# A LONGITUDINAL STUDY OF SPEECH FEATURE CONTRAST PRODUCTION IN CHILDREN WITH COCHLEAR IMPLANTS

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## ABSTRACT

This study examined changes in production of speech features by children with cochlear implants over a one year period. Sixteen children (Mean age = 4, Range 3;2 to 5;11) with a mean of 32 months experience with their implants and no additional disabilities served as participants. The children were asked to name a series of pictures designed to elicit production of the following speech characteristics: Vowel Height, Vowel Place, Consonant Place (Front and Back contrasts), Continuance and Consonant Voicing. Children were evaluated at both a baseline date, and approximately one year later. The results reveal that while all children appeared able to produce the range of vowel features, a number of younger children, particularly those under 4 years of age, experienced difficulty producing the consonant features. One year later nearly all children showed increased accuracy, although some children continued to show lower accuracy producing Back Place and Continuance feature contrasts.

**Keywords**: Phonetic features, speech features, cochlear implant, speech production, speech development, children

## 1. INTRODUCTION

Speech production development is a complex process that is dependent upon a range of factors. Among these factors are a child's perceptual functioning (visual and aided/unaided auditory abilities), cognitive and linguistic abilities, maturation, motor speech development, and instruction provided to the child. For the child with a significant hearing loss the acquisition of speech skills can be greatly impacted by limited access, or no-access to the acoustic elements of speech. This limitation can have a profound impact on spoken language development, making it significantly different than that of hearing children.

The advent of cochlear implants and their use with children has greatly increased auditory access to speech, although the sound received by the implant is greatly impoverished when compared to the intact signal available to hearing children. The importance of auditory input for developing speech patterns is evident. Given the impoverished speech signal, however, it is not clear how this more limited input might affect the pattern of acquisition of speech production. In particular it is important to understand the production development by children with cochlear implants (CIs) in order to better understand the course of typical acquisition in these children.

Previous work has shown that children with CIs demonstrate a hierarchy of speech feature contrast production accuracy that in many ways parallels the pattern of speech feature perception accuracy - vowel features being the most perceptible and most accurately produced while consonant features tend to be less perceptible and more likely to be incorrectly produced [1] [4] [5]. It is less clear how production of feature contrasts might change over time as the child matures and gains more experience with his/her implant. Accordingly, the purpose of the present study is to examine changes in selected speech feature contrast production in the utterances of children over one year period in order to better understand the process of speech sound development in these children.

## 2. PROCEDURES

The present paper describes results from a picture-naming task designed to assess children's ability to produce the speech feature contrasts of interest. The features that were examined are based on the Speech Pattern Contrasts tests developed to assess speech perception and described by Boothroyd & Boothroyd-Turner [1] and others. The features examined and examples of segments representing that contrast are: Vowel height (/u/ v. /a/); Vowel place (/u/ v. /i/); Place for anterior consonants (/b/ v. /d/); Place for back consonants (/ʃ/ v. /s/); Consonant voicing (/d/ v. /t/); and Consonant continuance (/s/ v. /tʃ/). The data collection session was part of a longitudinal study of the perception and production of speech features, and included additional tasks not reported in the present study, including standardized tests of vocabulary and articulation and a language sample.

Children's productions were audio and video recorded. Children wore a lavalier microphone

attached to an FM transmitter (WLX-PRO VHF wireless lapel microphone system). The FM receiver was input to the audio channel of a high definition camcorder (Sony Handycam HDR-XR500V) that was used to record the entire data collection session.

### 2.2. Participants

Sixteen children who met the following inclusion and exclusion criteria were recruited from the metropolitan Washington DC area. Participants were between 3;2 and 5;11 years of age (mean age = 4 years) and were profoundly deaf with the deafness detected at or near birth. The median age at implant was 12 months, with all but 2 of the children receiving their implants prior to 23 months of age. The median duration of usage was 32 months and ranged from 14 to 52 months. None of the children reported any other disability in addition to deafness.

