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Speech intelligibility and prosody production in children with cochlear implants

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ABSTRACT

Objectives: The purpose of the current study was to examine the relation between speech intelligibility and prosody production in children who use cochlear implants.
Methods: The Beginner's Intelligibility Test (BIT) and Prosodic Utterance Production (PUP) task were administered to 15 children who use cochlear implants and 10 children with normal hearing. Adult listeners with normal hearing judged the intelligibility of the words in the BIT sentences, identified the PUP sentences as one of four grammatical or emotional moods (i.e., declarative, interrogative, happy, or sad), and rated the PUP sentences according to how well they thought the child conveyed the designated mood.
Results: Percent correct scores were higher for intelligibility than for prosody and higher for children with normal hearing than for children with cochlear implants. Declarative sentences were most readily identified and received the highest ratings by adult listeners; interrogative sentences were least readily identified and received the lowest ratings. Correlations between intelligibility and all mood identification and rating scores except declarative were not significant.
Discussion: The findings suggest that the development of speech intelligibility progresses ahead of prosody in both children with cochlear implants and children with normal hearing; however, children with normal hearing still perform better than children with cochlear implants on measures of intelligibility and prosody even after accounting for hearing age. Problems with interrogative intonation may be related to more general restrictions on rising intonation, and the correlation results indicate that intelligibility and sentence intonation may be relatively dissociated at these ages.

Learning outcomes: As a result of this activity, readers will be able to describe (1) methods for measuring speech intelligibility and prosody production in children with cochlear implants and children with normal hearing, (2) the differences between children with normal hearing and children with cochlear implants on measures of speech intelligibility and prosody production, and (3) the relations between speech intelligibility and prosody production in children with cochlear implants and children with normal hearing.

1. Introduction

Cochlear implants are primarily aids to sound perception, but in both adults and children, they can also aid in the production of spoken language. The speech and spoken language of children with cochlear implants have been examined at several structural levels, including the articulatory, the phonological, and the morphological. For communication, however,

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overall speech intelligibility is the gold standard for assessing the benefit of cochlear implantation for the production of speech, because it addresses directly the communicative function of language. Speech intelligibility involves the transmission and reception of linguistic information and meaning, or, as Kent, Weismer, Kent, and Rosenbek (1989) define it, "the degree to which the speaker's intended message is recovered by the listener." Speaking to the importance of measuring intelligibility, Subtelney (1977) proposes that "intelligibility is considered the most practical single index to apply in assessing competence in oral communication."

Previous research in clinical and nonclinical populations has identified segmental and suprasegmental production factors that may be associated with overall speech intelligibility. An obvious potential factor is the articulation accuracy of consonants and vowels. De Bodt, Huici, & Van De Heyning (2002) report that articulation was the strongest contributor to intelligibility in a study of English-speaking dysarthria patients. However, although articulation may be a major factor for intelligibility, it is not equivalent to intelligibility. De Bodt et al. (2002) cite several other contributing factors, such as voice quality, nasality, and prosody, and Peterson and Marquardt (1994) note that "'Articulation' and 'intelligibility' are related, but they are not identical. If a speaker distorts the sound element but does so in a consistent manner, her speech may be easily intelligible because of the predictability of the errors" (p. 59). Weismer and Martin (1992) describe an extensive literature reporting moderate negative correlations between intelligibility and segmental errors in persons with hearing loss, including omissions of word-initial phonemes (Hudgins & Numbers, 1942; Levitt, Stromberg, Smith, & Gold, 1980); voicing and consonant cluster errors (Hudgins & Numbers, 1942); manner substitutions for consonants and substitution of non-English segments (Levitt et al., 1980); and vocalic errors (Smith, 1975). Suprasegmental and prosodic factors have also been implicated in the degree of speech intelligibility (Parkhurst & Levitt, 1978; Smith, 1975). Factors cited by Weismer and Martin (1992) that potentially affect the intelligibility of persons with hearing loss include rhythm (Hudgins & Numbers, 1942), segment and pause durations (Monsen, 1974), stress, fundamental frequency (Stevens, Nickerson, & Rollins, 1983), fundamental frequency contours (McGarr & Osberger, 1978), intonation, and voice quality. Thus, speech intelligibility may be affected not only by segmental characteristics but also by suprasegmental and prosodic characteristics as well.

