RESEARCH ON SPOKEN LANGUAGE PROCESSING
Progress Report No. 22 (1998)
Indiana University

The Structure of the Mental Lexicons of Pediatric Cochlear Implant Users: A Preliminary Report[1]

Steven B. Chin,[2] Ted A Meyer,[2] Marcia Hay-McCutcheon,[3] Gary A. Wright,[3] and David B. Pisoni[2]

Speech Research Laboratory
Department of Psychology
Indiana University
Bloomington, Indiana 47405

[1] This work was supported by NIH-NIDCD Institutional National Research Service Award T32 DC00012 and NIH/NIDCD Research Grants R01 DC00064 and R01 DC00423 to Indiana University. Portions of this research were presented at the Seventh Symposium on Cochlear Implants in Children, Iowa City, Iowa. We are grateful to Jan Charles-Luce, John Logan, Paul Luce, and Michael Vitevitch for suggestions and assistance with this study.
[2] Also DeVault Otologic Research Laboratory, Department of Otolaryngology–Head and Neck Surgery, Indiana University School of Medicine, Indianapolis, Indiana.
[3] DeVault Otologic Research Laboratory, Department of Otolaryngology–Head and Neck Surgery, Indiana University School of Medicine, Indianapolis, Indiana.

The Structure of the Mental Lexicons of Pediatric Cochlear Implant Users: A Preliminary Report

Abstract. At present, little is known about the structure of the mental lexicons of children who use cochlear implants. In this paper, we report preliminary analyses of errors from the Lexical Neighborhood Test, an open-set monosyllabic word recognition test, by children with profound hearing loss who use cochlear implants. Frequency and lexical neighborhood characteristics of errors were compared to those of target words using lexical databases derived from both child and adult word-frequency counts. Results demonstrate that pediatric cochlear implant users recognize words in the context of other, phonologically similar words. The structure of the mental lexicons of these children is discussed.

Introduction

Logan (1992) has proposed that children older than two years with normal hearing organize and retrieve words from their mental lexicons using a phoneme-based strategy similar to that used by adults. It is not clear if the mental lexicons of children with profound deafness who use cochlear implants are similarly organized, but understanding the structures of such lexicons is prerequisite to understanding how these children acquire the ability to recognize and produce spoken words. To examine this, errors produced by children with cochlear implants on the Lexical Neighborhood Test (LNT; Kirk, Pisoni, & Osberger, 1995), an open-set, monosyllabic word recognition test, were analyzed within the framework of the Neighborhood Activation Model (Luce, 1986; Luce & Pisoni, 1998).

The Neighborhood Activation Model (NAM) proposes that spoken word recognition occurs in the context of words that are phonemically similar to the target. A "similarity neighborhood" is comprised of the target and any words in the lexicon that differ phonologically from the target by substitution, deletion, or addition of a single phoneme. The neighborhood of the target /pik/, for instance, includes, among others, the neighbors /pɪk/ (substitution), /spik/ (addition), and /pi/ (deletion). Spoken word recognition is thus dependent on the frequency of occurrence (in the language) of the target, as well as two neighborhood characteristics: neighborhood density, which is the number of neighbors, and neighborhood frequency, which is the mean frequency of occurrence of the neighbors.

The Neighborhood Activation Model was originally proposed as an account of spoken word recognition by adults with normal hearing; it furthermore informs both the construction of the Lexical Neighborhood Test and the set of analyses presented here. It therefore provides a theoretical context in which the structure of the mental lexicons of children who use cochlear implants can be examined.

Method

Participants

Examined in this study were 15 children with prelingual (< 3 years old) profound hearing loss who received the Nucleus-22 cochlear implant (5 implementing MPEAK, 10 SPEAK). Mean age at onset of profound loss was 0.2 +/- 0.5 years, and mean age at implantation was 5.2 +/- 1.9 years. Seven of the children used oral communication (OC), and eight used total communication (TC). Children were selected based on their ability to complete the Lexical Neighborhood Test, a test of spoken word recognition.

Materials and Testing Protocol

At the two-year postimplant interval, each child was administered the Lexical Neighborhood Test (LNT). An open-set test was chosen over a closed-set test for this study, because the multiple-choice format of the latter is able to provide only minimal information about the structure of the lexicon and its contribution to spoken word recognition. The LNT includes target words that are "easy" and words that are "hard" to recognize, based on their frequency of occurence and characteristics of their competitors (neighbors). "Easy" words have a high frequency of occurrence in the language and reside in neighborhoods that are sparse and of low mean frequency. "Hard" words are of low frequency and reside in dense neighborhoods with high mean frequencies. The test was administered by live-voice presentation without visual cues at approximately 70 dB SPL, and participants were instructed to repeat the words they heard.

