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**Speech Perception in Children with the Clarion (CIS),
Nucleus-22 (SPEAK) Cochlear Implant or Hearing Aids¹**

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Abstract. Multichannel cochlear implants allow many children with prelingual (< 3 years of age) profound hearing loss to obtain high levels of speech perception. New devices and processing strategies provide substantial benefit to many children with cochlear implants (CIs). Two groups of children with profound prelingual hearing loss who received implants prior to the age of six participated in the study: (1) all children in the U.S. (N=179) who received a Clarion implant (CIS strategy) prior to June 1997 and participated in the clinical trials for FDA approval; and (2) all 40 children who received a Nucleus-22 implant (SPEAK strategy) and participated in the Indiana University CI program. Twenty-six children who wear hearing aids acted as the control group in the study. Speech perception was assessed with the Mr. Potato Head Test (Robbins, 1993) a modified open-set test of word recognition. Performance for the children who use CIs was compared to predictions from a linear regression analysis of chronological age on test score for the children who use hearing aids. By 12-18 months of implant use, average performance for the children with implants equaled average performance predicted for the children with hearing aids at the same chronological age. Significant differences were not found between the two groups of children who use implants, perhaps due to the small number of participants who were followed up to 18 months in this study.

Introduction

Recently, we examined the speech perception abilities of children with profound prelingual hearing loss acquired prior to the age of three who used either multichannel cochlear implants (CIs) or hearing aids (Meyer, Svirsky, Kirk & Miyamoto, in press; Svirsky & Meyer, in press). Speech perception scores for children who use CIs were compared to predicted scores from children with profound prelingual hearing loss and use hearing aids. The predictions for the children who used hearing aids were obtained by performing linear regression analyses of speech perception scores as a function of age. In the first study (Meyer, et al., in press), we examined both closed- and open-set speech perception in children who use the Nucleus-22 implant. In that study, few of the children with CIs used the SPEAK (Skinner et al., 1994) processing strategy, and many of the children changed speech processors over time. Nevertheless, after approximately three to five years of implant use, the average speech perception scores of the children using CIs matched those predicted for the children using hearing aids with pure-tone-average (PTA) hearing losses (at 500-, 1000-, and 2000-Hz) between 90-100 dB HL.

In the second study (Svirsky & Meyer, in press), we examined speech perception of all of the children in the United States with profound prelingual hearing loss who received a Clarion implant prior to the age of 12 and participated in the clinical trials for FDA approval. All of the children used the continuous-interleaved-sampling (CIS) processing strategy (Wilson et al., 1991) since implantation. In that study, we examined open-set word and phoneme recognition on the PBK Test (Haskins, 1949). Average scores for the children who use implants reached the average levels predicted for the children who use hearing aids with PTAs between 90-100 dB HL by approximately 12-18 months of implant use.

In the present study, we examined speech perception by children with profound prelingual hearing losses who received an implant before the age of six and used a single state-of-the-art speech processing strategy since implantation. One group used the Nucleus-22 implant and the SPEAK strategy, and the second group used the Clarion implant and the CIS strategy. Average performance over time by

the children who use implants was then compared to the average predicted performance for the children who use hearing aids. The comparisons were made only between children using the same form of communication, either Oral or Total Communication (the simultaneous use of signed and spoken English).

Methods

Participants

Children who use Hearing Aids. Twenty-six children with prelingual profound hearing losses with PTAs between 90 and 100 dB HL (HA_{90-100}) in their better ear participated in the study. Sixteen used Oral Communication and ten used Total Communication. The mean age at onset of deafness and age at the time the hearing aids were fit did not differ as a function of communication mode. The children were between 2 and 15 years of age at the time of testing.

Children who use Cochlear Implants. All children had prelingual profound hearing losses and received a CI prior to the age of six. Of the 40 children who received the Nucleus implant, 20 used Oral Communication and 20 used Total Communication. Of the 179 children who received the Clarion implant, 92 used Oral Communication and 87 used Total Communication. The average age at onset of deafness, the average age at implantation, and the average PTA in the better ear were virtually identical for the two groups of children (see Table 1).