Prosody is the melody and rhythm of spoken language. Operationally, prosody can be defined as "the suprasegmental features of speech that are conveyed by the parameters of fundamental frequency, intensity, and duration"; such suprasegmental features include stress, intonation, tone, and duration (Kent & Kim, 2008). How children acquire target-appropriate prosodic structure is important because it plays a role in many aspects of linguistic function, from lexical stress to grammatical structure to emotional affect; it is therefore important for the transmission of meaning and thus for intelligibility. Infants and children with normal hearing are sensitive to prosody in language (*motherese*: Fernald, 1985; *foot structure*: Jusczyk, Houston, & Newsome, 1999; Thiessen & Saffran, 2003; *phrase boundaries*: Hirsch-Pasek et al., 1987; *meter*: Jusczyk et al., 1992; Mehler et al., 1988). Typically developing children also exhibit cross-linguistic prosodic patterns in their speech productions. For example, 18- to 24-month-old children tend to omit unstressed syllables from their utterances (e.g., "banana" becomes "nana"). By the age of 2–3 years, children begin to master phrasal stress, boundary cues, and meter in their production of speech (e.g., Clark, Gelman, & Lane, 1985; Klein, 1984; Snow, 1994). Finally, by the age of 5 years, children are capable of reproducing intonation (Koike & Asp, 1981; Loeb & Allen, 1993).

Control over prosodic aspects of language such as stress and intonation can be problematic for children with hearing loss. In a study of intonation in children with hearing loss, O'Halpin (2001) cites various factors that may underlie problems with intonation: respiratory problems resulting in fewer syllables per breath unit (Forner & Hixon, 1977; Osberger & McGarr, 1982); problems coordinating respiratory and laryngeal muscles resulting in atypical pausing and lack of gradual decline in fundamental frequency toward the ends of sentences (Osberger & McGarr, 1982); problems with phoneme shortening or lengthening resulting in lack of differentiation of stressed and unstressed syllables (La Bruna Murphy, McGarr, & Bell-Berti, 1990). Furthermore, because constructs such as stress correspond to multiple physical parameters (e.g., duration, intensity, fundamental frequency), implementation by children with hearing loss may not correspond exactly to ambient implementation, even if there is a perception of apparent correctness. O'Halpin cautions against remediation that targets only single parameters without consideration of remaining parameters, as this may change a child's phonological system in undesired directions.

There have been no comprehensive investigations into prosody production in children with cochlear implants, although several studies have investigated specific areas of prosody production in this population. Lenden and Flipsen (2007) examined prosody and voice characteristics in 6 children aged 3–6 years with 1–3 years of cochlear implant experience using the Prosody–Voice Screening Profile (PVSP; Shriberg, Kwiatkowski, & Rasmussen, 1990), which was used to assess phrasing, rate, stress, loudness, pitch, laryngeal quality, and resonance quality in a sample of conversational speech. In their 6 children, Lenden and Flipsen found substantial problems with stress and resonance quality; some problems with rate, loudness, and laryngeal quality; and no consistent problems with phrasing or pitch. Also using conversational and narrative speech, Lyxell et al. (2009) examined prosody production in 34 children ages 5–13 years who had received cochlear implants between 1 and 10 years of age. Various prosodic characteristics were examined at both the word level (vowel length, tonal word accent, stress) and at the phrase level (questions, stress). Results indicated that children with cochlear implants had lower scores on measures of prosody production at both the word level and the phrase level than the children with normal hearing.

Using a nonword repetition task, Dillon, Cleary, and colleagues (Carter, Dillon, & Pisoni, 2002; Cleary, Dillon, & Pisoni, 2002; Dillon, Burkholder, Cleary, & Pisoni, 2004) found that 7- to 9-year-old children with 3–7 years of cochlear implant experience in English-speaking environments produced segmental characteristics more poorly than suprasegmental characteristics, such as the number of syllables and the placement of primary stress; in these studies, 64% of imitations