Acoustic Analysis of Vocal Development in Young Children With Cochlear Implants: A Preliminary Report

Kyoko Nagao, Allegra Cornaglia, H. Timothy Bunnell

Nemours Alfred I. duPont Hospital for Children

CPASS the Center for Pediatric Auditory & Speech Sciences
CPASS website http://www.medsci.udel.edu/cpass/

Introduction

Our Goals

1. Recognize the types of sounds produced by young children with cochlear implants (CIs) during their speech development.
2. Create an interactive software to supplement their habilitation in addition to regular speech therapy.

Speech development in Children with CI

- Earlier implantation tends to provide better speech language developmental outcomes.
- More research is needed to understand acoustic changes in young children's vocalization.
- Needs early assessments of speech and language development.

Acoustic Studies on Vowel development

- Previous studies reported frequency of vowels based on adult phonetic inventories (e.g. Kent & Bauer, 1985).
- Phonetic inventories become larger and more accurate.
- Except a handful studies, acoustic analysis is NOT commonly performed for speech by young children with or without CI.
  - van der Stelt (2005) Dutch- and Hungarian speaking kids with hearing impairment
  - Serkhane et al. (2007) kids with normal hearing at 4 and 7 months
- Phonetic transcription is time-consuming and difficult , especially for prelingual vocalizations or imprecise articulations.

Research Question

Can we observe vocal development in young children with CI without phonetically transcribing their utterances?

Method

Participants

- 5 prelingually deaf children (age range: 17- 46 months at study entry) who received cochlear implant(s) at Alfred I. duPont Hospital for Children
- Normal cognitive and motor development
- Use English as their primary language

subject	Sex	Age at study entry	Age Aided	Age of CI	Hearing age at study entry	CI use at study entry
02i	F	21;8	10;8	15;1	11;0	6;7

Data collection

- Audio and Video recordings during a 60-min regular speech therapy (once or twice per week)
- The audio recorder and microphone were attached to a customized vest that the child wears.
- Audio data was collected at 48kHz sampling rate with 16-bit quantization, and then down-sampled to 16kHz and high-pass filtered at 80Hz to remove room noises

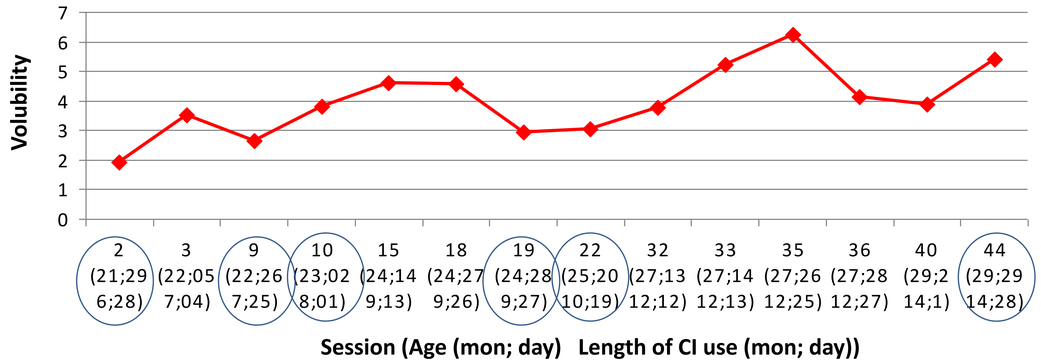
Current data

- Data from the Child 02 collected from 14 sessions over 8 month period (22 to 30 month) are presented here.