### 2.3. Procedures

A production task was developed in which the children named 32 pictures containing segments representing variants of the six contrasts of interest. For example, a picture of a 'bee' and the letter 'P' were presented to elicit tokens of the child's production of the voiced/voiceless contrast. The complete set of utterances provided between 10 and 18 opportunities to assess production of a particular feature contrast. Words were selected that would be familiar to a typical 3-year-old child. For most words, the children were able to identify the pictures without prompting.

### 2.4 Data measurement

Two transcribers independently and blindly transcribed children's productions in IPA using broad transcription in PHON (Rose et al., 2006) a phonological analysis program. Consensus methods of transcription were used so that when the two transcriptions were in agreement the transcription was taken as the actual production of the utterance. When the two transcribers disagreed a third transcriber with considerable experience transcribing children's speech listened to and transcribed the utterance.

Each target segment was analyzed for the accuracy of one or more of the six features of interest. If a child produced a particular feature correctly, she received a point for a correct production, even if the segment was incorrectly produced. For example, if the target feature was [+cont] as in the segment /ʃ/, the child received full credit for either /ʃ/ or /s/, so that regardless of the overall segmental accuracy, a child received credit for producing the target feature correctly.

## 3. RESULTS

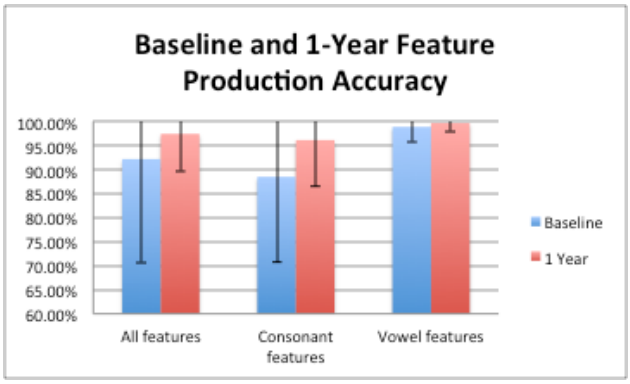
Figure 1 shows the mean scores for the six feature contrasts, for the combined consonant feature contrasts (front place, back place, continuance, and voicing) and the combined vowel feature contrasts (vowel height and vowel place).

### 3.1 Production accuracy across all features

The mean performance across the 6 features for the 16 children at the baseline session was 92.2% (SD = 17.75%). One year later, the mean accuracy had increased to 97.5% (SD = 7.9%). There was a significant difference for the group of children across all features ($p < .001$) over this one year period.

To further examine the source of this improvement, changes in production of the four consonant feature contrasts (Front Place, Back Place, Continuance, and Voicing) were further examined. At baseline, the mean accuracy for production of the consonant feature contrast was 88.5% (SD=21.3%). After one year, the average accuracy had increased to 96.2% (SD=9.6%). A T-test for repeated measures revealed a significant improvement in accuracy ($p<.001$) over this one year period.

Figure 1: Mean comparisons for various groupings of speech feature contrasts.




The vowel feature contrasts (Vowel Height and Vowel Place) and the consonant feature contrasts (Front and Back Place, Voicing, and Continuance) were also examined separately. At baseline the children showed high levels of accuracy for the vowels (99.4%) revealing a ceiling effect for vowels. The accuracy one year later was similarly high (99.7%). Statistical comparison of baseline and one year results revealed no significant difference in performance ($p=.212$).

### 3.2 Patterns of accuracy change for individual children

Figure 2 shows that 4 of the 16 children demonstrated some degree of reduced accuracy (arbitrarily defined as performance below 90% accuracy) during the initial data collection. Conversely 12 of the 16 children demonstrated abilities that surpassed the 90% accuracy level reflecting mastery of the ability to produce these feature contrasts in real words. It is noteworthy that the children that were unable to produce the features at accuracy levels greater than 90% accuracy during their initial visit were among the youngest. It is also noteworthy that there were an additional 8 children in the 3 to 4 1/2 year range that were able to produce these features accurately at the time of their initial visit. The remaining 4 children were older than 4.5 years of age and all demonstrated a high level of accuracy (above 90%) for all features combined, suggesting mastery of production of these features.