Analysis

Responses were scored according to percent phonemes and words correct, and were then analyzed according to parameters proposed in the Neighborhood Activation Model. Two computerized lexical databases were used to represent the mental lexicon: (1) to represent an adult lexicon, a 20,000-word on-line Webster's pocket lexicon (Nusbaum, Pisoni, & Davis, 1986), and (2) to represent a child lexicon, a 600-word lexicon for 5-year-old children (Wepman & Hass, 1969). Separate calculations were performed for users of OC and TC, as well as for the easy and hard words contained in the LNT.

Results

Percent Correct Words and Phonemes

Figure 1 shows percent correct scores for both whole words and phonemes in responses on the LNT. For OC users, words correct was 63.6% for easy words and 50.8% for hard words. For TC users, scores were 39.6% for easy words and 22.4% for hard words. For OC users, correct phonemes was 73.6% for easy words and 67.8% for hard words. For TC users, correct phonemes was 59.3% for easy words and 47.0% for hard words.

Insert Figure 1 about here

Within-Neighborhood Responses

Using an adult lexicon, it was determined whether or not responses resided in the neighborhoods of the relevant target words. Figure 2 shows the percent of total responses on the LNT that were either correct or incorrect but still in the neighborhood of the target.

Insert Figure 2 about here

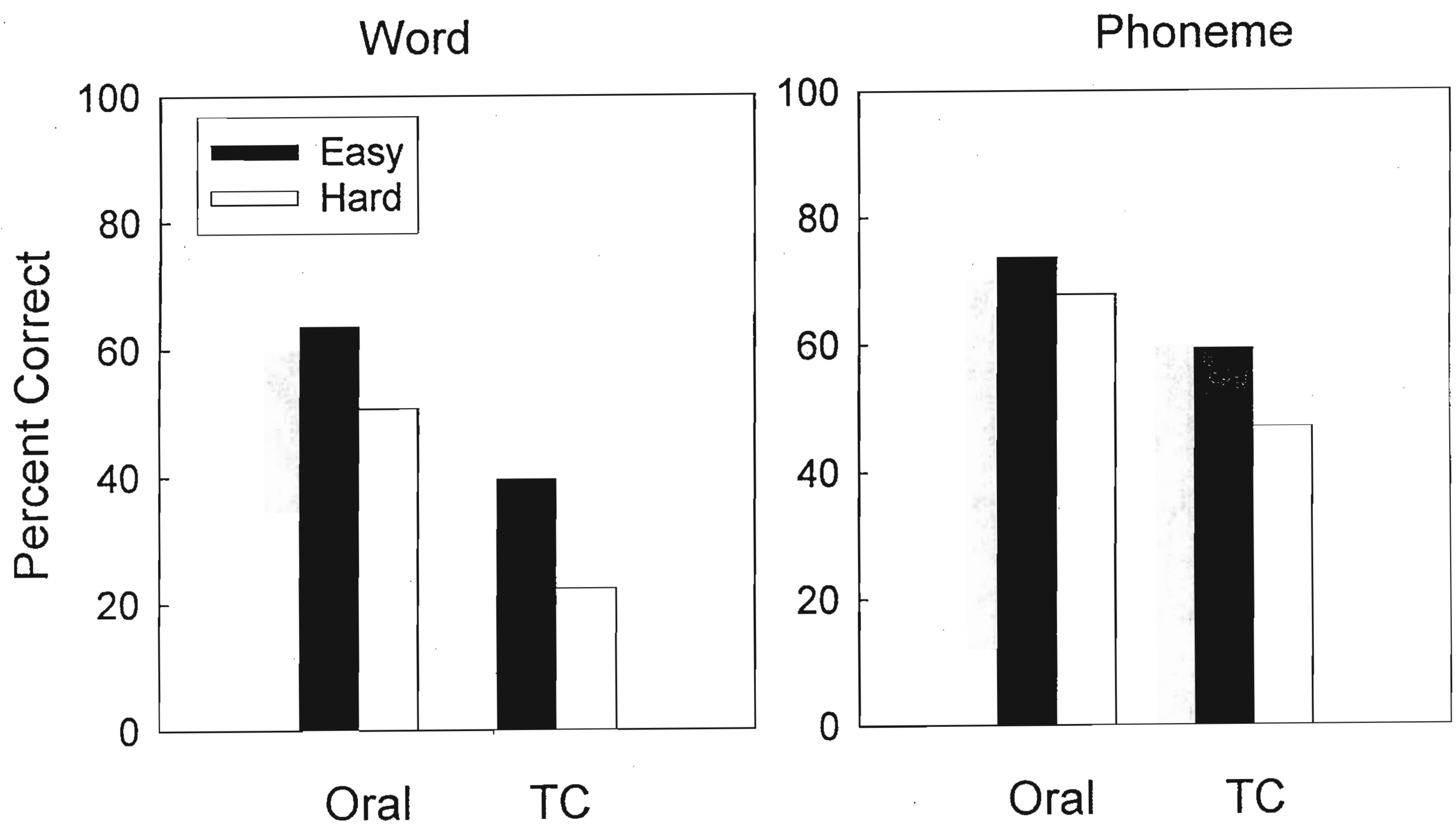

Figure 1. Percent correct words (left) and phonemes (right) on the LNT. (Easy - black, Hard - white).

