The Benefits of Bimodal Hearing for Adults and Children: Effect of Frequency Region and Acoustic Bandwidth

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DISCLOSURES

Member of Audiology Advisory Board for:

• Advanced Bionics
• Cochlear Americas
• MED-EL
Collaborative Effort

Sterling Sheffield, AuD—PhD student
  • Vanderbilt University

Michelle Simha—AuD student
  • University of South Florida
BILATERAL
BILATERAL
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?
Bimodal vs. Bilateral in adults

Similar levels of performance on measures of speech understanding

- best aided condition

(e.g., Yoon et al., 2012, Otol Neurotol; Gifford et al., in press, Audiol Neurotol)
Bimodal: $n = 120$
Bilateral: $n = 73$
BIMODAL: It doesn’t take much acoustic hearing in the non-CI ear to yield benefit...
PURPOSES: 1) Replicate Zhang et al. (2010) with steeper filter slopes (90 dB/oct), 2) multiple SNRs, and 3) low- and band-pass filters.

- Bimodal adults (n = 12)
- Mean age = 56.3 years
  - Range 42 to 82 years
- Mean CI experience = 54.9 months
  - Range 8 to 138 months
PURPOSES: 1) Replicate Zhang et al. (2010) with steeper filter slopes (90 dB/oct), 2) multiple SNRs, and 3) low- and band-pass filters.

- CNC words
  - 60 dB SPL
- AzBio in noise +10, +5, and 0 dB SNR
  - 65 dB SPL
- LP: <125, <250, <500, <750 Hz, and wideband
- BP: 125-250, 250-500, and 250-750 Hz
Tested for dead regions with TEN test

Presentation level in non-CI ear ➔

65 dBA signal + NAL-NL1 amplification
CNC words

adults
n = 12

percent correct

condition

A only
E only
Bimodal

500-Hz band

CNC words

A only
E only
Bimodal

wideband
AzBio +10 dB SNR

adults
n = 12

percent correct

condition

A only
E only
Bimodal

500-Hz band

wideband

A  E  BIMODAL

125 Hz  125-250 Hz  250 Hz  250-500 Hz  500 Hz  250-750 Hz  750 Hz  wideband

n = 12

250 Hz
500 Hz
750 Hz
wideband

0  20  40  60  80  100
AzBio +5 dB SNR

250-Hz band (including 500 Hz)

adults
n = 12

percent correct

condition

A only
E only
Bimodal

A
E
BIMODAL

wideband

A
E
BIMODAL

125 Hz
125-250 Hz
250 Hz
250-500 Hz
500 Hz
250-750 Hz
750 Hz
wideband

0 20 40 60 80 100

0

250 Hz

500 Hz

750 Hz

wideband

250-500 Hz

250-750 Hz

250-250 Hz

250-500 Hz

250-750 Hz

250-250 Hz

250-500 Hz

250-750 Hz
AzBio 0 dB SNR (n = 9)

250-Hz band (including 500 Hz)

percent correct

adults
n = 12

A only
E only
Bimodal

condition

A
E
BIMODAL

250 Hz
125 Hz
250-250 Hz
250-500 Hz
500 Hz
250-750 Hz
750 Hz
wideband
Sheffield & Gifford (in press). Audiol Neurotol.

- Bimodal benefit is possible with limited acoustic bandwidth
  - Even when F0 is not \textit{physically} present
  - We \textit{might not} have to worry too much about 125 Hz
    - Prescriptive targets, HA output, etc.
  - \textbf{250-500 Hz is the magic range}
<table>
<thead>
<tr>
<th>Phonetic Symbol</th>
<th>Example Word</th>
<th>$F_1$ (Hz)</th>
<th>$F_2$ (Hz)</th>
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</thead>
<tbody>
<tr>
<td>/ow/</td>
<td>bought</td>
<td>570</td>
<td>840</td>
</tr>
<tr>
<td>/oo/</td>
<td>boot</td>
<td>300</td>
<td>870</td>
</tr>
<tr>
<td>/u/</td>
<td>foot</td>
<td>440</td>
<td>1020</td>
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<td>/a/</td>
<td>hot</td>
<td>730</td>
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<td>/uh/</td>
<td>but</td>
<td>520</td>
<td>1190</td>
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<td>/er/</td>
<td>bird</td>
<td>490</td>
<td>1350</td>
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<td>bat</td>
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<td>/i/</td>
<td>bit</td>
<td>390</td>
<td>1990</td>
</tr>
<tr>
<td>/iy/</td>
<td>beet</td>
<td>270</td>
<td>2290</td>
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</tbody>
</table>

$F_1$ mean = 490 Hz
BIMODAL: It doesn’t take much acoustic hearing in the non-CI ear to yield benefit...

for adults with postlingual SNHL.
Why might children be different?
Why might children be different?
Why might children be different?

Children are not little adults.
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.
- Bimodal benefit will increase with increasing BW for children, as with adults.
Simha, Sheffield & Gifford (in prep).

- Children with normal hearing (n = 20)
- Mean age = 9.2 years
  - Range 6 to 12 years
- CI simulations (vocoder as in Litvak et al., 2007)
- Bimodal simulations: 90 dB/oct
  - <250, <500, <750, <1000, and <1500 Hz
- BabyBio sentences at variable SNR
  - SNR → ~50% for “CI-only” condition
  - Mean = 6.6 dB
$X^2 = 90.2, \ p < 0.0001$
**PRIMARY CONCLUSION**

Children require a wider acoustic BW to achieve **maximum bimodal benefit** than adults.

BUT...they demonstrated significant bimodal benefit with narrower BWs.

What about bimodal children (CI and HA)?
PRELIMINARY DATA
Mean age = 9 years (7.8, 7.6, & 11.4 years)

SNR
→ 50% CI only
→ 0 to 1 dB SNR!

Presentation level in non-CI ear
→

65 dBA signal + DSL amplification
BabyBio sentences

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Individual variability?
Flat loss at 70 dB HL
Flat loss 80-100 dB HL
Sloping loss 30 to 70 dB HL
SUMMARY

- Bimodal hearing $\rightarrow$ great benefit

- Little acoustic hearing is needed for significant benefit and for max benefit

- Much work is needed in this area!

Thank you for your attention!
Questions/comments