AUDITORY AND VISUAL CONTRIBUTIONS TO SPEECH FEATURE PRODUCTION IN DEAF CHILDREN WITH COCHLEAR IMPLANTS

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ABSTRACT

This study examines the ability of Deaf children with cochlear implants to perceive and produce the following speech features: Vowel Height, Vowel Place, Consonant Place of Articulation (anterior and back), Continuance and Consonant Voicing. Seven children between 3;4 and 4;10 with a minimum of 18 months of experience with their implants served as participants. Perception of the features was assessed using OLIMSPAC as described by Boothroyd, Eisenberg & Martinez [2] which permits examination of feature perception through audition alone and through audition and vision. Production was examined by having the children name a series of pictures containing word initial segments that reflected contrasts of each feature. Results showed a tendency for perception accuracy to be lower through audition alone than through audition and vision, and that production accuracy tended to be higher than perception accuracy.

Keywords: speech perception, speech production, phonetics and phonology, clinical phonetics

1. INTRODUCTION

There is considerable research that demonstrates the benefits to spoken language development of cochlear implants (CIs) for children with hearing loss (for example, [7, 8]). It's evident from these and other studies that the perception and production skills of children with CIs has led to improved accuracy for the population of children with hearing loss, but the same evidence points to a high degree of variability in perception and production skills in these children. Because of this variability it becomes important to better understand how children with CIs are using auditory information both for understanding and producing speech.

It is generally held that perception precedes production. Indeed, numerous tests of perception rely on a child's imitation of a segment as evidence of hearing or not hearing that segment or feature. Eisenberg, Martinez & Boothroyd [3] have suggested that assessment of visual perception is an important factor to consider. Indeed numerous studies point to enhanced speech perception by children with CI's when vision is added [1, 5, 9]. Recent research by Mahshie, Core, & Bakke [6] showed that for some children, auditory feature perception based on imitation of nonsense words is actually lower than the ability of children to produce these features in real words. Possible reasons for this disparity include the use of real vs. nonsense words, and the potential for additional information conveyed through alternate sensory modalities such as vision.

These findings suggest that the relationship between production and perception is more involved than might be initially suspected and that additional information is needed to better understand what a child with CIs perceives, and how it is related to their speech production abilities.

The present study examines the ability of children with CIs to both perceive (through audition alone, and through audition and vision) and produce specific features of speech. This research is part of a broader study examining the development of these skills in young children with implants as they mature and gain experience with the devices.

2. METHODS

The ability of the children to both perceive and produce a series of speech feature contrasts was examined through a series of tasks. The production task involved naming of pictures while the perception task involved imitation of VCV nonsense syllables that contained a series of contrastive segments. The features that were examined and examples of segments demonstrating that contrast are:

- Place for anterior consonants (/b/ v. /d/)
- Place for back consonants (/ʃ/ v. /s/)
- Consonant voicing (/d/ v. /t/)
- Consonant continuance (/s/ v. /tʃ/)
- Vowel height (/u/ v. /a/)
- Vowel place (/u/ v. /i/)

2.1. Participants

Children who met the following inclusion and exclusion criteria were recruited from the metropolitan Washington DC area. Participants were selected such that they: were between the age of 3 years and 5, were profoundly deaf with the deafness detected at or near birth, received their implants between the age of 18 and 36 months of age, had their implant activated for at least 18 months, and not longer than 6 years following their implantation, and had no additional disability in addition to their deafness.

Table 1: Participant Description – given are age, age of activation, duration of use, and pure tone aided thresholds for each participant.

Subject ID	Age	Age of Activation (R)	Age of Activation (L)	Duration of CI Use (R)	Duration of CI Use (L)	PTA Aided (dB)
Ci007	3;8	1;4	HA	2;4	N/A	20
Ci009	3;7	1;1	1;6	2;6	2;3	30
Ci011	3;6	2;1	1;1	1;5	2;5	22
Ci012	3;7	1;4	1;1	2;3	2;6	30
Ci014	4;10	0;10	3;9	3;11	1;1	23
Ci016	3;4	HA	1;3	N/A	2;1	18
Ci017	4;6	1;3	open	3;4	N/A	28

A group of 7 children with cochlear implants were identified for inclusion in the current study. These children are participants in a larger longitudinal study examining perception/ production characteristics of children with CIs [6]. Table 1 summarizes the characteristics of these children. As noted above, four of the children had bilateral cochlear implants; two wore hearing aids in one ear and were implanted in the other while the remaining child had a single implant.

