Bimodal hearing, bilateral cochlear implants, and hearing preservation: speech understanding and underlying mechanisms

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VANDERBILT

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Disclosures

Eagles vs. Patriots Final Score: Philadelphia stuns New England in an upset, 35-28

By Brandon Lee Gowton @BrandonGowton *on Dec 6, 2015, 7:40p* 461

Mark L. Baer-USA TODAY Sports

Patriots vs Eagles

Final - Yesterday, 2:25 PM

Gillette Stadium, Foxborough, Massachus

Philadelphia Eagles (5-7)	35
New England Patriots (10-2)	28

Recap

Disclosures

Audiology Advisory Board member for:

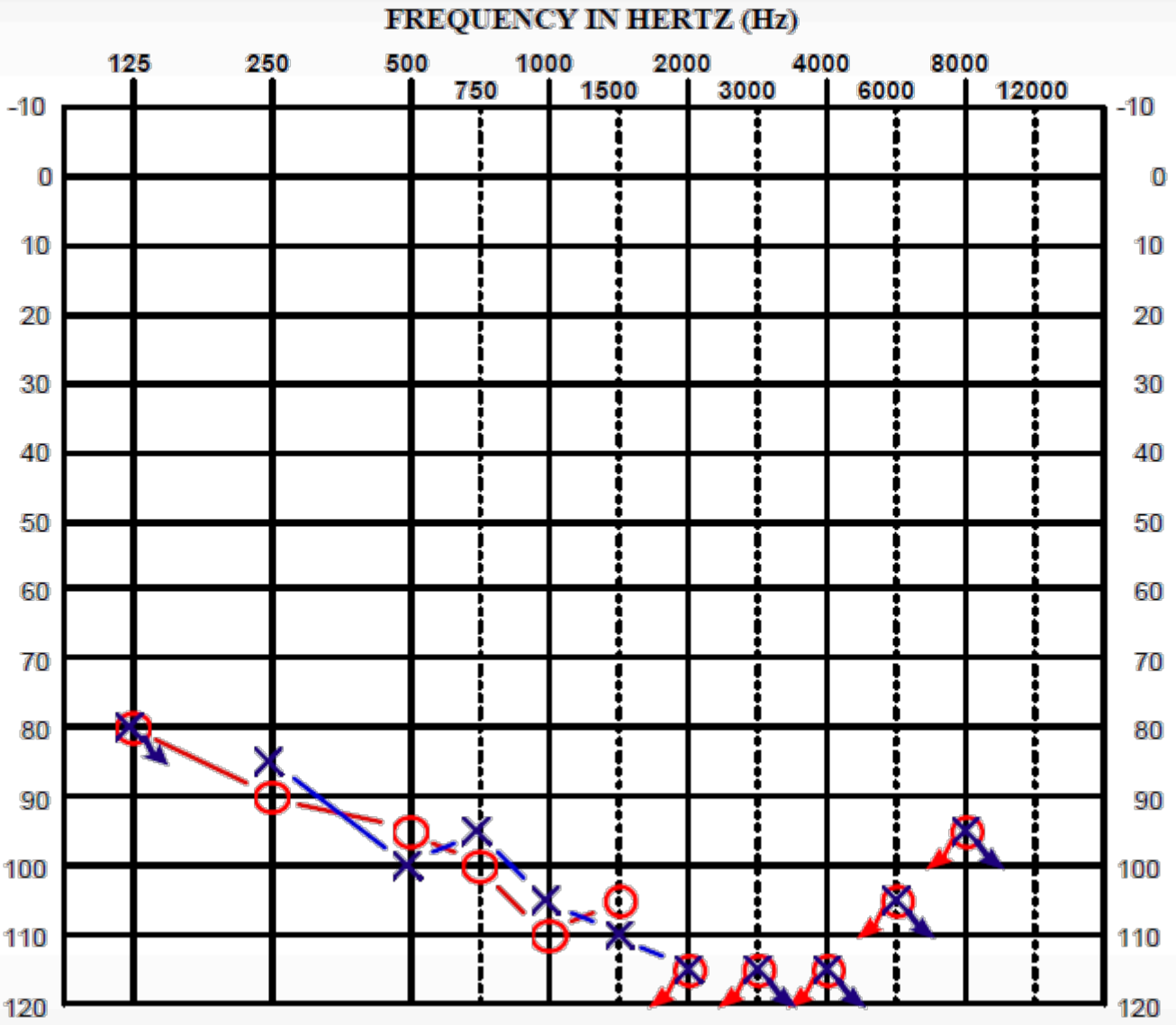
- Advanced Bionics
- Cochlear Americas
- MED-EL

Acknowledgements

NIH NIDCD R01 DC009404 & DC010821

National Institute on Deafness and Other Communication Disorders (NIDCD)

Michael Dorman, PhD, Tim Davis, AuD, Sterling Sheffield, AuD, Linsey Sunderhaus, AuD, Sarah Cook, MA, Louise Loiselle, PhD, Tony Spahr, PhD


FREQUENCY IN HERTZ (Hz)
125
250
500
750
1000
1500
2000
3000
4000
6000
8000
12000
-10
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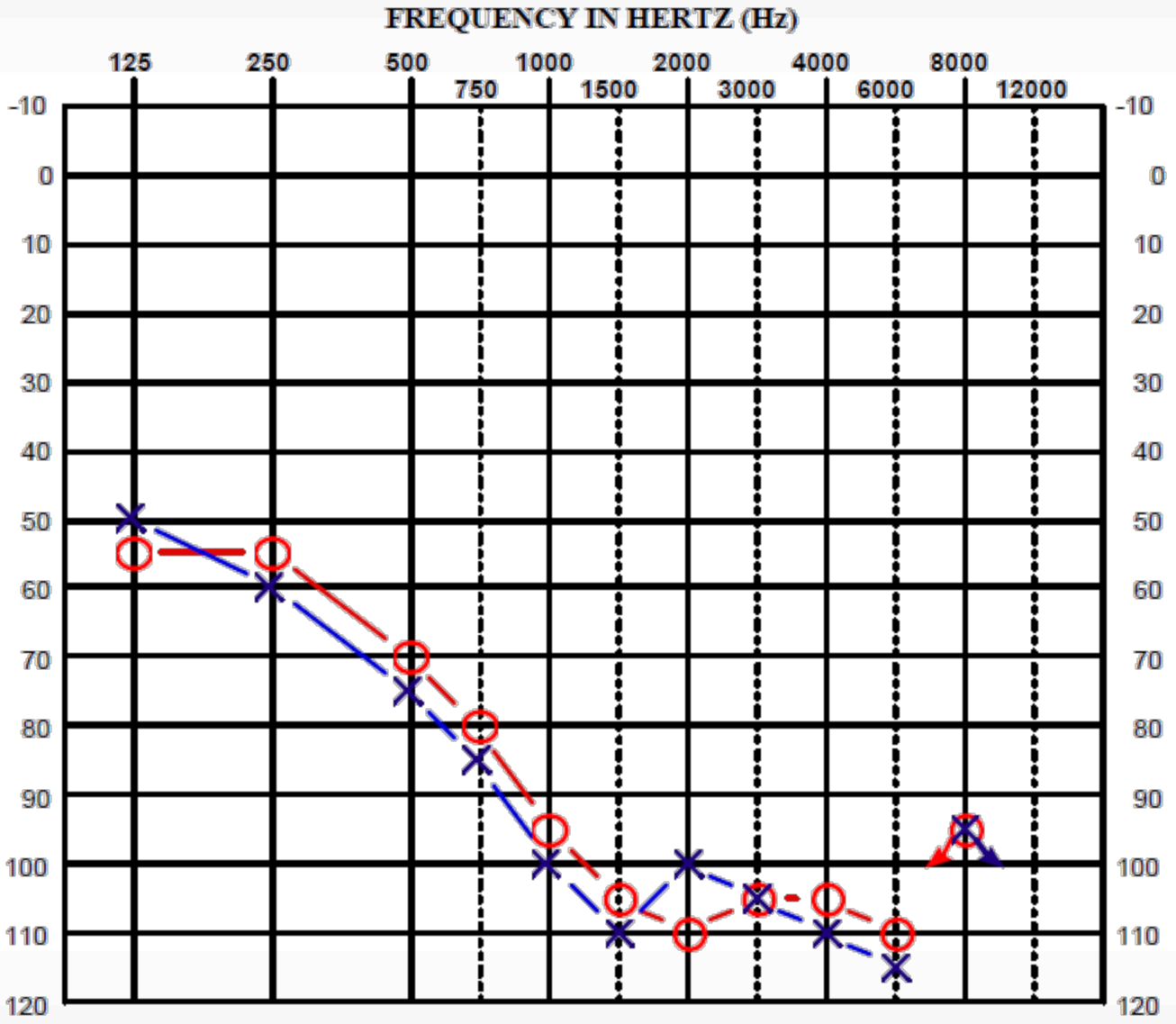
10
20
30
40
50
60
70
80
90
100
110
120


FREQUENCY IN HERTZ (Hz)
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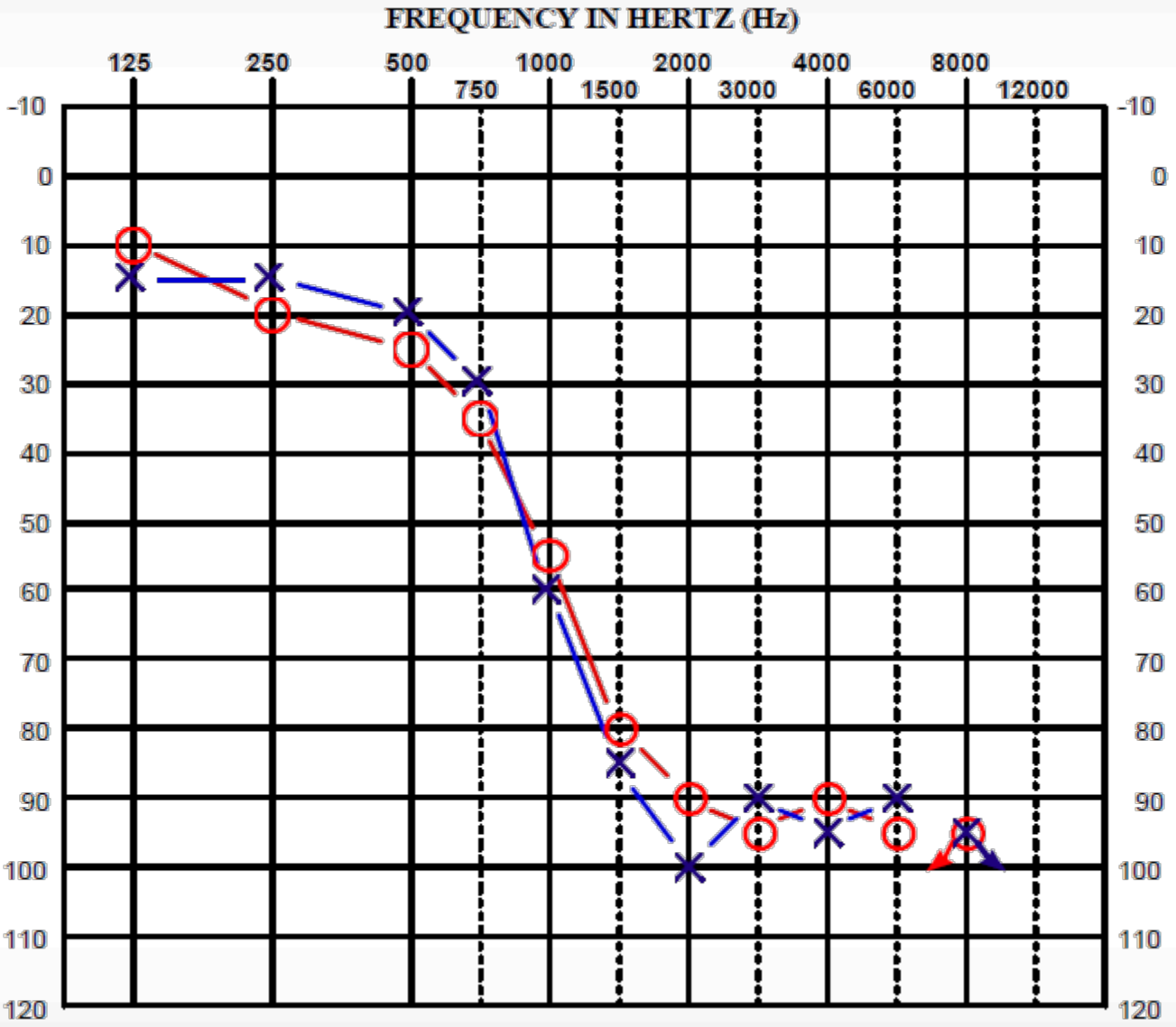
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80
90
100
110
120

