Binaural hearing – 2011

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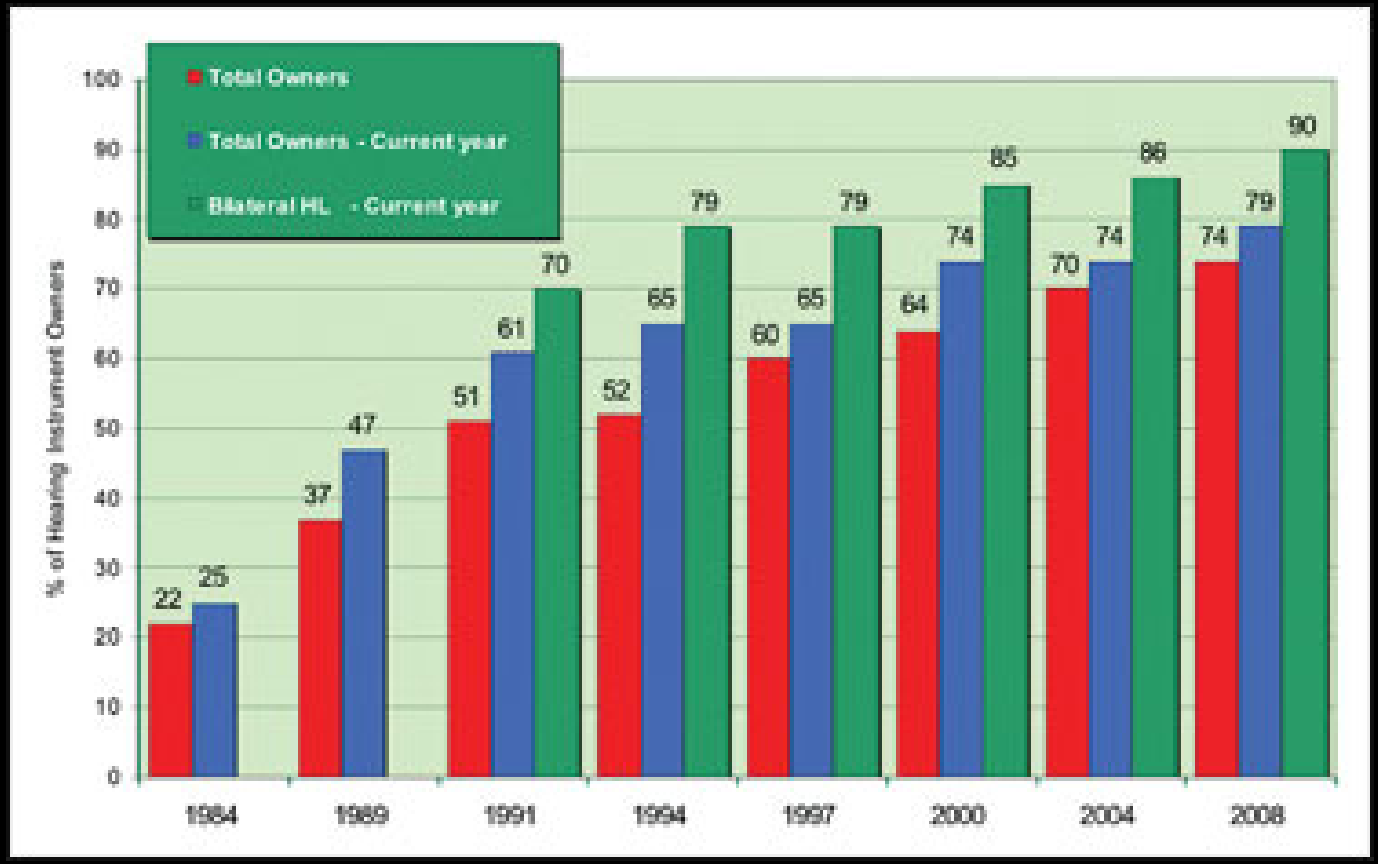
Outline

- Usage
- Known binaural advantages
- How hearing aids have interfered with binaural cues
- Current attempts at maintaining binaural cues

The general rule is that unless a significant asymmetry exists between the ears in either sensitivity or word recognition ability, the standard should be trial with binaural amplification.

Binaural usage (in the U.S.)



Kochkin, , 2009

Why binaural amplification has not become universally accepted

- Inadequate sensitivity of test materials leading to negative remarks in the early audiological literature
  - body aids; peak clippers; limited frequency bandwidth; monosyllabiic testing in quiet
- Stigma
- Occlusion
- Cost (time and money)
- Binaural interference (vs integration) in elderly
- Degradation of binaural cues by hearing aids

Why should binaural fittings be preferred?

- Elimination of the head shadow effect (6.5 – 13 dB)
- Binaural summation (~3-6 dB) ; so reduced gain needed (less distortion, less feedback
- Binaural squelch (low frequency unmasking)
- Sensory deprivation

"….evidence of neurological degeneration."

– Silman and Gelfand

Possible Deterioration of the Unaided Ear

"While it is debatable whether disuse of an ear will produce further reduction in peripheral loss (i.e. on pure tones), there is ample evidence of neurological degeneration."

– Silman and Gelfand

Additional binaural advantages

- Everything we knew in 1982 PLUS…….
- Spatial release from masking
  - Auditory scene analysis (grouping)
  - Separation of source and background
- Temporal characteristics of speech versus noise
- Importance of fundamental frequency
- Informational masking
- Neural binaural processing

Binaural interference

"Difficulty with bilateral amplification in some elderly patients might be attributable to "age-related progressive atrophy and/or demyelination of corpus callosal fibers, resulting in delay or other loss of the efficiency of interhemispheric transfer of auditory information."