2.2. Feature production task

A production task was developed in which the children named pictures that contained segments that represented the six contrasts of interest. All words pictured in the stimulus set were readily identified objects by young children and were selected because they are among the earliest words typically-developing children acquire and are pictureable. For most words, the children were able to identify the objects without prompting. In some cases productions were elicited through delayed imitation.

2.3. Analysis of production data

Two trained graduate students independently transcribed the words from audiovideo recordings of the children's utterances as described above. Discrepancies between the two transcriptions were decided by a third judge, a professor of Speech-Language Pathology with considerable experience transcribing child speech. Each target segment was analyzed for the features assessed in the perception tasks. If a child produced the segment correctly, she received a point for a correct production. If the segment was incorrectly produced but the feature was accurate, the child also received one point. For example, if the target feature was [+cont] and the target segment for the feature was /ʃ/, the child received full credit for either /ʃ/ or /s/, so that regardless of segmental accuracy, a child received credit for producing the target feature accurately. The production task was always given prior to either perception tasks.

2.4. Feature perception assessment

The On-Line Imitative Test of Speech Pattern Contrast Perception (OLIMSPAC) was designed by Boothroyd, Eisenberg & Martinez [2] to assess young children's perception of phonological contrasts through audition, audition and vision, or vision alone. Children were presented a series of VCV utterances and asked to imitate what they heard. Target segments occurred in medial position to provide the child with both pre and post-vocalic coarticulatory cues. Each of the six target features of interest were assessed through OLIMSPAC. This test relies on the child's imitation of patterns as a means of assessing what they perceive. The test was administered in two formats – audition only (AO) and Audio-Visually (AV) with AO given prior to AV. Stimuli were presented by the same speakers for both conditions. All stimuli were sound field presented at 70 dB SPL.

The test was originally designed to be administered by a single examiner, with the child's imitation scored immediately after the attempt using an eight alternative forced choice response. In our implementation we used the computer to administer the test stimuli and audiovideo recordings were made of the child's productions and were later scored by a panel of three listeners. Details of the procedures for scoring the production data are given below.

2.5. Analysis of perception data

Three listeners audited and scored recordings of each child's imitated response. Using the eight alternative forced choice schema designed for the OLIMSPAC the listeners selected the utterance that best matched the child's imitation. The consensus judgment of the three listeners was used to determine the utterance produced. Comparison of the features in the child's imitation to those of the utterance presented resulted in a feature accuracy score for each feature based on 8 opportunities for each feature.

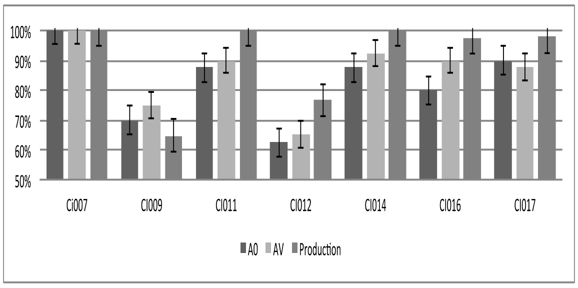
3. RESULTS

3.1. Mean perception and production accuracy for each child

Figure 1 shows the feature perception accuracy through audition alone (AO) and audition and vision

(AV), and production feature accuracy for each child. Data are averaged across the six features for both perception and production tasks.

Figure 1: Perception (AO and AV) and Production Accuracy of the average for the six features shown for each child. Shown are means and standard error for the six features.



Five of the children produced the target features with greater than 90% accuracy. One participant, (CI007) produced the target features with 77% accuracy, and one participant (CI009) produced the features with 65% accuracy.

Feature perception accuracy was 90% or greater for two of the children in the AO condition – Ci007 (100%) and Ci014 (93%) - and for five of the children in the AV condition – CI007 (100%), CI011 (90%), CI014(93%) and CI016 (90%). While there was a tendency for A0 perception to be better than AV perception, the differences were relatively small across the children (0-10%).

In comparing the mean production feature scores in real words to the results of the perceptual tasks it was noteworthy that all but one child showed production accuracy that was equal to or above feature perception accuracy. CI007 was 100% accurate for perception and production of all features, while the five children who showed better production than perception ranged from 7% to 10% higher production scores than their best perception scores. The single child for whom production scores were lower than perception tended to have overall lower scores on all measures.

Figure 2 contains the mean feature perception and production scores for all participants for each of the six phonological features. As a general trend, the more visible vowel features (vowel height and vowel place) were perceived with a high degree of accuracy. Mean AO perception accuracy for vowel height was 91% while mean AV feature perception accuracy was 100%. Mean production accuracy for the vowel height feature was similarly high (98%). Similar high perception and production scores were also observed for the vowel place feature.

