BINAURAL HEARING AND THE IMPORTANCE OF BILATERAL HEARING-AID FITTINGS

Sridhar Kalluri

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BINAURAL HEARING AND THE IMPORTANCE OF BILATERAL HEARING-AID FITTINGS

Sridhar Kalluri

Binaural hearing

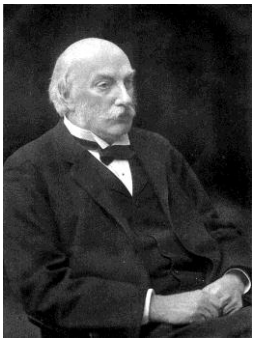
Bilateral fits

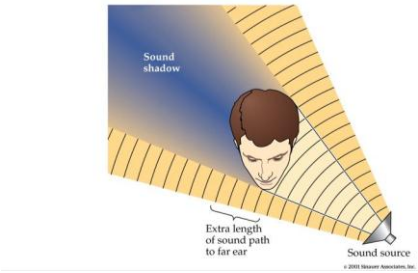
AGENDA

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

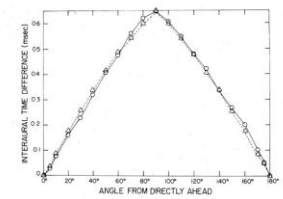
John William Strutt, 3rd Baron Rayleigh

1907: Duplex theory of sound localization





SOUND LOCALIZATION



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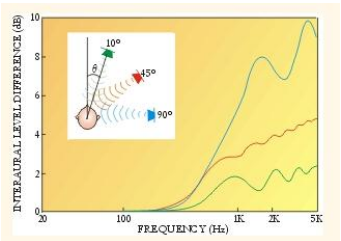
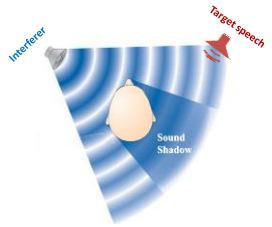


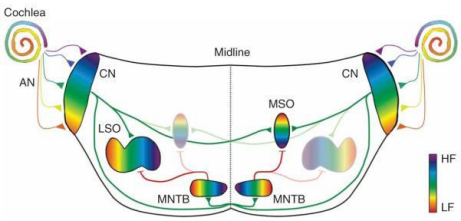
From Hartmann (1999)

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 fit benefits

- Speech perception in noise
  - –Head shadow
  - –Squelch
- Localization
- Sound quality
- Less auditory deprivation
- …

BILATERAL ADVANTAGE: TIMELINE OF SELECT FINDINGS

1948: Binaural advantage for speech intelligibility (Licklider/Hirsch)

1961: Bilateral benefit for localization (DeCarlo & Brown)

1981: Sound quality (Erdman & Sedge)

2002: Speech recognition in noise (Kobler & Rosenhall)

Year	Percent binaural fits
1983	*22*
1991	53
1994	57
1997	63
2000	68
2005	74
2009	90

From Kochkin

VS

Why?

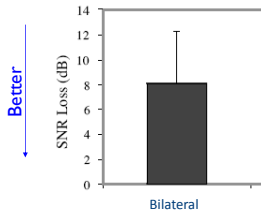
1. Low bilateral fit rates in most of the world

Region	Percent of bilateral fittings
Sweden	42
Denmark	40-50
Norway	50-70
Finland	5-20
Poland	40-60
Netherlands	40-60
Belgium	56
Germany	50-60
England	20-80
Australia	75
Ontario, Canada	50-60
USA	82

Arlinger, 2004

1. Low bilateral fit rates in most of the world
2. Research favors bilateral fitting, but also some cautionary findings

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

Design of current hearing technology

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

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

Higher-order brain function

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)

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
   - Failure to incorporate realism in outcome measures

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

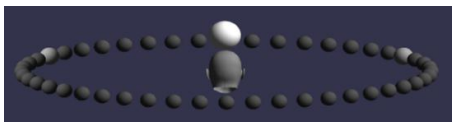
- Focus on the role of binaural and spatial hearing in complex, dynamic scenarios
  - Understand full scope of binaural hearing and bilateral fitting benefits
  - New outcome measures predictive of hearing-aid benefit in real-world use
  - Assess signal processing alternatives in new ways

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

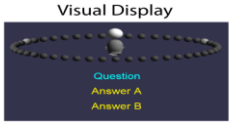
- Goal is comprehension, not just recognition
- Information flows continuously
- Information is processed from multiple sources



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.