Changing CI Population

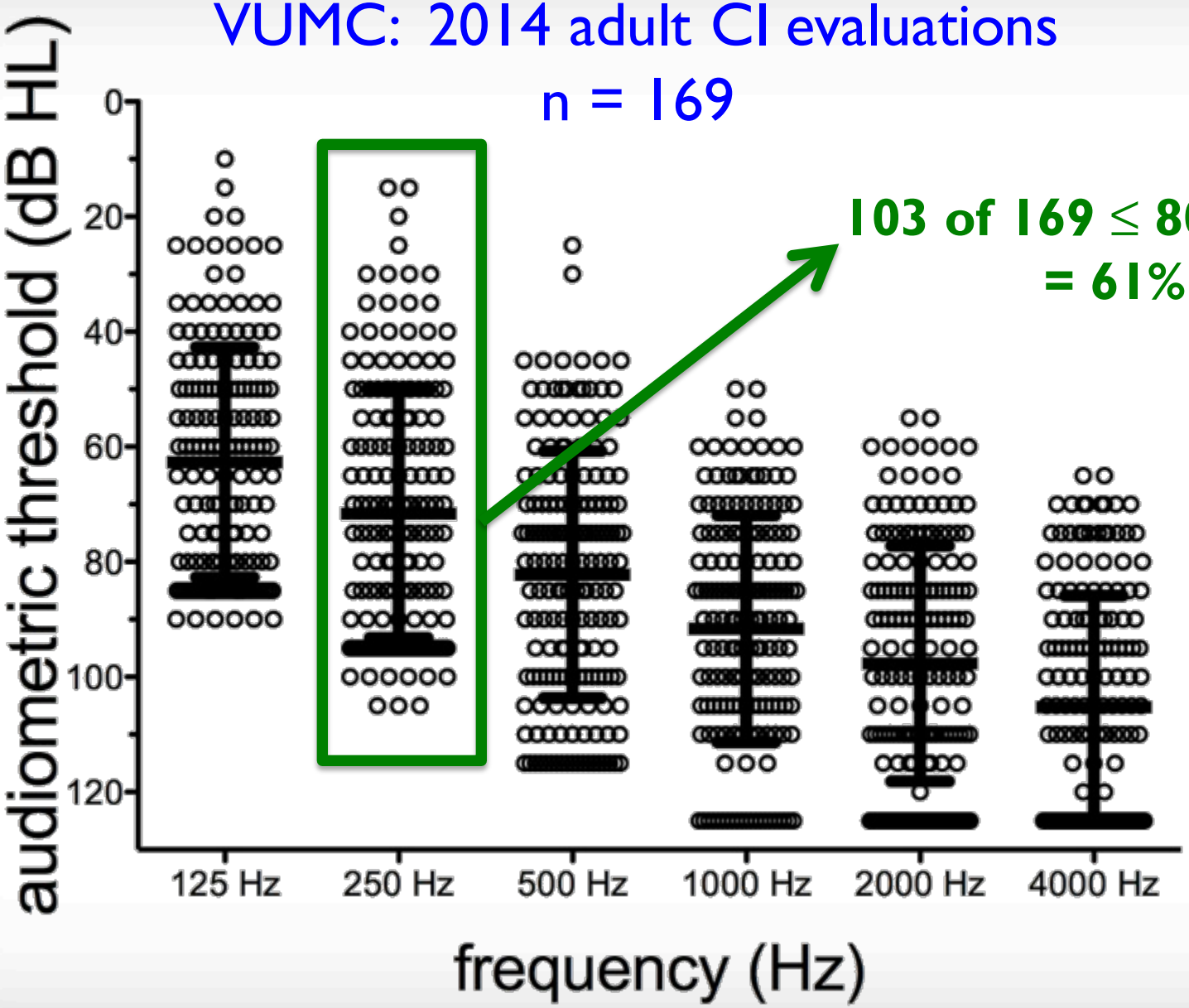
Table 1. Auditory thresholds at 250 Hz in the contralateral ear of 276 CI patients.

59.8% of the population

Threshold @ 250 Hz	*n*	Σ
<40 dB	19	
40–45 dB	15	34
50–55 dB	29	63
60–65 dB	27	90
70–75 dB	34	124
80–85 dB	41	165
90–95 dB	31	196
100+ dB	80	276

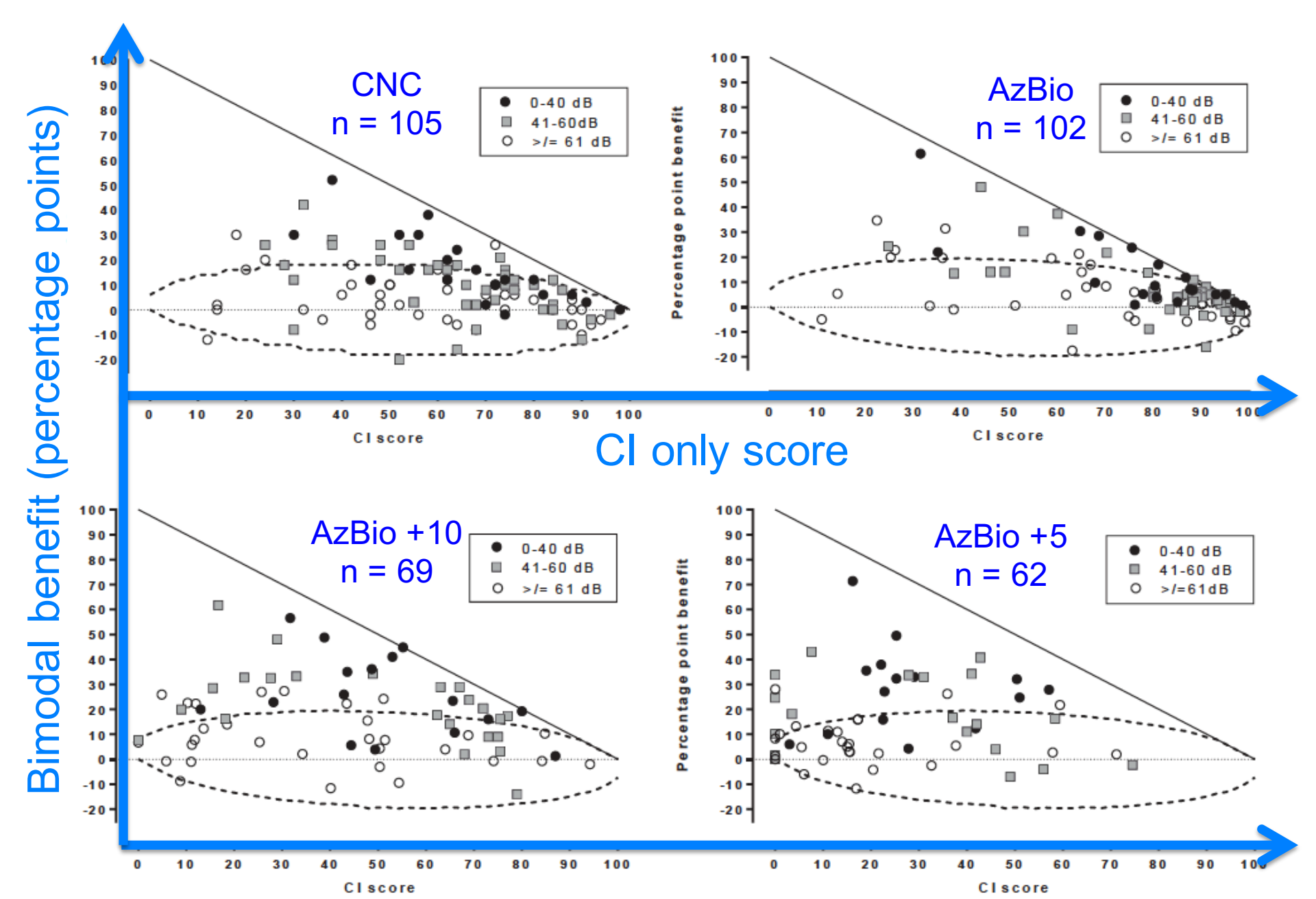
Dorman & Gifford 2010. International Journal of Audiology.

VUMC: 2014 adult CI evaluations
n = 169

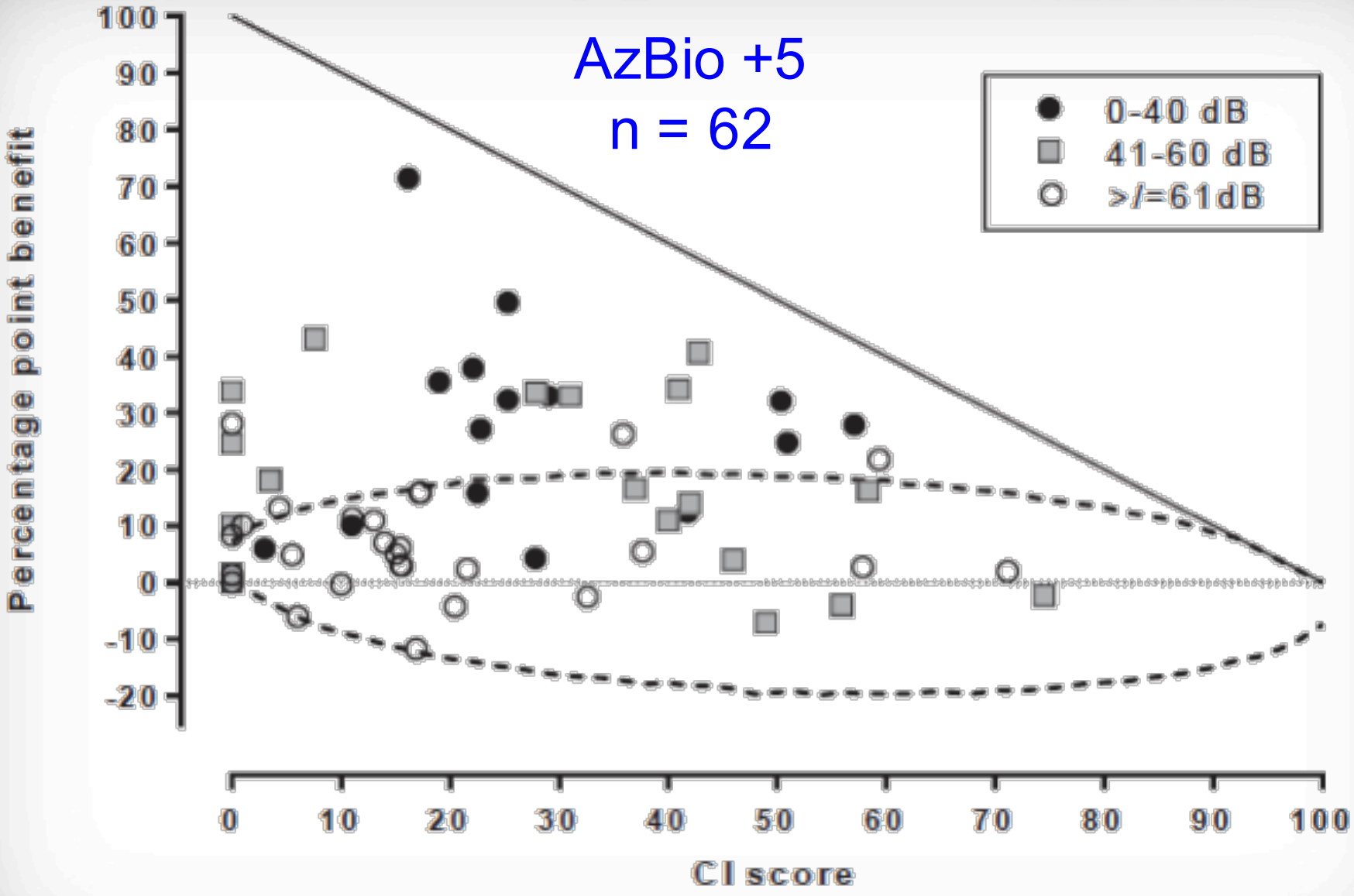


How much bimodal benefit can our patients obtain?