Chmiel et al (1997)

Binaural interference vs lack of binaural integration

Problems for older listeners

- No problem in ideal listening conditions
  - Quiet
  - One talker
  - Familiar person
  - Familiar topic, situation
  - Simple task, focused activity

- Difficulty in non-ideal listening conditions
  - Noise
  - Multiple talkers
  - Strangers
  - New topic, situation
  - Complex task, many concurrent activities
  - Fast pace

Impact of aging on speech perception

- Even in the absence of hearing loss, older subjects require 3-5 dB higher SNR than young listeners (Schneider, Daneman and Murphy, 2005).
- Older subjects with normal hearing perform approximately the same as young hearing impaired subjects (Wingfield and Tun, 2001)

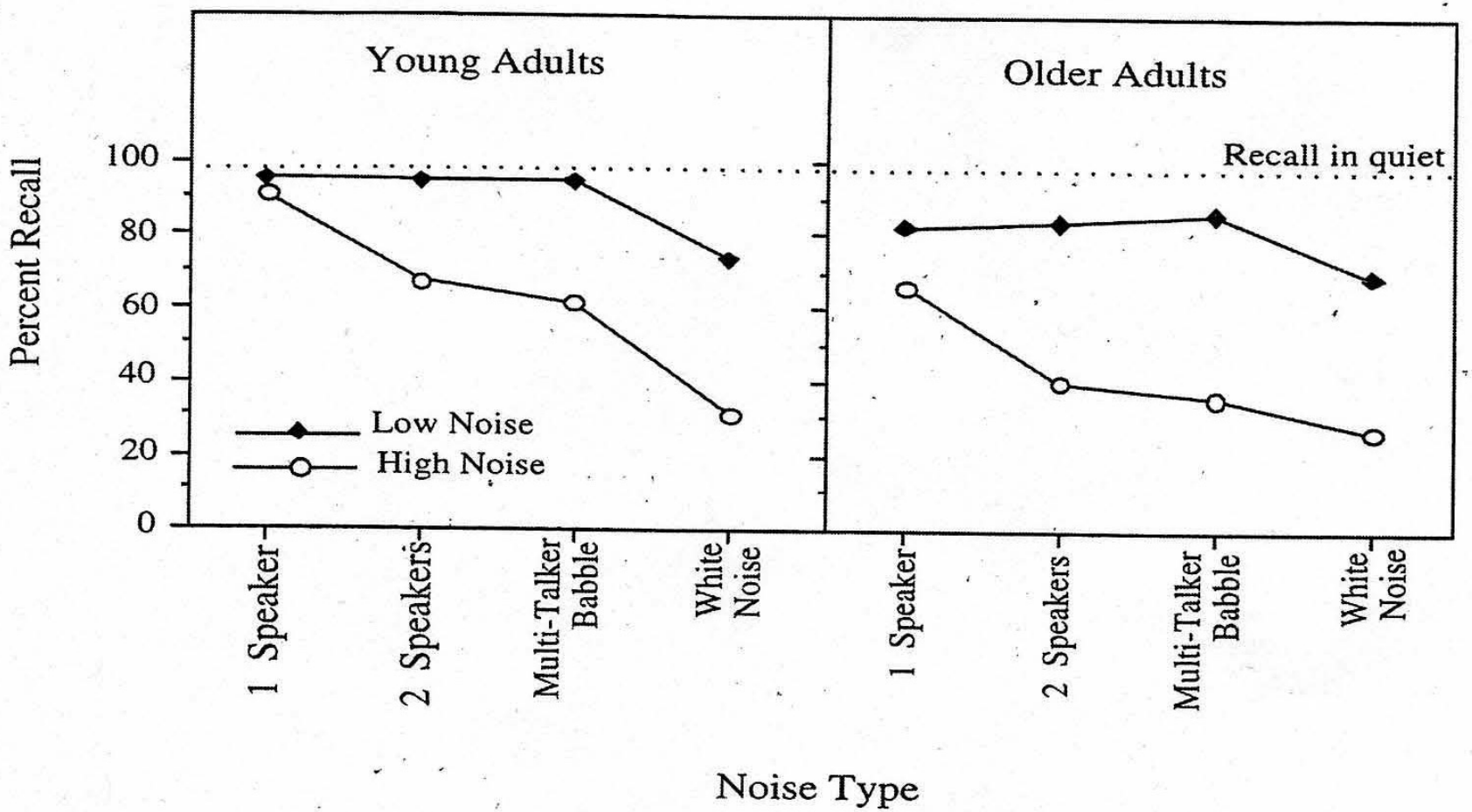


Figure 4 Percentage of words recalled from sentences heard in the presence of four types of background distraction presented at high or low amplitude (noise level) relative to the speech amplitude. Performance for young adults (mean age = 19 years) and older adults (mean age = 71 years) are shown in the left and right panels, respectively. The horizontal dotted line shows the baseline recall level for both participant groups for sentences heard in quiet. (From Tun and Wingfield.[66])

Young brain activity is more lateralized

Old brain activity is more distributed

What is auditory scene analysis?