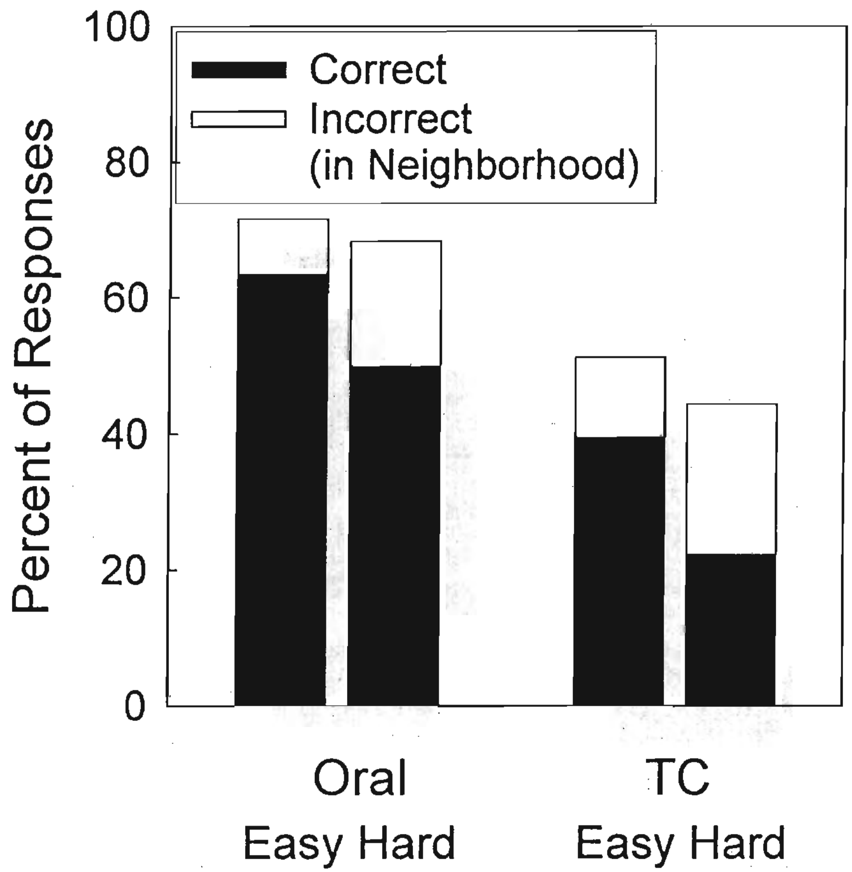

Figure 2. Percent of responses correct and incorrect but in the lexical neighborhood of the target (adult lexicon used).

For OC users, 63.6% of the easy word responses were correct, and 8.0% were incorrect but neighbors of the target; thus, 71.6% of the easy word responses were either the target word or neighbors of the target. Again, for OC users, 50.0% of the hard word responses were correct, with 18.4% of the responses incorrect but neighbors of the target; in total, 68.4% of the hard word responses were the target or neighbors of the target. Similar response patterns were displayed by the TC users, such that 39.6% of the easy word responses were correct, with 11.6% incorrect but in the neighborhood; thus, 51.2% of the responses were the target or neighbors of the target. Finally, TC users' responses to hard words were 22.4% correct and 22.0 incorrect but in the neighborhood, totaling 44.4% of responses for hard words as the target or neighbors of the target.

Frequency and Neighborhood Structures of Errored Responses

Frequency of occurrence and neighborhood characteristics (neighborhood density and neighborhood frequency) were determined for all errored responses. Separate calculations were performed using both an adult lexicon (Nusbaum et al., 1986) and a child lexicon (Wepman & Hass, 1969). Frequencies and neighborhood characteristics of target words and errored responses were then compared to determine whether these responses were "easier" or "harder" than targets.