- Dependent upon
  - CI only score
  - Residual hearing in non-CI ear
  - Cochlear integrity (i.e. dead regions)
  - How technology is programmed



Dorman et al. (2015). Hear Res, 322: 107-111.



Dorman et al. (2015). Hear Res, 322: 107-111.

How much bimodal benefit do patients obtain?

- Dependent upon
  - CI only score
  - Residual hearing in non-CI ear
  - Cochlear integrity (i.e. dead regions)
  - How technology is programmed
- Primary clinical & research questions:
  - What are the underlying mechanisms?
  - How much hearing is needed to obtain bimodal benefit?
  - Can we predict bimodal benefit?

What are the underlying mechanisms of bimodal benefit?

Underlying mechanisms: bimodal hearing

Primary theories:

Segregation

LF acoustic cues (e.g., F0 periodicity) → comparison across ears to better separate the target speech from the background noise (e.g., Zeng. 2004; Kong *et al*. 2005; Chang *et al*. 2006; Qin & Oxenham 2006; Sheffield & Zeng, 2012)

Glimpsing

spectrotemporal-dependent SNR varying over time, allowing target to be "glimpsed" in troughs → better perception LF target (Kong & Carolyn 2007; Li & Loizou 2008; Brown & Bacon 2009; Sheffield & Gifford, 2014)

How much acoustic hearing is needed to obtain bimodal benefit?

BIMODAL benefit does not require much acoustic hearing

125-150 Hz

Zhang et al. (2010). Ear Hear. 31: 63-69.
Brown and Bacon (2009). J Acoust Soc Am. 125:1658–1665.
Brown and Bacon (2009). Ear Hear. 30: 489–493.
Cullington & Zeng (2010). Ear Hear. 31: 70–73.
Sheffield & Zeng (2012). J Acoust Soc Am. 131: 518-530.
Kong and Carlyon (2011). J Acoust Soc Am. 121: 3717–3727.
Visram et al (2012). J Acoust Soc Am.131: 4042–4050.

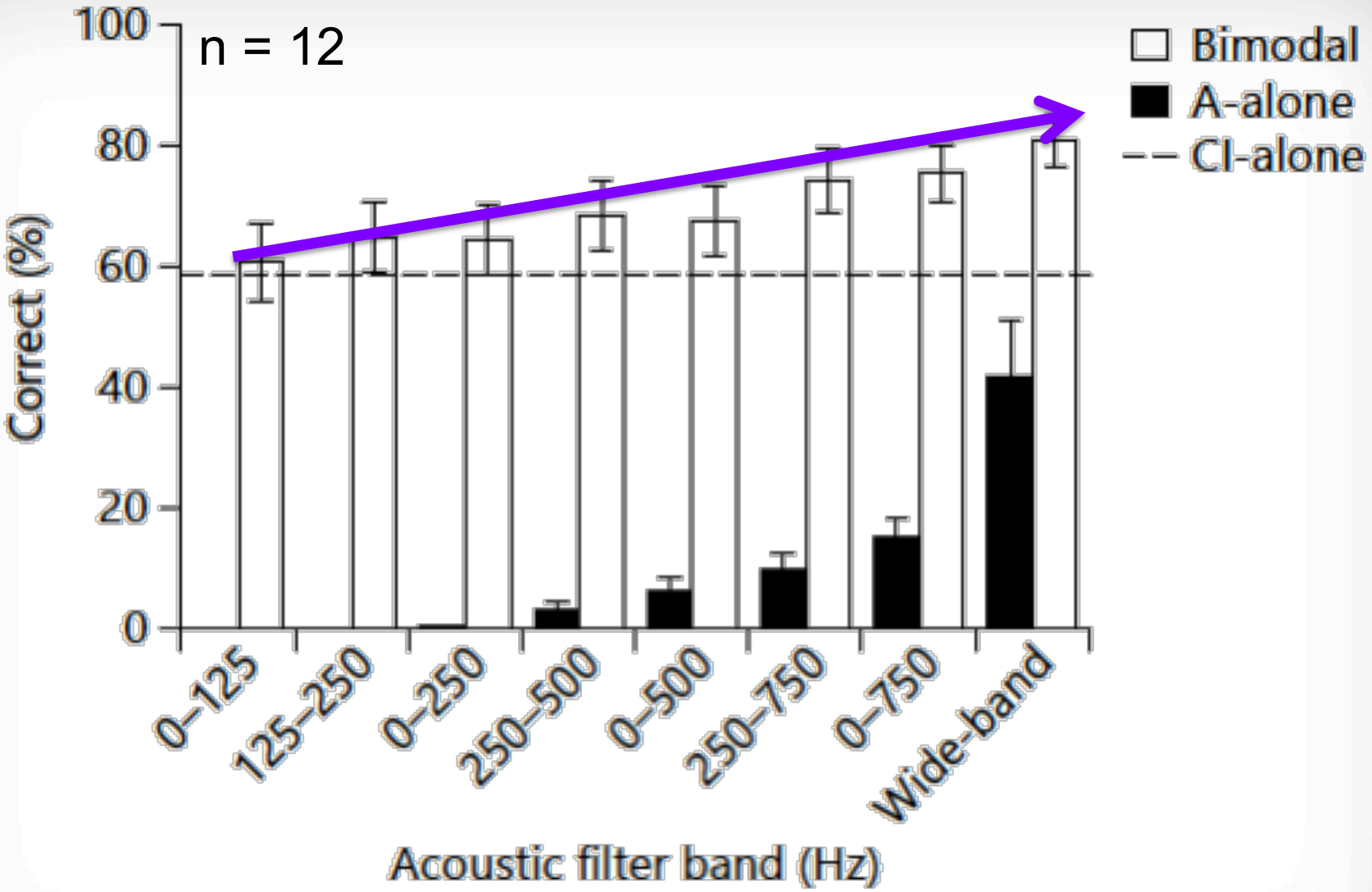
segregation

250 Hz (< 250 Hz & 250-500 Hz)

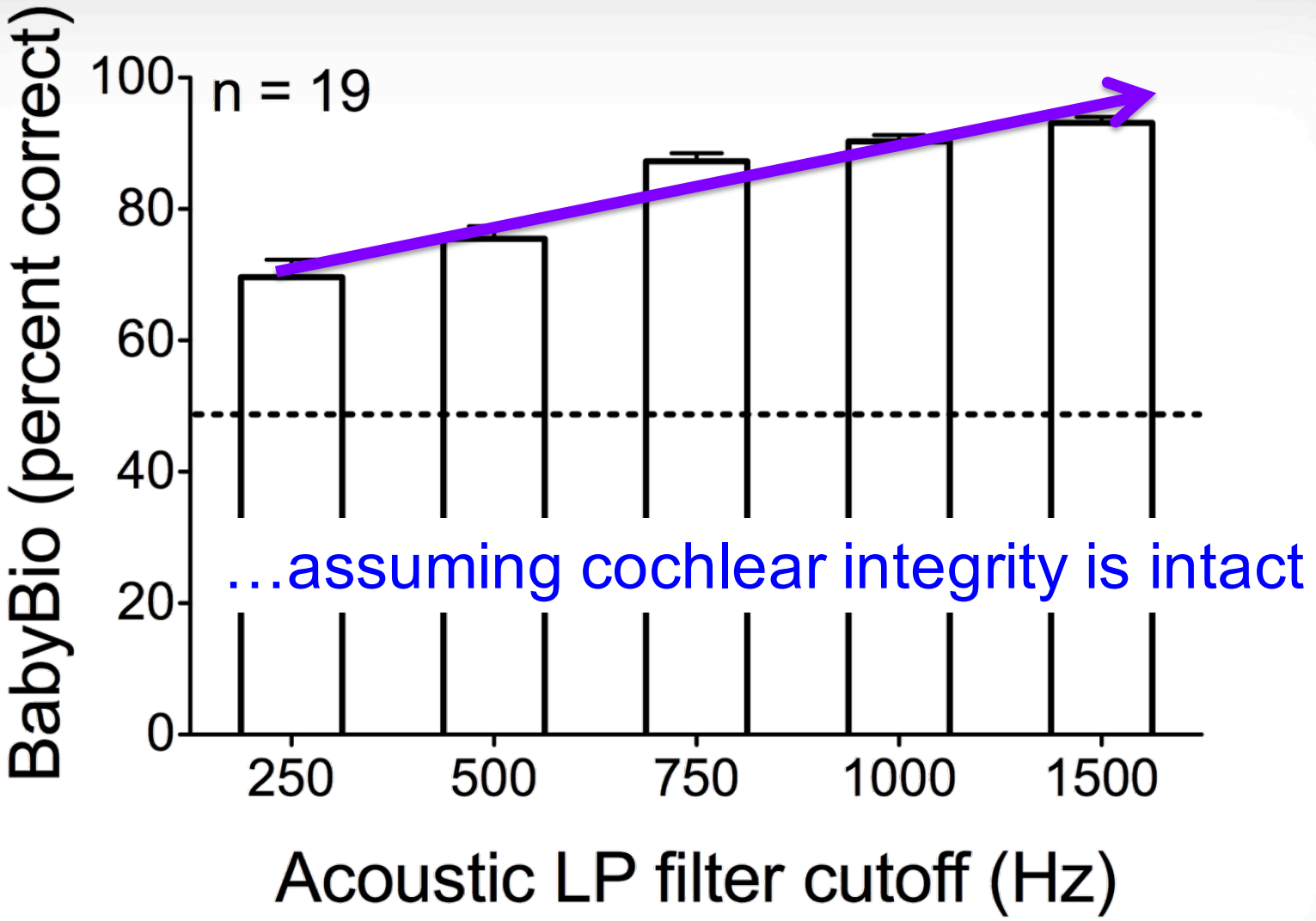
Sheffield & Gifford. (2014). Audiol Neurotol. 19:151–163.
Sheffield et al. (in press). Ear Hear.
Zhang et al. (2010). Ear Hear. 31(1): 63-69.

