

**Critical Review:**  
**Speech Perception and Production in Children with Cochlear Implants in Oral and Total Communication Approaches**

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This critical review examines the speech perception and production outcomes of children with cochlear implants in either oral or total communication settings. Results of several studies provide suggestive evidence for the advantage of oral communication for speech perception and production. However, one mixed groups longitudinal study provides compelling evidence of no significant difference in speech production outcomes between participants in either group, if children receive their implants in preschool. Clinical implications of results are explored below.

***Introduction***

The two communication methods commonly available for children with hearing impairment are oral and total communication (Bergeson, Pisoni & Davis, 2003). Oral Communication (OC) focuses on developing oral language and listening skills and includes methods like auditory verbal therapy and cued speech (Bergeson et al., 2003). In contrast, total communication (TC) methods include an emphasis on signed language, often with the use of sign and oral language simultaneously (Connor, Hieber, Arts & Zwolan, 2000). Families of children with profound hearing loss receiving cochlear implants are often faced with the decision of which communication method they would like their child to use. Therefore, professionals working with these families should be familiar with the research outcomes for both communication methods, in order to assist families in making informed decisions for their child.

***Objectives***

The primary objective of this review is to analyze and contrast the speech perception and production outcomes of children with cochlear implants who are in oral or total communication environments. The purpose is to understand whether any significant differences exist between outcome scores for children in either group.

***Methods***

**Search Strategy**

The following terms were searched in the computerized databases PubMed, PsychINFO and CINAHL: (Child\*) AND (Cochlear implants) AND (speech perception) OR (speech production) AND/OR (OC) AND/OR (TC). Some works meeting the selection criteria and referenced in other articles were included.

**Selection Criteria**

Papers were selected based on direct comparisons of pediatric cochlear implant users in oral and total

communication environments and on their inclusion of speech perception and/or production measures. This resulted in the exclusion of several papers, or the exclusion of larger portions of a study with the exception of specific speech-related measures.

**Data Collection**

Papers included in this review are mixed group longitudinal studies (2), between groups studies (2), mixed groups studies (1), and a within groups study including a between groups analysis relevant to the current review (1).

***Results***

**Miyamoto, Kirk, Svirsky & Sehgal (1999)**

This mixed groups study investigated the effects of age at cochlear implantation on development of speech and language skills. A group of 33 children participated and were divided by age at implantation (<3 years, 3- 3;11 and 4-5;3) and communication mode (OC or TC). Although the study provides demographic information on the mean length of implant use, mean age at testing and mean pure tone averages in each group, authors do not reveal the number of children in each communication mode group. Children had all received implants prior to 6 years of age. Data were analyzed from the test interval closest to the child's chronological age of 4;6 months, in order to control for chronological age, while leaving age of implantation as an independent variable. Tests were administered prior to implantation and at 6 months intervals thereafter. A number of objective and appropriate measures were employed to measure speech perception and production including 1. *Grammatical Analysis of Elicited Language: Pre-sentence Level (GAEL-P)*, measuring closed-set speech perception, 2. *The Mr. Potato Head Task*, measuring open-set speech perception and 3. *Beginner's Intelligibility Test (BIT)*, measuring speech intelligibility. Auditory-only live voice conditions were used for all speech perception tests.

Results were appropriately analyzed using ANOVAs. Findings revealed that children in OC settings performed significantly better on closed-set speech perception tests than children in TC settings, and earlier implanted groups achieved significantly higher closed-set speech perception scores. The OC group achieved significantly higher open-set word recognition and speech intelligibility than the TC group.

Although authors controlled for chronological age, they did not control for duration of implant use. Their sample size was not large (n=33), and they did not specify the number of children in OC and TC groups. Due to the above limitations, the study's evidence was determined to be suggestive of the advantage of OC over TC approaches for better speech perception and production outcomes.