Adult Lexicon. Using the adult lexicon, word frequency and neighborhood characteristics of errored responses to both easy and hard words were determined separately for users of OC and TC Results are illustrated in Figures 3 and 4.

Insert Figure 3 about here

Figure 3 shows the word frequency and neighborhood characteristics of errored responses to "easy" words on the LNT. For OC users, 23.1% of these responses were higher in frequency than the target (i.e., 76.9% were *lower* in frequency than the target), 78.6% came from neighborhoods that were more dense, and 64.3% came from neighborhoods with higher mean frequencies. For TC users, 33.1% of the errored responses to easy words were higher in frequency than the target (i.e., 66.9% of these responses were *lower* in frequency than the target), 61.6% were from more dense neighborhoods, and 61.6% were from neighborhoods with higher mean frequencies.

Figure 4 shows word frequency and neighborhood characteristics of errored responses to "hard" words on the LNT.

Insert Figure 4 about here

For OC users, 46.3% of the errored responses were higher in frequency than the target (i.e., 53.7% were *lower* in frequency than the target), 56.1% came from more dense neighborhoods, and 48.8% came from neighborhoods with higher mean frequencies. Finally, for TC users, 39.7% of the errored responses to hard words were higher in frequency than the target (i.e., 60.3% were *lower* in frequency than the target), 38.1% came from more dense neighborhoods, and 44.9% of the responses came from neighborhoods with higher mean frequencies.