segregation

Glimpsing

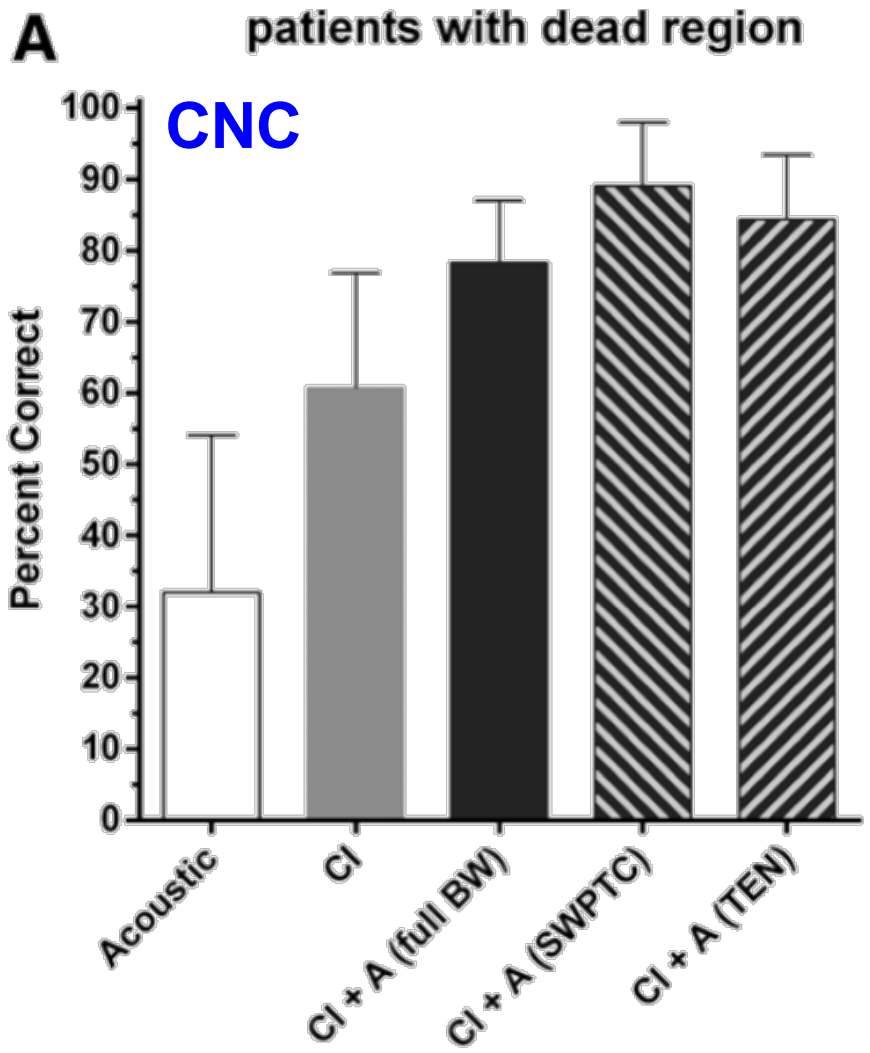


Sheffield and Gifford (2014). Audiol Neurotol, 19: 151-163.



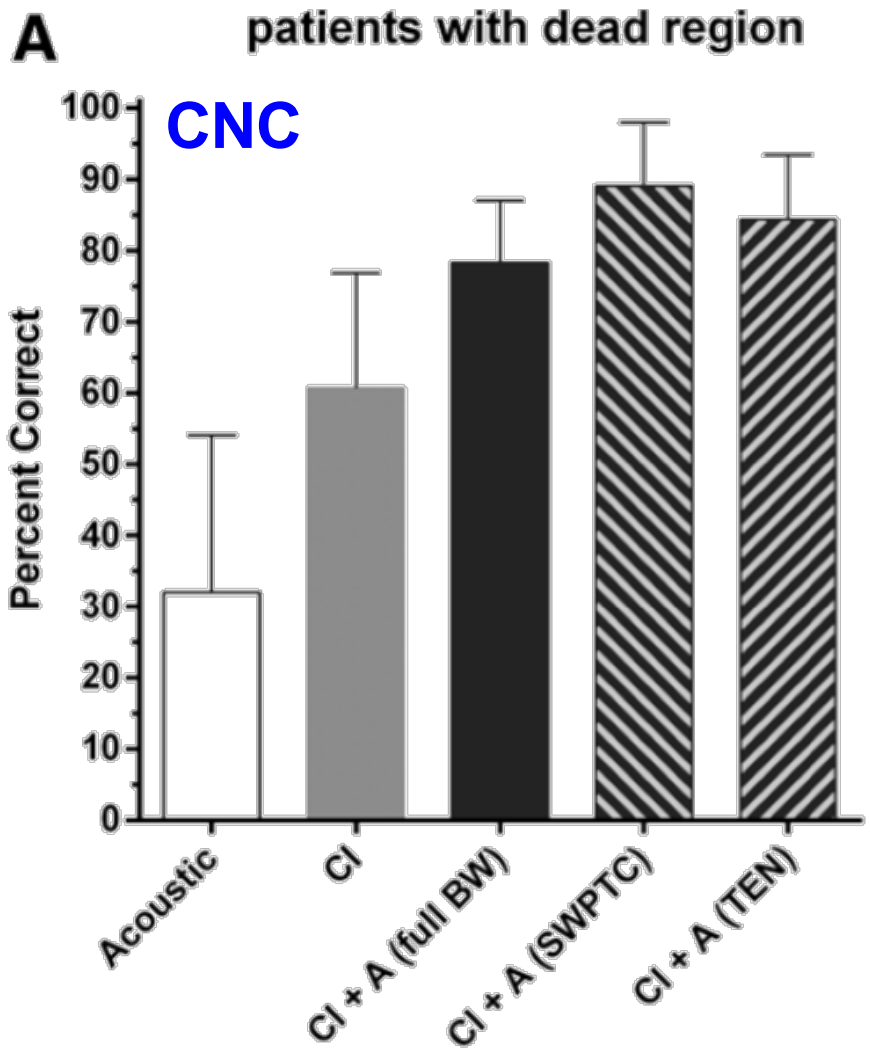
Sheffield et al. (in press). Ear Hear.

