As noted previously a sample size of 17 would have been required for the obtained correlation of .500 to be significant. Recall that Mondain et al. had 20 participants.

The third question asked in the current study deals with whether intelligibility differs according to listener familiarity. Intelligibility ratings were filled out by both parents and the primary clinician working with each participant. All individuals were asked to rate how much they understood and how much they think others understood of the child's speech. The ratings indicated that judgments of self-understanding were higher than how much they believed others' understood. This trend is reasonable, as mentioned earlier, since experienced listeners have the advantage of exposure to the child's speech, knowledge of their usual topics and areas of interest (Flipsen, 1995).

Further examination of the judgments of listener familiarity indicated that overall the mothers rated themselves as being able to understand more than the fathers. The fathers then rated themselves as being able to understand more than the clinicians. This finding of the mother understanding the most of their child's speech may be explained if they typically spend more time more time interacting with their children than the father or

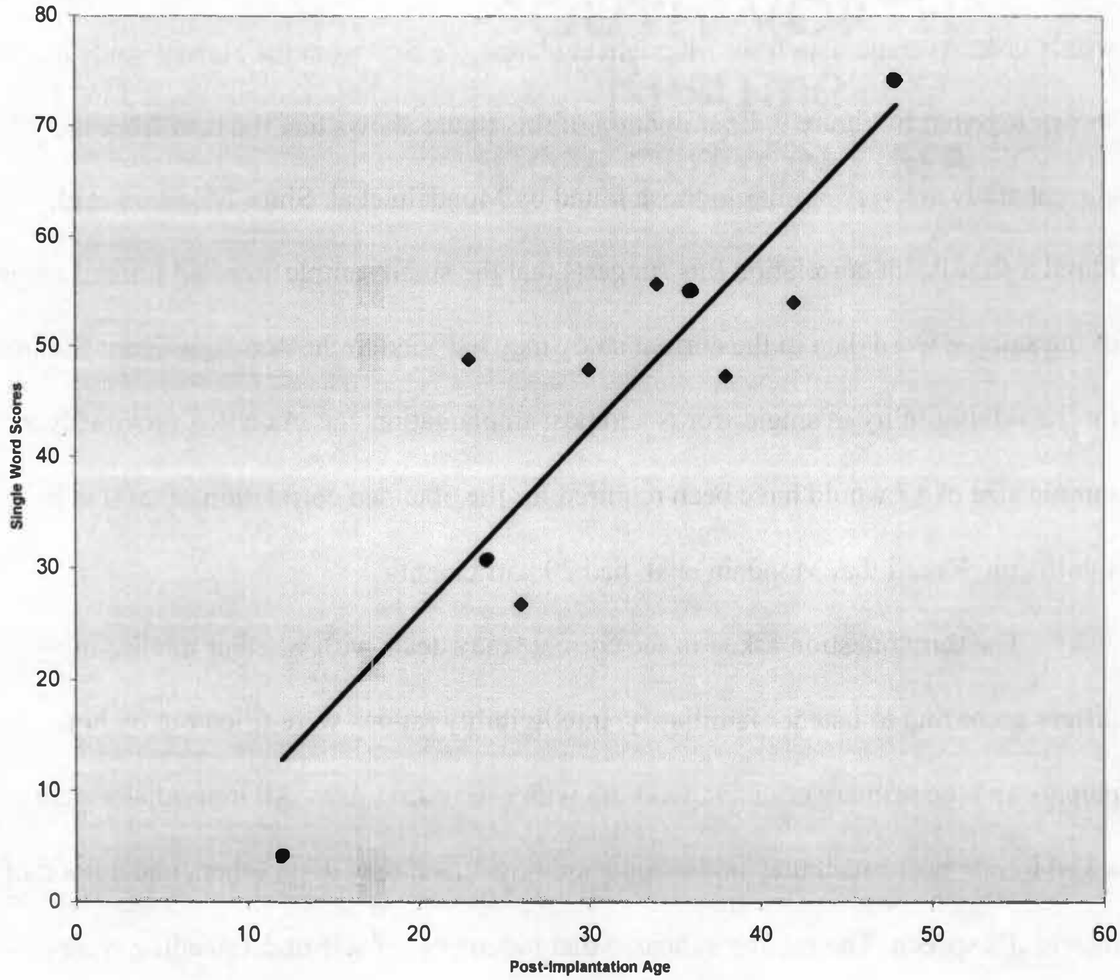

Figure 9: Comparison of Single Word Scores and PIA of Five Participants in the Current Study and Additional Data (group averages) from Mondain et al. (1997)

Note: The dark squares represent data from the current study and the dark circles represent data from Mondain et al.

clinician. Unfortunately no data were obtained on how much time each parent spent with the child. The fathers in the study rated their ability to understand their child slightly below the mothers. Since these ratings were completed individually this shows that overall the fathers think themselves as not being able to understand as well as the mothers. It might be thought that the clinician should be able to understand the children most efficiently since they have a "trained" ear. However, they rated themselves lower than both the mothers and fathers. It may be that these clinicians have higher expectations for the child's speech in order to consider them to be intelligible. Or they may be spending less time with the child than either parent.