Figure 2: Accuracy scores for the six feature contrasts combined shown for each child over a one-year period.

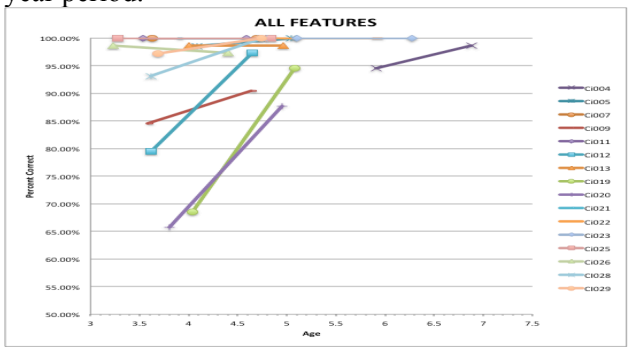



Figure 2 also shows that one year following the baseline session, all four of the children whose mean production accuracy was below 90% showed improvement, with three of the four children improving beyond 90% correct production. The remaining child showed a nearly 22% improvement in mean feature contrast accuracy following 1 year.

To better understand the source of difficulty demonstrated in consonant feature production at baseline, the individual children's performance for each of the consonant feature contrasts were further examined. Figure 3 shows each child's production of the Front Place contrast, in which three of the children (CI12, CI19 and CI20) showed lower accuracy at baseline. After 1 year all three of these children improved to 100% accuracy.

Figure 3: Individual children's production accuracy for Front Place feature contrast across two sessions.

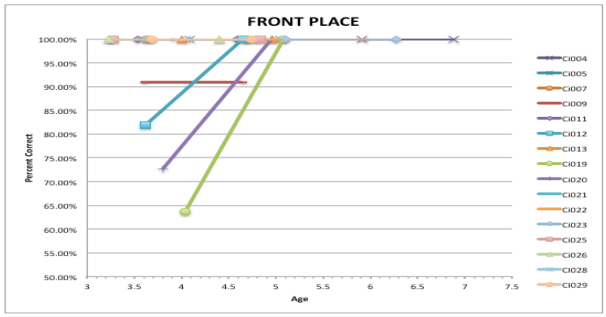



Figure 4 similarly shows performance for the Voicing Contrast. Four children showed reduced accuracy (CI09, CI012, CI019 and CI020). One year later all four of these contrasts were produced with accuracy approaching or reaching 100%.

Figure 4: Individual children's production accuracy for Voicing feature contrast across two sessions.

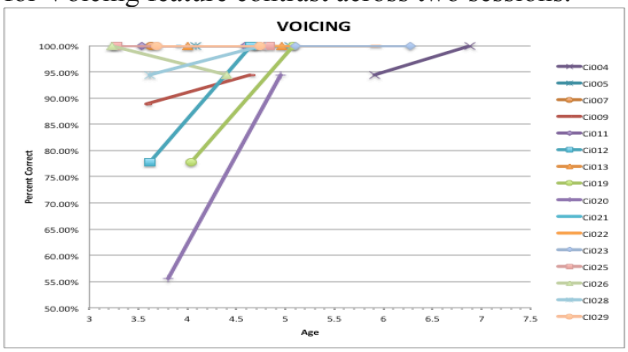
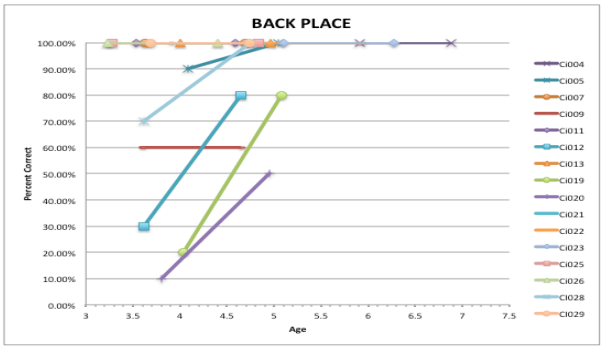



Figure 5 shows production accuracy for the Back Place contrast. Six of the sixteen children demonstrated reduced accuracy at baseline in producing this feature contrast (CI009, CI012, CI019, CI020 and CI028). After one year, five of the six children showed improvement in producing this contrast, while one maintained accuracy similar to that demonstrated during baseline. Of the five children showing improvement, two surpassed 90% accuracy.

