

# NONWORD REPETITION ACCURACY OF CHILDREN WITH BILATERAL COCHLEAR IMPLANTS: EFFECTS OF AGE AND VOCABULARY SIZE

Emilie A. Sweet<sup>1</sup>, Jan Edwards<sup>2</sup>, Ruth Litovsky<sup>3</sup>, Cynthia Zettler<sup>4</sup>, Mary E. Beckman<sup>5</sup>, and Timothy Arbisi-Kelm<sup>6</sup>  
 University of Wisconsin-Madison<sup>1-4,6</sup>; Ohio State University<sup>5</sup>

## INTRODUCTION

- Children with severe-to-profound hearing loss who use cochlear implants (CI) have much better speech and language skills than children who use hearing aids.
- However, children with CIs still trail their peers with normal hearing (NH) on speech and language skills:
  - CI users have more articulation errors than age peers with NH (reference)
  - CI users significantly worse on tasks requiring word-learning of familiar and unfamiliar proper nouns (Houston et al., 2002)
- Comparison groups:
  - Hearing age may be more appropriate measure rather than chronological age for forming comparison group.
- Nonword repetition tasks:
  - Often used as measure of phonological working memory.
  - Nonword accuracy related to vocabulary size in NH children (e.g., Gathercole & Baddeley, 1989; Edwards et al., 2004)
  - Should be particularly difficult for CI users as they may rely more heavily on semantic content of real words.
- Bilateral CI users:
  - Existing studies on bilateral CI users indicate improved sound localization and speech perception (Grieco-Calub & Litovsky, 2009; Litovsky, Johnstone, & Godar, 2006)

## RESEARCH QUESTIONS

- What are the relative differences in accuracy for initial consonants in nonwords relative to real words for children with CIs, as compared to two comparison groups of children with NH?
- What is the relationship between initial consonant accuracy in nonwords and real words relative to age in children with CIs and children with NH?
- What is the relationship between initial consonant accuracy in nonwords and real words relative to receptive vocabulary size in children with CIs and children with NH?

## METHODS

### PARTICIPANTS

- Children with bilateral CI users from larger study on binaural hearing.
  - No problems other than hearing loss
- Children with NH from larger cross-linguistic study on phonological acquisition.
  - Age-appropriate hearing, speech, and language
- Two NH comparison groups.
  - Hearing age (HA) comparison: matched based on age-of-implantation of first CI.
  - Chronological age (CA) comparison.
- All children were monolingual English speakers.

	Number of females	Number of Males	Mean hearing age in years	Mean PPVT-4 standard score (SD)
Children with CIs	12	6	4;1	98.56 (13.84)
Children with NH	12	6	4;1	99.16 (10.83)

### CI users and NH chronological age comparison group

	Number of females	Number of Males	Mean chronological age in years; month	Mean PPVT-4 standard score (SD)
Children with CIs	10	1	4;10	102.64 (13.49)
Children with NH	10	1	4;9	103.82 (12.61)

### STIMULI

- Real words and nonwords with initial singletons /t/, /d/, /k/, /g/ or clusters /tw/, /kw/, /kj/
- Phonotactic probability for nonwords. Included both:
  - High phonotactic-probability contexts (/kw/ in *quick, quiz, quilt*)
  - Low or zero phonotactic-probability contexts (/kjo/)

## PROCEDURES and ANALYSIS

- Auditory word repetition task:
  - Real words: Picture of object presented along with a digitized prompt and the child was asked to repeat the word.
  - Nonwords: Picture of novel object (unusual animal, tool, plant, etc.) presented along with a digitized prompt and the child was asked to repeat the nonword.
  - Real word and nonword tasks presented on separate days.
  - Children's productions recorded for subsequent transcription.
- Peabody Picture Vocabulary Test-4 (PPVT-4) included to measure receptive vocabulary.
- Children's productions coded as correct/incorrect and substitutions transcribed by a trained phonetician, using a combination of listening and visual inspection of the waveform and spectrogram.

