Acoustic Characteristics of Sibilant Fricatives in Children with Cochlear Implants

Ann E. Todd[1], Jan R. Edwards[1], Ruth Y. Litovsky[1], Fangfang Li[2], Cynthia M. Zettler[1], Mary E. Beckman[3]

University of Wisconsin-Madison[1], University of Lethbridge[2], Ohio State University[3]

Introduction

•Children with cochlear implants (CI's) exhibit delays in speech production relative to normally hearing (NH) children.
• The contrast of /s/ and /ʃ/ may be difficult for children with CI's because the concentration of energy characteristic of /s/ is above 4000 Hz, while the filter bands in CI's assigned to frequencies above 4000 are wide.
• The current study uses transcription and acoustic analysis to describe the production of /s/ and /ʃ/ by children with CI's.
• The current study compares children with CI's to NH children of similar chronological ages (CA's) and NH children of similar hearing ages (HA's).

Questions

•Do children with CI's show less distinction between /s/ and /ʃ/ than NH children?
•Do children with CI's show more variability in their production of /s/ and /ʃ/ than NH children?
•Do children with CI's produce /s/ and /ʃ/ with durations longer than those of NH children?

Method

Participants

• Eighteen 4- to 9-year old children with bilateral CI's
  -Average age of implantation 1;6
  -From a larger study
• Twenty-six 2- to 5-year old NH children
  -Passed a hearing screening
  -From a larger study
• All children spoke English as a first language

The children with CI's were compared to NH children of similar **hearing ages (HA)**. A subset of children with CI's were also compared to NH children of similar **chronological ages (CA)**.

Group	Mean age	Mean hearing age	Males/ total
CI	5;8	4;1	6/18
HA	4;1	4;1	6/18

Group	Mean age	Mean hearing age	Males/ total
CI	4;10	3;7	1/11
CA	4;9	4;9	1/11

Stimuli

	/a/	/i/	/u/
/s/	soccer sauce sun	seashore sister seal	super soup suitcase
/ʃ/	shark shop shovel	sheep shield ship	chute shoe sugar

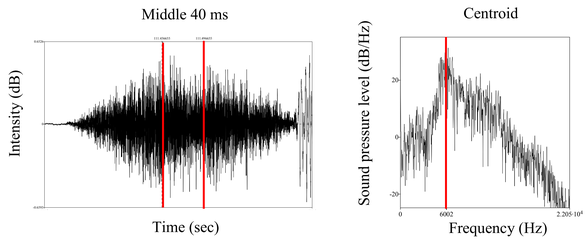
Picture for stimulus word "sister"

Procedure

• The children participated in an auditory word repetition task.
• The children saw pictures and heard digitized productions of the stimuli.
• The children were asked to repeat the stimulus word after the audio prompt.
• Productions were recorded for later analysis.

Analysis

• Each initial consonant (and following vowel) were transcribed as correct or incorrect by a phonetically-trained native-speaker transcriber.
• First spectral moment (centroid) was calculated from the middle 40 ms of correct productions of /s/ and /ʃ/.
  -The measure of centroid has been found to distinguish productions of /s/ and /ʃ/ with /s/ having a higher centroid than /ʃ/.
•The durations of the sounds /s/ and /ʃ/ were measured from the onset of frication noise to the first glottal pulse of voicing for correct productions of /s/ and /ʃ/.



Results from Transcription

Accuracy

Group	Correct /s/	Correct /ʃ/
CI (n=18)	66 %	84 %
HA	68 %	78 %

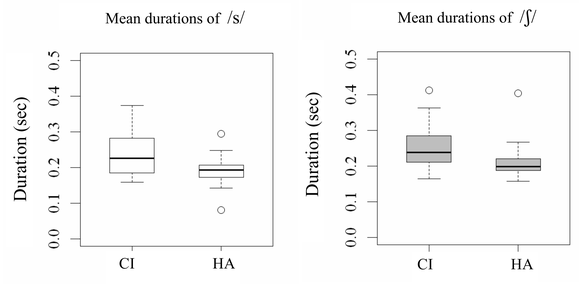
The children with CI's and the HA group showed similar accuracy levels for /s/ and /ʃ/.

Group	Correct /s/	Correct /ʃ/
CI (n=11)	57 %	77 %
CA	71 %	90 %

The children with CI's showed lower accuracy levels for /s/ and /ʃ/ than the CA group.