Intelligibility data from single words and conversation were compared to the mother, father, and clinician ratings of how much they understand and how much they think others understand of the child's speech. No significant correlations were obtained through comparisons with either all six participants or when excluding the outlier. This finding may be explained by the presence of many tied values. When several of the ratings available are tied or the same and the information is compared using Spearman rho correlations, the ability to obtain a significant relationship is decreased. The ability to find significant correlation is also adversely affected by the small number of participants in the current study.

These findings suggest that the rating scales used may lack the sensitivity required to gauge change or distinct levels of intelligibility. This can perhaps be seen with the ratings by fathers, which were the same for participants 1, 2, 3, 4, and 6 and yet they differed greatly on intelligibility in conversation. Clinician ratings on the other hand (see Figure 7) were more variable. This suggests that clinician ratings may be more realistic.

Since there were so many factors affecting intelligibility within the study, additional analyses were completed. Receptive vocabulary scores, which may be considered an indirect measure of speech perception, were correlated with both single word and conversational intelligibility scores. Vocabulary was thought to be important since according to Hulit and Howard, (1997) a child needs to have a competent language foundation in order to help facilitate successful communication. The obtained values from the two comparisons were not statistically significant with all six participants or when the outlier was excluded. This suggests that receptive vocabulary (speech perception) has poor affect on intelligibility. It is interesting, however, to note that the correlations between receptive vocabulary scores and single word scores with all six participants and excluding participant 1 were relatively high values. Both correlation values were larger than the values obtained when receptive vocabulary scores were compared to percent intelligible in conversation with all six participants and when excluding the outlier. A correlation of .657 was found between receptive vocabulary and single word scores with all six participants included and when participant 1 was excluded the value increased to .800, further supporting the evidence that participant 1 was indeed an outlier. It is likely in this case the correlation (excluding the outlier) is more representative of the relationship between receptive vocabulary (speech perception) and intelligibility. As mentioned previously, this relationship may have been statistically significant if the sample had been larger.

Since chronological age varied for the individuals in the current study, this factor was compared to intelligibility. Intelligibility is known to improve with chronological age in typically-developing preschool children (Weiss, Gordon, & Lillywhite, 1987). The ages for the six participants ranged from 3;9 to 6;2 at time of testing. This factor was not significantly correlated to either intelligibility of single words or conversational speech with all six participants nor when the outlier was excluded. Van Riper and Emerick (1990) suggest why this might be the case. Physical and communication development milestones are generally achieved according to chronological age. Hearing loss, however, changes a child's communication development which is not as dependent on chronological age of the child, as it is on amount of time receiving auditory information. This may explain why in the current study chronological age and speech intelligibility were not significantly correlated but time since implantation was.

Early identification of hearing loss is important to avoid depriving the child of auditory information. The earlier the child's hearing loss is identified and they are aided with a hearing device, the better chance to develop intelligible speech (Van Riper & Emerick, 1990). In this study, age at identification of hearing loss was compared to both single word scores and percent intelligible in conversation. Ages of identification ranged from birth to 1 year, 3 months. This factor was not significantly correlated to either speech intelligibility task. When participant 1 was excluded, the same comparisons were completed. Again, the correlation values were not significant. The participants included in the current study overall were identified at relatively early ages. A significant correlation was not found in this case perhaps due to the narrow range of early identification ages. They were all identified early and were becoming intelligible speakers. If the range of age at identification had been greater then a relationship between age at identification and intelligibility may have been found. Loizou (1998) stated that duration of deafness will affect the performance with a cochlear implant. In another words, the person with a short duration of deafness will have been deprived of their hearing for a shorter amount of time than a person with a longer duration of deafness. In this case, the earlier the hearing loss is identified, the sooner the individual may receive hearing amplification and thus receive auditory information needed for the development of communication.

Clinical Implications

Although many of the correlations obtained in the current study were relatively high, the fact that few reached statistical significance makes it difficult to determine the clinical importance each factor would have in treatment. However, general suggestions of treatment use can be made for the factors examined.

The findings in the current study suggest that speakers with high intelligibility in single words would not necessarily be highly intelligible in conversation may be helpful for clinicians working with children fitted with cochlear implants to consider. If a child has poor intelligibility at the single word level, then they may still have intelligible speech in conversation (as indicated by the non-significant value in the current study). This could affect the decision making when developing the child's treatment plan or prognosis for intelligible speech. The clinician in this situation may consider the findings in the current study, but should also keep in mind the findings of Chin et al. (2001) on the same subject. Clinicians should consider using multiple measures of intelligibility for decision-making.