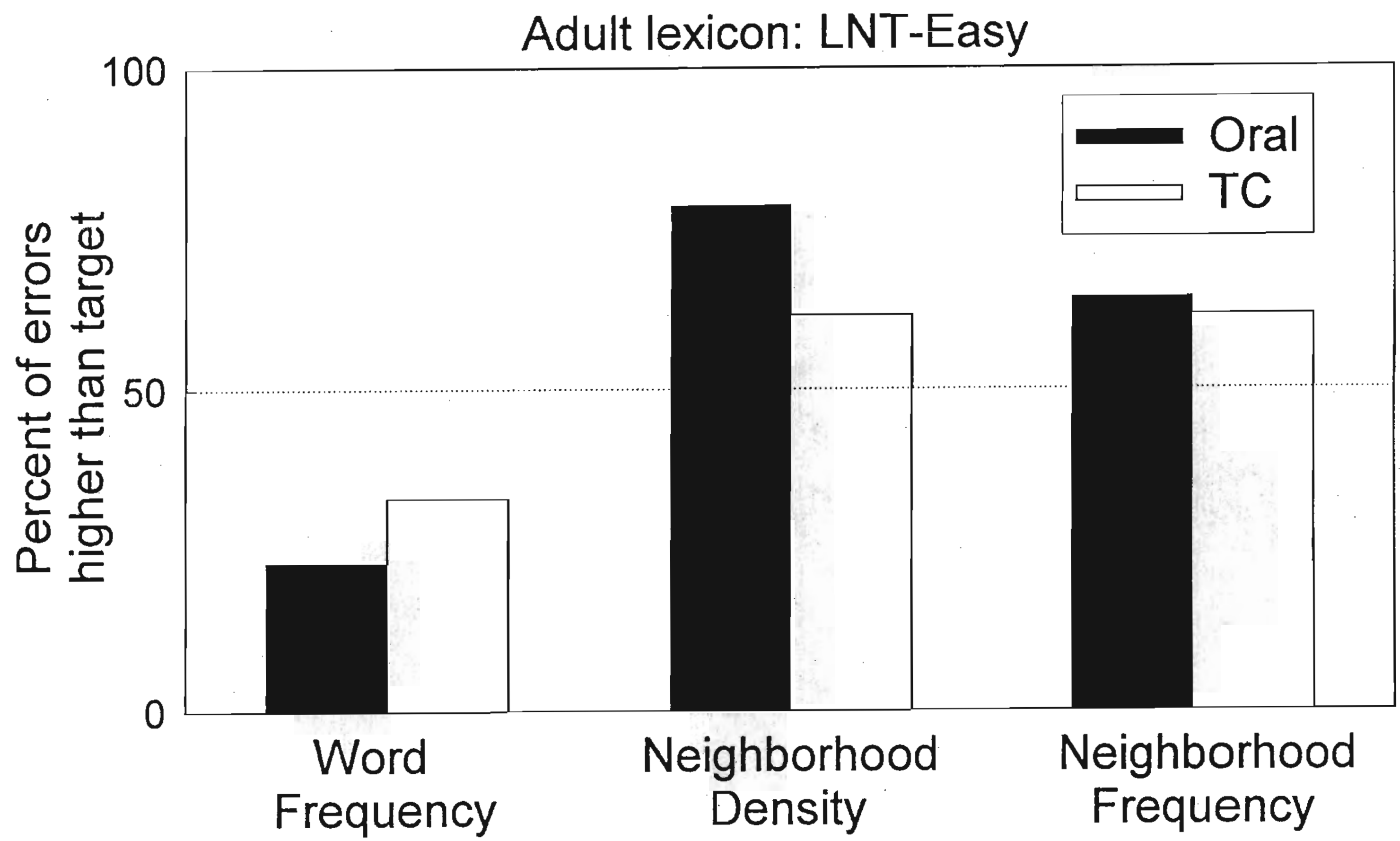

Figure 3. Percent of errors higher than target word in word frequency, neighborhood density, and neighborhood frequency (adult lexicon).

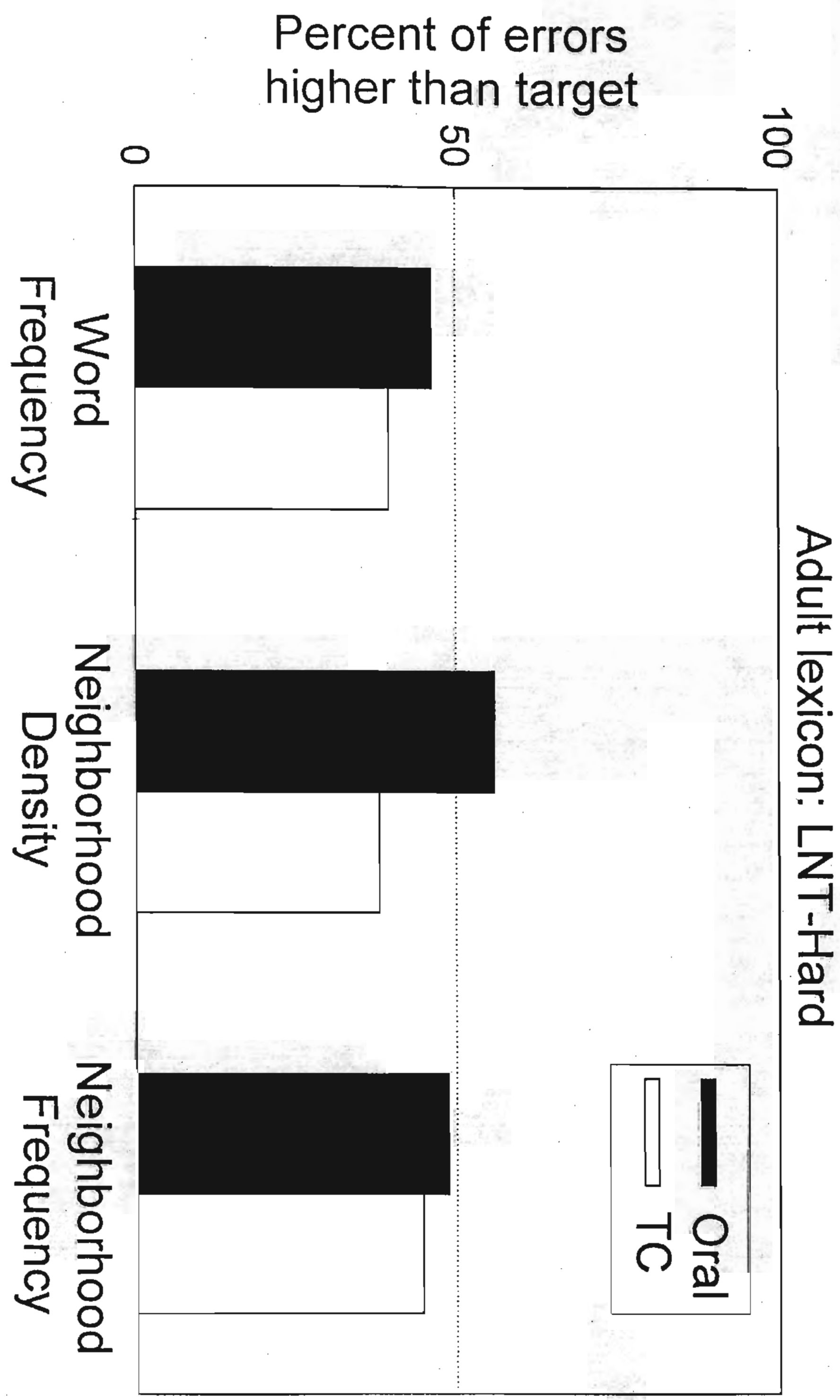

Figure 4. Percent of errors higher than target word in word frequency, neighborhood density, and neighborhood frequency (adult lexicon).

