Published in final edited form as:

Cochlear Implants Int. 2014 July ; 15(4): 222–229. doi:10.1179/1754762813Y.00000000046.

Emergence of Speech Sounds between 7 and 24 Months of Cochlear Implant Use

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Abstract

The process of speech development was investigated in five 42-month-old children with profound deafness who received cochlear implants (CI) between 19 and 36 months of age and five normal hearing (NH) age-mates. Analysis of target and targetless productions revealed that there was overlap in the total number of vowels and consonants produced by the two groups. The differences between the two groups were more evident in target conditions. The two groups were more similar in the targetless condition. The similarities in the targetless (phonetic) repertoire of CI and NH children underscores the importance of examining the emerging system (targetless) to predict the end-point system (target) in children with cochlear implants. Using target and targetless speech sound comparisons offers a supplementary view of the emergent process of speech sound development and as a valid method of analysis. Results suggest that early implantation may help some children with profound deafness develop speech sounds in a manner similar to normal hearing age-mates.

Keywords

Speech Production; Cochlear Implant; Target; Targetless; Phonetic Repertoire

1.0 Introduction

1.1 Sound Development: 0–23 Months

In the first months of life all infants produce reflexive vocalizations such as crying, squeals, feeding noises and comfort sounds (Oller, 1980; Stark, 1981). As they enter the expansion stage of vocalization between 4–6 months, labial trills, squeals, growls, yells, and whispers develop followed by marginal babbling characterized by fully-resonant vowel nuclei and consonant-like productions (Oller, Eiler, Bull & Carney 1985). Between 7 and 10 months, the canonical babble stage begins. This is where we begin to see a divergence in skills between normal hearing children and those with hearing loss. In this stage, consonant and vowel syllables take on adult-like timing, yet children with hearing loss enter this stage later and their overall amount of babbling becomes less and less (Maskarinec, Carins, Butterfield, & Weamer, 1981; Oller et al., 1985). During the second year of life, normal hearing children progress through canonical babbling to variegated babbling and first words (Kent & Bauer, 1985). Children with hearing loss will have varying patterns of onset and structure of first words as a result of decreased access to verbal input and inability to self-monitor during the babbling stage (Stoel-Gammon & Otomo, 1986).

1.2 Sound Development 24–36 Months

In the second year of life, normal hearing children develop a vocabulary of at least fifty words and begin to combine words before age two. In contrast, children with hearing loss produce fewer multisyllabic utterances and their repertoire of consonants is restricted (Stoel-Gammon, 1988). Short, three to four word sentences are produced by normal hearing children by their third year. Children with hearing loss, however, fail to develop this level of sophistication in oral speech (Nicholas, 2000).

1.3 Sound Development: Children with Cochlear Implants

When reviewing the literature on sound development in children with CI, it can be noted that researchers have focused on the end-product or the phonemic “target” production. This is one way of assessing accuracy of speech production in children younger than two years of age (e.g. Connor, Craig, Raudenbush, Heavner, Zwolan, 2006; Ertmer & Goffman, 2011; Ertmer & Kloiber, Jung, Kirleis, & Bradford, 2012; Flipson, 2011) and children above two years of age (Kirk, Diefendorf, Riley, & Osberger, 1995; Miyamoto, Kirk, Robbins, Todd, Riley, 1996; Miyamoto, Kirk, Svirsky, & Sehgal, 1999; Osberger, Maso & Sam, 1993; Osberger, Robbins, Todd & Riley, 1994; Tobey, Geers, & Brenner, 1994; Tobey & Hasenstab, 1991; Tobey, Pancamo, Staller, Brimacombe, & Beiter, 1991; Tye-Murray & Kirk, 1993; Tye-Murray, Spencer, & Woodworth, 1995).

Warner-Czyz, Davis, MacNeilage (2010) described the emergence of the accuracy of CV patterns over a six month period for four children who received CIs between 12 and 24 months of age. In general, these children were similar to their hearing peers with regard to pattern of speech sound acquisition for the consonant-vowel (CV) pairs. When reviewing classes of consonants, the labial/central CV pattern dominated the inventories of both the NH and CI groups. This CV pattern was the most frequent and the most accurate.