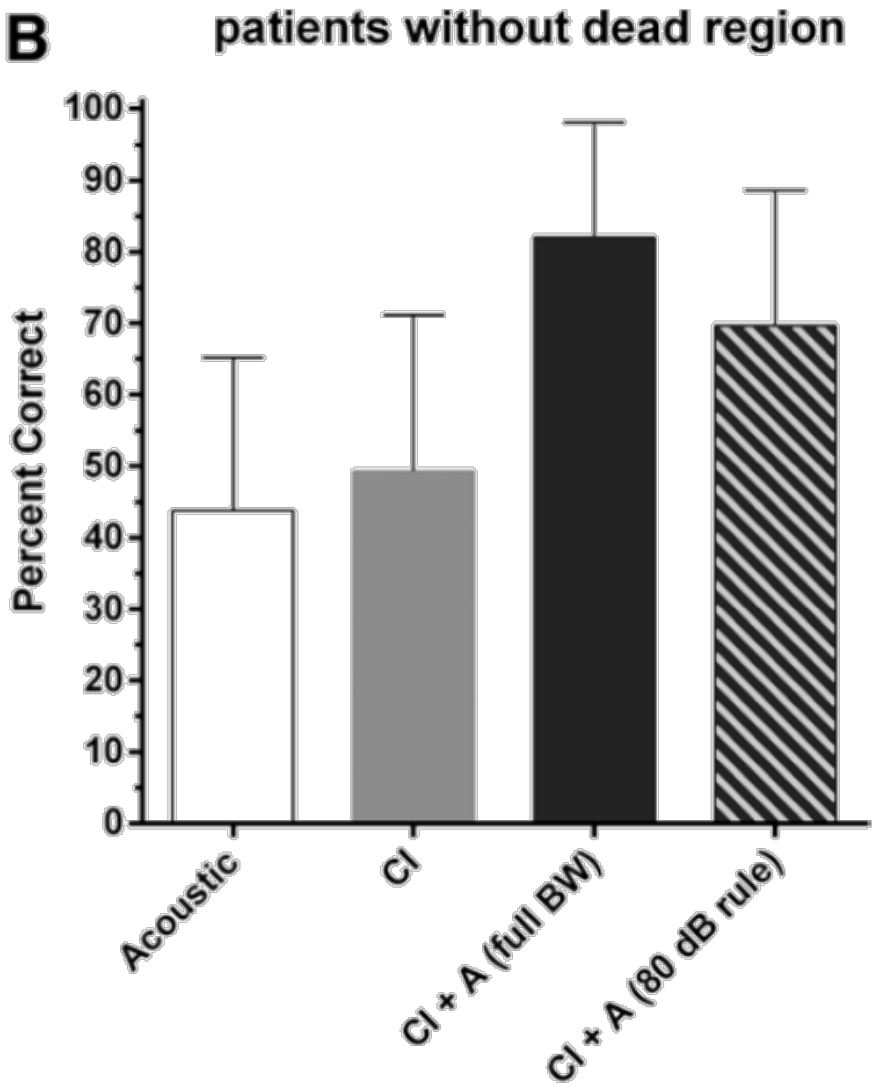
Cochlear Dead Regions



Zhang et al. (2014). Ear Hear, 35:410–417

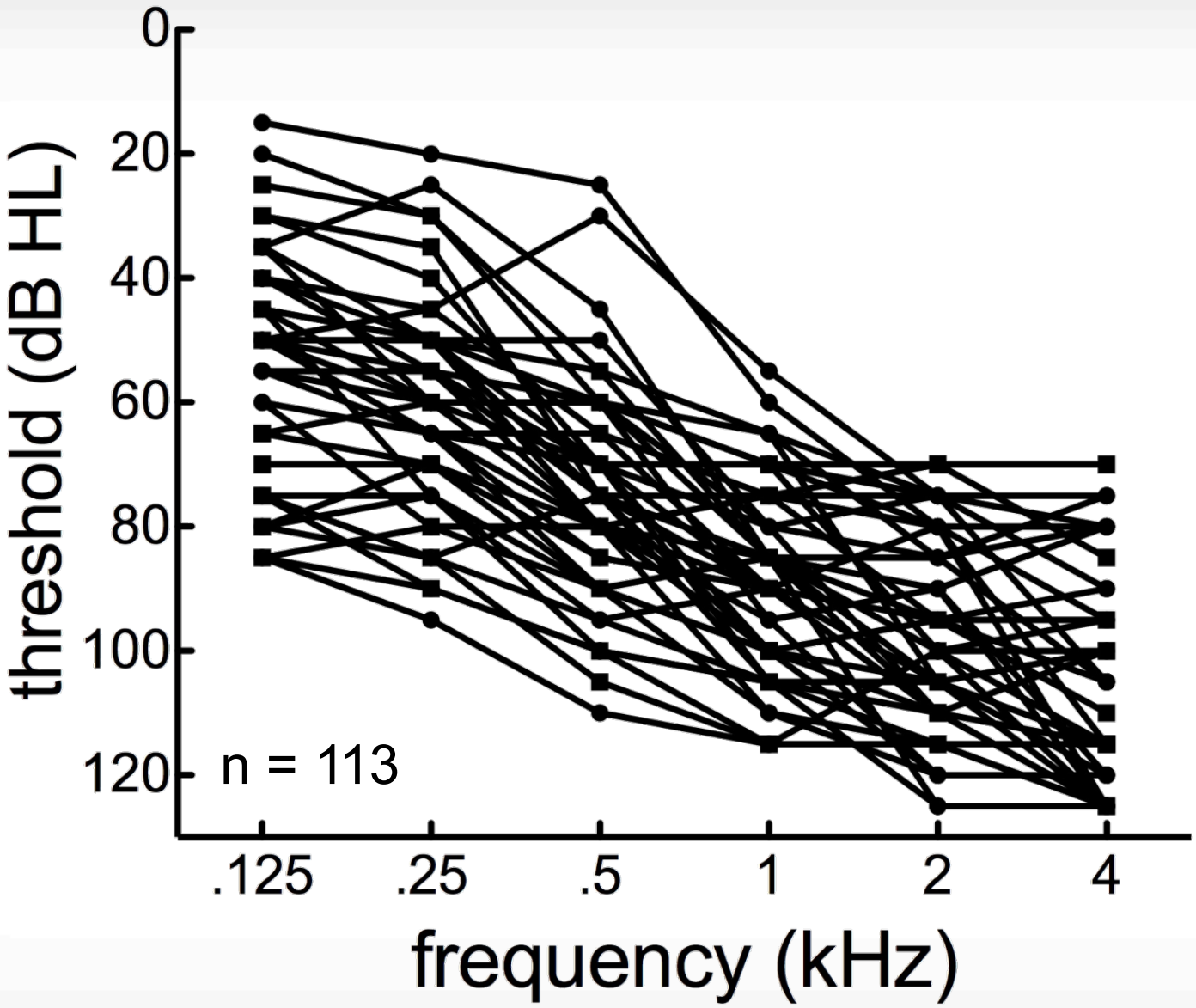
Cochlear Dead Regions



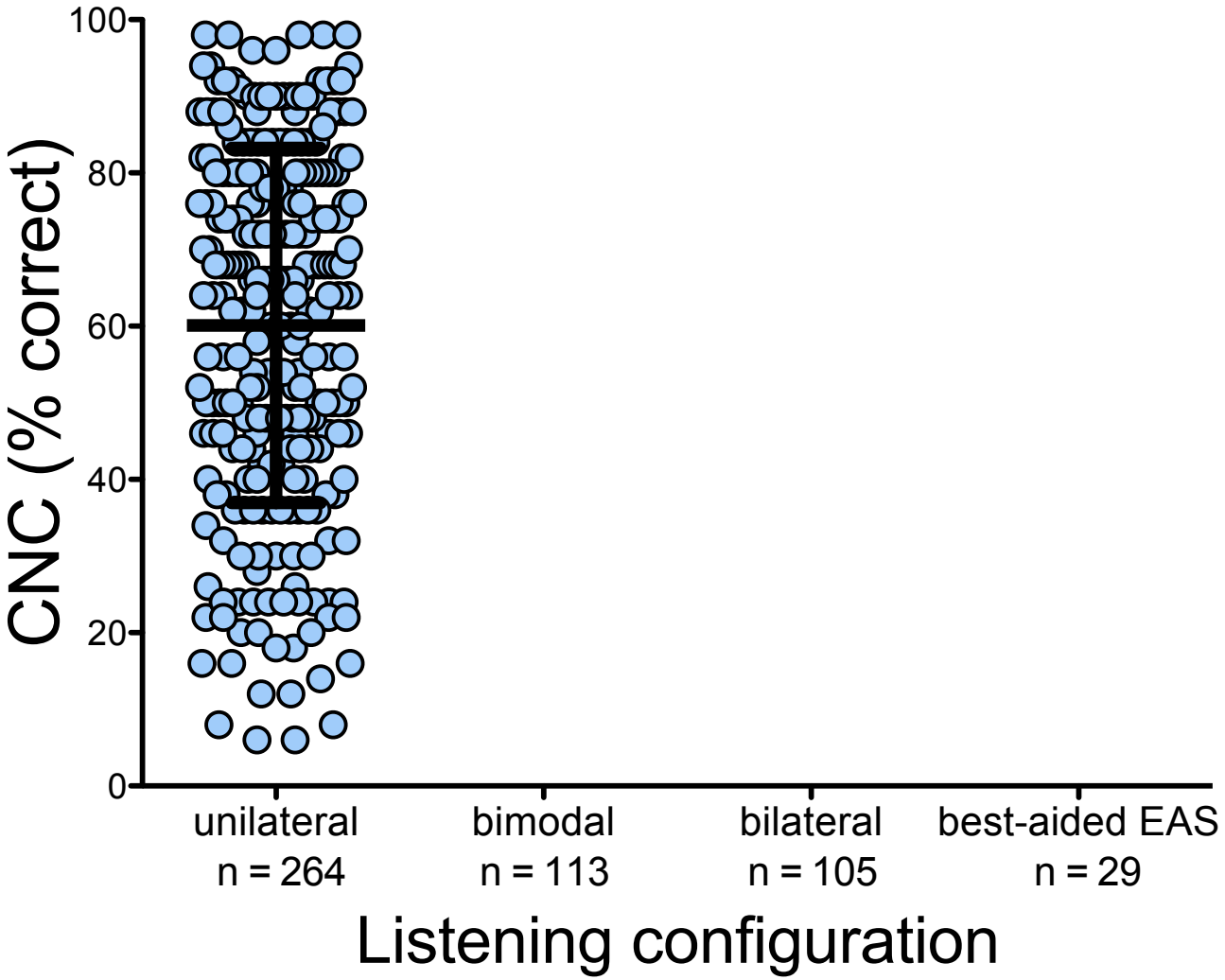


Zhang et al. (2014). Ear Hear, 35:410–417

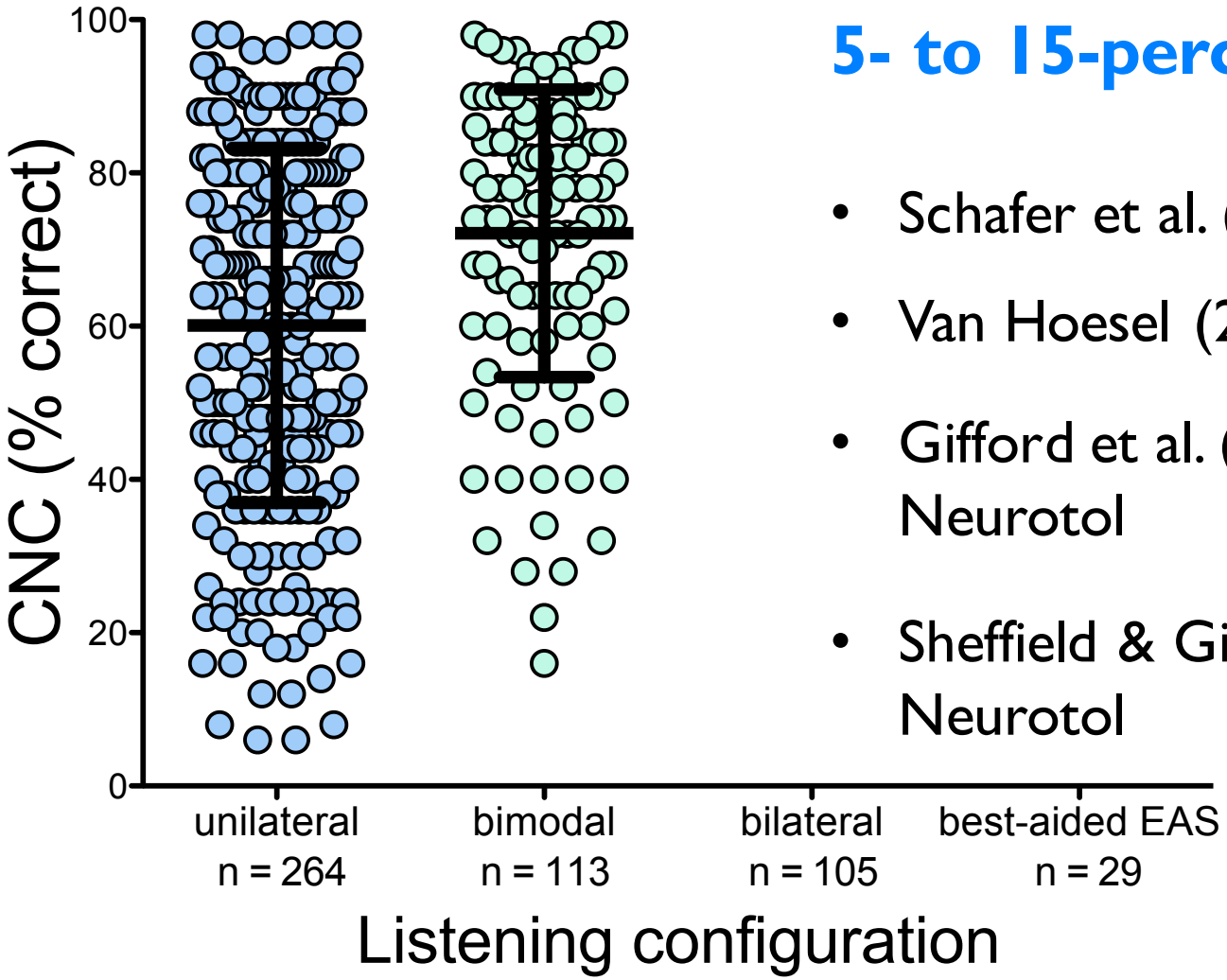
Bimodal benefit: Speech understanding


0
20
40
60
80
100
120
threshold (dB HL)
n = 113
.125
.25
.5
1
2
4
frequency (kHz)

Unilateral CI vs. bimodal: monosyllables



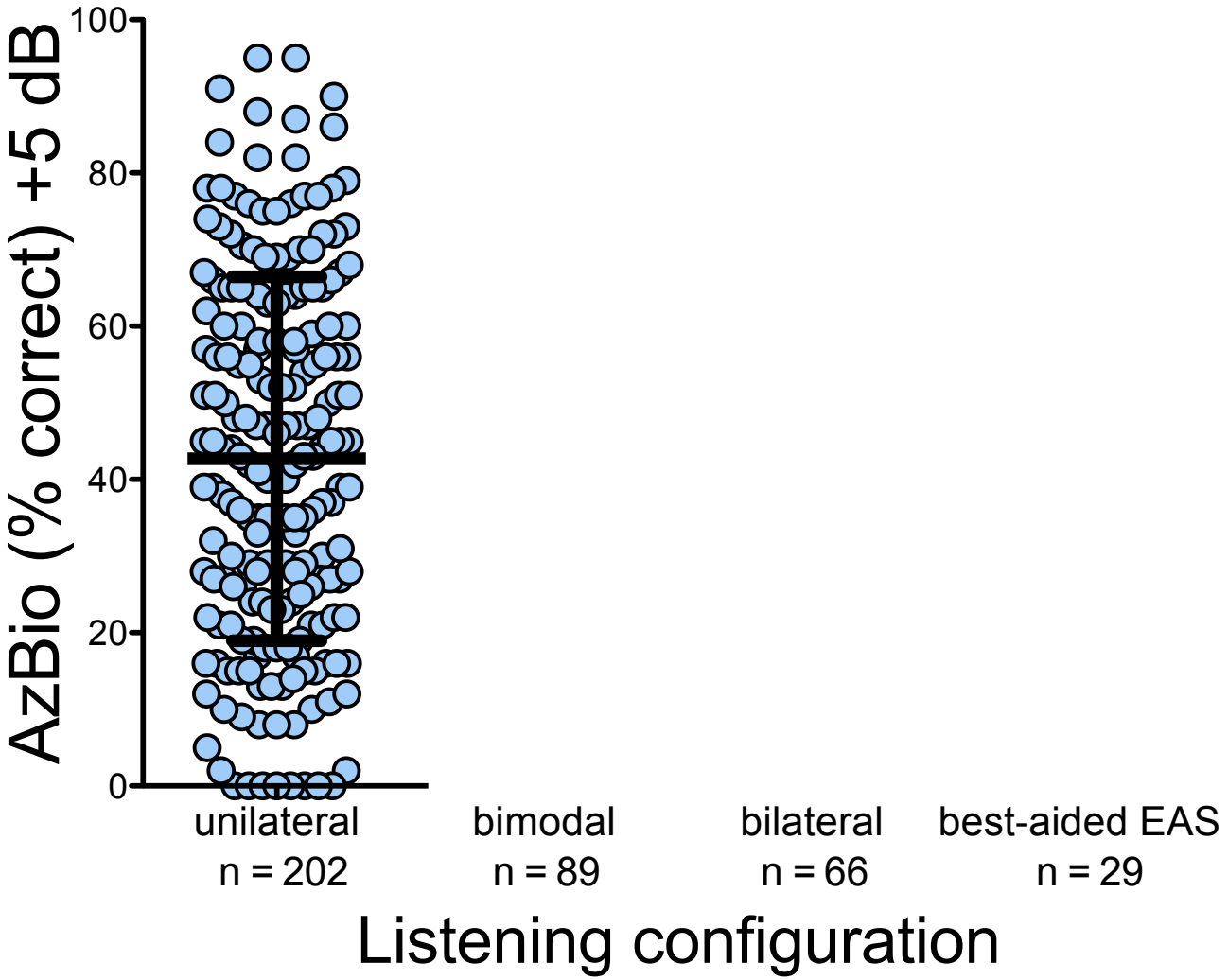
Unilateral CI vs. bimodal: monosyllables



