Poster # 22

Assessment of spectral resolution for speech: Implications for cochlear implants

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INTRODUCTION

Spectral resolution

Major limiting factor in listening with a cochlear implant

Important for distinguishing speech sounds

Our long-term goal is to improve spectral resolution and SHOW that it has been improved.

Measurement problem

Spectral components in typical speech sounds are not adequate for measuring spectral resolution because they are confounded with other variables like temporal, linguistic, and contextual factors. Non-speech tasks are excellent for discrimination, but not identification

Everyday speech perception is identification, not discrimination

Our approach

Isolate and modify specific spectral cues found in natural speech [1] & measure listeners' perception of spectrally-driven contrasts.

Perception of spectral cues in speech sounds should:

- … test for spectral perception more directly than word recognition tests
- … directly relate to performance for whole-words
- … predict listeners' level of difficulty
- … show greater variability across listeners compared to whole words

PARTICIPANTS

7 listeners with cochlear implants

	Code	Sex	Age	Years CI exp	Years BiCI exp	Implant Type (Left)	Implant Type (Right)	External Device (Left)	External Device (Right)
	IAJ	F	67	16	9	CI24M	CI24R (CS)	N5	N5
	IBF	F	62	7	5	Freedom Contour Adv.	Freedom Contour Advance	Freedom	Freedom
	IBK	M	72	9	3	Nucleus 24 Contour	Freedom Contour Advance	Freedom	N5
	IBM	F	59	7	3	CI512 (N5)	Freedom Contour Advance	N5	N5
	IBN	M	66	13	3	Freedom Contour Adv.	Nucleus 24 Contour	Freedom	Freedom
	IBO	F	46	6	3	CI512 (N5)	Freedom Contour Advance	N5	Freedom
	ICO	F	32	1	1	CI512 (N5)	CI512 (N5)	N5	N5

10 listeners with normal hearing

Age range: (19 – 29 years)

TEST CASE

Electrode interaction is a major source of degradation in the spectrum.

Interaction from overlap of current spread

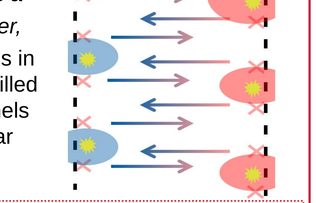
Spaced electrodes don't interact as much

To reduce it, current of alternating electrodes was set to zero

(they can still be selected for activation, but no current will be discharged)

Problem: this creates "holes" in the spectrum [2]

If the listener is a *bilateral CI user,* missing channels in one ear can be filled by active channels in the other ear



Dichotic spectral interleaving: Does it actually work? Which listeners can benefit from this approach?

Vocoder

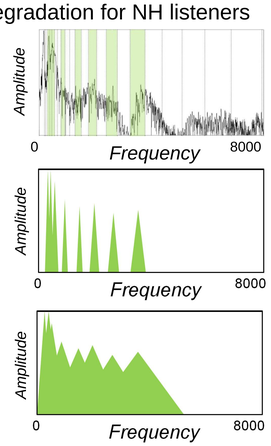
ACE-style vocoder using AngelSim [3]

* To control spectral degradation for NH listeners

Peak-picking
n-of-m style
8 of 22 channels

Carrier channels w/ little current spread (i.e. 18 dB/ oct. slope)

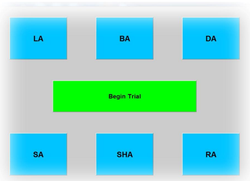
Carrier channels w/ more current spread (i.e. 6 dB/ oct. slope)



PROCEDURE

6-alternative forced choice
Target sounds: /ba/, /da/
Filler sounds:
/ʃɑ/, /sɑ/, /lɑ/, /rɑ/
(for variability)