Child Lexicon. Using the vocabulary list for 5-year-olds (Wepman & Hass, 1969), word frequency and neighborhood characteristics of errored responses to both easy and hard words were determined separately for users of OC and TC. Results are shown in Figures 5 and 6.

Insert Figure 5 about here

Figure 5 shows word frequency and neighborhood characteristics for errored responses to "easy" words on the LNT as analyzed within the child lexicon. For OC users, 31.0% of the errored responses were higher in frequency than the target (i.e., 69.0% were *lower* in frequency than the target), 72.8% were from more dense neighborhoods, and 65.2% were from neighborhoods with higher mean frequencies. For TC users, 41.7% of these responses to easy words were higher in frequency than the target (i.e., 58.3% were *lower* in frequency than the target), 68.9% were from more dense neighborhoods, and 63.6% were from neighborhoods with higher mean frequencies.

Insert Figure 6 about here

Figure 6 shows the word frequency and neighborhood characteristics for errored responses to "hard" words on the LNT as analyzed in the child lexicon. For OC users, 55.1% of these responses were higher in frequency than the target (i.e., 44.9% were *lower* in frequency than the target), 44.4% were from more dense neighborhoods, and 46.0% were from neighborhoods with higher mean frequencies. Finally, for TC users' errored responses to hard words, 50.5% were of higher frequency of occurrence (i.e., 49.5 were of *lower* frequency) than the target, 42.0% were from more dense neighborhoods, and 42.7% were from neighborhoods with higher mean frequencies.

Discussion

As expected, phonemes correct scores were higher than words correct scores for both easy and hard words and for both OC and TC users. As the mean length of words on the LNT is three phonemes, this is evidence that children receive at least partial information regarding phonemes in words through the cochlear implant. Also as expected, both phonemes and words correct scores were higher for users of OC than for users of TC; this may indicate greater attention to acoustic information for the OC users than for the TC users. Further evidence that cochlear implants transmit information regarding the phoneme structure of words lies in the fact that between 44.4% and 71.6% (depending on communication mode and the easy vs. hard distinction) of responses were in the neighborhood of the target. For users of OC especially, these results indicate a structure of the lexicon much like that of adults, that is, a phoneme-based strategy of organization and extraction of words.

When analyzed within the adult lexicon, and depending on neighborhood structure of targets and communication mode, between 53.7% and 76.9% of responses were lower in frequency than targets, between 38.1% and 78.6% of responses came from neighborhoods more dense than those of targets, and between 44.9% and 64.3% of responses came from neighborhoods with higher mean frequencies than those of targets. There were thus a large number of responses that were "harder" than corresponding targets, when assessed within the context of the adult lexicon. Similar results were found when responses were analyzed within a children's lexicon. This type of result is not unexpected in the case of responses to "easy" words on the LNT, given that targets are near the "easy" ceiling. On the other hand, although "harder" responses to "hard" words may be counterintuitive, the fact is that the open-set

