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**Speech Feature Discrimination in Deaf Children
Following Cochlear Implantation¹**

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Abstract. Speech feature discrimination is a fundamental perceptual skill that is often assumed to underlie word recognition and sentence comprehension performance. To investigate the development of speech feature discrimination in deaf children with cochlear implants, we conducted a retrospective analysis of results from the *Minimal Pairs Test* (Robbins et al., 1988) selected from patients enrolled in a longitudinal study of speech perception and language development. The MP test uses a 2AFC procedure in which children hear a word and select one of two pictures (bat-pat). All children were prelingually deafened, received a cochlear implant before 6 years of age, and used either oral or total communication. Children were tested once every six months to a year for seven years; not all children were tested at each interval. By two years post-implant, the majority of these children achieved near-ceiling levels of discrimination performance for vowel height, vowel place, and consonant manner. Most of the children also achieved plateaus but did not reach ceiling performance for consonant place and voicing. Finally, children's performance was related to measures of speech feature discrimination, spoken word recognition, and sentence comprehension.

Introduction

Speech feature discrimination is assumed to be a fundamental perceptual skill that underlies word recognition and sentence comprehension performance in normal-hearing listeners. With the advent of cochlear implants in young children, it is important to understand how effectively deaf children use input from their cochlear implants to discriminate such speech features. Previous research has shown that deaf children with cochlear implants (2 years post-implant) perceive spoken words using "broader" phonetic categories than normal-hearing children normally do (Pisoni et al., 1999). However, do deaf children with cochlear implants eventually catch up with their normal-hearing peers in terms of discriminating phonetic features in words?

To investigate the development of speech feature discrimination in deaf children with cochlear implants, we conducted a retrospective analysis of results from the *Minimal Pairs Test* (Robbins et al., 1988) administered to patients enrolled in a longitudinal study of speech perception and language development at the Indiana University School of Medicine. A minimal pair consists of two words that differ in sound by only one feature (e.g., key-pea, big-bug). The MP test uses a 2-alternative forced-choice procedure in which children hear a spoken word and select one of two pictures that depict a minimal pair. If speech feature discrimination underlies word recognition and sentence comprehension performance, we would also expect the results from the *Minimal Pairs Test* to be correlated with measures of spoken word recognition and sentence comprehension. Thus, we also conducted a retrospective analysis of results from the *Phonetically Balanced Kindergarten Words* (PBK) test (Haskins, 1949), a test of spoken word recognition, and the *Common Phrases* test (Osberger et al., 1991), a test of sentence comprehension. In these tests, children are asked to repeat either a word or a sentence spoken by the clinician. All children in the present study were prelingually deafened, received a cochlear implant before 6 years of age, and used either oral or total communication. Children were tested once every 6 or 12 months for seven years. We predicted that the children's performance on all tests would improve over time and that children with oral communication experience would perform more accurately compared to children with total communication experience, particularly on the tests with an open-set response format. Moreover, we predicted that children's scores on tests of speech feature discrimination,

spoken word recognition, and sentence comprehension would be positively correlated, consistent with the notion that speech feature discrimination skills underlie word recognition and sentence comprehension.

Method

Data Selection

We conducted a retrospective analysis of results from a subset of tests administered to patients enrolled in a longitudinal study currently being conducted at the Indiana University School of Medicine. Children were tested once every 6 or 12 months for seven years. Not all children were tested at each interval because of time constraints, child inattention, or cancelled appointments due to family issues.

Participant Characteristics

Table 1 shows a summary of participant characteristics. All children in the present study were prelingually deafened (i.e., deafened under the age of three years) and received a cochlear implant between one and six years of age. The age at the time of the first test session ranged from 2.8 to 6.9 years. Finally, children were tested over a span of three to seven years and accumulated at least four years of cochlear implant use by the date of the last test session. All tests were administered by speech-language pathologists or audiologists in a quiet room at Riley Hospital for Children, Indianapolis, IN.

	Age at Onset	Age at Implantation	Age at First Test
Oral Communication (N = 18)			
Average (years)	0.35	4.2	5.8
Minimum (years)	0	1.4	4.5
Maximum (years)	2.42	5.8	6.9
Total Communication (N = 18)			
Average (years)	0.36	4.1	5.0
Minimum (years)	0	2.2	2.8
Maximum (years)	1.67	5.8	6.7

Table 1. Oral Communication and Total Communication participant characteristics.