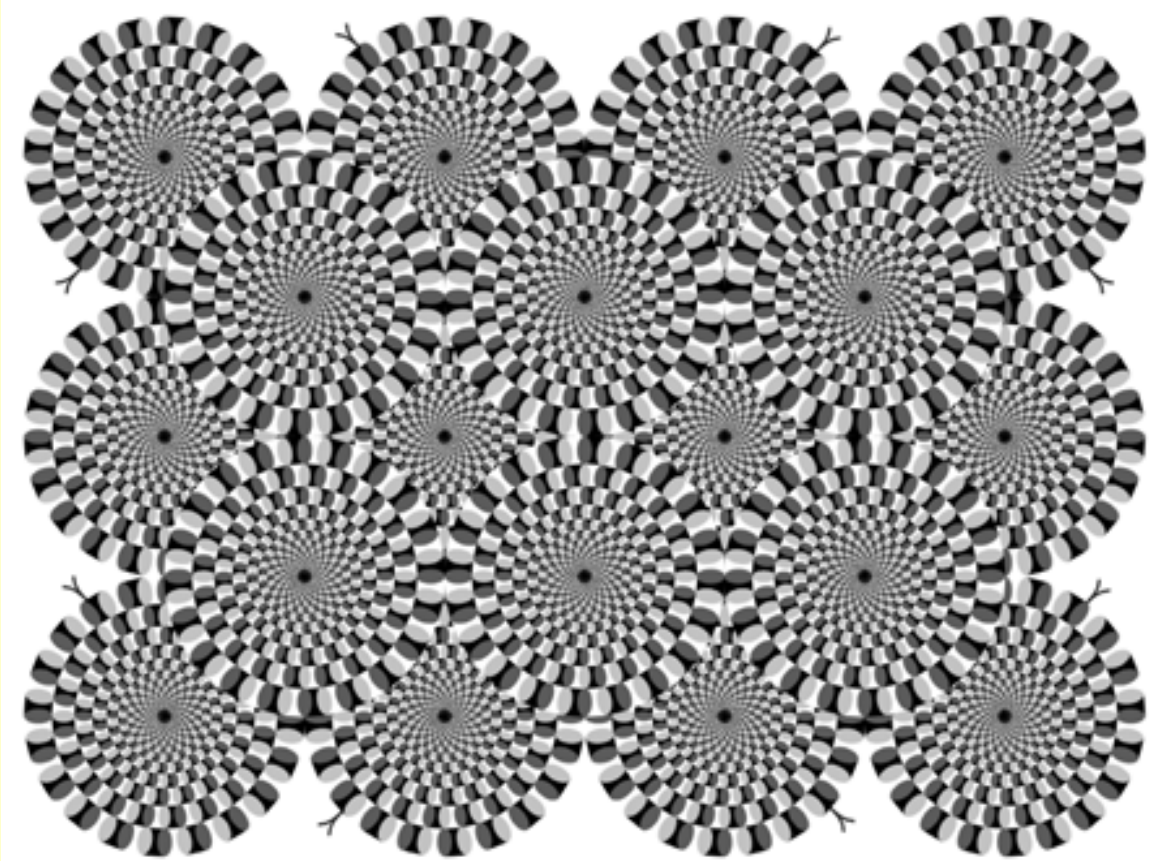
- Ability to know your environment and identify objects through sound
- “the organization of sound scenes according to their inferred sources” (Bregman, 1990)
- Grouping of elements of sound from one direction versus elements of interfering sound from other directions

Gestalt Laws of Organization:
Principles of how our visual systems group together elements

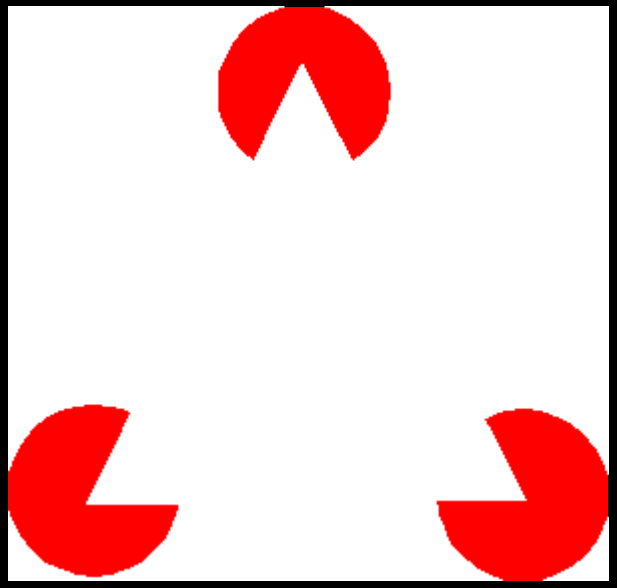
- **Proximity……**
  – Elements that are close are often grouped together.
- **Similarity…….**
  - Similar elements tend to be grouped together.
- **Common fate……**
  - Things that move together tend to group.
- **Good continuation……**
  – Perceptual mechanisms tend to preserve smooth continuity in favor of abrupt edges.
- **Closure……**
  – Of several possible perceptual organizations, ones yielding "closed“ figures are more likely than those yielding "open" ones.

Failure of grouping

If figures do not yield a consistent grouping, the visual system struggles, and may switch back and forth between several possible groupings



Kaniza illusion



Why is this important?

- Errors in simultaneous grouping can lead to the blending of sounds that should be heard as separate, the blended sounds having different perceived qualities (such as pitch or timbre) than any of the actually received sounds.
- Errors in sequential grouping can lead, for example, to hearing a word created out of syllables originating from two different voices. The job of ASA is to group incoming sensory information to form an accurate mental representation of the environmental sounds

Why is auditory localization important?

- Allows us to pinpoint a sound of interest
- Locate the position of another person
- Locate direction and distance of a moving sound source
- Allows us to quickly locate and attend to a speaker, esp. in multi-talker situations

How do we tell where a sound is coming from?

