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Early predictors of phonological and morphosyntactic skills in second graders with cochlear implants

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A R T I C L E I N F O

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Purpose: Newborn hearing screening has made it possible to provide early treatment of hearing loss to more children than ever before, raising expectations these children will be able to attend regular schools. But continuing deficits in spoken language skills have led to challenges in meeting those expectations. This study was conducted to (1) examine two kinds of language skills (phonological and morphosyntactic) at school age (second grade) for children with cochlear implants (CIs); (2) see which measures from earlier in life best predicted performance at second grade; (3) explore how well these skills supported other cognitive and language functions; and (4) examine how treatment factors affected measured outcomes.
Methods: Data were analyzed from 100 second-grade, monolingual English-speaking children: 51 with CIs and 49 with normal hearing (NH). Ten measures of spoken language and related functions were collected: three each of phonological and morphosyntactic skills; and four of other cognitive and language functions. Six measures from preschool and seven from kindergarten served as predictor variables. The effects of treatment variables were examined.
Results: Children with CIs were more delayed acquiring phonological than morphosyntactic skills. Mean length of utterance at earlier ages was the most consistent predictor of both phonological and morphosyntactic skills at second grade. Early bimodal stimulation had a weak, but positive effect on phonological skills at second grade; sign language experience during preschool had a negative effect on morphosyntactic structures in spoken language.
Conclusions: Children with CIs are delayed in language acquisition, and especially so in phonological skills. Appropriate testing and treatments can help ameliorate these delays.

What this paper adds?

Numerous studies have assessed the spoken language skills of children with cochlear implants. Mean performance is reliably found to be one standard deviation below that of peers with normal hearing, and variability is typically large. The current study extended those earlier investigations by asking if those performance levels are consistent across language domains, if they could be predicted from language measures obtained during the preschool years, and how early treatment

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factors affect outcomes. In particular, skills based largely on sensitivity to phonological versus morphosyntactic structure were examined separately: the first should be greatly and negatively affected by the signal degradation introduced by implant processing, while the latter should be more immune to such effects. This study contributes new knowledge to our understanding of language acquisition by children with cochlear implants with the separate analyses of language skills in the phonological and morphosyntactic domains, and with the longitudinal analyses. It was discovered that acquisition of phonological and morphosyntactic skills is largely independent of each other, but that early morphosyntactic abilities strongly predict school-age performance in both domains for children with cochlear implants. Basic models of language development are enhanced by the finding that children's initial linguistic schemas are reorganized into phonological and morphosyntactic structures during the early grade-school years. Finally, two treatment variables frequently implemented early in a child's life were found to have differing effects on later language abilities: a period of bimodal stimulation weakly, but positively affected phonological skills, while early exposure to sign language negatively affected morphosyntactic skills for spoken language.

1. Introduction

Children born with severe-to-profound hearing loss are at risk for significant delays in learning language. Fortunately, the recent implementation of mandatory hearing screening for all newborns, rather than only those with risk factors for hearing loss, has meant these children are now often identified shortly after birth, so treatment can begin early. Evidence from several investigators has reliably shown that the early initiation of both medical interventions, especially cochlear implantation (CI), and behavioral interventions can substantially ameliorate delays in language learning imposed by congenital hearing loss (Geers & Nicholas, 2013; Houston et al., 2012; Moeller, 2000; Ramos-Macías, Borkoski-Barreiro, Falcón-González, & Plasencia, 2014; Robbins, Osberger, Miyamoto, & Kessler, 1995). Nonetheless, mean performance of these children remains below that of children with normal hearing (NH) (Geers & Hayes, 2011; Spencer & Tomblin, 2009; Tobey et al., 2013) and gaps exist in our understanding of why that is. Further investigation into the challenges faced by children with hearing loss is warranted, so we may continue to refine the diagnostic language measures we use with these children, as well as our intervention practices.

Language is typically conceptualized as a unitary construct, but it is actually a network of interrelated cognitive structures. In the past, there has been little investigation into the relative degree of challenge imposed by hearing loss on learning for each of these separate structures. A useful way to categorize these structures for present purposes is to consider language as consisting of two primary layers: morphosyntactic and phonological. Morphosyntax refers to the way that words are selected and combined to generate meaningful sentences. Knowing how to select and combine words appropriately is foundational to skills such as understanding meaning in the spoken language of communication partners, and being able to generate sentences that others can comprehend. Knowledge of word classes and how words fit together can also constrain potential word choices when listening to speech, which is an aid to communication in adverse listening conditions or when a hearing impairment exists. Of course, that advantage is only realized by listeners who have sufficient knowledge of morphosyntactic structure.

Phonological structure refers to the internal structure of words, and is usually viewed as having three layers itself: syllabic structure within words, onsets and rimes within syllables, and the consonants and vowels (phonemes) that form those word constituents. The ability to readily recognize phonological (especially phonemic) structure in spoken language is fundamental to a variety of language functions, including learning to read, working memory, and comprehending speech under adverse conditions, including hearing loss. As with morphosyntax, knowledge of how phonemes can be concatenated to form words allows listeners to recognize linguistic structure when incomplete sensory information is available (e.g., Ahissar, Lubin, Putter-Katz, & Banai, 2006; Caldwell & Nittrouer, 2013).

Although both are likely essential to language function, the degree of transparency in the acoustic signal of these two levels of language structure differs, as illustrated in Fig. 1. This figure displays a waveform at the top, which reveals that global structure is rather well preserved just in the pattern of rising and falling amplitude across time. This pattern exists because syllables always contain a vowel nucleus, and frequently have consonantal constrictions on one or both sides. Vowel production generally involves a more open vocal tract than consonant production, so the undulating amplitude pattern helps to delineate words and syllables. Furthermore, the relative amplitude of the syllables as well as their length provides information about prosody. Accordingly, infants usually display adult-like syllable structure in their own productions very early in life. They start to produce 'canonical' syllables with power envelopes differing by at least 10 dB from peak to valley, with peak-to-peak durations of 100–500 ms and language-specific prosodic structure by 6 months of age (Oller, 1986). Thus, the acquisition of morphosyntactic structure, as well as of syllable structure, begins early.

Children's awareness of phonemic structure, on the other hand, does not start to emerge until near the end of preschool, just as they are about to enter the elementary school grades (Vihman, 1991). The reason for this protracted developmental course is found in the lower portion of Fig. 1, which displays a spectrogram. The continuous nature of this display illustrates that phonemes are not discretely represented in the acoustic speech signal. Instead, acoustic structure contributing to recognition of any single phoneme is spread broadly across the signal, and the spectral composition of any narrow slice of that signal is influenced by articulatory gestures affiliated with more than one phoneme. Listeners must apply language-specific strategies during speech perception in order to recover phonemic structure, and those strategies are acquired over the better part of the first decade of life. In tests requiring children to report (e.g., by counting) the number of smaller