Dependent Measures

Speech Feature Discrimination. The *Minimal Pairs Test* (Robbins et al., 1988) is a closed-set test of speech feature discrimination, with a total of 80 minimal pair items. A minimal pair consists of two monosyllabic words that differ in sound by only one feature (e.g., key – pea, big – bug; see Figure 1). Target items were presented in a live-voice auditory-only format. That is, the clinician covered his or her face with a mesh screen while saying the target item aloud. The child was asked to point to only one of the two pictures corresponding to what they perceived.

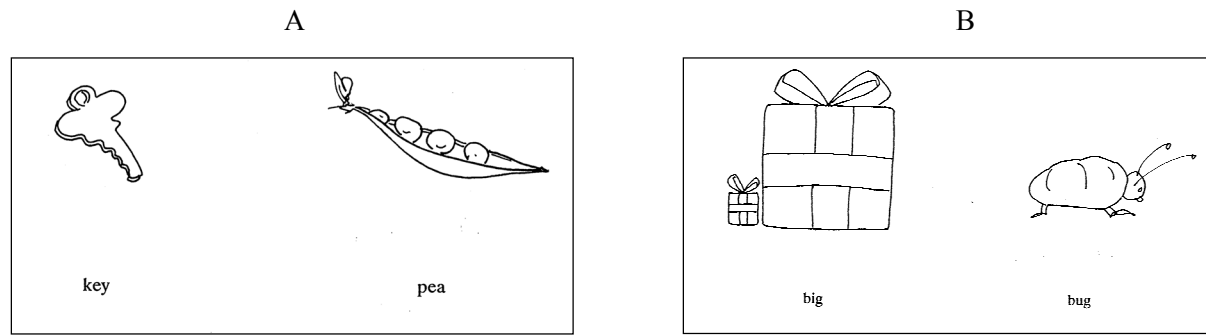


Figure 1. Examples of plates from the *Minimal Pairs Test* (Robbins et al., 1988). A) “Key” and “pea” differ by consonant place. B) “Big” and “bug” differ by vowel place.

Spoken Word Recognition. The *Phonetically Balanced Kindergarten Words* (PBK) test (Haskins, 1949) is an open-set test of spoken word recognition, with a total of 25 items in each list. There are four available lists of 50 words, but only three lists and 25 of the 50 words on each list were used in the present study. Each child was presented with only one list in each testing session. Like the *Minimal Pairs Test*, words in the PBK test were presented in an auditory-only live-voice format. Children were then asked to repeat the word they perceived. For example, the clinician said “sled” and the child should have responded, “sled” if they correctly heard the word. Children’s responses were scored according to percent words correct.

Sentence Comprehension. The *Common Phrases* test (Osberger et al., 1991) is an open-set test of sentence comprehension, with a total of 30 items. Sentences were presented in one of three formats: Auditory-only (CPA), Visual-only (CPV), and Combined Auditory+Visual (CPAV). Children heard and/or saw a sentence spoken by the clinician and were asked to repeat the sentence back to the clinician or answer appropriately. For example, the clinician might say, “When is your birthday?” The child’s response would be considered correct if he or she repeated, “When is your birthday?” or answers “August.”

Independent Measures

Communication mode was determined by consulting the medical charts for each child on file at the Indiana University Medical Center.

Results

By 2 years post-implant, most children achieved near-ceiling levels of discrimination performance for vowel height, vowel place, and consonant manner (see Figures 2 & 3). Most children achieved plateaus in performance, but not ceiling performance, for consonant place and voicing. Consistent with previous findings in closed-set tests, there were no overwhelming differences in performance between Oral Communication and Total Communication children. However, Oral Communication children’s performance was consistently more accurate across all tests compared to that of Total Communication children.