McCaffrey, Davis, MacNeilage and von Hapsburg (1999) suggest that deaf children implanted at early ages may take advantage of “basic motor propensities” found in infants with normal hearing. They speculate that the phonetic content or diversity of phonetic inventory in a child with hearing loss may be constrained by the degree of audition available to the child. However, the organization of the CV framework may be determined by basic motor planning principles of development for both deaf and normal hearing children. This CI child followed an organized pattern of development of the CV syllable, although the child’s productions were limited to a few vowels and predominantly consisted of nasal consonants.

Others have looked at a process approach that included the “targetless” productions (Bouchard, Le Normand, & Cohen 2007; Blamey, Barry, & Jacq, 2001; Blamey, Barry, Bow et al., 2001; Serry & Blamey, 1999; Warner-Czyz, et al., 2010). In a sense, this is a type of dynamic assessment which emphasizes the value of the learning process and allows one to take into account the elements (targetless phonemes) already present in the system. According to the American Speech-Language dynamic assessment “seeks to identify the skills that an individual child possesses as well as their learning potential.”“Assessing Children” (2012).

Blamey and colleagues (Blamey et al., 2001; Blamey, Barry, Bow et al., 2001; Serry & Blamey, 1999) completed a series of studies examining the speech development of nine children who received cochlear implants between 29 and 62 months of age, and were 72 months post-implant. Four of the subjects were implanted under 45 months of age and of these, and one child was 29 months of age at the time of implantation. Phone productions were described using a “target” versus “targetless” criteria. Target criteria included “at least two correct productions of the phone in recognizable words” with at least 50% accuracy (Serry & Blamey, 1999). Targetless criteria required “two phonetically recognizable productions of a phone in a spontaneous speech sample.” The investigators found a systematic but slower development of speech in the CI children compared to normal hearing age-mates. Syllables in intelligible and unintelligible utterances became longer, showing an increase in mean number of syllables from 1.7 to 5.2 during this period of time. The increase in length of utterance began 24 months post implant, using a process they described as similar to the transition from babbling to one-element utterances that occurs in hearing children at 9 to 18 months and is followed by one-element to two-element transition at 18–24 months. Expansion of the utterance continued to occur as no plateau was found in length of utterance even at six years post implant. Bouchard, et al., (2007), also used a target (acquired phone) and targetless (emergent phone) to describe the speech of 22 French-speaking children who received CI between 25 and 78 months. They found that stops were the predominant class of consonants after six months of CI use.

These studies show that the speech of children who have a CI can be analyzed using a process (targetless/phonetic) or end-point (target/phonemic) criterion. This study will show how the process of speech development is as critical and informative as studies of the end-point of speech production in providing a comprehensive analysis of a child’s true potential.

The objectives of the present study were to: a) ascertain if diversity of phonetic repertoire (using target and targetless criteria) was similar in NH children with typical speech development and children with CI, and b) determine if diversity of phonemic repertoire (using target and targetless) criteria was similar in NH children with typical speech development and children with CI. We hypothesize that the *phonetic* (targetless) repertoire of the two groups will be more similar than the *phonemic* (target) repertoire of the two groups; reflecting that early in development, the process is parallel, and later in development, the children with CI fall behind.

2.0 Materials and Methods

2.1 Participants

Five children with profound deafness who received cochlear implants (CI) between 19 and 36 months of age and five normal hearing (NH) children participated. These five participants were randomly chosen from a larger data set in order to investigate phoneme repertoire development. The original data set was part of an NIH study to investigate language development in young CI users. Table 1 provides relevant background information on the participants. All children in the CI group were enrolled in auditory oral education settings and were reported to have been deaf from birth.