#### **Jiménez, Pino & Herruzo (2009)**

This between groups study examined speech perception outcomes of children in OC and TC environments. Participants included 18 prelingually deaf children between 4;3 and 8 years of age (M=6.25 years). All children had received unilateral cochlear implants between the ages of 15 months and 5 years (M=3.2 years). Children were divided by communication mode used (OC and TC) prior to and post-implantation. The number of children in each group was not included. The lack of significant group differences in the characteristics of gender, age, age of implantation, age of diagnosis, and duration of implant use was confirmed using appropriate statistical analyses. Highly recognized standardized tests and other evaluations were completed by the lead author of the paper and two clinical psychologists viewed recordings of the assessments, resulting in an inter-observer reliability of 100%.

An appropriate ANOVA analysis was used to compare the OC and TC groups. OC children performed significantly better than TC children on subtests of the *Illinois Test of Psycho-linguistic Abilities (ITPA)* pertaining to speech perception (Auditory Reception and Auditory Association) as well as had significantly greater intelligibility scores. However, the TC group performed better on subtests of manual expression (gesture use) and verbal expression (verbal fluency). The authors explain that the TC children were able to use more words using a picture stimulus, suggesting generalization of signing skills into spoken language.

Strengths of this study include the matching of particular children based on common characteristics and confirming similarities statistically. However, the study's sample size was small and the authors do not reveal how many children were in the OC and TC

groups. Due to the above limitations, the study provides suggestive evidence of the advantage of OC approaches for speech perception outcomes.

#### **Bergeson, Pisoni & Davis (2003)**

This mixed longitudinal study examined the development of audiovisual perception skills in children with cochlear implants. Selection criteria included profound hearing loss before 36 months and implantation before the age of 9. Participants were divided into groups by communication mode (either OC or TC) and date of implantation (early <53 months and late > 53 months of age). There were 38 participants in the OC group and 42 in the TC group, which were divided further into early and late implanted groups. The *Pediatric Sentence Intelligibility (PSI)* test was employed to assess closed-set speech perception in auditory-only, visual-only, and audiovisual conditions. In addition, the *Phonetically Balanced Kindergarten (PBK)* test was used as an open-set auditory alone speech perception measure and the *Beginner's Intelligibility Test (BIT)* was used as a speech intelligibility measure. Children were tested every 6 months to a year for 3 years.

An appropriate Maximum Likelihood estimation method was employed to avoid eliminating participants due to missing data, and a SAS Mixed procedure was used to analyze effects within the study. Results indicate that overall across groups, closed-set speech perception was consistently better in the audiovisual conditions compared to auditory-only and visual-only conditions. Results of open-set speech perception and speech intelligibility were combined across groups and used to determine if they were correlated with closed-set speech perception outcomes.

Results indicated that children in OC educational settings had consistently higher closed-set speech perception scores than children in TC settings and showed larger improvements over time. OC children performed better than TC children on visual alone and auditory alone presentation conditions prior to implantation and 3 years post-implantation. These outcome scores in auditory-only, visual-only, and audiovisual conditions were highly correlated with speech intelligibility scores, suggesting that children who had better speech perception in each of the conditions also had greater speech intelligibility scores. TC children's performance reached that of the OC children 2 years post implantation.

A strength of this study is its large sample size (n=80). However, due to its limited control for duration of implant use and not revealing the age range of

participants, it presents suggestive evidence of stronger speech perception skills for children in OC settings.

#### **Lachs, Pisoni & Kirk (2001)**

This within groups study examined the influence of audiovisual information on speech perception in children with cochlear implants. Participants included 27 children (4.2-8 years) with prelingual deafness who had used their implants for 2 years. Mean age of implantation was 4.52 years (range 2.2-5.8 years), and mean age for onset of deafness was 0.51 years. Mean unaided pure tone averages were 112 dB HL. During the study, all participants were enrolled in aural rehabilitation programs that provided training and therapy. The *Common Phrases Test* was administered live voice to children under auditory-only, visual-only and audiovisual conditions. The following open-set tests were also administered in auditory-only conditions: *The Lexical Neighborhood Test (LNT)*, *Multisyllabic Lexical Neighborhood Test (MLNT)*, *Phonetically Balanced Kindergarten (PB-K)* word lists. Although this study was a within group study, authors included a between group analysis of children in OC and TC environments. Speech intelligibility of 11 children in OC settings and 12 children in TC settings was measured with the *The Beginner's Intelligibility Test (BIT)*.