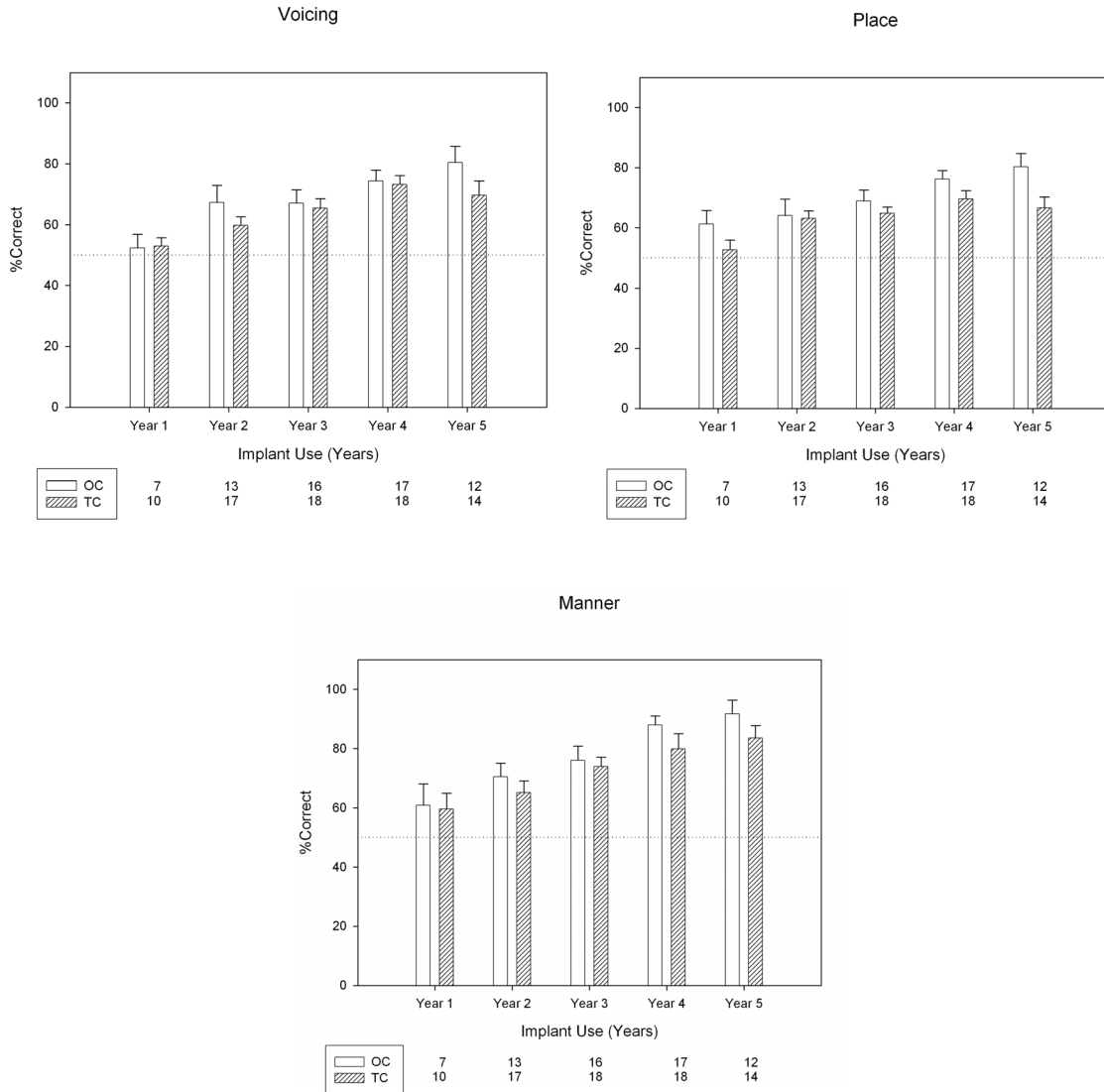


Figure 2. Percent correct for consonant features in the Minimal Pairs Test. Numbers below each graph represent sample size for the Oral Communication and Total Communication groups at each year of implant use. Error bars represent standard error.

Spoken word recognition and sentence comprehension scores increased over time but never reached ceiling levels, regardless of communication mode (see Figure 4). Nevertheless, Oral Communication children exhibited superior performance for measures of spoken word recognition and sentence comprehension compared to Total Communication children. Speech feature discrimination skills appear to increase in parallel with spoken word recognition and sentence comprehension skills.

Speech feature discrimination performance (Minimal Pairs) was strongly correlated with open-set spoken word recognition performance (PBK) and sentence comprehension (Common Phrases) (see Table 2). The correlations were stronger for Oral Communication children compared to those for Total Communication children.