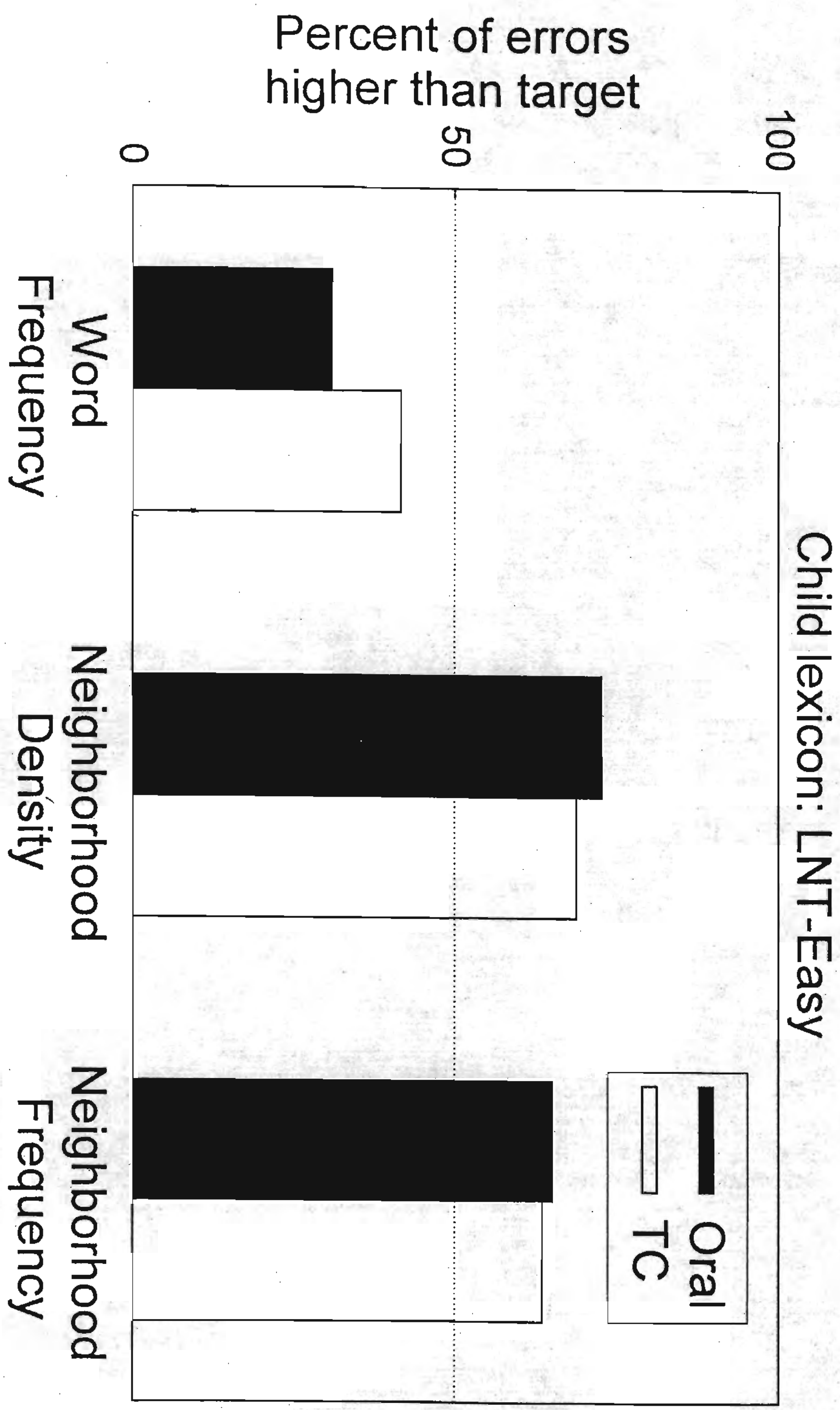

Figure 5. Percent of errors higher than target word in word frequency, neighborhood density, and neighborhood frequency (child lexicon).