2.2 Speech Production Procedures

The speech samples were taken from a larger set of existing videotapes completed for early language studies (Nicholas & Geers, 1997). The children and their parents were videotaped for 30 minutes using age-appropriate toys in a schoolroom or therapy center. The parent was instructed to play and talk with their child in the same manner as they might while playing at home. They were told not to provide any special prompting beyond that which they would normally offer their child at home. All children played with the same set of toys presented to them in intervals of approximately 10 minutes. The child wore a lapel microphone and the audio signal was recorded for later playback at a comfortable listening level.

Speech samples were presented through free-field speakers or earphones for transcription. The video signal from the videotape also was used to assist in the transcribing of more difficult phone productions. The number of transcribed utterances in the 30-minute sample ranged from 77 to 151 for the CI children and from 84–100 for the NH children. The length of utterance ranged from two-word utterances for the CI children, to as many as 15-word utterances for the NH children. Approximately 95% of the utterances for both groups of children could be transcribed.

Broad transcription was carried out using the International Phonetic Alphabet. All decisions regarding transcription were made by the first investigator. A second transcriber was trained to 80% agreement with the investigator (Shriberg, Kwiatkowski, & Hoffman, 1984). The second transcriber retranscribed a speech sample that included 269 words and 420 phonetic symbols. The interrater agreement was 88% for broad transcription. Intra-rater reliability was performed using the same procedure for a second set of 150 words with 376 phonetic symbols. The intrarater agreement between the two transcriptions was 95%.

2.3 Data Analysis

A computer software package called CASALA (Computer Aided Speech and Language Analysis) was used to analyze the phonetically transcribed speech samples (Serry, Blamey, Spain, & James, 1997).

CASALA allows an investigator to input an utterance using normal orthography in line 1 of the transcription. Unintelligible utterances are entered as xxx xxx. This orthography line generates a phonetic transcription line which can be modified by a transcriber to adjust for dialect. A third line matching the second line is generated and edited to match the child's production. Individual reports were generated after the transcriptions were compiled and checked for accuracy. Data for this study was acquired from the Phonetic Inventory Broad Transcription report and the Percentage Consonant Correct (PCC) report.

CASALA allows for the placement of phones into target and targetless categories based on the definitions of Serry and Blamey (1999). Both target and targetless phones are phonetically recognizable phones. The target phone criteria includes: a) phones produced in intelligible words (for example, the production of /kip/ for the word ("keep")) results in the three target phones /k/, /i/, and /p/; b) at least two correct tokens of a phone must occur in the sample; and c) at least 50% of the phones (regardless of position) must be correct. The targetless phone criteria are as follows: a) phones found in words as substitutions (for example, the production of /kit/ for the word ("keep")) results in two target phones /k/ and /i/ and one targetless phone /t/; b) phones found in words where the target was unknown (for example the word "bwik" in an unknown context has four targetless phones /b/, /w/, /i/ and /k/); c) phones found in prelinguistic babbling (for example, the utterance /bababa/ has six targetless phones, three /b/ phones and three /a/ phones); and d) there must be at least two recognizable tokens of the phone.

3.0 Results

3.1 Vowels

Table 2 shows the number of vowels produced by each child (CI, NH) based on target and targetless criteria. If at least four of the five (80%) children in each group of cochlear implant (CI) or normally hearing (NH) children produced the vowel correctly based on target or targetless criteria, that vowel was listed in the vowel inventory for that group in the follow in table 3.

In table 3, vowels were grouped by front [i, ɪ, ε, æ,], back [u, ʊ, o, ɔ, ɒ,], central [ə, ʌ, ɜ, ɹ, a,], and diphthongs [eɪ, aɪ, oʊ, aʊ, ɔɪ]. Using the 80% criteria for inventory inclusion, the *target vowel and diphthong* inventory for the CI group included [ɪ, ε, æ], and the NH group included [ɪ, ε, ʊ, ɒ, ʌ, eɪ, aɪ, aʊ]. The *targetless vowel and diphthong* inventory for the CI group included [i, ɪ, ε, æ, u, ʊ, ɔ, ʌ, ɜ, ə, a, eɪ, aɪ, oʊ], and for NH group included [i, ɪ, ε, æ, ʊ, ɔ, ʌ, ɜ, ə, ae, aɪ, aʊ, oʊ].