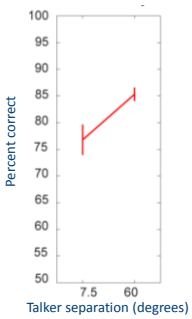
Visual Display



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

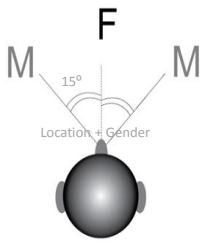
Phonetic Question:
The woman was
A) instinctively nervous
B) usually calm

Improvement of speech comprehension with increasing talker separation



EXAMPLE 2

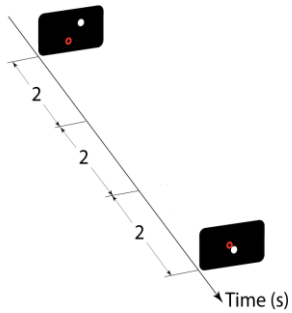
- Binaural hearing reduces the cognitive load of recognizing speech in noisy environments with varied talkers

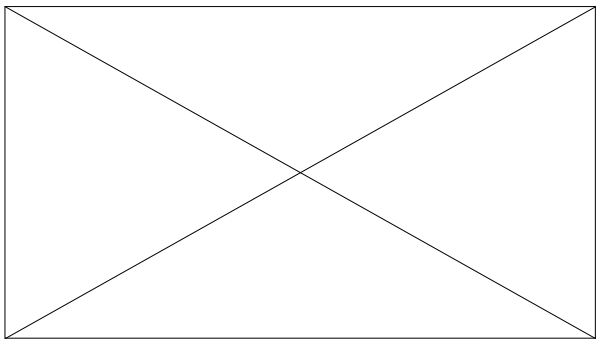


Cognitive load measured with dual-task paradigm

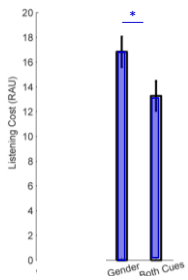
- Primary task:
  - Repeat keywords of target speech
- Secondary task:
  - Continuous visual tracking

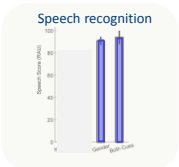
Visual-only Trial





Cognitive load

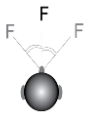




- Additional *Location* cue did not increase speech recognition but reduced the cognitive load

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 

for  vs 

1.5 dB advantage for bilateral fittings over unilateral fittings

Dawes et al, 2013

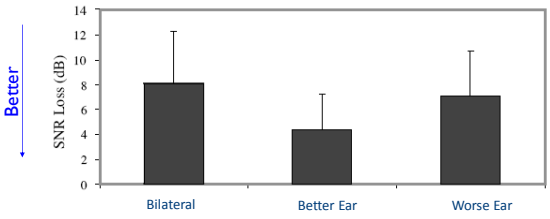
OTHER EXAMPLES OF NEW RESEARCH

- 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



Walden and Walden (2005)

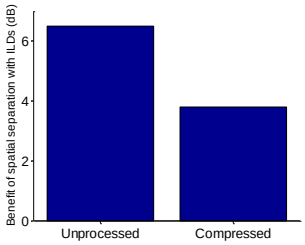
AGENDA

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

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

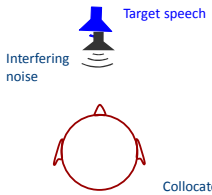


Kalluri and Edwards (2006)

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

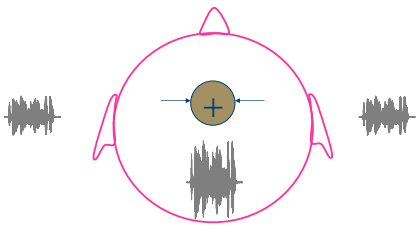
Limited possibility for bilateral advantage with collocated configuration



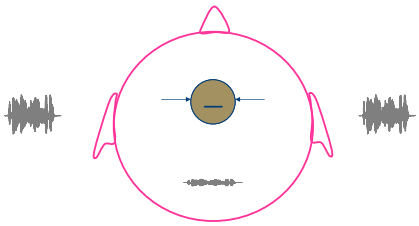
Collocated speech and noise configuration in Walden and Walden (2005)

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



~ 10% of elderly patients (Jerger et al)

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)

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