Results from Duration Analysis

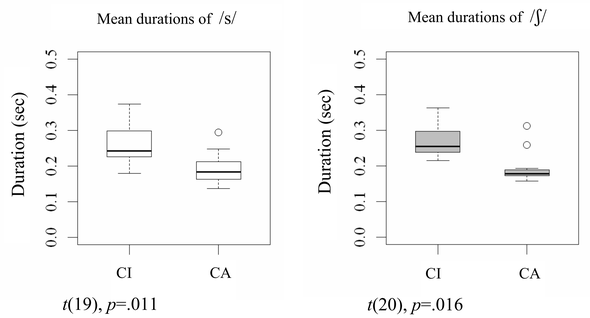
CI group compared to HA group



t(33), *p*=.014 *t*(33), *p*=.08

The children with CI's showed longer durations of /s/ and /ʃ/ than the HA group.

CI group compared to CA group



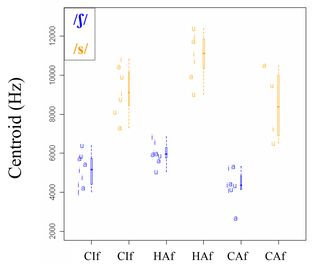
t(19), *p*=.011 *t*(20), *p*=.016

The children with CI's showed longer durations of /s/ and /ʃ/ than the CA group.

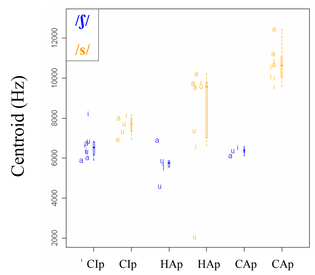
Results from Spectral Analysis

Individual subjects

The two graphs below show centroids of /s/ and /ʃ/ produced by a child with CI's and the two NH children who were matched on hearing age and chronological age. Letters indicate the vowels that followed /s/ and /ʃ/.



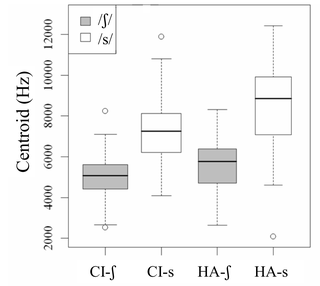
This child with CI's shows a similar amount of distinction between /s/ and /ʃ/ and a similar amount of variability as the two NH children.



This child with CI's shows less distinction between /s/ and /ʃ/ and less variability in productions of /s/ than the two NH children.

CI group compared to HA group

The graph shows centroids of all productions transcribed as correct /s/ and /ʃ/.



• Significant main effect of group (p = .006)

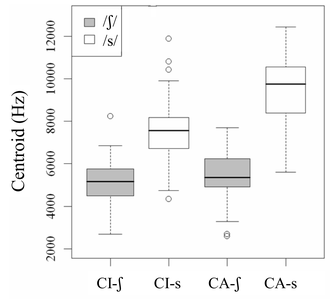
• Significant main effect of sound (p < .001)

• Significant group by sound interaction (p = .03)

• Reduced variability in productions by CI group may be due to reduced within-subject variability.

CI group compared to CA group

The graph shows centroids of all productions transcribed as correct /s/ and /ʃ/.



• Main effect of group marginally significant (p = .056)

• Significant main effect of sound (p <. 001)

• Significant group by sound interaction (p = .028)

•Reduced variability in productions by CI group may be due to reduced within-subject variability.

Conclusion

• The acoustic analysis revealed group differences that did not show up in the transcription analysis.

•The centroids of /s/ produced by children with CI's were lower in frequency than those of NH children, which may be due to CI's providing poor frequency resolution above 4000 Hz.

• Reduced variability was apparent in the centroids of /s/ and /ʃ/ produced by children with CI's. Further research is needed to explain the causes of this reduced variability.

•Children with CI's produced durations of /s/ and /ʃ/ that were longer than those of the children with NH.

• The children with CI's exhibited a wide range of performances. Further research is need to determine what characteristics distinguish children who perform similarly to NH children from those who do not.

Acknowledgments

This research is supported by NIH Grant R01DC008365 (Litovsky), NIH Grant R01DC02932, and NSF Grant BCS-0729140 (Edwards). I would like to thank the members of the Binaural Hearing and Speech Laboratory and the members of the Cross-Linguistic Phonology and Word Learning Laboratory.