Table 4 compares the target and targetless production accuracy of the vowel and diphthong inventories listed above. Front vowel accuracy was the highest for target and targetless condition for both CI and NH groups. In contrast, both groups were much more accurate in

the targetless condition for back vowels. Of all the vowel categories, back vowels in the target condition were the most difficult for both groups. Both groups produced central vowels in the targetless condition with over 90% accuracy. In the target condition for central vowels, the CI children were 20% less accurate than their hearing peers. Finally, with regard to diphthongs, both groups were more accurate in the targetless condition. The children with CI had lower accuracy for both conditions (target/targetless) than the children with NH.

Table 5 looks at the vowel data from the perspective of target and targetless categories in Serry and Blamey (1999), and compares production between CI and NH groups. Recall that in the target phone criteria, at least two correct tokens of a phone must occur in the sample, and at least 50% of the phones (regardless of position) must be correct. The targetless phone criteria include phones produced as substitutions and phones found in words where the target was unknown. Vowel (monophthong) results indicated that both CI and NH children had fewer target productions than targetless productions. Diphthong productions overall were the lowest in quantity with fewer target productions than targetless productions for both groups. For monophthongs, the number of targetless productions was similar for both groups using Serry and Blamey criteria. Diphthongs showed a similar pattern with the exception of one CI outlier.

3.2 Consonants

Table 6 shows the number of consonants produced by each child (CI, NH) based on target and targetless criteria. If at least four of the five (80%) children in each group produced the consonant correctly based on target or targetless criteria, the consonant was listed in the consonant inventory for that group in table 7.

In table 7, consonants were grouped by manner of production following Stokes & Surendran (2005). They described factors that account for order of acquisition including articulation complexity and environmental input. Because stops, nasals and glides are acquired before fricatives and affricates, they will be grouped in this manner. Using the 80% criteria for inventory inclusion, the *target consonant* inventory for the CI group included [p, b, m, h, s] and for the NH group included [p, b, g, k, m, n, w, j, h, f, s] The *targetless consonant* inventory for the CI group included [p, b, g, k, d, t, m, n, w, j, h, f, s, z, ʃ, tʃ] and for the NH group included [p, b, g, k, d, t, m, n, w, j, h, f, s, z, ʃ, tʃ,].

Table 8 compares the target and targetless production accuracy of the consonant inventories listed above. For both groups in the target category, accuracy of production followed the expected order of acquisition from stops to affricates. Both groups produced stops in the targetless category with 100% accuracy. Nasal consonants were similar for both groups in the target and targetless categories. Production of liquids and glides in the targetless condition increased almost three-fold compared to the target condition for the children with CI and reached 100% for the children with NH. For targetless fricatives, the children with normal hearing achieved an accuracy rate of 90%, whereas the children with CI were 55% accurate. As expected, affricates were the most difficult for both groups. Children with CI increased their accuracy by 40% from target to targetless conditions. Yet, the children with NH remained at 47% accuracy in both conditions.

Table 9 looks at the consonant data from the perspective of target and targetless categories in Serry and Blamey (1999). Refer to the definition of target and targetless criteria in the vowel summary (see above). Consonant results were similar to vowel results in that there were fewer target productions than targetless productions for both groups. Three out of the five children with CI had similar numbers of targetless productions as their NH peers using Serry and Blamey's criteria.

4.0 Discussion

The phonetic repertoires were similar for both groups when the results of the targetless phone productions were analyzed. The two groups appear more homogenous in their vowel and consonant productions when the phonetic (targetless) criteria are used. The phonemic (target) repertoire was more diverse in the children with NH. These findings support our stated hypothesis that the *phonetic* (targetless) repertoire of the two groups will be more similar than the *phonemic* (target) repertoire of the two groups, reflecting that early in development the process is parallel, and later in development, the children with CI fall behind.