Consonant place features for the more anterior consonants were perceived more accurately in the AV condition (93%) than in the AO condition (82%). Place features for the anterior consonants were also produced with a relatively high degree of accuracy. Place feature perception for less visible back consonants, however, was considerably less accurate in both the AO condition (67%) and the AV condition (73%). Production of these less visible features was the least accurate of all features tested (80%).

Mean performance for perception of the continuant v. non-continuant features showed a somewhat unexpected trend. Mean AV perception of this feature was actually lower than AO production (AO = 77%, AV =68%). This trend was evident in both the mean data and for five of the seven children. The remaining two children had comparable performance for the AV and AO conditions. Mean production accuracy of the continuant feature was higher than the perception scores (86%).

The Voicing feature was also somewhat unexpected, in that while it would appear to be a minimally visible feature, the mean AV perception accuracy of voicing was 89% and the mean AO perception accuracy was 79%. Production of the feature was more accurate than either the mean scores for either AO or AV perception (96%).

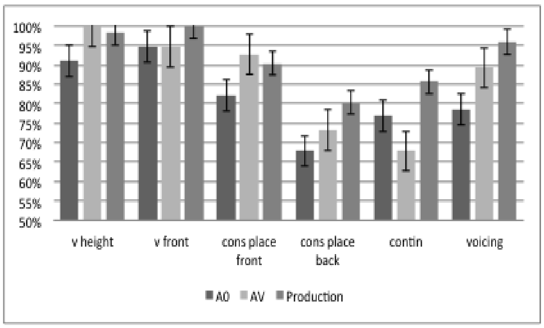
4. DISCUSSION AND CONCLUSIONS

The current findings showed a modest increase in AV over A0 perception by children with CI's when the perception and production of all features are considered.

While consistent with results reported by Eisenberg et al. [3] and others [1, 9], the current findings also suggest that the benefit of AV perception may not be comparable for all features. AV performance was higher than A0 for vowel height and front consonant place production, and comparable for vowel place. Moreover production accuracy was high suggesting that the added information from vision aided the ability to accurately produce these features. For the less visible features of place for back consonants, and continuants, it is unclear how much information was added through vision. Perception accuracy was relatively low for both AV and A0 with the continuant feature performance on the AV condition being lower than on the A0 condition. This finding suggests that there may be some confusion introduced when visual information is added to auditory information. The interaction of visual and auditory information in speech perception has been reported in hearing and deaf individuals [1,5,6] and may play a role in perception/production of features such as continuance.

Figure 2: Mean and standard error for perception accuracy (AO and AV) and production accuracy (real words) for the six features assessed. Shown are the features Vowel Height (v height), Vowel Place (v place), Place for Anterior Consonants (cons place ant), Place for Back Consonants (cons place back).

More Visible Features	Less Visible Features



The findings also suggest that the apparent visibility of features may not account for the expected benefit of the AV v. AO condition. Visual information associated with consonant voicing appeared to provide a benefit to participants despite the less visible nature of this feature. Perhaps there are other, more visible, durational cues that may be relied on for perception of voicing, such as pre- or post-consonantal vowel lengthening.

The present findings also showed that for most participants, the production accuracy of these features was comparable to, or more accurate than perception. This suggests that the notion that perception precedes production may not be the case for all features. The higher accuracy of feature production than feature perception for less visible features despite some benefit of visual information suggests that there may be additional factors accounting for the perception-production disparity than the addition of vision alone, including the possible interaction of perception and production [10, 11].

One possible basis for the disparity between perception and production is a task affect related to the use of nonsense word imitation to characterize speech perception. It has been suggested that estimates of perception based on imitation are necessarily minimal estimates of auditory ability since they rely on the speech production skills of the child [2]. This may have accounted for the pattern seen in two of the children (CI009 and CI012). It is also feasible that the use of nonsense words played a role in these estimates of perception. Hoff, Core & Bridges [4] found that even when real words and nonsense words contained the same sounds in the same word positions, children at 22- and 30-months produced real words significantly more accurately than nonwords. This suggests that the use of nonwords in the VCV imitation task of perception could affect the children's performance on the perceptual tasks and would result in higher production scores when the sounds occurred in real words, as in our production task. The findings of the current study are clearly preliminary but point to the need for further examination of task effects and specific features when characterizing the speech perception skills of children with cochlear implants.

5. ACKNOWLEDGEMENTS

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