The previous discussion concerning the current findings and those by Yorkston and Beukelman (1978) may have clinical importance. In the clinical setting the clinician working with children with cochlear implants will likely be able to determine the individuals on their caseload that are "more involved" and "less involved". According to the current findings and those of Yorkston and Beukelman, there is an interaction between severity and intelligibility. In treatment, those children who are "more involved" may be unintelligible in conversation thus often creating frustration for the speaker and listener. In this case, focusing on production of single words or short phrases may lead to a more successful communication interaction. Those children who are "less involved" may experience the most successful communication interactions by using conversational speech.

In the current study, experience with a cochlear implant was found to be a determining factor in speech intelligibility in conversation. This notion of intelligibility increasing with implant experience or post-implantation age is also supported in many additional studies (Tobey et al., 1998; Osberger et al., 1994; Miyamoto, et al., 1996; & Mondain, et al., 1997). The clinician working with a child in this population can now more assuredly use this data to educate the parents or caregivers of the child on the development of speech intelligibility over time.

The non-significant value obtained between chronological age and intelligibility further confirmed the notion that intelligibility is affected more by post-implantation age (time receiving auditory information) than by chronological age. The professional working with an individual with a cochlear implant should keep this relationship in mind to avoid using chronological age as the primary indicator of what level the child should be functioning communicatively.

As mentioned previously, the small number of statistically significant correlations makes the process of assigning clinical importance to the many factors examined very difficult. The comparison between receptive vocabulary (speech perception) and intelligibility at the single word level revealed a relatively high (non-significant) value when the outlier was excluded. If in future studies this factor is confirmed to be a determining factor of intelligibility, then receptive vocabulary might be an essential goal to address in therapy.

Conclusion

As mentioned earlier there are many factors that may play a part in the facilitation of intelligible interactions. In the current study, the only factor to reach statistical significance was post-implantation age when compared to intelligibility in conversation with the five participants.

So few statistically significant correlations within this study may have been in part due to the small number of participants included in the study. Having such a small number required that the values be extra high to be considered significant. In addition, most of the participant's hearing loss etiologies were unknown. There is no way to know if each of these unknown causes were the same or not or how they individually might have affected speech intelligibility.

Due to the complex nature of intelligibility various factors were analyzed in order to discover which might affect intelligibility (single words and conversation). In the current study few statistically significant values were obtained. A comprehensive list of all obtained correlation values is provided in Appendix F. However, it is important to note that many of the comparisons revealed correlations of relatively high status, .500 and above (negative and positive). One particularly high correlation obtained was between receptive vocabulary scores and intelligibility in single words when the outlier was excluded. Using a chart provided by Welkowitz, Ewen, and Cohen (1987) the number of participants needed in order for the value to be considered statistically significant was determined. The value of .800 was not statistically significant in the current study, due perhaps due to the small sample, but would have been statistically significant if there had been one more (6) participant included. A smaller yet relatively high correlation was obtained when chronological age (excluding the outlier) and intelligibility in conversation were compared. The value of .700, was not considered statistically significant in the current study, but would have been if their had been 8 more participants. These two examples suggests that although many of the values obtained did not appear to strongly affect intelligibility, these and the other factors analyzed in the current study may be considered significant factors in further studies with larger samples. This supports the need for future research examining factors such as post-implantation age, mother and clinician ratings of intelligibility, receptive vocabulary (or speech perception), chronological age, and age of identification and their affect on intelligibility.

The use of cochlear implants with deaf children and adults is a relatively young practice. The majority of the research available today deals with speech perception abilities within implanted persons. Research in the areas of speech production and intelligibility is limited, which illustrates that additional data on this topic is needed. Future studies should incorporate more than one measurement to assess each particular domain (ie. perception, production, intelligibility, etc.). Intelligibility, as mentioned earlier, is an especially complex phenomenon. Using more than one assessment to examine the various facets of intelligibility may help clinicians increase their understanding of this event (Kent et al., 1994), help identify specific sources of intelligibility deficits, and better focus treatment.

REFERENCES

References

Advanced Bionic Corporation (2000). Processing Strategies. Available: http://www.cochlearimplant.com/clarionsystem_strategies.html

Allen, M., Nikolopoulos, T., & O'Donoghue, G. (1998). Speech intelligibility in children after cochlear implantation. The American Journal of Otology, 19(6), 742-746.

American Psychological Association (1994). Publication Manual of the American Psychological Association. Washington, DC: American Psychological Association.

Bess, F. H. & Humes, L. E. (1995). Audiology: The Fundamentals. (2nd ed.). Maryland: Williams & Williams.

Boone, D. (1966). Modification of the voices of deaf children. Volta Review, 68, 686-692.

Bracken, B. A. (1998). Bracken Basic Concept Scale – Revised. San Antonio, TX: The Psychological Corporation.

Brill, S., Gstoettner, W., Helms, J., von Ilberg, C., Baumgartner, W., Muller, J., & Kiefer, J. (1997). Optimization of channel number and stimulation rate for the fast continuous interleaved sampling strategy in the COMBI 40+. American Journal of Otology, 18(6, Suppl), S104-106.