Acoustic analysis

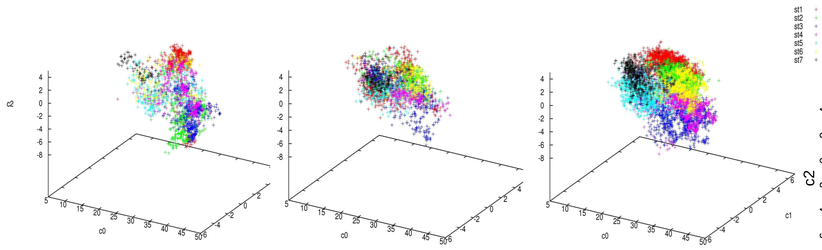
- Labeled each child's utterance as speech-like or non-speech
- Excluded speech-like utterances that are overlaid by extraneous noises or adult speech
- Built 7-state Hidden Markov Model (HMM)s based on the speech-like utterances
- The speech-like utterances were automatically labeled with one of the 7 sound categories using the speech recognition based on the trained HMM
- The first 3 cepstral coefficients (c0, c1, and c2) were computed every 10 msec for each of the 7 sounds

Results



1. An increasing trend of volubility (number of speech-like utterances per min) indicates increased vocalizations of the child.
2. Well-separated clusters emerged until Session 19.
3. More recent sessions (e.g. 40 and 44) show diffused data, suggesting the 7 sound categories may be too small for her developing sound systems.
4. Varied quality of sessions can be captured by both volubility and cepstral coefficients (e.g. session 9 vs. 10).

Session 2 (21;29 6;28) **Session 9 (22;26 7;25)** **Session 10 (23;2 8;1)**



Session 19 (24;28 9;27) **Session 22 (25;20 10;19)** **Session 44 (19;29 14;28)**

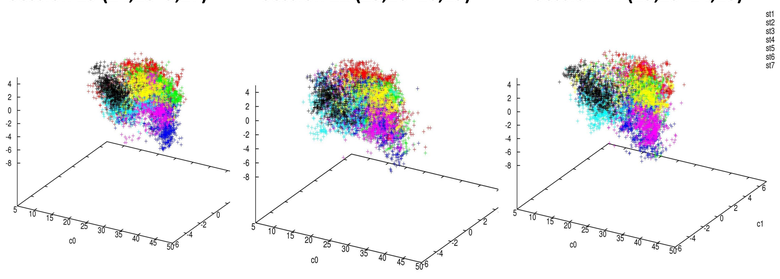
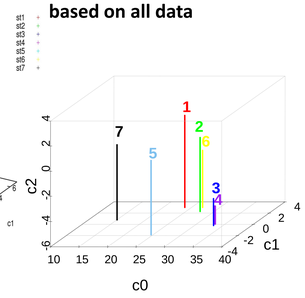


Fig. Centoid of each state based on all data



Type of Sounds associated with each state

- st 1 High Front Vowels
- st 2 High Front Vowels, Liquids, or Glides
- st 3 Low Back Vowels
- st 4 Low Back Vowels
- st 5 Fricatives
- st 6 Schwa-like Vowels, Liquids, or Glides
- st 7 Silence or stops

Conclusions

- Audio data automatically labeled by the HMMs indicates the child's vocal development.
- Variability among sessions can be captured by the volubility and acoustic results.

Acknowledgments

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References

Kent, R. D., & Bauer, H. R. (1985). Vocalizations of one-year-olds. *Journal of Child Language, 12(03), 491-526.*

Moeller, M. P., Hoover, B., Putman, C., Arbataitis, K., Bohnenkamp, G., Peterson, B., et al. (2007). Vocalizations of infants with hearing loss compared with infants with normal hearing: Part I–phonetic development. *Ear Hear, 28(5), 605-627.*

Serkhane, J. E., Schwartz, J. L., Boë, L. J., Davis, B. L., & Matyear, C. L. (2007). Infants' vocalizations analyzed with an articulatory model: A preliminary report. *Journal of Phonetics, 35(3), 321-340.*

van der Stelt, J. M., Zajdó, K., & Wempe, T. G. (2005). Exploring the acoustic vowel space in two-year-old children: Results for Dutch and Hungarian. *Speech Communication, 47(1-2), 143-159.*