- Horizontal
  - –Interaural time and phase differences
  - –Interaural intensity differences
- Vertical and Front-Back
  - –Spectral shaping from pinna, head, and upper torso

Unilateral hearing loss

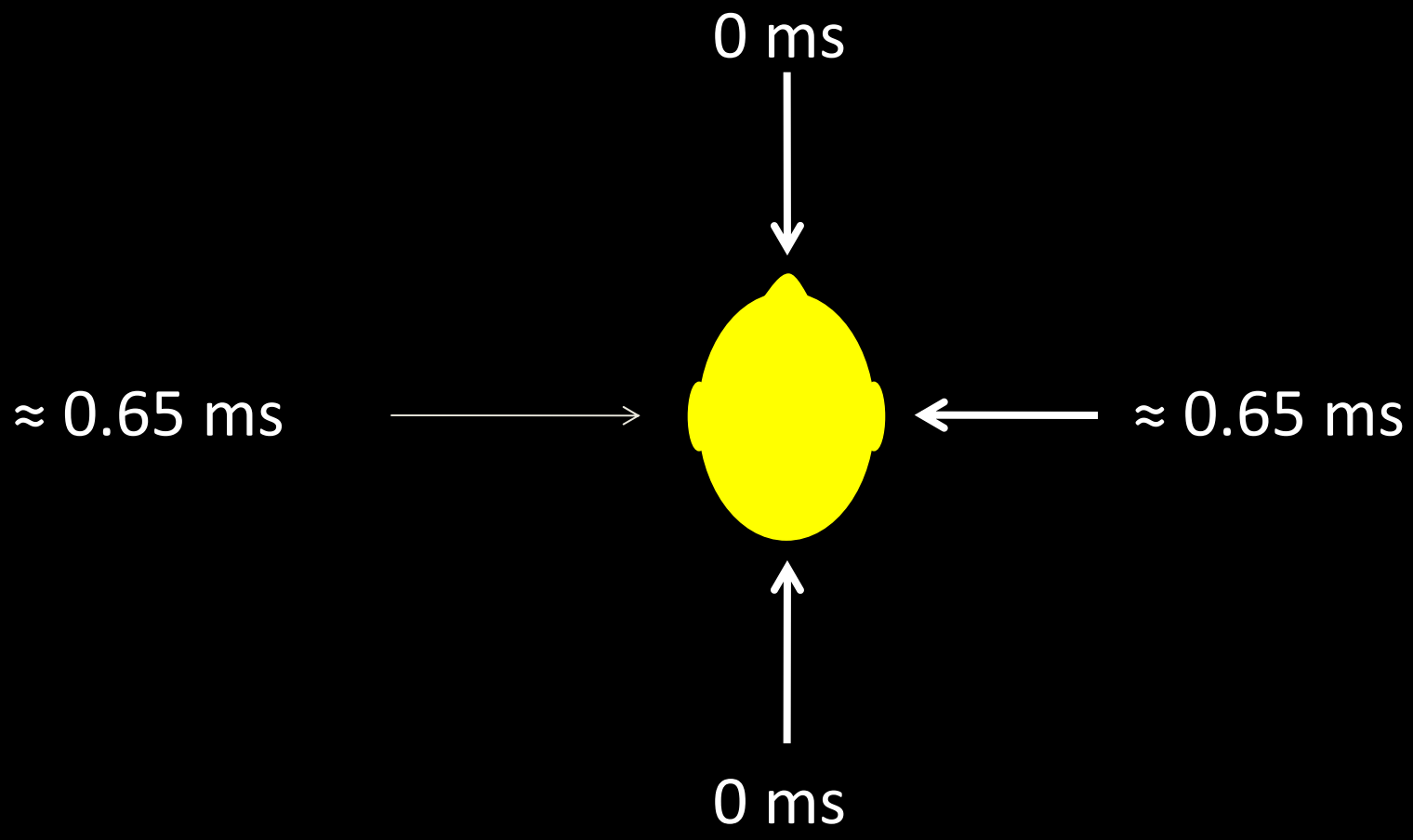
- Severely disrupts horizontal localization ability
- Front to back localization remains intact (some studies disagree)
- Vertical localization only slightly affected provided the other ear is adequate

Horizontal Localization (L vs R)

Comparing the signal input between two ears……..

- Interaural time difference (ITD) (medial superior olive)
- Interaural level difference (ILD) (lateral superior olive) –
- Inter-aural phase difference
- Duplex theory : High frequency (>1600 Hz) location determined by ILD; low frequency (<800 Hz) location determined by phase or time differences

Interaural Time Difference and Head Shadow Effect



- ITD was also thought to be based on the rise time of the input signals; had been thought to be identical processing at the two ears
- Recent NYU computer model study suggests rise time of ipsilateral signal is faster than that of contralateral signal
- Thus, neurons not only encode coincidence in arrival time, but they also detect details about the input's shape

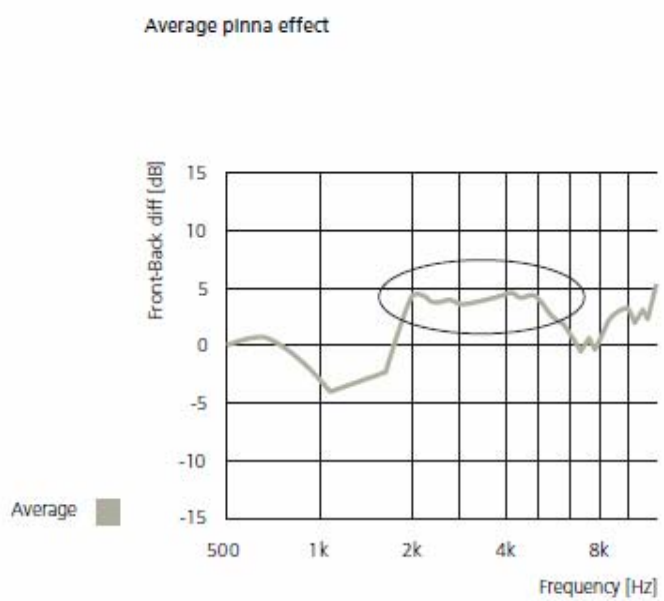
Interaural Phase Difference

- Coincident with the time delay (ITD)
- Varies systematically with source azimuth and wavelength due to distance from source and refraction around the head
- Most useful for frequencies up to about 700 - 800 Hz.
- Sound envelope provides similar information for higher frequencies, but to a lesser degree
- Dominant cue for horizontal localization for frequencies up to 1600 Hz.