Chin, S., Finnegan, K., & Chung, B. (2001). Relationships among types of speech intelligibility in pediatric users of cochlear implants. Journal of Communication Disorders, 34, 187-205.

Cochlear (2001a). Nucleus 24: Cochlear implant system. Lecture given by Dr. Crossman at the University of Tennessee on 1-29-01.

Cochlear (2001b). Nucleus. Available: http://www.cochlear.com/rcs/cochlear/publisher/web/nucleus/nucleus_22/SPEAK/index.jsp and http://cochlear.com/rcs/cochlear/publisher/web/products/speech_strategies/ACE/index.jsp

Cochlear (2002). Nucleus. Available: http://www.cochlear.com/rcs/cochlear/publisher/web/candidates/step_by_step/candidacy/index.jsp

Dawson, P. W., Blamey, P. J., Dettman, S. J., Rowland, L. C., Barket, E. J., Tobey, E. A., Busby, P. A., Cowan, R. C., & Clark, G. M. (1995). A clinical report on speech production of cochlear implant users. Ear and Hearing, 16(6), 551-561, Dorman, M. F., Loizou, P. C., Fitzke, J., & Tu., Z. (1998). The recognition of sentences in noise by normal-hearing listeners using simulations of cochlear-implant signal processors with 6-20 channels. Journal of Acoustical Soc Am, 104, 3583-3585.

Doyle, J. (1987). Reliability of audiologists' ratings of the intelligibility of hearing-impaired children's speech. Ear and Hearing, 8(3), 170-174.

Dunn, L. M. & Dunn, L. M. (1997). Peabody Picture Vocabulary Test – Third Edition. Circle Pines, MN: American Guidance Service.

Eisenberg, L. S. (1982). Use of the cochlear implant by the prelingually deaf. Annals of Otology, Rhinology, and Laryngology Supplement, 91, 62-66.

Ellis, L. W. & Fucci, D. J. (1992). Effects of listeners' experience on two measures of intelligibility. Perceptual and Motor Skills, 74, 1099-1104.

Fisher, H. & Logemann, J. (1971). Test of Articulation Competence. New York: Houghton and Mifflin.

Fishman, K., Shannon, R. V., & Slattery, W. H. (1997). Speech recognition as a function of the number of electrodes used in the SPEAK cochlear implant speech processor. Journal of Speech Language Hearing Research, 40(5), 1201-1215.

Flipsen, P. (1995). Speaker-listener familiarity: Parents as judges of delayed speech intelligibility. Journal of Communication Disorders, 28, 3-19.

Fu, Q. J. (1997). Speech perception in acoustic and electric hearing. Doctoral dissertation, University of Southern California.

Gold, T. (1980). Speech production in hearing-impaired children. Journal of Communication Disorders, 13, 397-418.

Guilian, E. & Hinds, P. (1981). Response bias in the perception of deaf speech by experienced and naive listeners. British Journal of Audiology, 15, 165-171.

Hoffman, R. A. (1997). Cochlear implant in the child under two years of age: Skull growth, otitis media, and selection. Otolaryngology Head Neck Surgery, 117, 217-219.

Hudgins, C. (1946). Speech breathing and speech intelligibility. Volta Review, 48, 642-644.

Hudgins, C. & Numbers, F. (1942). An investigation of the intelligibility of the speech of the deaf. Genetic Psychology Monographs, 25, 289-392.

Hulit, L. M. & Howard, M. R. (1997). Born to Talk: An Introduction to Speech and Language Development (2nd ed.). Massachusetts: Allyn and Bacon.

Kent, R. D. (1992). Intelligibility in speech disorders. Amsterdam: John Benjamins.

Kent, R. D., Miolo, G., & Bloedel, S. (1994). The intelligibility of children's speech: A review of evaluation procedures. American Journal of Speech Language Pathology, 3(2), 81-93.

Kirk, K. I. & Hill-Brown, C. (1985). Speech and language results in children with a cochlear implant. Ear and Hearing, 6(3, Suppl), 36-47.

Klinke, R. & Hartmann, R. (1997). Basic neurophysiology of cochlear implants. American Journal of Otology, 18(6, Suppl), S7-10.

Lawson, D. T., Wilson, B. S., Zerbi, M., & Finley, C. C. (1996). Speech processors for auditory prostheses. Third Quarterly Progress Report. Available: http://www.rti.org/capr/qpr3.html

Leake, P. A., Snyder, R. L., Hradek, G. T., & Rebscher, S. J. (1995). Consequences of chronic extracochlear electrical stimulation in neonatally deafened cats. Hearing Research, 82, 65-80.

Levitt, H. (1971). Speech production for the deaf child. In T. Gold (1980). Speech production in hearing-impaired children. Journal of Communication Disorders, 13, 397-418.

Levitt, H. (1977). Conference on Sensory Aids for the hearing Impaired. In Parkhurst & Levitt (1978). The effect of selected prosodic errors on the intelligibility of deaf speech. Journal of Communication Disorders, 11, 249-256.