Bimodal summation:
5- to 15-percentage points

- Schafer et al. (2007). JAAA
- Van Hoesel (2012). Hear Res
- Gifford et al. (2014). Audiol Neurotol
- Sheffield & Gifford (2014). Audiol Neurotol

Unilateral CI vs. bimodal: speech in noise (S_0N_0)



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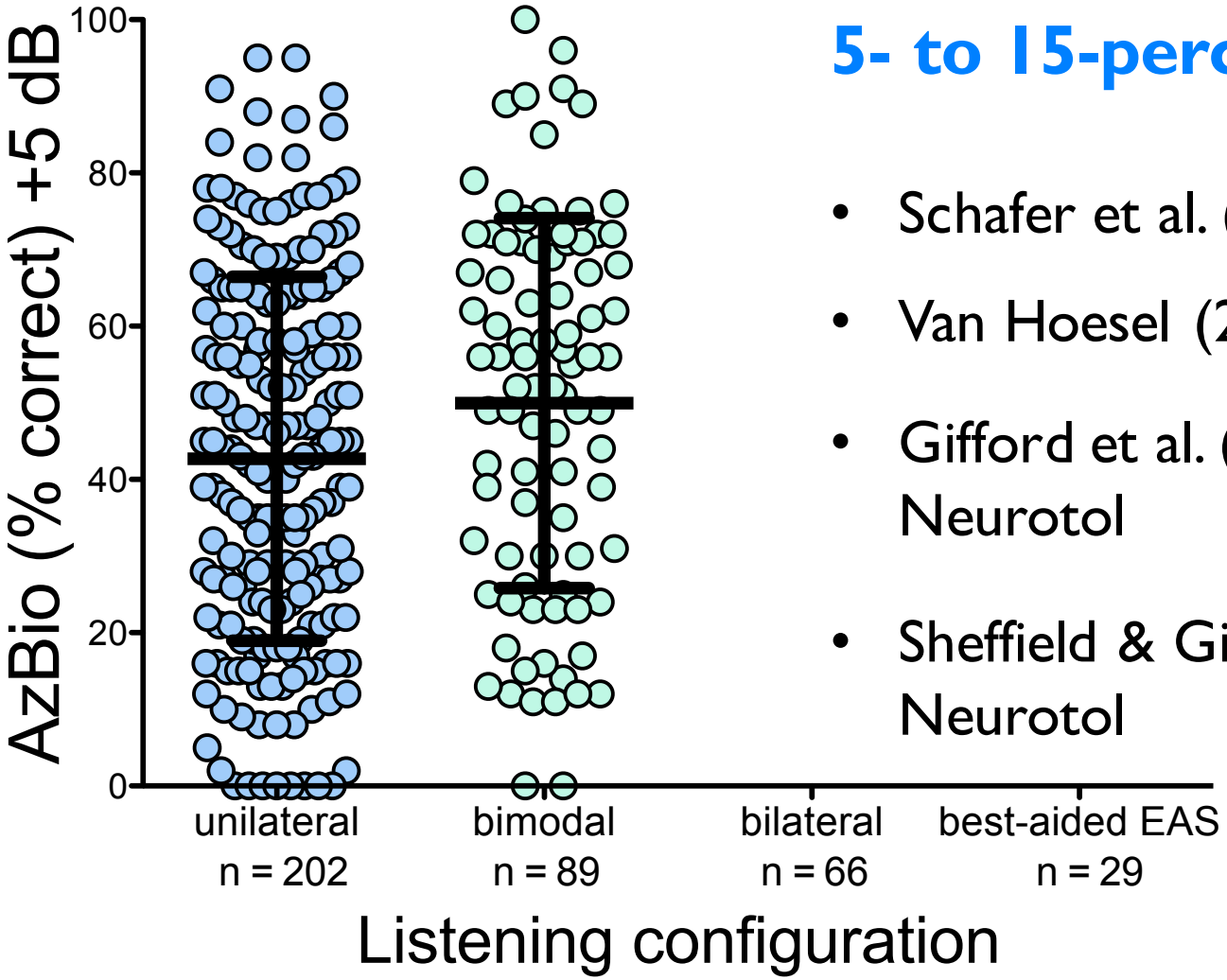

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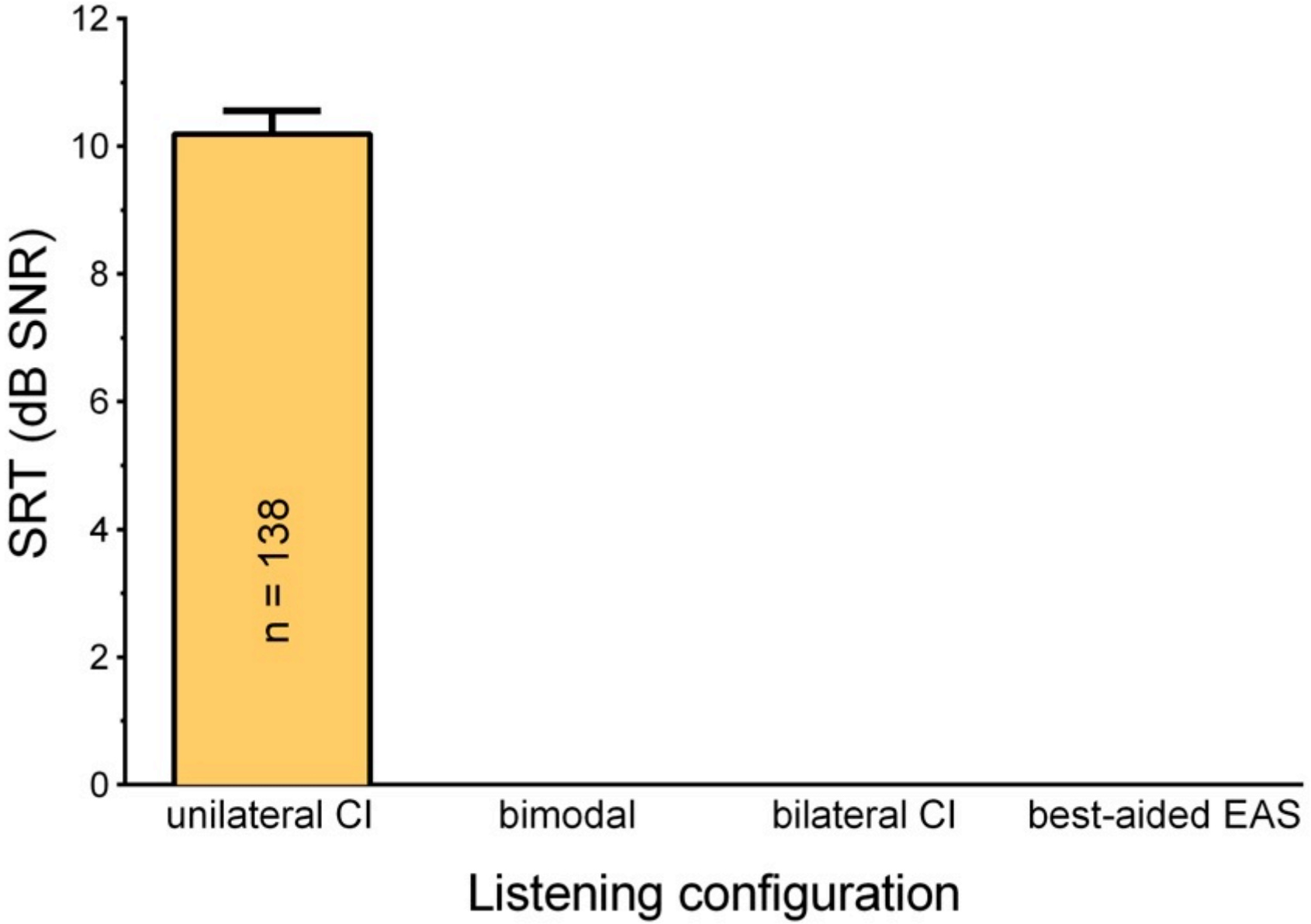
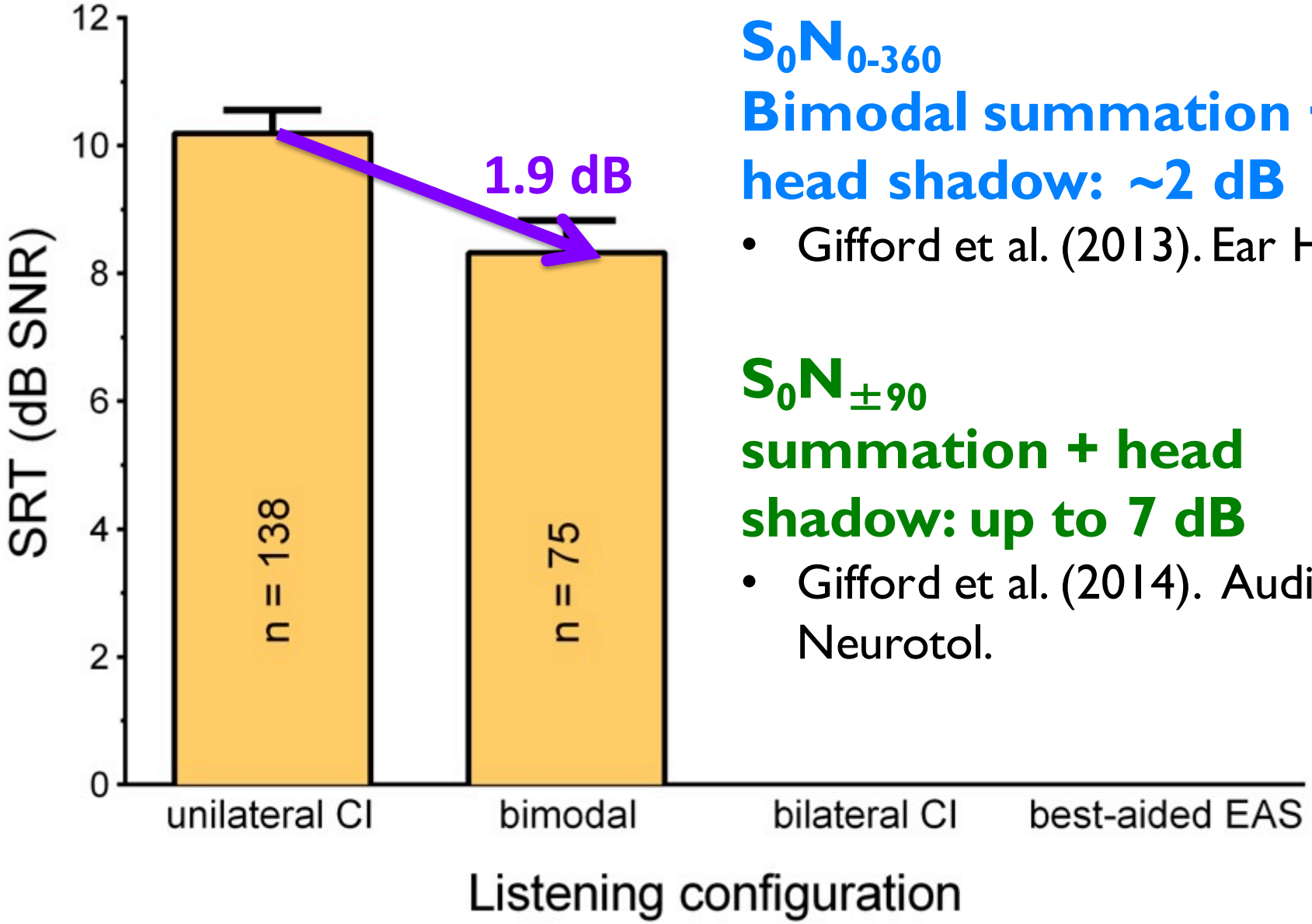
- Sheffield & Gifford (2014). Audiol Neurotol