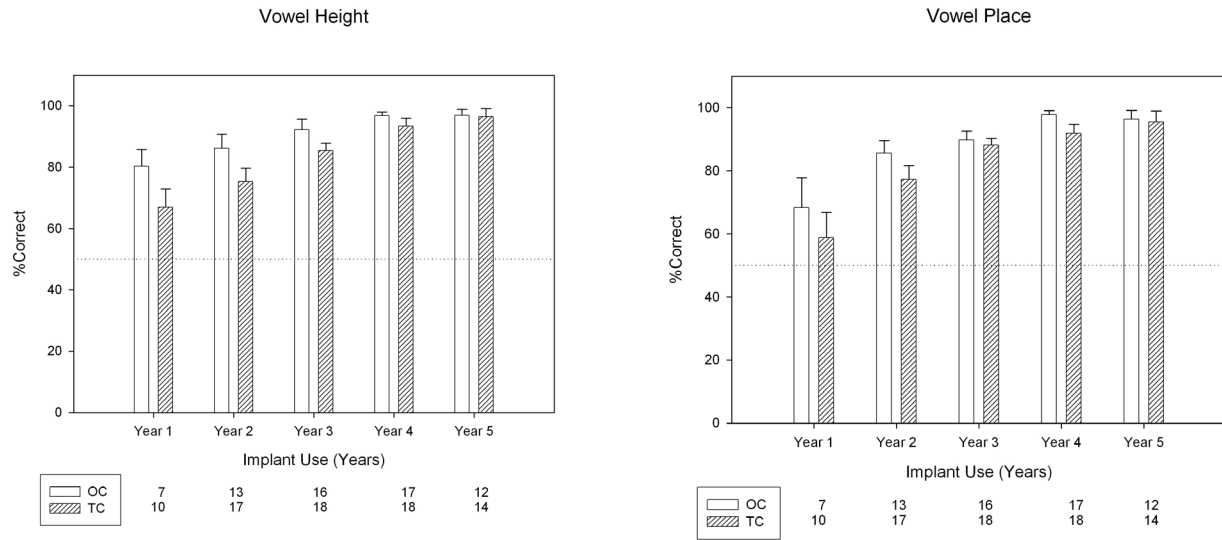


Figure 3. Percent correct for vowel features in the Minimal Pairs Test. Numbers below each graph represent sample size for the Oral Communication and Total Communication groups at each year of implant use. Error bars represent standard error.

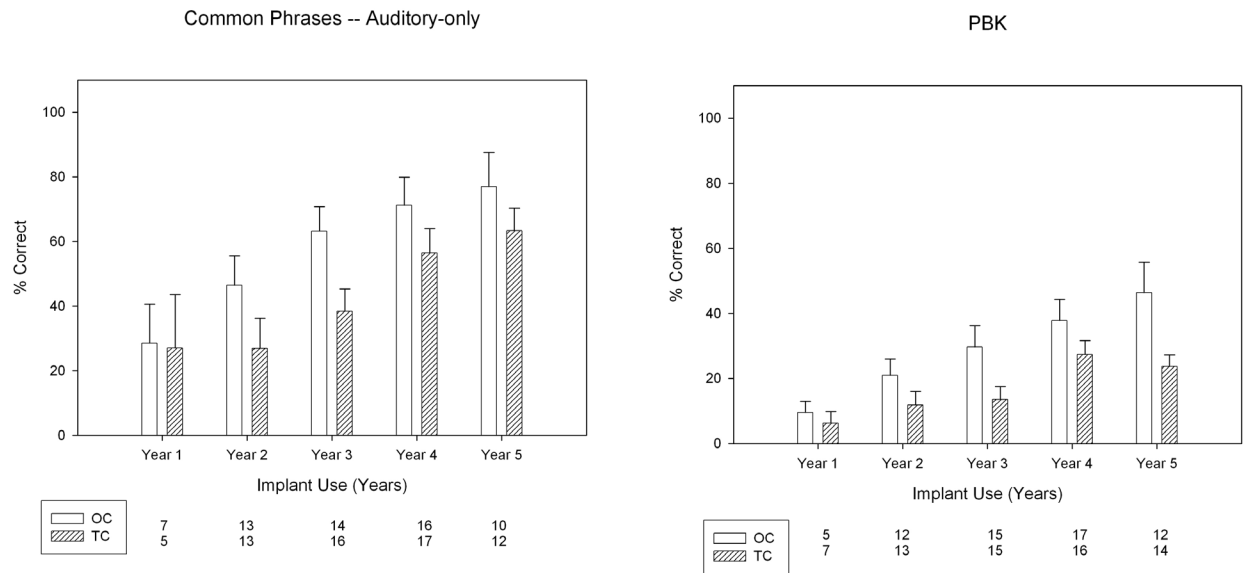


Figure 4. Percent correct for CPA and PBK. Numbers below each graph represent sample size for the Oral Communication and Total Communication groups at each year of implant use. Error bars represent standard error.