Levitt, H. (1980). Speech assessment: Intermediate and secondary levels. In J. D. Subtelney (Ed.), Speech Assessment and Speech Improvement for the Hearing Impaired. (pp.30-44). Washington, DC: Alexander Graham Bell Association for the Deaf.

Loeb, G. & Kessler, D. (1995). Speech recognition performance over time with the Clarion cochlear prosthesis. Annals of Otology, Rhinology and Laryngology, 166, 290-292.

Loizou, P. C. (1998). Mimicking the human ear: An overview of signal-processing strategies for converting sound into electrical signals in cochlear implants. IEEE Signal Processing Magazine, 101-130.

Mangan, K. (1961). Speech improvement through articulation testing. American Annals of the Deaf, 106, 391-396.

Markides, A. (1970). The speech of deaf and partially-hearing children with special reference to factors affecting intelligibility. British Journal of Disorders of Communication, 5, 126-140.

McGarr, N. S. (1983). The intelligibility of deaf speech to experienced and inexperienced listeners. Journal of Speech and Hearing Research, 26, 451-458.

MED-EL (2000). The MED-EL COMBI 40 +. Available: http://www.cochlear implants.com/language/us/products/combi40+/combi40+.html

Miyamoto, R. T., Kirk, K. I., Robbins, A. M., Todd, S., & Riley, A. (1996). Speech perception and speech production skills of children with multichannel cochlear implants. Acta Otolaryngology, 116, 240-243.

Miyamoto, R. T., Kirk, K. I., Svirsky, M. A., & Sehgal, S. T. (1999). Communication skills in pediatric cochlear implant recipients. Acta Otolaryngology, 119, 219-224.

Mondain, M., Sillon, M., Vieu, A., Lanvin, M., Reuillard-Artieres, F., Tobey, E., & Uziel, A. (1997). Speech perception skills and speech production intelligibility in French children with prelingual deafness and cochlear implants. Archives of Otolaryngology: Head and Neck Surgery, 123(2), 181-184.

Moog, J. S. & Geers, A. E. (1999). Speech and language acquisition in young children after cochlear implantation. Otolaryngology Clinics of North America, 32(6), 1127-1141.

National Institutes of Health. (1995). Consensus Conference: Cochlear implants in adults and children. Journal of the American Medical Association, 274(24), 1955-1961.

Nober, E. (1967). Articulation of the deaf. Exceptional Child, 33, 611-621.

O'Neill, J. (1975). Measurement of hearing by tests of speech and language. In S. Sadanand (Ed.), Measurement Procedures in Speech, Hearing, and Language. (pp. 219-252). Baltimore, MD: University Park Press.

Osberger, M. J. (1997). Cochlear implantation in children under the age of two years: Candidacy considerations. Otolaryngology Head Neck Surgery, 117, 145-149.

Osberger, M., Robbins, A., Todd, S., Riley, A., & Miyamoto, R. (1994). Speech production skills of children with multichannel cochlear implants. In I. J. Hochmair-

Desoyer, & E. S. Hochmair (Eds.), Advances in Cochlear Implants (pp. 503-508). Manz: Wien.

Parkhurst, B. & Levitt, H. (1978). The effect of selected prosodic errors on the intelligibility of deaf speech. Journal of Communication Disorders, 11, 249 – 256.

Porter, K. F. & Bradley, S. (1985). A comparison of three speech intelligibility measures for deaf students. American Annals of the Deaf, 130(2), 514-525.

Schiavetti, N. & Metz, D. E. (1997). Evaluating research in communication disorders. Boston, MA: Allyn & Bacon.

Shriberg, L. D. (1986). PEPPER: programs to examine phonetics and phonologic evaluation records. Madison, WI: University of Wisconsin-Madison.

Skinner, M. W., Clark, G. M., Whitford, L. A., Seligman, P. M., Staller, S. J., Shipp, D. B., Shallop, J. K., Everingham, C., Manapace, C. M., Arndt, P. L., Antogenelli, T., Brimacombe, J. A., Pije, S., Daniels, P., George, C. R., McDermott, H., J., & Beiter, A. L. (1994). Evaluation of a new spectral peak (SPEAK) coding strategy for the Nucleus 22 channel cochlear implant system. American Journal of Otology, 15(Suppl 2), 15-27.

Smith, C. R. (1975). Residual hearing and speech production in deaf children. Journal of Speech and Hearing Research, 18, 795-811.

Stevens, K., Nickerson, R., Boothroyd, A., & Rollins, A. (1976). Assessment of nasalization in the speech of deaf children. Journal of Speech and Hearing Research, 19, 393-416.

Tobey, E. A., Geers, A. E., Douek, B. M., Perrin, J., Skellett, R., Brenner, C., & Toretta, G. (1998). Factors associated with speech intelligibility in children with cochlear implants. Platform presentation at the 7th Symposium on Cochlear Implants in Children, Iowa City, IA, June 4-7.