## RESULTS

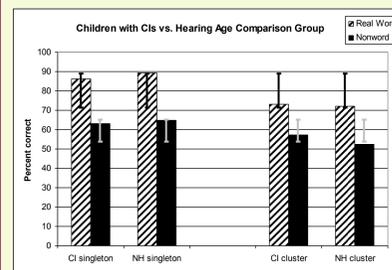


Figure 1. Mean accuracy scores for word-initial consonants in real words and nonwords by group and syllable structure (CA comparison group).

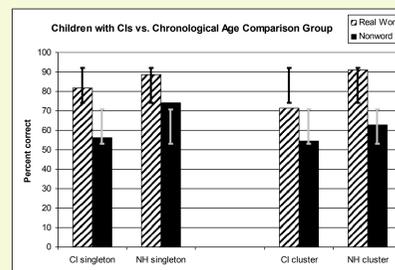


Figure 2. Mean accuracy scores for word-initial consonants in real words and nonwords by group and syllable structure (HA comparison group).

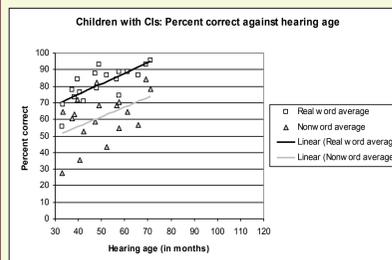
Children with CIs vs. HA comparison group

- Significant main effect of word type.
- Significant main effect of syllable structure.
- Main effect of group and all interactions were not significant.

Children with CIs vs. CA comparison group

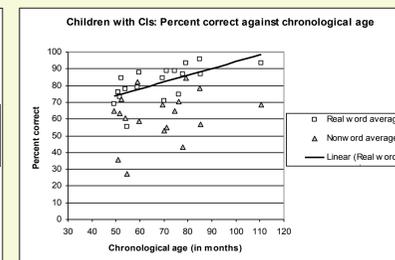
- Significant main effect of word type
- Significant main effect of group
- Main effect of syllable structure and all interactions were not significant.

## ACCURACY AGAINST AGE



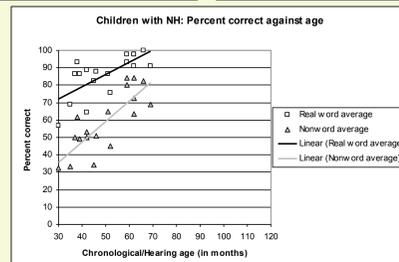
•Hearing age is correlated with real word accuracy ( $r^2 = .56$ )

•Hearing age is marginally correlated with nonword accuracy ( $r^2 = .22$ )



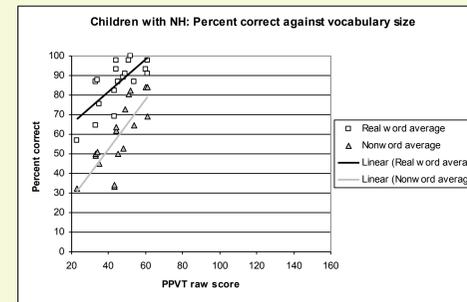
•Chronological age is correlated with real word accuracy ( $r^2 = .40$ )

•Chronological age is NOT correlated with nonword accuracy

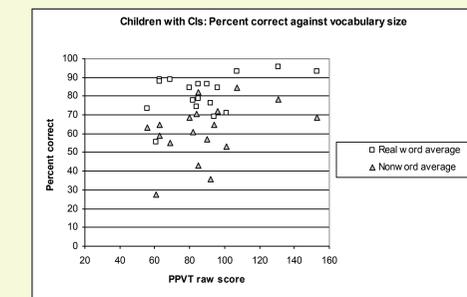


•Age is highly correlated with both real word accuracy ( $r^2 = .49$ ) and nonword accuracy ( $r^2 = .66$ )