The sound production systems of some CI children appear similar to their NH peers whose sound systems also continue to develop at 42 months of age. Both groups of children produced greater numbers of different targetless phones (monophthongs, diphthongs and consonants) than targeted phones. These observations support the previous work of Serry and Blamey (1999) who proposed the use of a targetless category as a means of showing the developmental nature of speech sound acquisition in young children. During the development of speech, phones occur more often in unintelligible utterances, in babbling, and as substitutions in intelligible words (targetless criteria). Accurate target production of phones occurs less often in intelligible words when compared to targetless phones. Unexpectedly, this phenomenon occurred in a similar manner for both groups of children. Future studies should examine a larger number of children in order to further support this finding.

Quantitatively, the number of different phones was similar for CI children and NH children within the targetless phone categories for monophthongs, diphthongs, and consonants. Quantitative similarities between the two groups of children suggest that the sounds produced in unintelligible speech and the use of substituted sounds in intelligible speech is similar across groups.

The NH children generally produced a wider variety of monophthongs and consonants than the CI children. It appears that when phones are targeted (i.e. must be the correct phone production in an intelligible utterance), NH children are more accurate at this task than the CI children. When looking at the endpoint of the acquisition process, the NH children are producing greater numbers of different phones, indicating that their sound system development is more advanced. Interestingly, the production of different diphthongs was similar for both target and targetless phones and similar across both groups. The development of diphthongs may be a motorically difficult task that is challenging to all children.

Two children with CI who had 24 months and 19 months of CI experience produced a similar number of vowels and consonants as their hearing peers. The evolving speech profile for children with CI suggests that they have many speech production skills similar to their hearing age-mates, while some children with CI surpass the speech skills of their age-mates in some areas. When we used Serry and Blamey's criteria (1999) and described the sound inventories based on 80% of all children who had achieved this criterion, the phonetic (targetless) similarities became more evident as noted in Tables 4 and 8.

5.0 Conclusions

The findings of this study support the use of cochlear implantation in children prior to three years of age. They prompt us to take a closer look at the emergent process of speech sound development rather than limiting ourselves by defining speech success based only on the end product. This is especially important in the case of children with CI because they experience a period of auditory deprivation (the time before implantation) followed by an adjustment process during which their system is reorganizing and adapting to the new sensory input. The phonetic (targetless) productions at this reorganization stage are valuable and should be considered as a true representation of a working system in progress. The output of this working system, when targetless productions are considered, are diagnostic because they can alert and inform us whether the system is evolving in an expected fashion. Incorporating targetless productions is a dynamic assessment approach which can confirm that the system is on the correct path to producing the phonemic (target) inventory essential for continued speech development.

Admittedly, the group sizes were small. The use of a larger pool of children would allow us to further study the observed differences and similarities between children. Another beneficial comparison group would be hearing children with similar amounts of auditory experience to the cochlear implant group (i.e., matching CI-age with chronological age in children with normal hearing).

Acknowledgments

The authors gratefully acknowledge Ann Geers and Nancy Tye-Murray for their contributions during the development and data analysis stage of this work. We also wish to thank Ann Geers for her comments and suggestions during the development of this manuscript. We would like to acknowledge the work of Kari Delzer, graduate student at Central Institute for the Deaf, for her assistance with phonetic transcription and data input to CASALA.

This work was funded in part by NIH-NIDCD grants #DC01259 (Nicholas, PI), #DC04168 (Nicholas, PI), and the Oberkötter Foundation.