Tong, Y. C., Busby, P. A., & Clark, G. M. (1988). Perceptual studies on cochlear implant patients with early onset of profound hearing impairment prior to normal development of auditory, speech, and language skills. Journal of the Acoustical Society of America, 84(3), 951-962,

Van Riper, C. & Emerick, L. (1990). Speech Correction: An Introduction to Speech Pathology and Audiology. (8th ed.). New Jersey: Prentice-Hall, Inc.

Voelker, C. H. (1938). An experimental study of the comparative rate of utterance of deaf and normal hearing speakers. American Annals of the Deaf, 83, 274-284.

Waltzman, S. B. (2000). Variables affecting speech perception in children. In S. B. Waltzman & N. L. Cohen (Eds.), Cochlear Implants (pp. 199-206). New York: Thieme.

Weiss, C. E., Gordon, M. E., & Lillywhite, H. S. (1987). Clinical Management of Articulatory and Phonologic Disorders (2nd ed.). Baltimore, MD: Williams & Wilkins.

Welkowitz, J., Ewan, R. B., & Cohen, J. (1987). Introductory Statistics for the Behavioral Sciences. San Diego, CA: Harcourt Brace Jovanovich, Publishers.

Weston, A. D. & Shriberg, L. D. (1992). Contextual and linguistic correlates of intelligibility in children with developmental phonological disorders. Journal of Speech and Hearing Research, 35, 1316-1332.

Wilcox, K. M. & Morris, S. (1999). Children's Speech Intelligibility Measure. Orlando, FL: The Psychological Corporation.

Williams, L. A. (2000). Multiple Oppositions: Theoretical foundations for an alternative contrastive intervention approach. American Journal of Speech-Language Pathology, 9, 282-288.

Willemain, T. & Lee, F. (1971). Tactile pitch feedback for deaf speakers. Volta Review, 73, 541-553.

Yorkston, K. M. & Beukelman, D. R. (1978). A comparison of techniques for measuring intelligibility of dysarthric speech. Journal of Communication Disorders, 11, 499-512.

Zwolan, T. A. (2000). Selection Criteria and Evaluation. In S. B. Waltzman & N. L. Cohen (Eds.), Cochlear Implants (pp. 309-330). New York: Thieme.

APPENDICES

Appendix A

Informed Consent Statement

A Longitudinal Investigation of the Development of Speech Skills
In Children with Cochlear Implants

You and your child are invited to participate in a research study. The purpose of this study is to examine how hearing-impaired children fitted with cochlear implants develop the ability to speak. We would like to know if their pattern of learning is similar to that seen in children without hearing impairments.

GENERAL INFORMATION

Procedure: Your child will be recorded during three speech tasks:

1. Imitating some vowel sounds (e.g., "eee", "uuu", "aaa")
2. Repeating a series of 50 single words
3. Having a conversation with a graduate student

In addition, your child's perception and understanding of words will be assessed.

You will participate by filling out a questionnaire about your child's speech. A similar questionnaire will be completed by the clinical supervisor who works with your child at Child Hearing Services.

Testing will be carried out in the sound-proof booth that is usually used for testing your child's hearing. You can watch all the testing through the window of the booth. If your child is uncomfortable with entering the booth by themselves you may sit in the booth with them. Your child will wear a microphone attached to their clothing. The microphone will be connected to a tape recorder.

Time Required for Participation. Because we are interested in how speech develops over time, the above recordings will be repeated every 3 months for a total period of 2 years. That means your child will be recorded a total of 9 times.

Only the three speech tasks and the test of speech perception will be done at all of the sessions. The test of understanding will only be done twice (at the beginning and at the end of the study). You will only be required to complete the questionnaire 3 times (at the beginning, middle and end of the study). The first and last test sessions should last approximately 60-75 minutes. Sessions 2-8 should last 30-40 minutes each.
You will be paid $10.00 for each test session that your child participates in. In addition, if your child participates in at least 7 of the 9 sessions, you will receive an additional $60.00 (a total of up to $150.00 over the course of the study).

RISKS

There are no known risks from these procedures.

BENEFITS

Results of this study will help us understand how children with cochlear implants learn to speak. Other than helping us with this and the monetary compensation (up to $150.00), there are no immediate direct benefits to you or your child from this study.

CONFIDENTIALITY

The information in the study records will be kept confidential. Data will be stored securely and will be made available only to persons conducting the study unless you specifically give permission in writing to do otherwise. No reference will be made in written or oral reports, which could link you or your child to the study.

CONTACT

If you have questions at any time about the study or the procedures, you may contact the Principal Investigator, Dr. Peter Flipsen Jr. at 425 South Stadium Hall on the University of Tennessee, Knoxville campus or by phone at (865) 974-0354. If you have questions about your rights as a participant, contact the University of Tennessee Compliance Section of the Office of Research at (865) 974-3466.