## ACCURACY AGAINST VOCABULARY SIZE



•PPVT-4 raw score significantly correlated with real word ( $r^2 = .52$ ) and nonword accuracy ( $r^2 = .61$ )



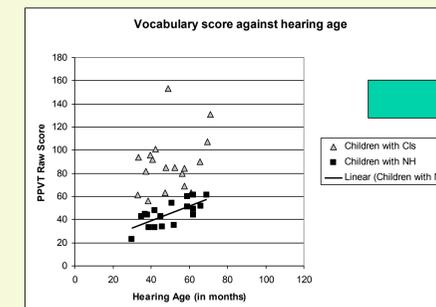
•PPVT-4 raw score is not significantly correlated with real word or nonword accuracy

•Why is PPVT-4 raw score not correlated with production accuracy for children with CIs?

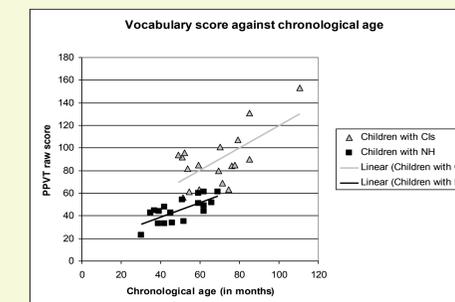
•We did an additional analysis to examine the relationship between PPVT-4 raw score and age to address this question.

## VOCABULARY SCORE AGAINST AGE

- Children with CIs: Hearing age NOT correlated with PPVT raw score
- Children with NH: Age correlated with PPVT raw score ( $r^2 = .52$ )



- Children with CIs: Chronological age correlated with PPVT raw score ( $r^2 = .42$ )
- Children with NH: Age correlated with PPVT raw score ( $r^2 = .52$ )



## DISCUSSION AND CONCLUSIONS

- Do children with CIs have particular difficulty with nonword repetition?
  - No, at least not for the initial consonants analyzed in this study.
  - There was no significant word type by group interactions, for either comparison group. for the CI users and the NH chronological age and hearing age match comparison groups.
  - Also, no group effect at all for CI users and their hearing age matches.
- Question 2:
  - CI users' accuracy more strongly correlated with hearing age than chronological age
  - As expected, NH children's accuracy correlated with chronological age
- Question 3:
  - Accuracy and vocabulary size correlated for NH children, but not for CI users

## CLINICAL IMPLICATIONS

- CI users' accuracy and vocabulary size are not correlated
  - Poor speech production skills do not necessarily imply poor vocabulary skills for CI users as it would for NH children
- Speech production accuracy more correlated with hearing age
  - CI users can be expected to have speech production skills more like their HA peers
- Language more correlated with chronological age
  - CI users can be taught age appropriate vocabulary
- Disconnect in word learning for CI users
  - CI users learn conceptual and semantic representations from birth
  - Once implanted, they can create phonological representations of conceptual vocabulary

## FUTURE DIRECTIONS

- Test a unilateral CI user comparison group would provide a valuable comparison
  - If bilateral CI users' results are improved, may provide evidence supporting additional cost and surgical risk of second CI.
- Use stimuli that are more difficult to perceive
  - CI users in this study performed well on these stimuli as they were fairly easy for them to perceive. More challenging stimuli may provide more insight into areas of difficulty for CI users.
- Administer expressive vocabulary measures
  - In this study receptive vocabulary was correlated with chronological age.
  - And speech production was correlated with hearing age.
  - Since expressive vocabulary measures require semantic and phonological representations, it is unclear whether expressive vocabulary would be correlated with hearing age or chronological age for bilateral CI users.

## ACKNOWLEDGMENTS

- This research was supported by NIDCD grants R01DC008365 and R01DC02932 and NSF Grant BCS-0729140.
- Thanks to Ann Todd, Shelly Godar, Sarah Schellinger, Hyunju Chung, Mina Syrika, and Gretchen Dalquist.
- Thanks especially to:
  - the children who participated in both of these studies
  - all of the parents who contributed their time and provided consent