Development of Vowel Production in Young Children With Cochlear Implants

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 interactive software to supplement their habilitation in addition to regular speech therapy.

Vocal development in Children with CI

- Children with CIs produce smaller phonetic inventories than the age-match children with normal hearing (NH) (e.g. Stoel-Gammon, 1988; Moeller et al, 2007).
- Children with CIs show a delayed but similar development of phonetic inventories compared to the NH children.
- Some studies report differences in speech characteristics between children with CI and children with normal hearing (e.g. Ertmer, 2001; Moeller et al, 2007).
  - Ertmer (2001) reported that frequent production of the high vowels (/i/ and /u/) was observed in Hannah's vocalizations.

Acoustic Studies on Early Vocalization

- Studies on early vocal development are usually based on some phonetic inventories classified by transcribers (e.g. Kent & Bauer, 1985; Ertmer et al, 2007; Moeller et al, 2007).
- Acoustic characteristics of prelinguistic early vocalization of children with or without hearing impairment are not fully understood.
- Ranges of F1 and F2 expand with age (Kent & Murray, 1982).
- Children with hearing loss show restricted vowel space (Kent et al, 1987).

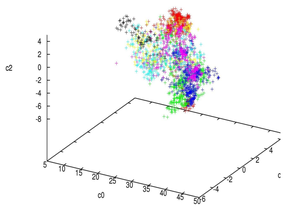
Early Vocalization and Phonetic Transcription

- Phonetic transcription is time-consuming and difficult , especially for prelingual vocalizations or imprecise articulations.
- Recently, analysis of early vocalization has been conducted with unlabeled data.
  - 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

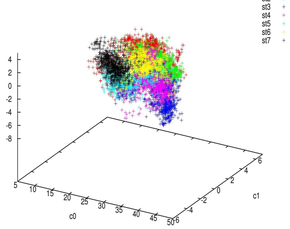
Our Previous Study (Nagao et al, 2010)

- Speech-like vocalizations from one child with CI collected over 10 months (21 to 30 month) were automatically segmented with a 7-state Hidden Markov Model.
- The first 3 cepstral coefficients (c0, c1, and c2) were computed from the center of each segment to describe the phonetic space for both consonants and vowels.
- Vocal development was observed by well-separated clusters emerged by around age 25 months.
- Data started to diffuse after age 25 months.

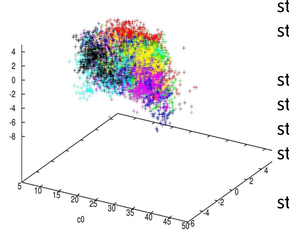
Age(mon;day): 21;29
CI use (mon; day): 6;28



Age: 24;28
CI use: 9;27



Age: 25;20
CI use: 10;19



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

Nemours

Nemours is one of the largest pediatric group practices in the United States, serving children in Delaware, Maryland, New Jersey, Pennsylvania, Florida, and Georgia. Visit us online at www.Nemours.org and www.PedsEducation.org.

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

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

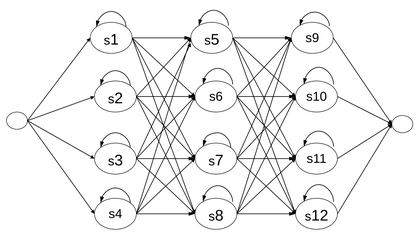
Current data

- Data from the Child 02 collected from 20 sessions over 12 month period (21 to 31 month) are presented here.

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

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
- Based on the first 3 cepstral coefficients (c0, c1, and c2) computed for each of the 7 sounds, new training data was prepared.
  - 2 of 7 sound categories were relabeled as Consonants
  - 5 of 7 sound categories were relabeled as Vowels
- Rebuild a 5-state HMM model, and retrained the model by splitting each state three times based on the new training data
- Relabeled the speech-like utterances by the new model.

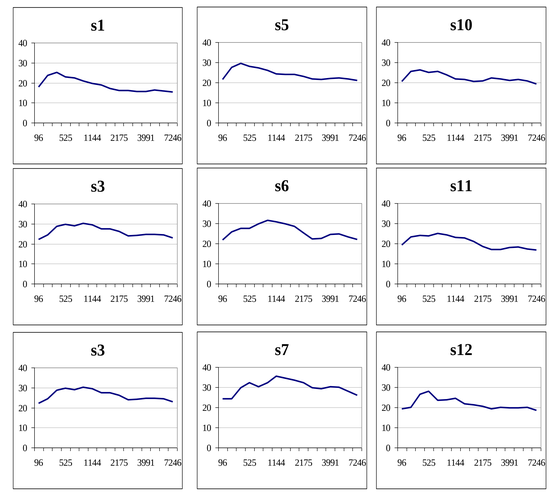


Results

Table: The most frequently used paths and perceptual correlates

path	Frequency (total=5909)	Perceptual characteristics
s1-s5-s10	535	/i/ or /u/
s3-s6-s11	428	/a/ or schwa
s3-s7-s12	304	/ae/

Fig: Spectral shapes of the states used in the most frequent paths



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