Minimal Pairs Test

	Oral Communication					Total Communication				
	Consonants			Vowels		Consonants			Vowels	
	Manner	Place	Voice	Height	Place	Manner	Place	Voice	Height	Place
	r =	r =	r =	r =	r =	r =	r =	r =	r =	r =
Speech Feature Discrimination										
Minimal Pairs – Place	.81**	--	--	--	--	.62**	--	--	--	--
Minimal Pairs – Voicing	.50*	.30	--	--	--	.44*	.36	--	--	--
Minimal Pairs – Vowel Height	.55*	.61**	.33	--	--	.34	.17	.36	--	--
Minimal Pairs – Vowel Place	.33	.57*	.31	.75**	--	.44*	.36	.43*	.15	--
Spoken Word Recognition										
PBK	.65**	.58*	.51*	.52*	.64**	.36	.43	.56*	.58*	.41
Sentence Comprehension										
Common Phrases – A	.50*	.58*	.46*	.47*	.71**	.38	.24	.63**	.45*	.41
Common Phrases – V	.30	.01	.33	.26	.08	-.11	-.43	-.04	-.19	.10
Common Phrases – A+V	.76**	.63**	.37	.47*	.43	.14	.10	.33	.47*	.12

* p < .05, ** p < .01 (n = 14-18)

Table 2. Correlations with the Minimal Pairs Test for Oral Communication and Total Communication groups at Year 3 of implant use.

General Discussion

Speech feature discrimination skills in deaf children with cochlear implants do improve across time, but may not reach the levels typically observed in normal-hearing children, particularly for minimal pairs involving discrimination of fine phonetic features such as consonant place and consonant voicing. By two years post-implant, the majority of these children achieved near-ceiling levels of discrimination performance for vowel height, vowel place, and consonant manner. Most of the children also achieved plateaus in performance but did not reach ceiling performance for consonant place and voicing. Communication mode affected outcome measures, with a slight advantage for Oral Communication children over Total Communication children in speech feature discrimination, spoken word recognition, and sentence comprehension. If speech feature discrimination underlies spoken word recognition and sentence comprehension, we would expect positive correlations between performance on the MP test and measures of word recognition and sentence comprehension (e.g., Blamey et al., 2001; Rabinowitz et al., 1992). As expected, we found that children who performed better on the MP test also performed better on more complex speech and language measures that rely on more basic speech feature discrimination skills. We also found that the relationship between speech feature discrimination, spoken word recognition, and sentence comprehension was stronger for children in oral-only communication environments compared with children in total communication environments. Moreover, these skills appear to increase in parallel rather than hierarchically (i.e., speech feature discrimination → spoken word recognition → sentence comprehension). Correlations among measures of speech feature discrimination, spoken word recognition, and sentence comprehension are consistent with the recent proposal that individual differences and variability in performance may arise not only from traditional demographic variables but also from central cognitive or psychological processes such as perception, learning, and memory (Pisoni et al., 1999).

References

- Blamey, P.J., Sarant, J.Z., Paatsch, L.E., Barry, J.G., Bow, C.P., Wales, R.J., Wright, M., Psarros, C., Rattigan, K., & Tooher, R. (2001). Relationships among speech perception, production, language, hearing loss, and age in children with impaired hearing. *Journal of Speech, Language, and Hearing Research, 44*, 264-285.
- Haskins, H. (1949). A phonetically balanced test of speech discrimination for children. Unpublished Master's Thesis, Northwestern University, Evanston, IL.
- Pisoni, D.B., Cleary, M., Geers, A.E., & Tobey, E.A. (1999). Individual differences in effectiveness of cochlear implants in children who are prelingually deaf: New process measures of performance. *The Volta Review, 101*, 111-164.
- Osberger, M.J., Miyamoto, R.T., Zimmerman-Phillips, S., Kemink, J.L., Stroer, B.S., Firszt, J.B., & Novak, M.A. (1991). Independent evaluation of the speech perception abilities of children with the Nucleus-22 channel cochlear implant system. *Ear & Hearing, 12*, S66-S80.
- Rabinowitz, W.M., Eddington, D.K., Delhorne, L.A., & Cuneo, P.A. (1992). Relations among different measures of speech reception in subjects using a cochlear implant. *Journal of the Acoustical Society of America, 92*, 1869-1881.
- Robbins, A.M., Renshaw, J.J., Miyamoto, R.T., Osberger, M.J., & Pope, M.J. (1988). *Minimal Pairs Test*. Indianapolis, IN: Indiana University School of Medicine.