Vertical and front-back localization: Pinna effect

- The pinna creates echos
- Affects localization in the vertical plane (because of cues >4K)

The Pinna



Data plotted for 45 different heads (CIPIC database).

Why hearing aids have not taken advantage of binaural cues

- If the Inter-aural Level Difference is to be maintained, the relative volume has to be unaffected;
- If the hearing aid user changes the volume in only one ear, the relative ILD is destroyed;
- The ILD can also be destroyed if the hearing aid user chooses to have different programs or two different microphone arrays in each hearing aid;
- Some types of compression could reduce ILD (Byrne and Noble [1998])
- Compression may affect high frequency ILD (and different programs could also affect ITD)

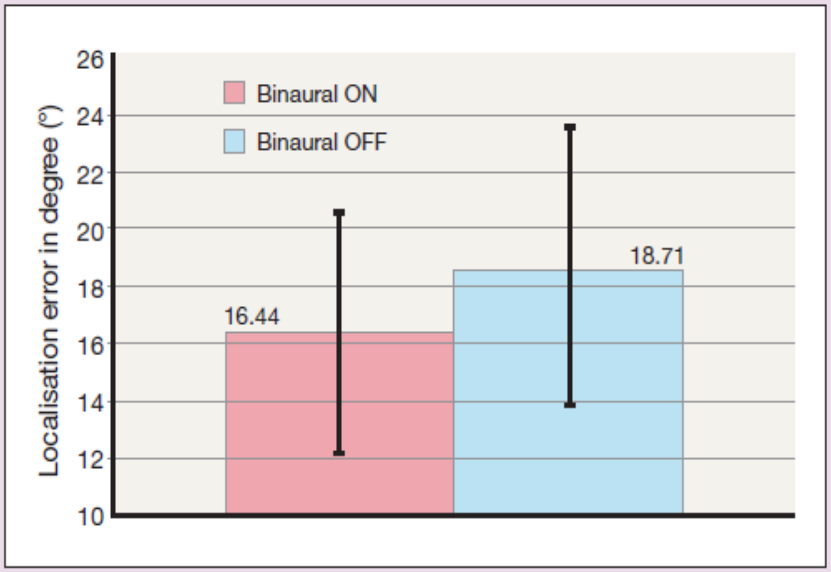


Figure 2. *Mean (±1 SD) localization errors (in degree) in noise in Binaural ON and Binaural OFF conditions from 0° to -105° and 0° to +105°. There were significantly more localization errors in the Binaural OFF condition (p<0.05).*

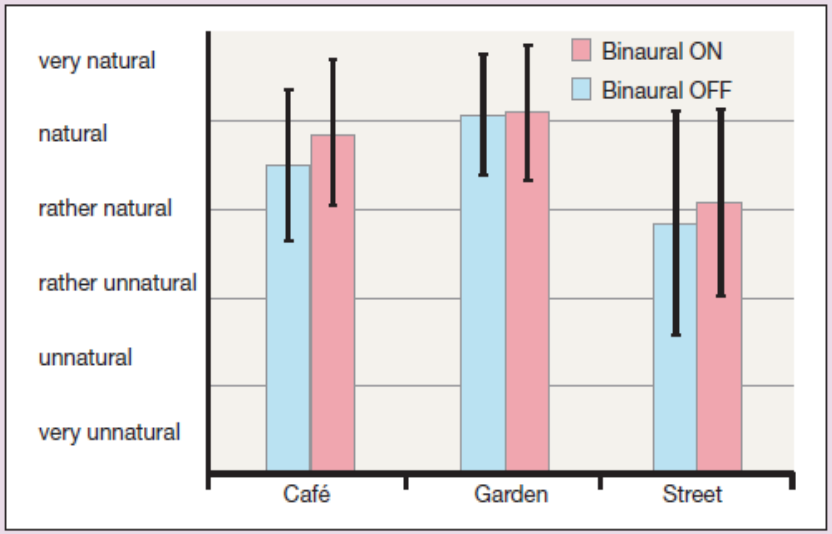
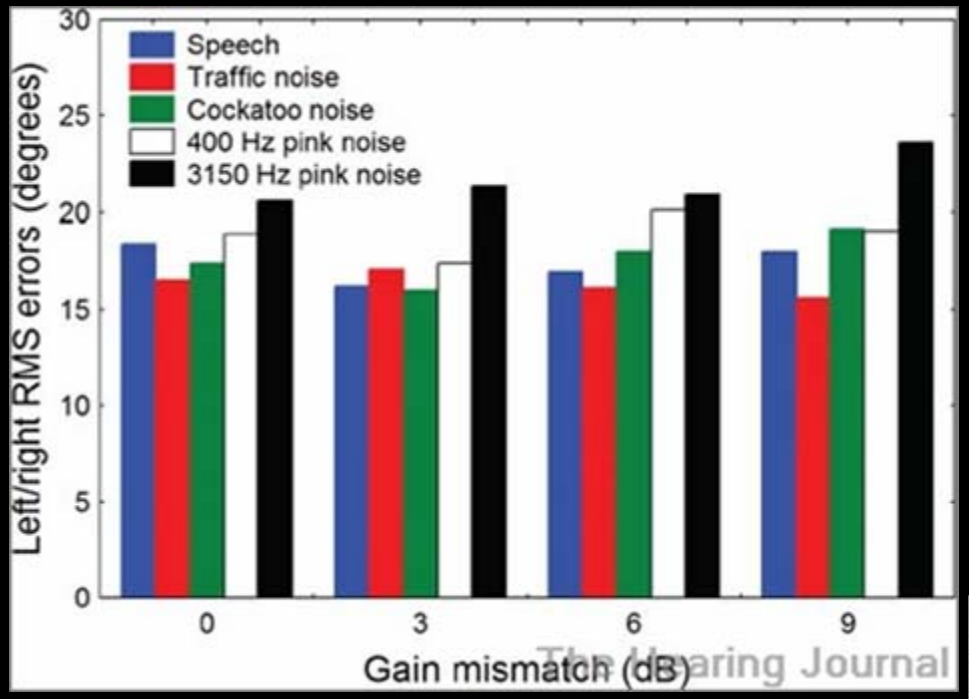
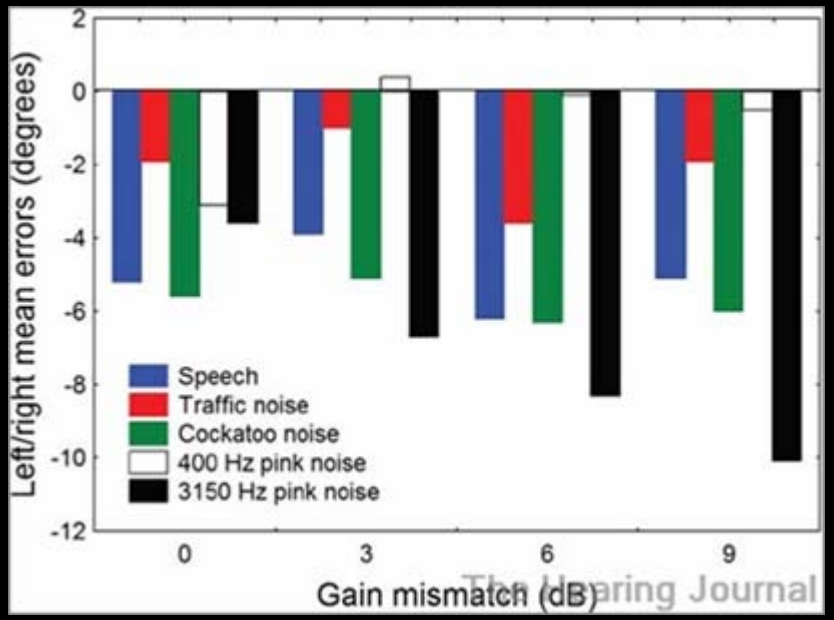