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Table 1

Participant Demographics

Participant	Gender	Race/Ethnicity	Age at Hook Up	Age at Taping	Duration of Implant
CI 1	F	Asian	19m	43m	24m
CI 2	M	Caucasian	24m	43m	19m
CI 3	M	Caucasian	27m	42m	15m
CI 4	M	Caucasian	32m	42m	10m
CI 5	F	Caucasian	36m	43m	7m
NH 1	M	Caucasian		42m	
NH 2	F	Caucasian		41m	
NH 3	F	Caucasian		42m	
NH 4	M	Caucasian		42m	
NH 5	M	Caucasian		41m	

Table 2

Individual data for vowels that meet target (T) and target (TL) criteria for normal hearing (NH) children (X) and cochlear implant (CI) children (O).

	i	e	a	ɛ	ɪ	ɔ	ʊ	ʌ	æ	u	ʊ	ə	oʊ	ei	ai	ɔi	ao
T1	X		X	X	X	X	X	X	X					X	X	O	
TL1	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	O	X
T2	O	X	X	X	X		X	X	X		O			X	X		X
TL2	X	X	X	X	X	X	X	X	X		X	X	X	X	X		X
LT3		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
TL3	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
T4	X	X	O	X	X	X	X	X	O				X	X	X	O	X
TL4	X	X	X	X	X	X	X	X	X	O	X	X	X	X	X	O	X
T5		X		X	X		X	X	O		X	X	X	X	X		X
TL5	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X
T	2	4	3	5	5	3	5	5	3	1	2	1	3	5	5	2	4
CI	1	3	3	4	5	̄	1	3	5	̄	1	1	1	3	3	3	2
TL	5	5	4	5	5	5	5	5	4	3	5	5	5	5	5	2	5
CI	5	5	5	5	5	4	4	5	5	4	5	5	4	4	4	3	3

X=vowel produced by NH child

O=vowel produced by CI child

Table 3

Vowels and diphthongs produced in target and targetless conditions in 80% of the children with cochlear implants and children with normal hearing

Vowels	CI		NH	
<i>Position</i>	Target in repertoire	Targetless in repertoire	Target in repertoire	Targetless in repertoire
Front candidates [i, ɪ, ε, æ]	[ɪ, ε, æ]	[i, ɪ, ε, æ]	[ɪ, ε,]	[i, ɪ, ε, æ]
Back candidates [u, ʊ, o, ɔ, ɑ]		[u, ʊ, ɔ,]	[ʊ,ɑ]	[ʊ,ɔ]
Central candidates [ə, ʌ, ɤ, a]		[ə, ʌ, ɤ, a]	[ʌ]	[ə, ʌ, ɤ, a]
Diphthong candidates [eɪ, aɪ, ɔʊ, əɪ]		[eɪ, aɪ, ɔʊ]	[eɪ, aɪ, əʊ,]	[eɪ, aɪ, ɔʊ, əʊ,]

Table 4

Percent correct for vowels and diphthongs in target and targetless productions in children with cochlear implants and children with normal hearing

Vowels	CI		NH	
<i>Position</i>	Target	Targetless	Target	Targetless
Front [i, ɪ, ε, æ]	64%	100%	68%	96%
Back [u, ʊ, o, ɔ, ɑ]	06%	80%	60%	87%
Central [ə, ʌ, ɜ, a]	60%	100%	80%	93%
Diphthongs [ei, ai, ou, au, ɔɪ]	40%	76%	68%	86%

Table 5

Vowels and diphthongs produced in target and targetless condition by each Child in Group CI and Group NH

Group	Monothongs		Diphthongs	
	Target	Targetless	Target	Targetless
CI 1	5	11	3	4
CI 2	5	9	2	1
CI 3	4	11	2	4
CI 4	7	11	5	5
CI 5	5	10	0	3
NH 1	8	11	2	4
NH 2	7	10	3	4
NH 3	10	11	5	5
NH 4	7	10	5	5
NH 5	6	10	4	4