Appropriate t-tests for independent samples found that speech intelligibility scores for the OC group were significantly higher than the scores for the TC group. Scores in auditory-only and audiovisual conditions on the *Common Phrases Test* were used to compute the relative improvement in speech perception due to additional visual information. A significant correlation was found between speech intelligibility scores and audiovisual gain. Correlations suggest that children who receive more gain from audiovisual information have more intelligible speech, suggesting a link between speech perception and production skills in implanted children. A marginally significant correlation was found between audiovisual enhancement and speech intelligibility for children in the OC group but no significant correlation was found for the TC group. Authors concluded that speech intelligibility scores could be predicted from the audiovisual gain scores for children in OC environments, but not for children in TC environments.

The strengths of this study include that it controlled for duration of implant use and that all children had similar access to aural rehabilitation services during the study. Limitations of this study include smaller sample sizes for the OC (n=11) and TC groups (n=12). Due to the above limitations, this study provides suggestive evidence for stronger speech production outcomes for children in OC approaches.

#### **Hodges, Dolan Ash, Balkany, Schloffman & Butts (1999)**

This between groups study examined factors contributing to speech perception outcomes of children using cochlear implants. Participants were 40 children (2-17 years) who received their implants at a mean age of 6 years old (range 2-14 years old). CI use ranged from 3 months to 5 years. There were 21 children using TC and 19 using OC who did not differ significantly on preoperative pure tone averages. Speech perception tests administered included the *Early Speech Perception Test (ESP)*, *Northwestern University Children's Perception of Speech Test (NU-CHIPS)*, *Minimal Pairs*, and *Phonetically Balanced Kindergarten (PBK)* word lists. Speech perception testing was done in auditory-only conditions. Implants were verified to be functioning before testing.

Results, using appropriate t-tests, demonstrated that those in OC environments achieved significantly higher scores on both closed and open-set speech perception tests than those in TC environments. In addition, authors used regression analysis to analyze other factors contributing to speech perception outcomes. Results indicated that children who were in oral communication environments, attending private schools, in higher SES groups and with access to private therapy scored higher on speech perception measures. Factors which least influenced speech perception outcomes were age at surgery, device type, and bilingualism in the home. The strongest correlation to open-set speech perception scores was communication mode. However, authors note that children in oral communication environments were more likely to come from higher SES groups, attended private schools and received private therapy services. It should be noted that children in the study using TC approaches all attended public school programs, while only 2 children in the OC group attended public schools. In examining the results of TC and OC children in SES group 4 (both groups with n=8), the OC group scored significantly higher on speech perception tests, suggesting that although SES is a contributing factor, it alone does not account for the differences in speech perception outcomes.

This study had a reasonable sample size (n=40), but the range of age at implantation (2-14 years) and duration of use (3 months to 5 years) was large. These factors were not controlled for in the data analysis, and although the regression analysis states that age of implantation and length of use did not significantly impact results, other studies have shown that these are significant factors in communication outcomes (Connor et al., 2000), putting the validity of results in question.

Due to the above limitations, the evidence in this study is equivocal.