Figure 3. *Mean (±1 SD) ratings of naturalness of sound on a six-point scale in the Communication Acoustic Simulator. Dual XW was rated significantly more natural (p<0.05) in the Binaural ON condition than in the Binaural OFF condition in the café environment.*

Sockalingham, et al, 2009





Keidser, Convery, and Hamacher

The effect of gain mismatch on horizontal localization performance. The Hearing Journal. 64(2):26,30,32-33, February 2011.

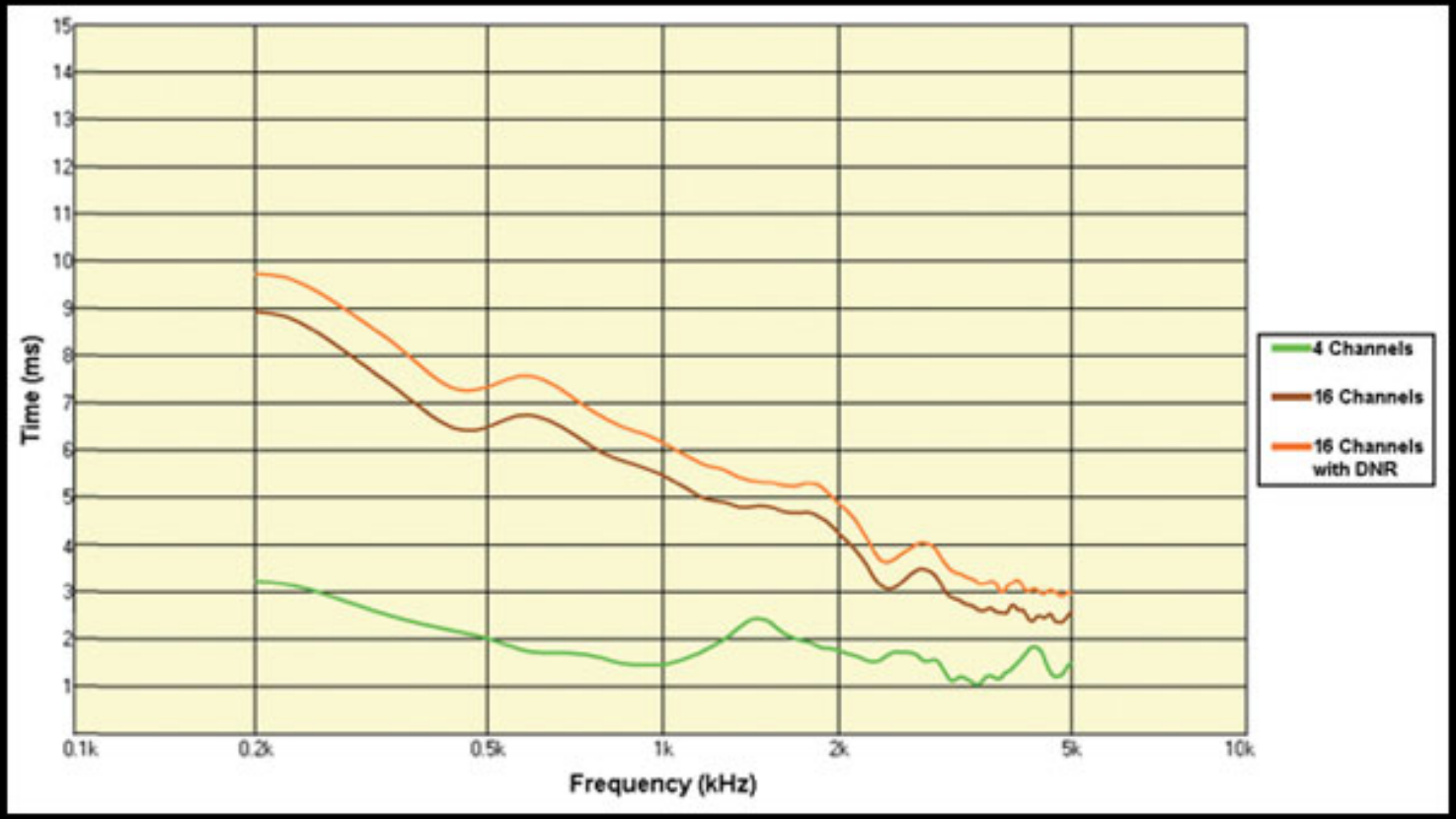
Why hearing aids have not taken advantage of binaural cues (continued)

