Optimizing outcomes with electric and acoustic stimulation (EAS): speech understanding, music perception, and auditory cortical activation

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A Sound Foundation Through Early Amplification

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DISCLOSURES

Member of Audiology Advisory Board for:

• Advanced Bionics
• Cochlear Americas
• Frequency Therapeutics
Bilateral CI = standard of care treatment for bilateral severe-to-profound SNHL

e.g., Balkany et al. 2008; Papsin & Gordon, 2008; Peters et al., 2010; Ramsden et al., 2012

What amount of acoustic hearing is beneficial in a bimodal hearing configuration?
2 primary theories of bimodal benefit:

1) Segregation
   • LF acoustic cues (e.g., F0 periodicity) → allow for comparison across the ears to form *perceptual streams* to separate the target from the background noise (e.g., Kong *et al.* 2005; Chang *et al.* 2006; Qin & Oxenham 2006)

2) Glimpsing
   • spectral-dependent SNR varies over time, allowing for target to be “glimpsed” so that SNR modulations over time → better perception LF target (e.g., Kong & Carolyn 2007; Li & Loizou 2008; Brown & Bacon 2009)
Tested for dead regions with TEN test

Presentation level in non-CI ear →

65 dBA signal + NAL-NL1 amplification

n = 12

![Graph showing percent correct responses for different conditions.](image)

- **Adults, n = 12**
- **500-Hz band**

**Condition**
- A only
- E only
- BIMODAL
  - 125 Hz
  - 250 Hz
  - 500 Hz
  - 750 Hz
  - Wideband

**Percent Correct**
- 0 to 100

- Children (n = 19) & adults (n = 10) w/ normal hearing
  - Mean age = 9.2 years
    - Range 6 to 12 years
- CI simulations (e.g., Litvak et al., 2007)
- Bimodal simulations: 90 dB/oct
  - <250, <500, <750, <1000, and <1500 Hz
- BabyBio sentences at variable SNR
  - SNR $\rightarrow$ ~50% for “CI-only” condition
  - Mean = 6.6 dB
Hypotheses

• Children will need a broader acoustic BW for bimodal benefit than adults.
  • Adults are better able to combine top-down and bottom-up processing.
  • Stelmachowicz et al., 2000, 2001, 2004, 2007; Pitmann et al., 2005

• Bimodal benefit will increase with increasing BW for children, as with adults.

Mean SNR: +6.2 dB
n = 10
adult NH

750-Hz band

SNR: +5 dB

percent correct

n = 10 adult NH

condition

A only

E only

Bimodal
BIMODAL

C1

HA
Gifford et al. (in prep).

- Mean age: 9.5 yrs
  - range: 6.8 to 13.3 yrs
- 3 male, 9 female
- Mean age at CI: 6.5 yrs
  - range 1.3 to 10.7 yrs
- 65 dBA signal + DSL v5 amplification
Gifford et al. (in prep).

A | E
---|---
250 Hz | 250 Hz | 250 Hz | 250 Hz | 250 Hz

Mean SNR: -1.6 dB

n = 12 peds bimodal
Gifford et al. (in prep).

Mean + SNR: +2.5 dB
Mean - SNR: -3.9 dB
Gifford et al. (in prep).

Mean + SNR: +2.5 dB
Mean - SNR: -3.9 dB
Summary

• Significant bimodal benefit observed with acoustic hearing < 250 Hz
• Children may be using different cues for bimodal listening (streaming > glimpsing?)
  – But, broader BW did not impair performance
• Clinical Rec: Aid that non-CI ear!
We spend a great deal of time talking about speech understanding. What about music? ...and might children be different?
Review: bimodal benefit for speech understanding

Adult
n = 48

Peds
n = 12
Adult bimodal listeners

n = 48

percent correct

speech measure

CNC
BabyBio
BabyBio +5
Pediatric bimodal listeners

n = 12

percent correct

speech measure

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Speech & music perception: bimodal adults and children

Behavioral measures:
• isochronous melody recognition
  • ABC song, Old MacDonald, Yankee Doodle, London Bridge, This Old Man, BINGO, Frere Jacques
• pitch discrimination (UW-CAMP)
• chord discrimination

Subjective qualitative judgments:
• visual analog scale (VAS)
• favorite music

Neuroimaging
• Functional near infrared spectroscopy (fNIRS)
Speech & music perception: bimodal adults and children

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Neuroimaging
• Functional near infrared spectroscopy (fNIRS)

• HA alone
  • DSL v5
• CI alone
  • 20-25 dB HL
• BIMODAL
  • n = 4
  • 10, 12, 15, & 17 years

More later!
HA > CI
Bimodal = HA

NH mean

percent correct

isochronous melodies

chords

music measure

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HA
CI
BIMODAL
HA $<$ CI
(i.e. HA better than CI)
Bimodal = HA
Subjective ratings: Judgment of sound quality
Gabrielsson et al., 1988. JSLHR. 31:166-177.
Subjective ratings

![Bar chart showing VAS ratings for different listening configurations: HA, CI, BIMODAL.](image-url)
Subjective ratings

VAS rating

listening configuration

HA  CI  BIMODAL

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Subjective ratings

VAS rating

listening configuration

HA
CI
BIMODAL

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Functional neuroimaging
Functional neuroimaging for speech & music perception

• Could be beneficial to guide clinical decisions and counseling, particularly in young children
  – Candidacy recommendations (re: 2nd CI)
  – Therapy recommendations
  – Counseling for expectations
  – Programming strategies
Functional near-infrared spectroscopy (fNIRS)

- BOLD signal
- Safe with CIs
- No electrical artifact
- Pediatric friendly
Methods

• Passive listening task
• 9 sentences per 20s block
• Multiple-choice question after each block (to maintain attention)

Which sentence did you hear?

A) I need a second cup of coffee.
B) Do you still have the lizard?
C) My battery is charging now.
D) Speak a little more slowly.
Time

Frequency (kHz)

Unfiltered Speech

Speech-correlated Noise
CI only – Unintelligible Speech-correlated Noise

Bimodal – Unintelligible Speech-correlated Noise
CI only – Speech > Noise

Bimodal – Speech > Noise

<table>
<thead>
<tr>
<th>speech measure</th>
<th>percent correct</th>
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<tbody>
<tr>
<td>CNC</td>
<td>80</td>
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<tr>
<td>AzBio</td>
<td>80</td>
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<tr>
<td>AzBio +5</td>
<td>80</td>
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Summary

Bimodal hearing → significant benefit over CI alone
• Speech understanding in quiet & noise
• Music perception tasks
• Subjective ratings of music sound quality
• Auditory cortical activation

Significant bimodal benefit can be obtained with very little acoustic hearing
• 250 to 500 Hz
• Increases in acoustic BW → increased performance
Summary

Functional neuroimaging:
• Greater understanding re: neural integration of electric & acoustic stimuli
• Guidance for clinical decision making?
• Outcomes?

What might the future hold?
• Music coding strategies for CI
• Bilateral CI + acoustic hearing preservation
• HAs & prescriptive fittings designed for music listening
Thank you for your attention.
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A. Patients with dead region

B. Patients without dead region

CNC words

12-percentage points