Table 1

**Age at onset of profound hearing loss, age at initial fitting with device, and PTA.
Mean \pm standard deviation (range).**

Group	Onset (yrs)		Fit (yrs)		PTA, better ear (dB HL)	
	Oral Comm	Total Comm	Oral Comm	Total Comm	Oral Comm	Total Comm
Clarion Implant	0.3 \pm 0.6 (0.0-2.5)	0.2 \pm 0.5 (0.0-2.5)	3.2 \pm 1.1 (1.6-5.8)	3.3 \pm 1.2 (1.5-5.9)	107.8 \pm 8.6 (88.3 - 120)	113.6 \pm 7.9 (86.7 - 120)
Nucleus-22 Implant	0.3 \pm 0.6 (0.0-2.1)	0.1 \pm 0.4 (0.0-1.5)	3.2 \pm 1.1 (1.5-5.3)	3.3 \pm 1.0 (1.8-5.3)	110.8 \pm 6.1 (98.3-120)	114.2 \pm 5.7 (100-120)
HA₉₀₋₁₀₀	0.1 \pm 0.3 (0.0-1.0)	0.5 \pm 0.8 (0.0-2.5)			95.2 \pm 3.6 (90 - 100)	96.5 \pm 2.6 (93.3 - 100)

Speech Materials

For the present analysis, one measure (Mr. Potato Head Test [Robbins, 1993]) was selected, as this was given to virtually every child with an implant in the two databases. The Mr. Potato Head Test is a 10-item modified-open-set test of speech perception appropriate for a young child. The child responds by placing items on Mr. Potato Head or by having Mr. Potato Head perform specific tasks. The test is scored for total sentences and number of key words correct. The test is administered in an auditory-only mode via live-voice at approximately 70 dB SPL.

Testing Intervals

The children who used the Nucleus implant were tested preoperatively, and at 6-month or yearly intervals by one of seven speech-language pathologists or audiologists. The children who used the Clarion implant were tested preoperatively, and at 3-, 6-, 12-, and 18-months postimplantation at one of approximately 30 sites involved in the Clarion clinical trials. The average ages of the children in the two CI groups did not differ significantly at any of the testing intervals.

Statistical Analysis

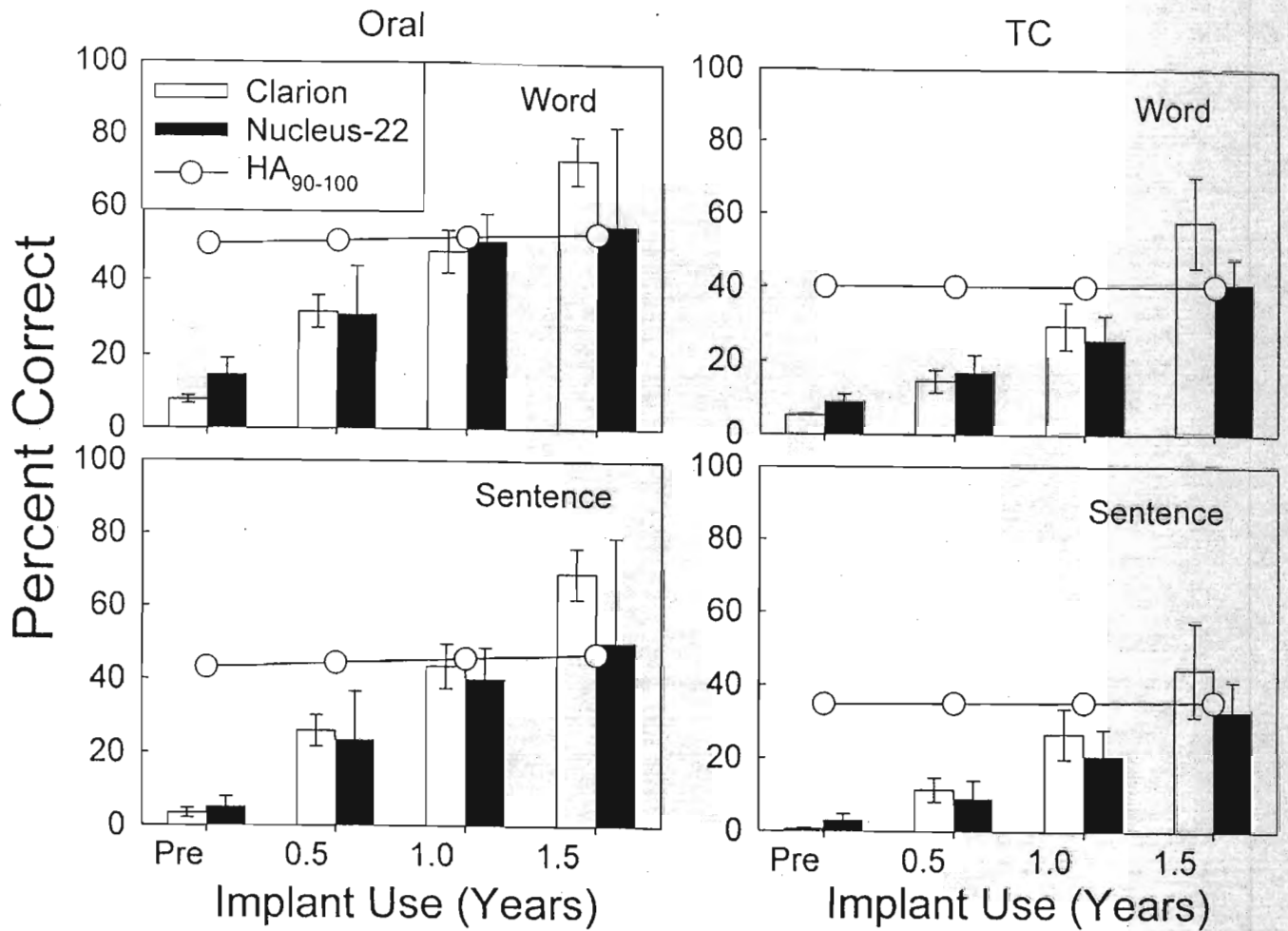
Linear regression analyses of speech perception scores as a function of age at testing were carried out for the children who use hearing aids. This was done to assess the effects of maturation on speech perception scores in the absence of implantation. Regressions were carried out separately for the children using Oral and Total Communication. Some of the children who use hearing aids were young enough to be given the Mr. Potato Head Test, and the rest were given the PBK Test. If the child was given the Mr. Potato Head Test, that score was used. If the child was given the PBK Test, performance on the Mr. Potato Head Test was estimated from performance on the PBK Test. Previous data collected in our laboratory demonstrated a strong positive linear correlation ($r = .90$) between performance on the PBK and Mr. Potato Head Tests for children with profound prelingual hearing loss who use either CIs or hearing aids (Pisoni, Svirsky, Kirk & Miyamoto, 1997).

