Using sociolinguistic phonetic perception to fine tune cochlear implant simulations

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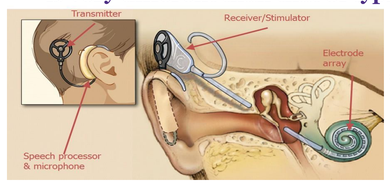
SPEECH AND HEARING SCIENCES

Acoustical Society of America 2016

#42

INTRODUCTION

The sound quality of a cochlear implant (CI) is very different than that of typical acoustic hearing.



Simulating the sound of a cochlear implant can be useful for research and counseling

We want to make the simulations as accurate as possible

The good news:

Common simulations using noise and sinewave vocoders do a good job predicting CI speech intelligibility

The problem:

People with a CI and acoustic hearing in the opposite ear report that common simulations don't sound like their implant

Vocoder simulations tend to use parameters that do not actually approximate what a CI speech processor does.

Parameters to explore: number of channels, spread of cochlear excitation, frequency-electrode allocation, dynamic range, processing strategy, pulsatile stimulation, etc.

The strategy to solve the problem:

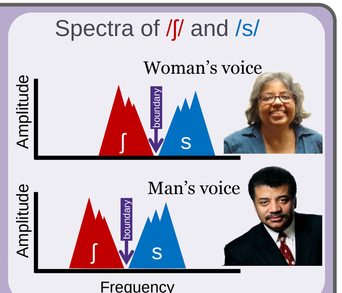
1. Use a speech perception task that is more subtle than basic intelligibility, where CI performance doesn't match vocoder performance
2. Vary vocoders by parameters that are relevant to CI processing and stimulation
3. Compare the performance of the different vocoders in matching subtle speech perception abilities of the real CI listeners

PHONETIC ACCOMODATION OF TALKER GENDER

/s/ and /ʃ/ have different acoustic properties when spoken by a man compared to a woman

A shift in the ***perceptual boundary*** between /ʃ/ and /s/ will reflect perception of subtle differences in speech production

This shift is observed in data from CI listeners, but not for NH listeners using the 8-channel noise vocoder



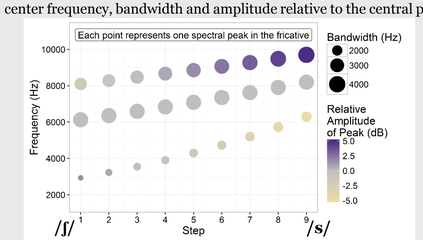
METHODS

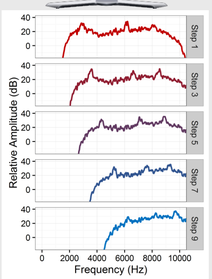
PARTICIPANTS: 43 young listeners with normal hearing (ages 18 – 32 y)
19 listeners with cochlear implants (ages 40– 67 y)

PROCEDURE: Click on the word that is spoken →

STIMULI: **9-step continuum of fricative sounds ranging from /ʃ/ ("sh") to /s/** appended to /i/ and /u/ vowels ***spoken by a female or a male talker***

Fricatives contained three spectral peaks varying by three parameters: center frequency, bandwidth and amplitude relative to the central peak

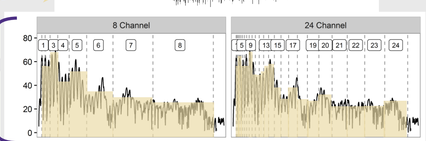




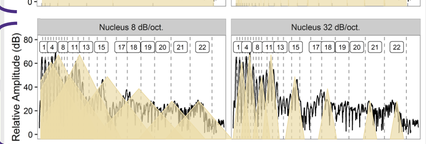
The vocoders

Unprocessed (normal) speech

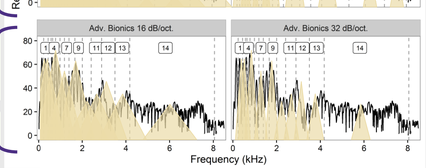
Noise vocoder with 8 or 24 channels Spanning 150 – 8000 Hz (equal cochlear spacing)

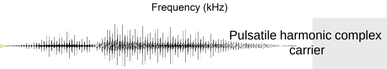


Noise vocoder matching "Nucleus" frequency-electrode allocation between 188 and 7938 Hz and peak-picking (8 channels of 22) spectral resolution determined by "spread of excitation"