Individual data for consonants that meet target (T) and target (TL) criteria for normal hearing (NH) children and cochlear implant (CI) children

	p	m	n	w	h	b	g	K	f	d	q	j	t	f	lf	l	r	d ₃	Θ	v	s	z	3	?
T1/NH CI	X O	X O	X O	X O	X O	X O	X O	X O	X O	X		X O		X O	X O						X O			
TL1/NH CI	X O	X O	X O	X O	X O	X O	X O	X O	X O	X O		X O	X O	X O	X O	X O	X O	O	X	X O	X O	X		O
T2/NH CI	X O	X O	X O	X O	X O	X	X	X	X O	X O		X O		X				X		X O				
TL2/NH CI	X O	X O	X O	X O	X O	X O	X O	X O	X	X O		X O	X O	X O	O	X O	X O	X	X	X O	X O	X		X O
T3/NH CI	X O	X O	X O	X O	X O	X O	X O	X O	X			X		X O	X O	X O	X O	X		X O				
TL3/NH CI	X O	X O	X O	X O	X O	X O	X O	X O	X O	X O	X	X O	X O	X O	X O	X O	X O	X O	X	X O	X O	X O	X O	X O
T4/NH CI	X O	X O	X O	X O	X O	X O	X O	X O	X O	X O		X O			X	X		X		X O				
TL4/NH CI	X O	X O	X O	X O	X O	X O	X O	X O	X O	X O	X O	X O	X O	O	X O	X O	X O	X O	X	X O	X O	X O	X O	X O
T5/NH CI	X O	X O	X O	X O	X O	X O	X	X	X O	X O		X O			X					X				O
TL5/NH CI	X O	X O	X O	X O	X O	X O	X O	X O	X O	X O		X O	X O	X O	X O	X	X		X	X	X			O
Target Total NH CI	5 5	5 5	5 3	5 3	5 5	5 4	5 3	5 3	5 1	3 2	0 0	5 3	0 1	3 2	4 2	2 0	1 0	3 0	0 0	5 4	2 0	0 0	0 0	0 1
T/L Total NH CI	5 5	5 5	5 5	5 5	5 5	5 5	5 5	5 5	5 2	5 5	2 1	5 5	5 5	4 5	5 5	5 3	5 3	3 2	4 0	5 4	5 4	4 1	0 1	3 5

O=consonant produced by CI child

Table 7

Consonant Inventory categorized by manner of production produced in target and targetless productions in 80% children with CIs and children with NH

Consonants	CI		NH	
<i>Manner</i>	Target	Targetless	Target	Targetless
Stops [p, b, t, d, k, g]	[p, b]	[p, b, t, d, k, g]	[p, b, k, g]	[p, b, t, d, k, g]
Nasals [m, n, ŋ]	[m]	[m,n]	[m, n]	[m,n]
Liquids/Glides [w, j, l, r, h]	[h]	[w, j, h]	[w, j, h]	[w, j, l, r, h]
Fricatives [f, v, θ, ð, s, z, ʃ, ʒ]	[s]	[f, s, z, ʃ]	[f, s]	[f, v, θ, ð, s, z, ʃ]
Affricates [tʃ, dʒ]	[tʃ]			[tʃ]

Table 8

Consonants categorized by manner of production produced in target and targetless productions in 80% children with cochlear implants and children with normal hearing

Consonants	CI		NH	
<i>Manner</i>	Target	Targetless	Target	Targetless
Stops [p, b, t, d, k, g]	[p, b]	[p, b, t, d, k, g]	[p, b, k, g]	[p, b, t, d, k, g]
Nasals [m, n, ŋ]	[m]	[m, n]	[m, n]	[m, n]
Liquids/Glides [w, j, l, r, h]	[h]	[w, j, h]	[w, j, h]	[w, j, l, r, h]
Fricatives [f, v, θ, ð, s, z, ʃ, ʒ]	[s]	[f, s, z, ʃ]	[f, s]	[f, v, θ, ð, s, z, ʃ]
Affricates [tʃ, dʒ]	[tʃ]			[tʃ]

Table 9

Consonants produced in target and targetless condition by each Child in Group CI and Group NH

Consonants		
Group	Target	Targetless
CI 1	13	21
CI 2	9	17
CI 3	10	21
CI 4	8	19
CI 5	7	14
NH 1	14	21
NH 2	14	21
NH 3	17	23
NH 4	16	23
NH 5	12	20