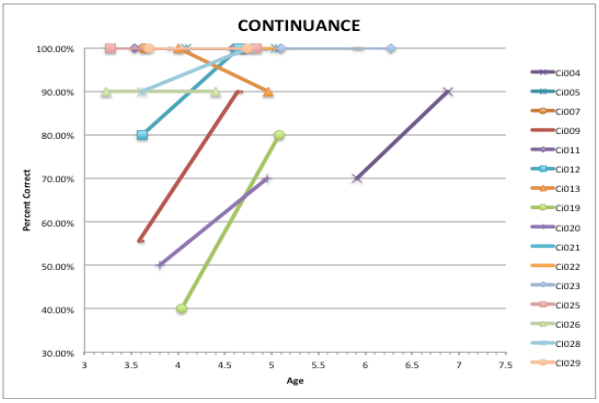
Figure 5: Individual children's production accuracy for Back Place feature contrast across two sessions.




The largest number of children demonstrating difficulty did so for production of the Continuance Feature contrast (Figure 6). Seven of the 16 children showed some difficulty accurately producing this feature contrast during the baseline session (CI009, CI004, CI012, CI019, CI020, CI026 and CI028) as reflected in accuracy scores at or below 90% correct. It is noteworthy that 6 of these children were between the age of 3;3 and 4;0 at the time of

baseline data collection. Following one year, 6 of the 7 children demonstrated improved accuracy, although 5 of 7 children still produced this contrast with accuracy at or below 90%. One child (CI026) showed no change in production accuracy of the Continuance contrast over the one-year period of this study.

Figure 6: Individual children's production accuracy for Continuance feature contrast across two sessions.




## 4. DISCUSSION AND CONCLUSIONS

The children with CIs in the present study were able to produce many of the feature contrasts examined with high levels of accuracy. The children all produced the Vowel Place and Vowel Height features with a high level of accuracy, and this accuracy was maintained over the course of one year. Among the youngest children, there were those who did not attain mastery of the consonant features at the time of the baseline session although there were many that did. The Front Place and Voicing contrasts appeared less difficult for the children and were more likely acquired over the course of one year. The less-visible Back Place and Continuance feature contrasts were produced with reduced accuracy by more of the children, with Continuance proving to be the most challenging. Moreover during the course of one year there were still some of the children with CIs who demonstrated difficulty producing these contrasts although nearly all showed some increased accuracy over the course of one year.

The present findings are consistent with previous work examining segmental accuracy in young children with CIs. Ertmer & Goffman [2] studied consonant and vowel production in six children who received their implants by 30 months and had two years of experience with CIs (mean age=49 months). They found highly accurate vowel production (79-83%). Our children tended to be younger but demonstrated highly accurate vowel feature production even at the very youngest age. Ertmer & Goffman further found that consonant accuracy depended on the manner of articulation. Stops were produced more accurately (>80% on average) than fricatives and affricates (25-50% accurate). Again the current findings were somewhat consistent with Ertmer & Grossman's results – the manner and voicing features were among the least accurately produced at baseline, although the voicing feature did tend to improve beyond 90% accuracy over the course of 1 year. Ertmer and colleagues [3] showed that word-initial consonant accuracy for fricatives and affricates was below 70% for children with 24 months experience using CIs. This is consistent with the relatively low accuracy rates seen in our youngest children for the continuance contrast, even after an additional year of experience.

The present study examined wide age range with younger children who are likely to show more change over time as they acquire sounds/contrasts while older children are likely to have a more stable sound system given their experience and age. The findings are thus consistent with the expectation of greater change in the younger children and less change for the older children.

The present findings are based on a limited number of children and there is evidence of subgroups, even among children of similar age. While the findings suggest that the less visible speech features are among the later characteristics to be developed, the basis for differences among children of similar age needs further examination.

## 5. REFERENCES

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