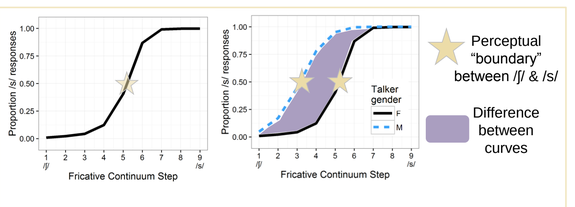
Pulsatile harmonic complex carrier (smoother temporal envelope) matching Advanced Bionics frequency-electrode allocation for current-focused map (14 channels) spectral resolution determined by "spread of excitation"





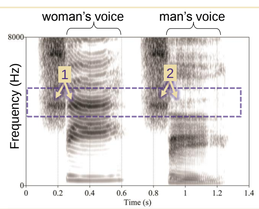
RESULTS:

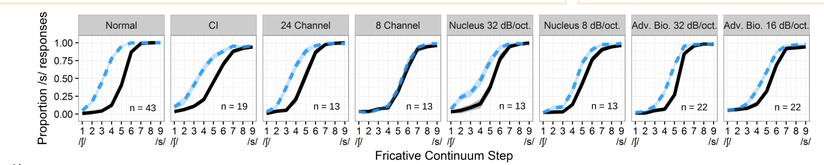
All vocoder styles yield better results than the 8-channel noise vocoder



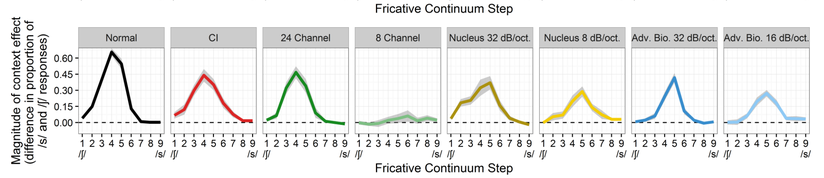
The effect emerges strongly for ambiguous fricatives… here's (partly) why:

1. vowel formant for the woman's voice (left) aligns with the fricative spectral peak, reducing spectral contrast (leading to /ʃ/ perception).
2. More local spectral contrast for the male vowel formants, leading to /s/ perception

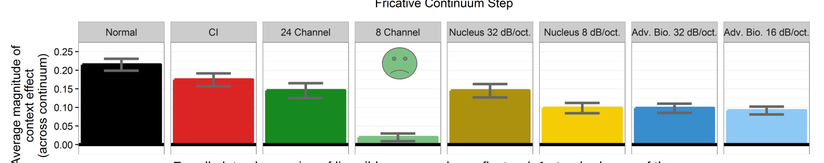




Responses for male voices are shifted toward /s/



Context effect (accommodation of talker gender) is greatest for center of continuum (ambiguous stimuli)



Context effect is virtually absent for 8-channel noise vocoder

All other vocoder styles approximate the CI performance more accurately.

For all plots above: size of line ribbon or errorbar reflects +/- 1 standard error of the mean

CONCLUSIONS

Perceptual categorization of /ʃ/ & /s/ reflects accommodation of vocal acoustic differences between women and men. People with cochlear implants also demonstrate this accommodation.

The most common vocoder simulation of a cochlear implant (8-channel noise vocoder) *does not* elicit phonetic accommodation
The phonetic accommodation effects emerges for *other* vocoders that use parameters designed to replicate various aspects of cochlear implant processing

Phonetic accommodation is a subtle aspect of speech perception that can reveal differences in the ability of a vocoder to accurately predict perception of speech by a person with a cochlear implant.

REFERENCES

[1] Mann,V., & Repp,B.(1980). Influence of vocalic context on perception of the /ʃ/ - /s/ distinction. Perception & Psychophysics

[2] Winn, Rhone, Chatterjee, & Idsardi (2013) The use of auditory and visual context in speech perception by listeners with normal hearing and listeners with cochlear implants. *Frontiers in Psychology*

Brianna Vandyke, Ashley Moore and Steven Gianakas assisted with data collection.
Data from 7 of 19 CI listeners from publication by Winn, Rhone, Chatterjee and Idsardi (2012), Frontiers in Psychology.
Financial Support provided by NIH-NIDCD R03 DC014309 (Winn), NIH-NIDCD 5R01 DC03083 (Litovsky), the UW-Madison Department of Surgery, and the NIH Loan Repayment Program

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