- Interaural phase and time differences (ITD) can be altered by processing delays, compression characteristics, and vent sizes
- Absence of pinna and concha effect in BTEs and some ITEs

Interaural Time Difference

- Short delay in hearing aids = 3-6 ms in speech frequencies
- ITD is maximum at about 0.65 – 0.70 ms
- Vent differences
- Microphone differences

Processing delay times as a function of channels



Because of the pinna effect….

- Localization with no hearing aid is better than hearing aid

- Disadvantage of localization with CIC/ITE is relatively small but is high above 2KHz, exceeding 7 dB at 3150 Hz
  - Keidser et al. 2006; Dittberner and Bentler , 2007

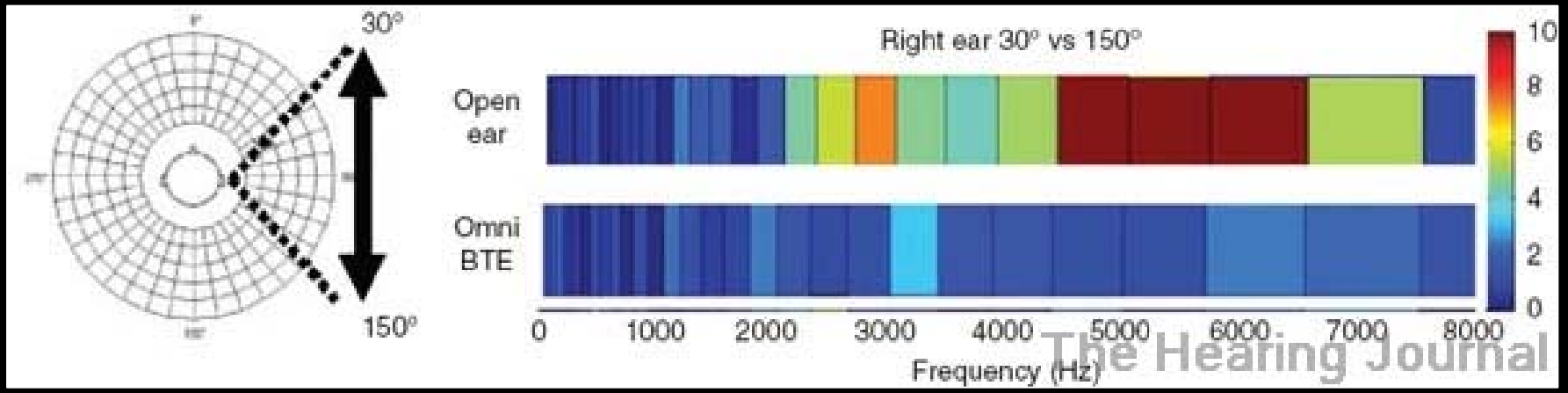
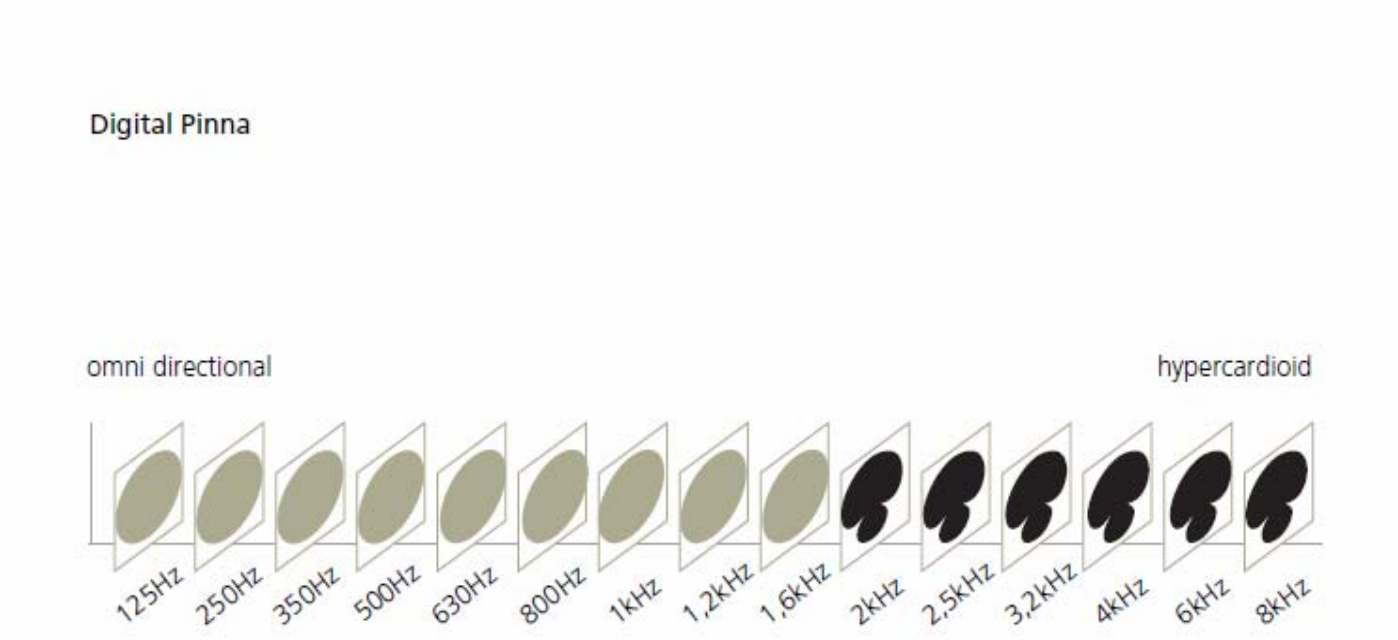