CI vs. bimodal: speech in semi-diffuse noise ($S_0N_{0\text{-}360}$)



CI vs. bimodal: speech in semi-diffuse noise ($S_0N_{0\text{-}360}$)

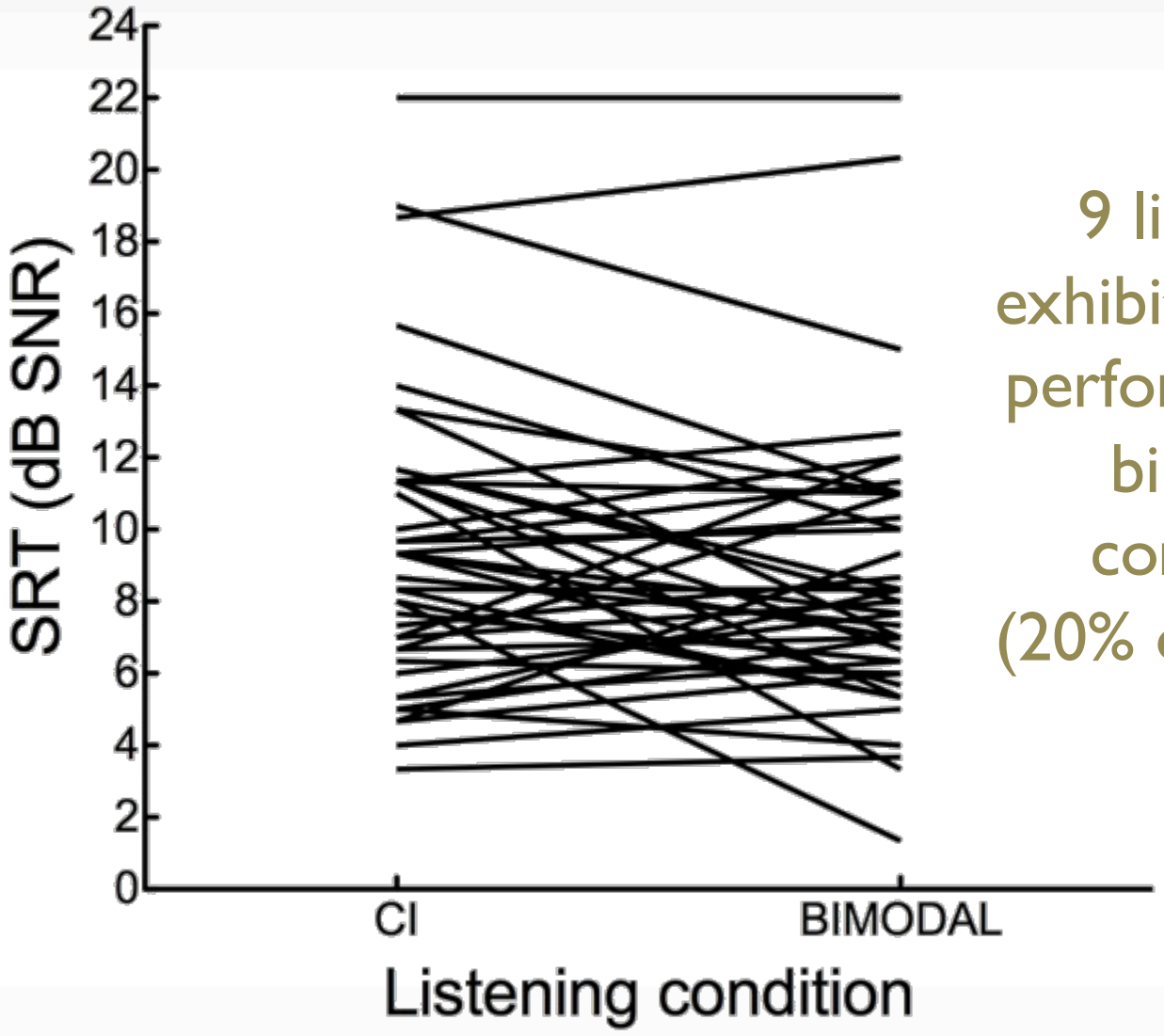


$S_0N_{0\text{-}360}$
Bimodal summation + head shadow: ~2 dB

- Gifford et al. (2013). Ear Hear.

$S_0N_{\pm 90}$
summation + head shadow: up to 7 dB

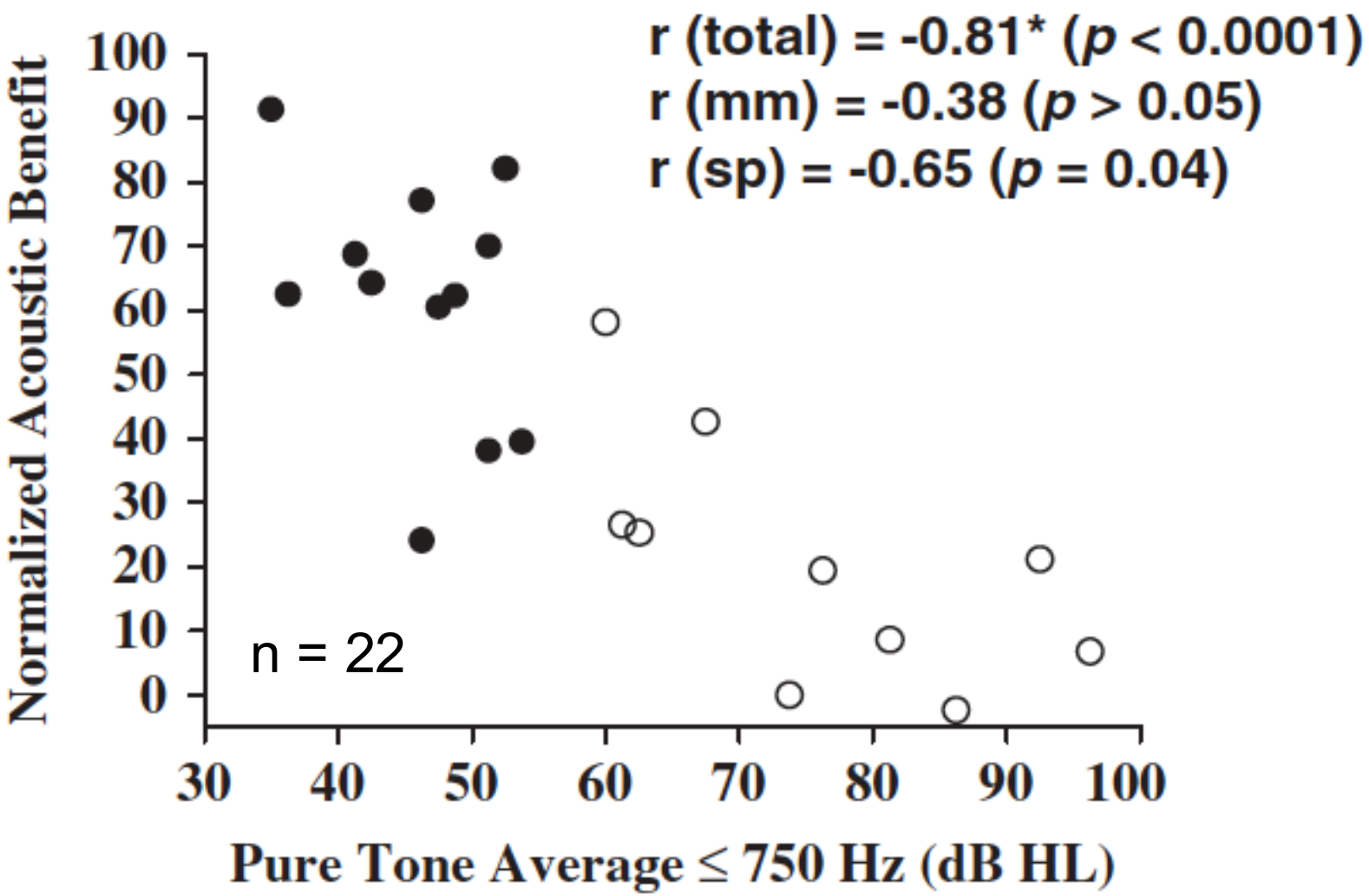
- Gifford et al. (2014). Audiol Neurotol.



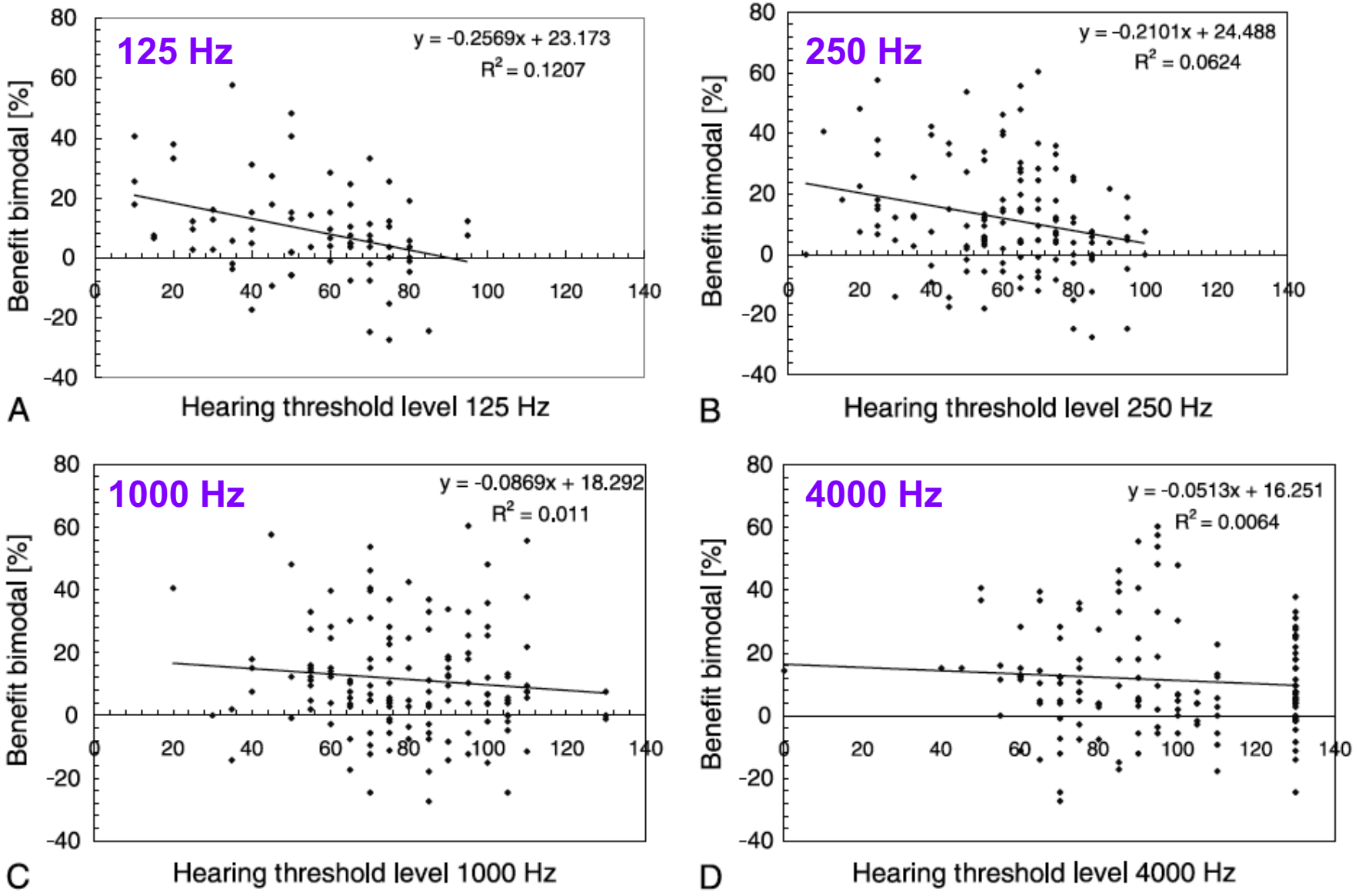
9 listeners exhibited *poorer* performance in bimodal condition (20% of sample)

Can we predict bimodal benefit?