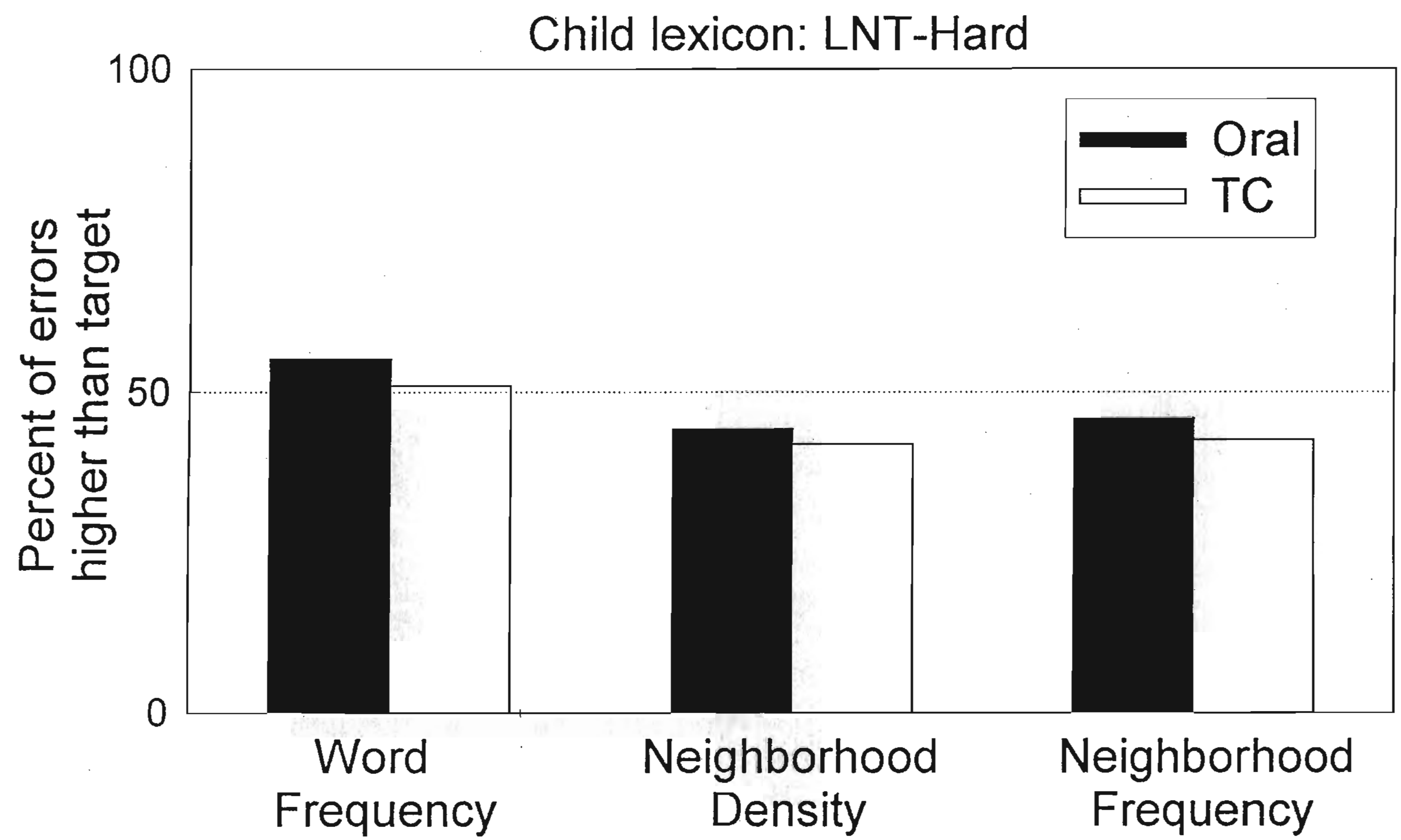

Figure 6. Percent of errors higher than target word in word frequency, neighborhood density, and neighborhood frequency (child lexicon).

response format of the LNT makes it effectively both a perception and production task, and little research has been conducted on the neighborhood characteristics of responses in a production task.

A related question addresses the proper context in which to analyze the frequency and neighborhood structure of responses on the LNT. Frequency and neighborhood structure have traditionally been assessed in the context of adult vocabularies (Luce, 1986). As has been shown elsewhere (Charles-Luce & Luce, 1990), however, the large differences between children's and adults' lexicons give rise to similarly large differences in the neighborhood structures of words contained in those lexicons. Test items for the LNT were selected from analyses of the vocabularies of 1- to 5-year-olds (Logan, 1992), somewhat younger than the children in the present study. The present study analyzed children's lexicons in the context of a spoken word list (Wepman & Hass, 1969) that had been investigated in previous studies of children's lexicons (Charles-Luce & Luce, 1990); moreover, this list was most likely more appropriate than Logan's for the age of the children under study here, given delays in language development. However, of the 100 stimulus items on the LNT, 45 do not appear in the child lexicon used, so that almost half of the target items had to be assigned zero frequencies when analyzed within the children's lexicon. A similar strategy was necessary for many of the responses. Further questions arise regarding elicitation procedures (e.g., spontaneous [Logan, 1992] vs. elicited [Wepman & Hass, 1969]) and the status of grammatically inflected forms.

Thus, although it may be the case that neighborhood structure analyses of children's responses have more face validity when conducted within the context of a putative children's lexicon, it is also true that determining the appropriate children's lexicon is a matter of debate. In fact, for longitudinal studies, it may well be that adult lexicons are still the best context within which to perform neighborhood structure analyses.

References

Charles-Luce J, & Luce PA. (1990). Similarity neighbourhoods of words in young children's lexicons. *Journal of Child Language*, **17**, 203-15.

Kirk KI, Pisoni DB, & Osberger MJ. (1995). Lexical effects on spoken word recognition by pediatric cochlear implant users. *Ear and Hearing*, **16**, 470-81.

Logan JS. (1992). *A computational analysis of young children's lexicons* (Research on Spoken Language Processing Technical Report No. 8). Bloomington, IN: Department of Psychology, Indiana University.

Luce PA. (1986). *Neighborhoods of words in the mental lexicon* (Research on Spoken Language Processing Technical Report No. 6). Bloomington, IN: Department of Psychology, Indiana University.

Luce PA, & Pisoni DB. (1998). Recognizing spoken words: The neighborhood activation model. *Ear and Hearing*, **19**, 1-36.

Nusbaum HC, Pisoni DB, & Davis CK. (1986). Sizing up the Hoosier mental lexicon: Measuring the familiarity of 20,000 words. In *Research On Speech Perception Progress Report No. 10* (pp. 357-376). Bloomington, IN: Department of Psychology, Indiana University.

Wepman JM, & Hass, W. (1969). *A spoken word count (children—ages 5, 6 and 7)*. Chicago: Language Research Associates.