PARTICIPATION

Your participation in this study is voluntary, you may decline to participate without penalty. If you decide to participate, **you may withdraw from the study at any time** and it will not affect the services that you receive from the University of Tennessee Child Hearing Services or any other benefits to which you are otherwise entitled. If you withdraw from the study before data collection is completed your data will be returned to you or destroyed.

I have read and understand the above information. I have received a copy of this form. I agree to participate in this study.

Parent's signature ______________________________ Date ______________

Investigator's signature ___________________________ Date ______________

Appendix B

Rating Form A

Participant code ____________________

Relationship of person completing form to child ____________________

Date Completed ____________________

Part 1: When you are speaking with your child in everyday situations, how much of what he/she says do you usually understand? [check one]

_____ Everything (or almost everything)

_____ Most (more than half)

_____ About half

_____ Some (but less than half)

_____ Very little or none

Part 2: When other people (who don't know your child very well or at all) speak with your child in everyday situations, how much of what your child says do you think these other people usually understand? [check one]

_____ Everything (or almost everything)

_____ Most (more than half)

_____ About half

_____ Some (but less than half)

_____ Very little or none

Rating Form B

Participant code ________________________

Title of person completing form ________________________

How long have you worked with this child? ________________________

Date Completed ________________________

Part 1: When you are speaking with this child in casual conversation, how much of what he/she says do you usually understand? [check one]

______ Everything (or almost everything)

______ Most (more than half)

______ About half

______ Some (but less than half)

______ Very little or none

Part 2: When adults other than the child's parent (those unfamiliar with the child) speak with this child in casual conversation, how much of what this child says do you think those other people usually understand? [check one]

______ Everything (or almost everything)

______ Most (more than half)

______ About half

______ Some (but less than half)

______ Very little or none

Appendix C

Research Project Subject Payment Form

Full Name ____

Subject's Social Security Number: ________/_________/________

Subject's Address: _______________________________________

____

US Citizen? Yes ___ No ___
If No, I must have a copy of the subject's current visa.

Name of Project to be Charged: ______________________________

# of hours: _____

Hrly rate: ______

Listener Gender: _____

Listener Age: ______

Appendix D

Transcriber Instructions

1. Our primary interest is in how much of what the child in the recording says is understandable to you. We are not interested in phonetic accuracy of his/her productions. Therefore you only need to transcribe orthographically (i.e., using regular spelling).

2. We are not interest in anything more than what the child says. Therefore don't worry about transcribing what the examiner or any other adult on the recording says.

3. There will be times when you won't understand portions of what the child says. Because we are going to be calculating % understood, we need a way to figure out exactly how much is contained in those parts you don't understand. Please don't leave those parts out.

If you don't understand what is intended, of course you can't be certain how many words are really there. That's OK. Listeners are generally very good at hearing syllables (which are peaks of loudness). So whenever you encounter portions that you don't understand, simply put an X for each syllable that you hear. For example:

I went X X X yesterday.

In this case, there was a string of 3 syllables that were not understood. It might have been 3 single syllable words or 1 three-syllable word. Don't worry about which it is. Only count syllables. We have a way to estimate how many words there are based on this kind of transcription but we'll handle that later. If you're interested we'll tell you how we do it after you've completed the transcription of the samples.

Note: As happens in normal conversation, people sometimes talk at the same time. If you find occasions where an adult on the recording "talks over" what the child says, indicate this by writing "overtalk" at the end of the utterance.

4. We've identified 3 samples that have been previously transcribed so you can get a feel for transcribing this way. Listen to these samples (and follow along the transcripts) as many times as you like.

5. There are 6 different conversational samples that we want you to transcribe. The samples vary in length (15-30 minutes) because we try to get a sample containing at least 90 different words (not a particular number of utterances). This helps us ensure we get as broad a sample of English phoneme targets as possible (we may do phonetic transcription later). Please try to transcribe everything the child says in each sample.

6. You will notice two unique things about these samples which (unfortunately) will make your job a little harder. First the examiner will rarely "gloss" or repeat the child's utterances. This was a conscious choice on our part (the reasons are too difficult to explain here). Second in most cases there are 2 and sometimes 3 adults in the room who may participate in the conversation. It should be fairly easy to tell who the child is however.

7. Our goal is to get a "consensus" transcription. Once you're finished with the transcription of the 6 samples, get together with your transcription partner and compare your transcripts. If there are differences, listen to the samples together and discuss what you're hearing. Decide between the two of you what makes the most sense. <u>Please submit only the final version you agree on.</u>

Thank-you very much for your assistance.

Appendix E

Listener Instructions

Thank you for agreeing to assist us with our research project. Your task today is to listen to a sample of speech produced by a young hearing-impaired child who uses a cochlear implant. We want to know how much of what they say you can understand.

The child will produce up to 50 single words. Each word was selected from a set of 12 similar sounding words. Your task will be multiple-choice – you will have the 50 sets of 12 possible words in front of you to select from.