#### **Connor, Hieber, Arts & Zwolan (2000)**

This mixed group longitudinal study followed 147 children with cochlear implants to determine the effects of communication mode in educational settings on speech production and receptive and expressive language. Participants were grouped according to age at implantation and communication mode (OC or TC). Communication mode groups consisted of 81 and 66 children, respectively, which were classified based on teaching approach in the school setting and parent report. All children attended public schools, however, the degree of inclusion in mainstream classes in both communication groups was variable. Participant selection criteria included: deafened prelinguistically, age at implantation of 1-10 years, and nonverbal cognitive abilities that were within normal limits as assessed by a clinical psychologist. Participants used the Nucleus 22 Processor with MPEAK of SPEAK encoding strategies. Speech production skills were measured using either the *Arizona Articulation Proficiency Scale: Revised* or the *Goldman-Fristoe Test of Articulation* and were modified in order to better describe speech errors produced by deaf children. Pictures were presented without a verbal model and productions were transcribed fully, including additional words produced. Transcribed data was entered into PROPH + software, which calculated a percent consonants correct (PCC) score. Appropriate inter-rater reliability measures were taken and found to be acceptable. Two levels of hierarchical linear modeling (HLM) were appropriately used to analyze the trajectory of outcome growth curves by chronological age over time for each variable. Authors controlled for age at implantation, preoperative aided speech detection thresholds, type of cochlear implant used, and whether active electrode arrays were implanted.

Results indicated that overall, children in the OC group achieved higher expected PCC scores and their scores grew at a more rapid rate in comparison to the TC group. There was no significant difference in effect size and rate of growth over time between PCC outcome scores for children in OC and TC groups if they received their implants in preschool. When comparing OC and TC groups within the early elementary and late elementary age of implantation groups, OC children had significantly higher expected PCC scores with greater rates of growth than children in the TC group. However, the effect of communication mode was either mitigated or enhanced by factors including age of implantation, the sophistication of implant technology and the presence of active electrode arrays.

Strengths of this study include its large sample size and variety of variables controlled. This study was also longitudinal and provided a realistic picture of speech development over time for children with cochlear implants. This study provides compelling evidence for no difference in speech production outcomes between the two groups, provided children are implanted in preschool.

#### **Discussion**

Several of the above studies suggest that children with cochlear implants in oral communication environments have better speech perception and production skills (Miyamoto et al., 1999; Jiménez et al., 2009; Bergeson et al., 2003 & Lachs et al., 2001). Bergeson et al. (2003) suggests that children in OC environments have more experience combining both auditory and visual cues during speech, while children in TC environments typically divide their attention visually between the hands and mouth of the speaker, accounting for the difference in speech perception outcomes between the two groups. Lachs et al. (2001) suggests that better perception of these auditory and visual cues results in greater speech intelligibility. Although evidence suggests that communication mode has a significant effect on outcome scores, several studies identified crucial factors affecting speech perception and production outcomes including socioeconomic status, enrollment in private schools, access to private therapy (Hodges et al., 1999);, and age at implantation (Connor et al., 2000; Miyamoto et al., 1999). Despite studies suggesting the advantage of OC approaches for speech production outcomes (Miyamoto et al., 1999; Lachs et al., 2001), Connor et al. (2000) provides compelling counter evidence indicating no significant difference in speech intelligibility between communication mode groups if children are implanted in preschool. It is important to note that speech perception and production skills are not a measure of the overall effectiveness of a child's communication skills. Both receptive and expressive language skills are required for effective communication. Although Connor et al.'s (2000) study found no significant difference between OC and TC receptive vocabulary scores in age at implant groups, the TC group achieved overall significantly higher expected receptive vocabulary scores over time. TC children also achieved significantly higher expected expressive vocabulary scores over time overall and if they received their implant in preschool or early elementary (ages 5-6.9 years) (Connor et al., 2000). Ultimately, regardless of communication mode, children implanted in preschool achieved significantly greater expressive vocabulary scores in comparison with children who were implanted after the age of 5 (Connor et al., 2000). Therefore, it seems that for overall speech and language development, age at implantation, rather

than communication approach, is a key factor influencing the development of skills required for effective communication. Further longitudinal research needs to be done with this population to investigate communication outcomes of these two approaches, ensuring the use of large sample sizes, the monitoring of progress over time, and the control for a variety of variables.

#### ***Clinical Implications***

Based on the above evidence, it is essential for clinicians to advocate for early diagnosis and implantation, and to present both oral and total communication methods as valid communication approaches for children and families. In addition, to ensure effective speech perception and production development, clinicians should support children in developing audiovisual speech perception skills by learning to perceive audiovisual cues for the articulatory movements of speech.

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