Figure 1. Energy differences for broadband sound presented from front (30°) and back (150°) for an open manikin ear and for an omnidirectional BTE mounted on the ear. Note the energy difference of up to 10 dB between 4000 and 6000 Hz. These spectral cues are missing for the BTE condition.

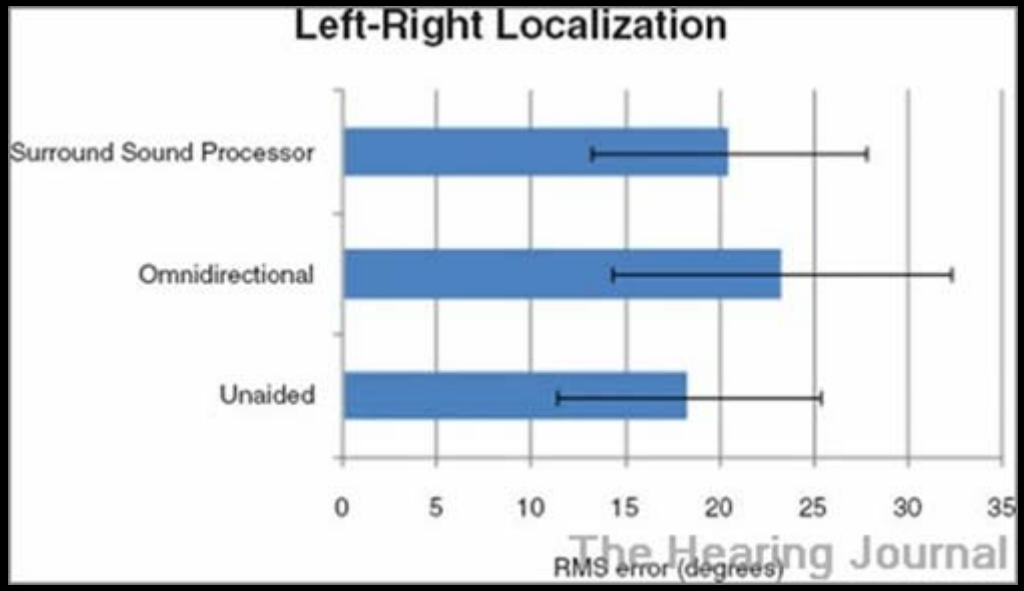
Groth and Laureyns,

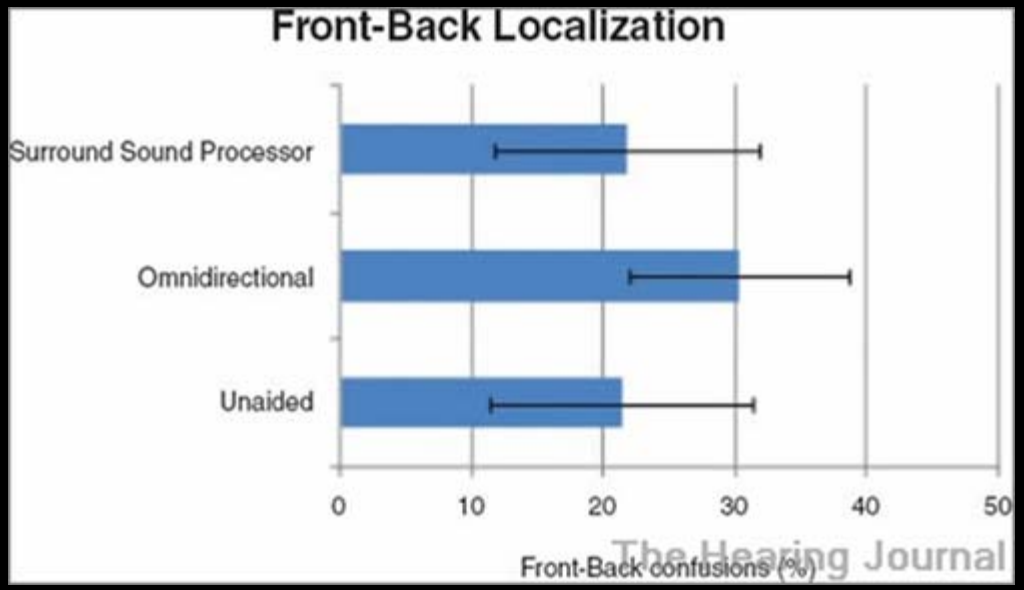
The Hearing Journal. 64(2):34-38, February 2011.

Digital pinna in CLEAR440



The increased low frequency gain from the omni directional microphone is acceptable because Walden, et al 2004; 2007 and others have shown that when visual cues are available, low frequency gain is important for consonant perception ; but when only visual cues are available, high frequencies are more important!!!!!!!


Left-Right Localization
Surround Sound Processor
Omnidirectional
Unaided
0
5
10
15
20
25
30
35
RMS error (degrees)
The Hearing Journal


Front-Back Localization
Surround Sound Processor
Omnidirectional
Unaided
0
10
20
30
40
50
Front-Back confusions (%)
The Hearing Journal

Other benefits

- InterEar communication
  - For compression
  - For program changes
  - For volume control
  - For feedback
- Extended bandwidth

Thanks for listening