BINAURAL HEARING
AND THE IMPORTANCE
OF BILATERAL
HEARING-AID FITTINGS

Sridhar Kalluri

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QUIZ.

BINAURAL HEARING
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OF BILATERAL
HEARING-AID FITTINGS

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AGENDA
• Benefits of binaural hearing and bilateral fits
• New research on benefits of binaural hearing and bilateral fits
• What limits the benefits of bilateral fittings
John William Strutt, 3rd Baron Rayleigh

1907: Duplex theory of sound localization

From Hartmann (1999)
HEAD SHADOW IS BENEFICIAL FOR SPEECH RECOGNITION

FOCUS SPATIAL ATTENTION ON SOUND OF INTEREST

BINAURAL PROCESSING STARTS IN THE MIDBRAIN

From Kandler et al (2009)

BENEFITS OF BINAURAL FUNCTION

- Sound Localization
- Speech perception in noise
  - Head shadow
  - Squelch
- Perception of echoes
- Focusing of attention in space
  - …

BILATERAL ADVANTAGE: TIMELINE OF SELECT FINDINGS

<table>
<thead>
<tr>
<th>Year</th>
<th>Findings</th>
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<tbody>
<tr>
<td>1948</td>
<td>Binaural advantage for speech intelligibility (Licklider/Hirsch)</td>
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<tr>
<td>1961</td>
<td>Bilateral benefit for localization (DeCarlo &amp; Brown)</td>
</tr>
<tr>
<td>1981</td>
<td>Sound quality (Erdman &amp; Sedge)</td>
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<tr>
<td>2002</td>
<td>Speech recognition in noise (Kobler &amp; Rosenhall)</td>
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</tbody>
</table>
1. Low bilateral fit rates in most of the world

2. Research favors bilateral fitting, but also some cautionary findings

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<table>
<thead>
<tr>
<th>Year</th>
<th>Percent binaural fits</th>
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<tr>
<td>1991</td>
<td>53</td>
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<tr>
<td>1994</td>
<td>57</td>
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<td>1997</td>
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<td>2005</td>
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<td>2009</td>
<td>90</td>
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</table>

From Kochkin

<table>
<thead>
<tr>
<th>Region</th>
<th>Percent of bilateral fittings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweden</td>
<td>42</td>
</tr>
<tr>
<td>Denmark</td>
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<td>Norway</td>
<td>50-70</td>
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<td>Australia</td>
<td>75</td>
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<tr>
<td>Ontario, Canada</td>
<td>50-60</td>
</tr>
<tr>
<td>USA</td>
<td>82</td>
</tr>
</tbody>
</table>

Arlinger, 2004

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WORSE SPEECH RECOGNITION WITH BILATERAL THAN UNILATERAL

Walden and Walden (2005)
1. Low bilateral fit rates in most of the world

2. Research favors bilateral fitting, but also some cautionary findings

3. Benefits of binaural and spatial hearing and bilateral fits are underappreciated
   - Cost/benefit tradeoff not readily apparent

Stuart Gatehouse characterized hearing disability as being embodied by poorer:

- Speech communication
- Access to environmental sounds
- Spatial hearing
- Selective, switching, divided attention
- Ease of listening

Need for outcome measures that engage higher-order brain processing

SCENARIOS FOR SELF-REPORTED BILATERAL ADVANTAGE VS UNILATERAL

- Multi-stream processing
- Dynamic listening scenarios
- Attention switching
- Attention sharing and focusing
- Fluctuating, complex backgrounds
- Perception of reverberation
- Speech reception
- Distance perception
- Listening effort

Noble and Gatehouse (2006)

Design of current hearing technology

- Focus on restoring audibility
- Driven by goal of improving speech recognition

AGENDA

- Benefits of binaural hearing and bilateral fits
- New research on benefits of binaural hearing and bilateral fits
- What limits the benefits of bilateral fittings
• Focus on the role of binaural and spatial hearing in complex, dynamic scenarios
  - Understand full scope of binaural hearing and bilateral fitting benefits
  - New outcome measures predictive of hearing-aid benefit in real-world use
  - Assess signal processing alternatives in new ways

EXAMPLE 1

• Binaural hearing is important for comprehending speech in realistic multiple talker environments like cocktail parties
  - Research in collaboration with UC Berkeley

NATURAL COCKTAIL PARTY LISTENING DIFFERS FROM TRADITIONAL SPEECH TESTS

- Goal is comprehension, not just recognition
- Information flows continuously
- Information is processed from multiple sources

Auditory Stream
Ever since a young child she had been instinctively nervous, jumping at shadows all too often. At one time it had made her parents laugh.

Visual Display

Semantic Question:
The woman was
A) easily startled
B) usually calm

Phonetic Question:
The woman was
A) instinctively nervous
B) usually calm

Improvement of speech comprehension with increasing talker separation
EXAMPLE 2

• Binaural hearing reduces the cognitive load of recognizing speech in noisy environments with varied talkers

Cognitive load measured with dual-task paradigm

• Primary task:
  – Repeat keywords of target speech

• Secondary task:
  – Continuous visual tracking

Visual-only Trial

Cognitive load

• Additional Location cue did not increase speech recognition but reduced the cognitive load
EXAMPLE 3

- Benefit of bilateral fits over unilateral fit evident in ability to recognize speech in the presence of other interfering speech
  - Research collaboration with University of Manchester

Speech recognition performance in

1.5 dB advantage for bilateral fittings over unilateral fittings

Dawes et al, 2013

OTHER EXAMPLES OF NEW RESEARCH

- Spatial awareness of acoustic environment when under high cognitive load
- Switching focus of attention between talkers

WHAT HAVE WE LEARNED

- More complete picture of the role of binaural hearing and the importance of bilateral fits emerge from outcome measures that incorporate greater realism

RECALL

Better Ear

AGENDA

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- New research on benefits of binaural hearing and bilateral fits
- What limits the benefits of bilateral fittings

Walden and Walden (2005)
FACTORS LIMITING BENEFIT OF BILATERAL FITS

• Mild hearing loss
• Good low-frequency hearing
• Disruption of binaural cues by hearing-aid signal processing

Fast-acting compression acting independently at the ears can reduce the benefit of spatial separation for understanding speech, by distorting inter-aural level differences

Kalluri and Edwards (2006)

FACTORS LIMITING BENEFIT OF BILATERAL FITS

• Mild hearing loss
• Good low-frequency hearing
• Disruption of binaural cues by some hearing-aid signal processing
• Scenarios where binaural hearing has limited role

Limited possibility for bilateral advantage with collocated configuration

Collocated speech and noise configuration in Walden and Walden (2005)

FACTORS LIMITING BENEFIT OF BILATERAL FITS

• Mild hearing loss
• Good low-frequency hearing
• Disruption of binaural cues by some hearing-aid signal processing
• Scenarios where binaural hearing has limited role
• Listeners experiencing binaural interference
Negative binaural interaction

CONCLUSION

• Except in 10% of elderly patients experiencing binaural interference, bilateral hearing aids should be beneficial especially in complex, dynamic, and noisy scenarios

WHAT DOES THIS MEAN FOR CLINICAL PRACTICE?

• Bilateral fits by default, unilateral as exception
• Counsel that bilateral beneficial in complex dynamic scenarios
  - Benefit for ease of listening as well as speech understanding
• Future outcomes tools will incorporate significantly more realism (environment and task)

THANKS FOR YOUR LISTENING EFFORT

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