Interspersed with other listening tasks



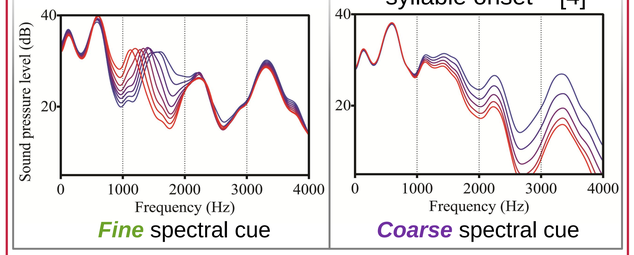
CI listeners →tested with map & novel map
NH listeners →tested with normal speech and all vocoder conditions, including spectrally interleaved vocoders

STIMULI

The /ba/-/da/ contrast was the crucial contrast.
It is difficult for CI listeners & requires **spectral** cues
It can be distinguished via:

formant transitions

spectral tilt at syllable onset [4]



Fine spectral cue

Coarse spectral cue

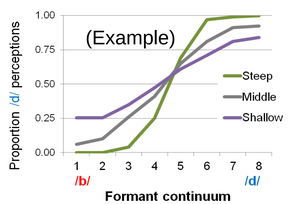
8-step formant transition continuum

5-step spectral tilt continuum

Listeners with better spectral resolution will use the formant cues.

ANALYSIS

Each listener's psychometric function along the spectral cue continua are modeled in R [5,6] using logistic regression (binomial family).

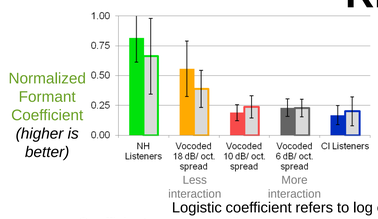


Each psychometric function yields a coefficient that represents the listener's use of the cue being varied.

Steep *= more reliance, larger coefficient*

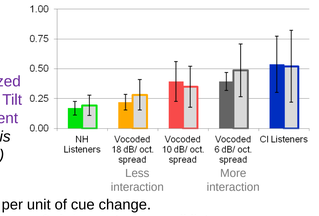
Shallow *= less reliance, smaller coefficient*

RESULTS



Use of spectral cues

■ Normal
□ Interleaved

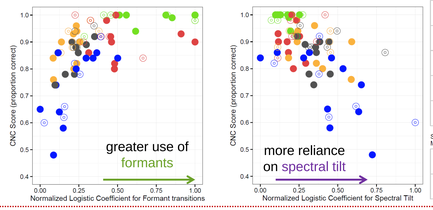


Logistic coefficient refers to log odds of perceptual change per unit of cue change.
Coefficients on a normalized scale: 1 → Highest coefficient among all listeners; 0 → Lowest among all listeners

Relationship to open-set word recognition

Spectral cue-weighting has a direct relationship with CNC scores.

Note: number of CI data points is greater than the number of listeners because some ears were tested individually (without interleaved channels).

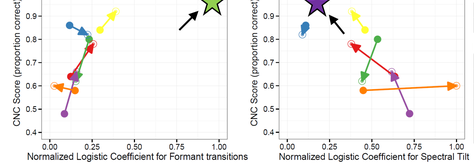


Individual CI patterns

Arrows reflect the change in performance between regular and interleaved maps.

The goal is: high CNC scores, high formant coefficient, low tilt coefficient.

Some CI listeners benefited from interleaving (their arrow points toward the goal), while others did not.



Here, you want your performance to move toward the green star

Here, you want your performance to move toward the purple star

CONCLUSIONS

For listeners with cochlear implants,
We are able to measure perception of fine spectral cues in speech sounds

corresponds to word recognition

can be placed within a spectrum of performance modeled by NH listeners

- Listeners with poorer perception of fine cues compensate with use of coarse cues, and this can yield poorer performance on CNC words
- 4 of 6 CI listeners tested with interleaved spectral channels improved on CNC scores and the use of formant cues.

NEXT STEPS

Does better spectral resolution promote listening with less effort?

Using this approach to evaluate other interventions, such as current steering & current focusing *(do they really improve spectral perception as advertised?)*

REFERENCES

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