Before you begin listening, we ask that you read through all word lists on the form so you can be familiar with the kinds of words you will be hearing.

You will hear each word spoken one at a time (we let you hear each word twice). Look at all 12 possible words for that item and circle the one you think the child said. Despite what you might hear, the child actually did attempt to produce one of those 12 words.

If you are not sure please guess!!!!!

Be sure you only circle one word for each item. If you change you mind, be sure to clearly indicate your final choice.

Thank you again for your assistance.

Appendix F

List of Correlations

Intelligibility and Sampling Methods
Intelligibility in single words versus intelligibility in conversation .... r = .314, p > .05

Intelligibility and Post-Implantation Age
Six Original Participants
Intelligibility in single words versus post-implantation age...,,,,,,............ r = .314, p > .05
Intelligibility in conversation versus post-implantation age.................. r = .086, p > .05
Without Outlier
Intelligibility in single words versus post-implantation age.................... r = .500, p > .05
Intelligibility in conversation versus post-implantation age...................... r = .900, p < .05

Intelligibility and Listener Familiarity
Six Original Participants
Mother self ratings versus intelligibility in single words........................ r = -707, p > .05
Mother other ratings versus intelligibility in single words..................... r = -.497, p > .05
Father self ratings versus intelligibility in single words.......................... r = .393, p > .05
Father other ratings versus intelligibility in single words......................... r = .393, p > .05
Clinician self ratings versus intelligibility in single words .... r = -.632, p > .05
Clinician other ratings versus intelligibility in single words..................... r = -.224, p > .05
Mother self ratings versus intelligibility in conversation........................ r = .354, p > .05
Mother other ratings versus intelligibility in conversation........................ r = .112, p > .05
Father self ratings versus intelligibility in conversation......................... . r = -.131, p > .05
Father other ratings versus intelligibility in conversation........................ r = -131, p > .05
Clinician self ratings versus intelligibility in conversation....................... r = .527, p > .05

Clinician other ratings versus intelligibility in conversation.................. r = .447, p > .05

Without Outlier

Mother self ratings versus intelligibility in single words........................ r = -.707, p > .05

Mother other ratings versus intelligibility in single words........................ r = .447, p > .05

Father self ratings versus intelligibility in single words........................ r = .354, p > .05

Father other ratings versus intelligibility in single words........................ r = .354, p > .05

Clinician self ratings versus intelligibility in single words..................... r = -.894, p > .05

Clinician other ratings versus intelligibility in single words.................... r = -258, p > .05

Mother self ratings versus intelligibility in conversation........................ r = . 354, p > .05

Mother other ratings versus intelligibility in conversation...................... r = .112, p > .05

Father self ratings versus intelligibility in conversation........................ r = -354, p > .05

Father other ratings versus intelligibility in conversation...................... r = -.354, p > .05

Clinician self ratings versus intelligibility in conversation.................... r = .000, p > .05

Clinician other ratings versus intelligibility in conversation.................. r = -.258, p > .05

Intelligibility and PPVT-III

Six Original Participants

Intelligibility in single words versus receptive vocabulary.................... r = .657, p > .05

Intelligibility in conversation versus receptive vocabulary...................... r = .314, p > .05

Without Outlier

Intelligibility in single words versus receptive vocabulary...................... r = .800, p > .05

Intelligibility in conversation versus receptive vocabulary......................r = .300, p > .05

Intelligibility and Chronological Age

Six Original Participants

Intelligibility in single words versus receptive vocabulary...................... r = .314, p > .05

Intelligibility in conversation versus receptive vocabulary…………………… r = .314, p > .05

Without Outlier

Intelligibility in single words versus receptive vocabulary…………………… r = .000, p > .05

Intelligibility in conversation versus receptive vocabulary…………………… r = .700, p > .05

Intelligibility and Age of Identification

Six Original Participants

Intelligibility in single words versus age of identification…………………… r = -.543, p > .05

Intelligibility in conversation versus age of identification…………………… r = -.543, p > .05

Without Outlier

Intelligibility in single words versus age of identification…………………… r = -.500, p > .05

Intelligibility in conversation versus age of identification…………………… r = -.200, p > .05

VITA

Lana Greer Colvard was born in Crossville, TN on November 18, 1977. She grew up as a child in Pikeville, TN, later moving back to Crossville for her high school years. It was during high school that Lana took interest in the special education population. After volunteering three summers to work with the children attending a special needs summer school, she observed a speech pathologist and took interest in that field. In May 1996, after graduating from Cumberland County High School, she attended Middle Tennessee State University (MTSU) in Murfreesboro, TN. Lana's major at that time was communication disorders with an emphasis in speech-language pathology. Her minor was in special education. A Bachelor of Science degree was received from MTSU during the May 2000 graduation ceremony. She graduated with Cum Laude honors. It was in the fall of 2000, that Lana began graduate work at the University of Tennessee, Knoxville. Soon after defending her master's thesis, Lana received a Master of Arts degree in speech pathology in May 2002.