Results

As illustrated in Figure 1, average scores were just slightly above chance levels immediately prior to implantation for the groups of children using CIs, regardless of communication mode or device. Within each mode of communication, average performance for the children who use implants improved at a faster rate than the predicted performance by the children who use hearing aids. For the children who use Oral Communication, average performance for the children who use implants approached the average predicted performance by the children in the HA₉₀₋₁₀₀ group after 12-18 months of implant use. For the children who use Total Communication, average performance for the children who use implants approached the average predicted performance by the children in the HA₉₀₋₁₀₀ group after 18 months of implant use.

Insert Figure 1 about here

No significant differences were found at any test interval for the two groups of children who use implants. Average performance levels were very similar for the two groups of children who use CIs up to 12 months postimplantation. At the 18-month testing interval, the average performance for the children who use the Clarion implant was approximately 15% higher than the average performance for the children with the Nucleus-22 implant. However, due to the small sample size, and the large amount of intersubject variability, this difference was not statistically significant for either mode of communication (e.g., for the children who use Total Communication, $t = 1.24$, $p = .233$). Given the average performance levels and variability in the data at the 18-month testing interval, a power analysis revealed that the probability of finding a significant difference between performance between the two implant devices for those children who use Total Communication was approximately 20%, assuming that such an underlying difference existed. To make a comparison with 80% power (a much more reasonable figure) would require 46 children in each group.



Clarion	N = 92	54	40	19			
Nucleus-22	N = 14	6	18	3	87	45	25
					17	17	15
							9
							10

Figure 1. P(C) vs. implant use for the Mr. Potato Head Test for the children using CIs. Word scores are shown in the top panels and sentence scores are shown in the bottom panels. Data from the children in Oral Communications programs are shown in the left two panels while data from the children in Total Communications programs are in the right two panels. Error bars are the SEM. The number of cochlear implant users tested are listed below each testing interval. Data from the children using hearing aids are predictions from linear regressions based on the average age of the children using CIs at each testing interval.

Summary

We compared the performance of children who used the latest speech processing strategies continuously since implantation for the two implants currently approved for routine clinical use in children in the United States: the Clarion device and the Nucleus-22 device. No statistical differences were found for the two groups of children who use CIs. Further longitudinal studies with larger numbers of children may yet reveal differences in performance with the two devices. After 12-18 months of implant use the average performance for children with implants matched the average word and sentence identification scores predicted for the children with PTAs between 90-100 dB HL who use hearing aids. As CI technology improves, it may become important to compare the speech perception of children with cochlear implants to that of children with hearing losses in the severe range (70-90 dB HL), some of whom may become candidates for cochlear implantation in the future. Audiological criteria for implantation clearly warrants further examination and the criteria will certainly change as the scientific knowledge in this area increases.

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