Critical for audiologic management, programming HA/CI, & clinical recommendations.

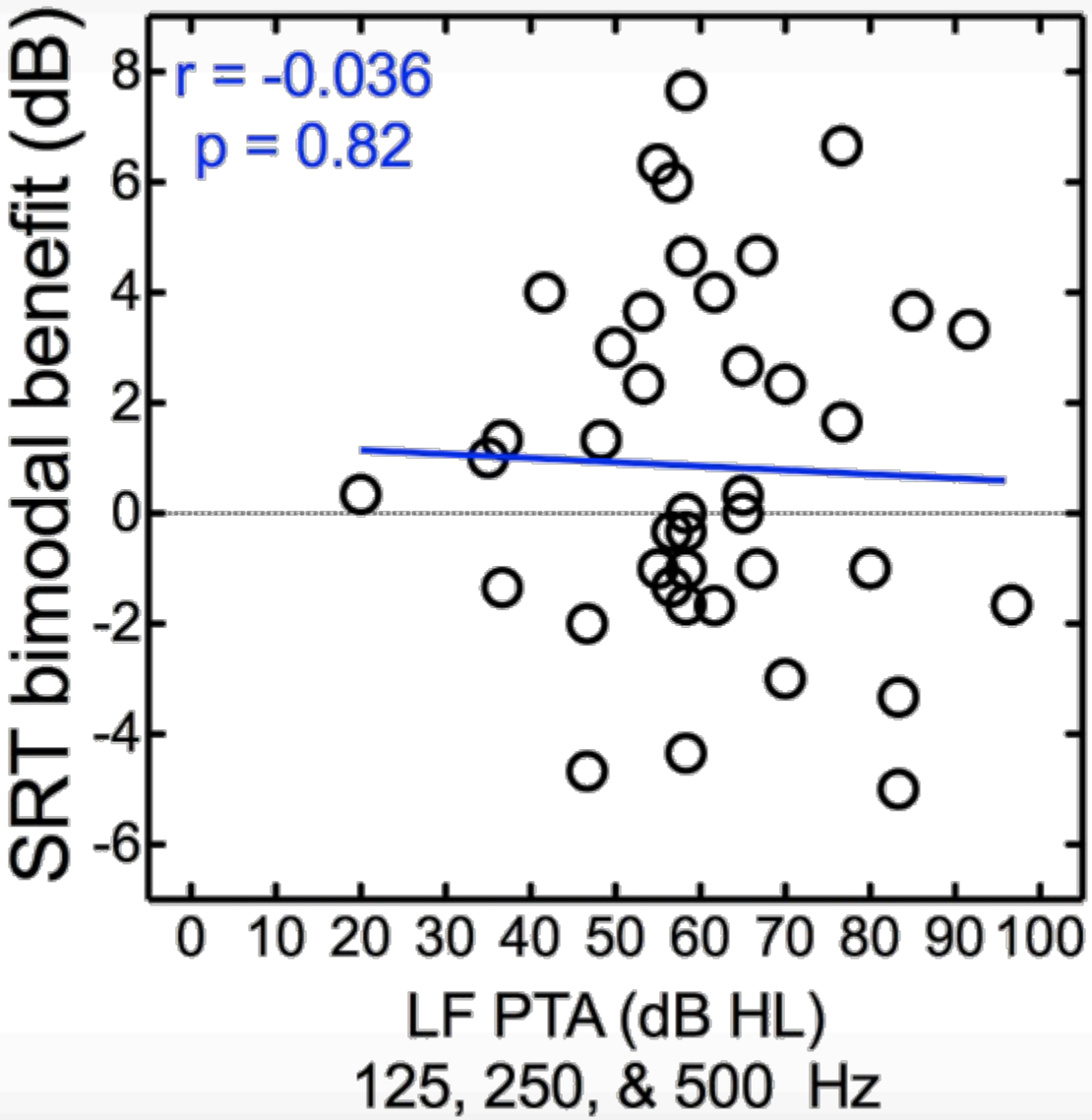


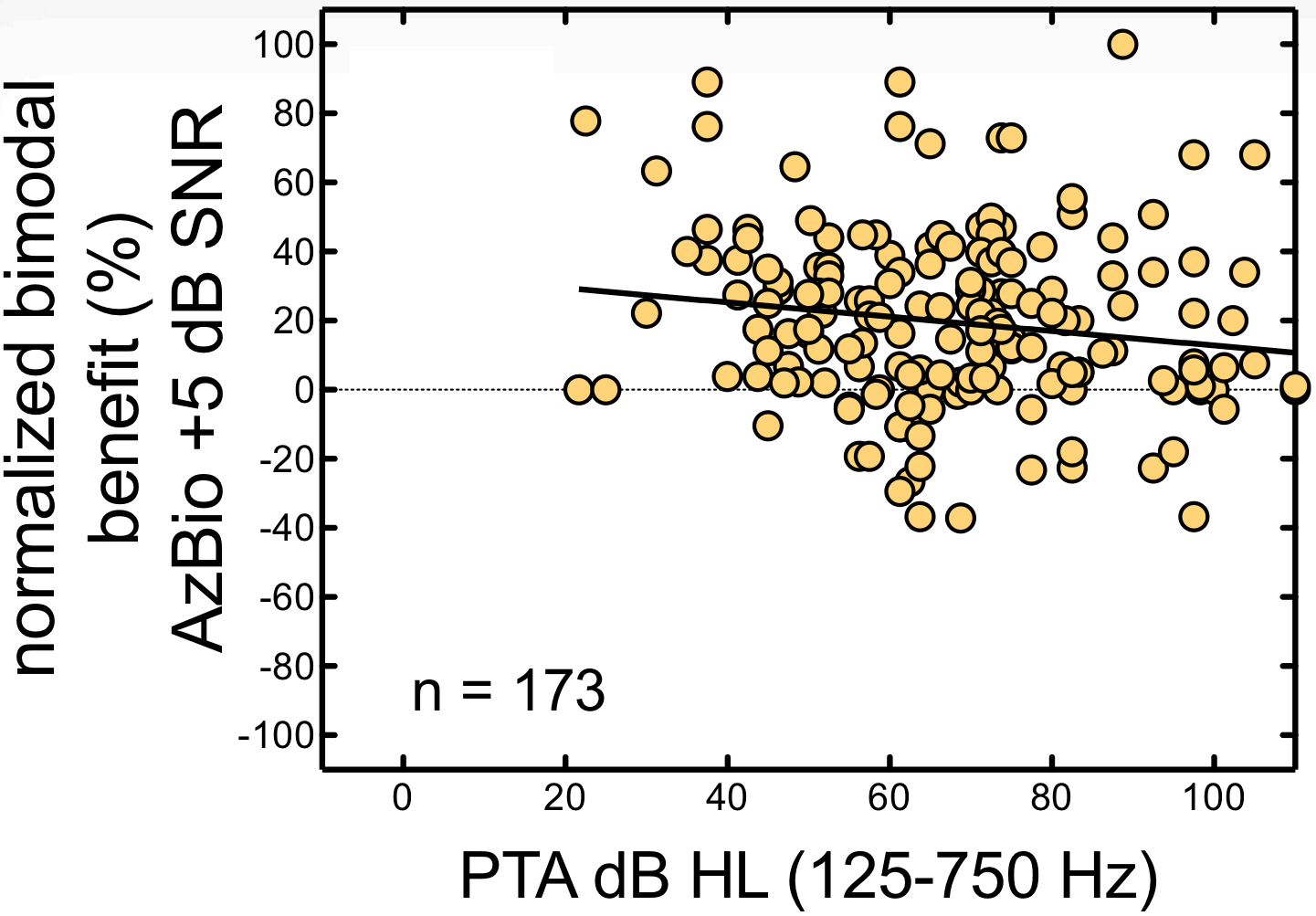
Zhang et al. (2013). Ear Hear, 34:133-141



n = 141

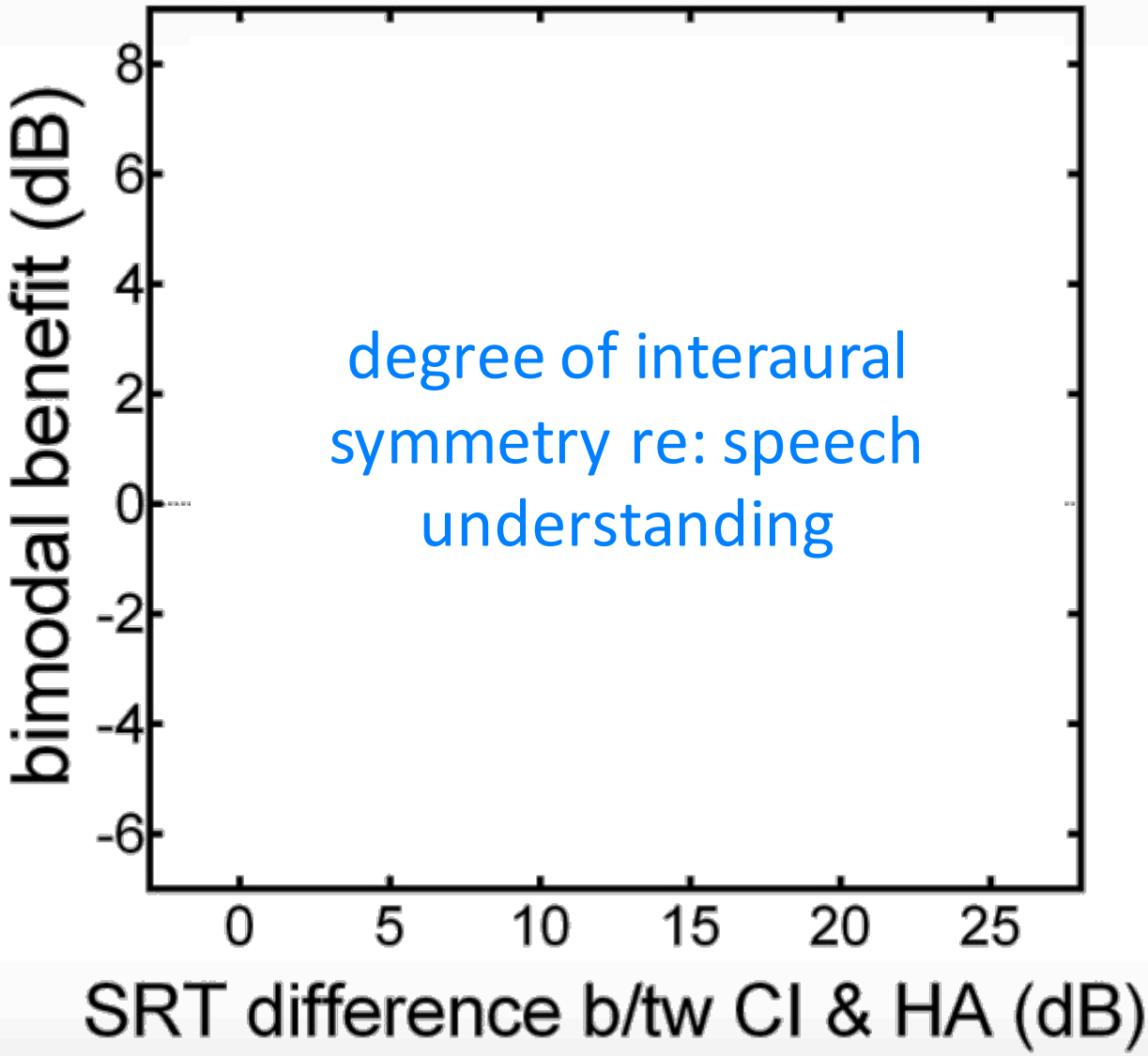
Illg et al. (2014). Otol Neurotol, 35:e240-e244

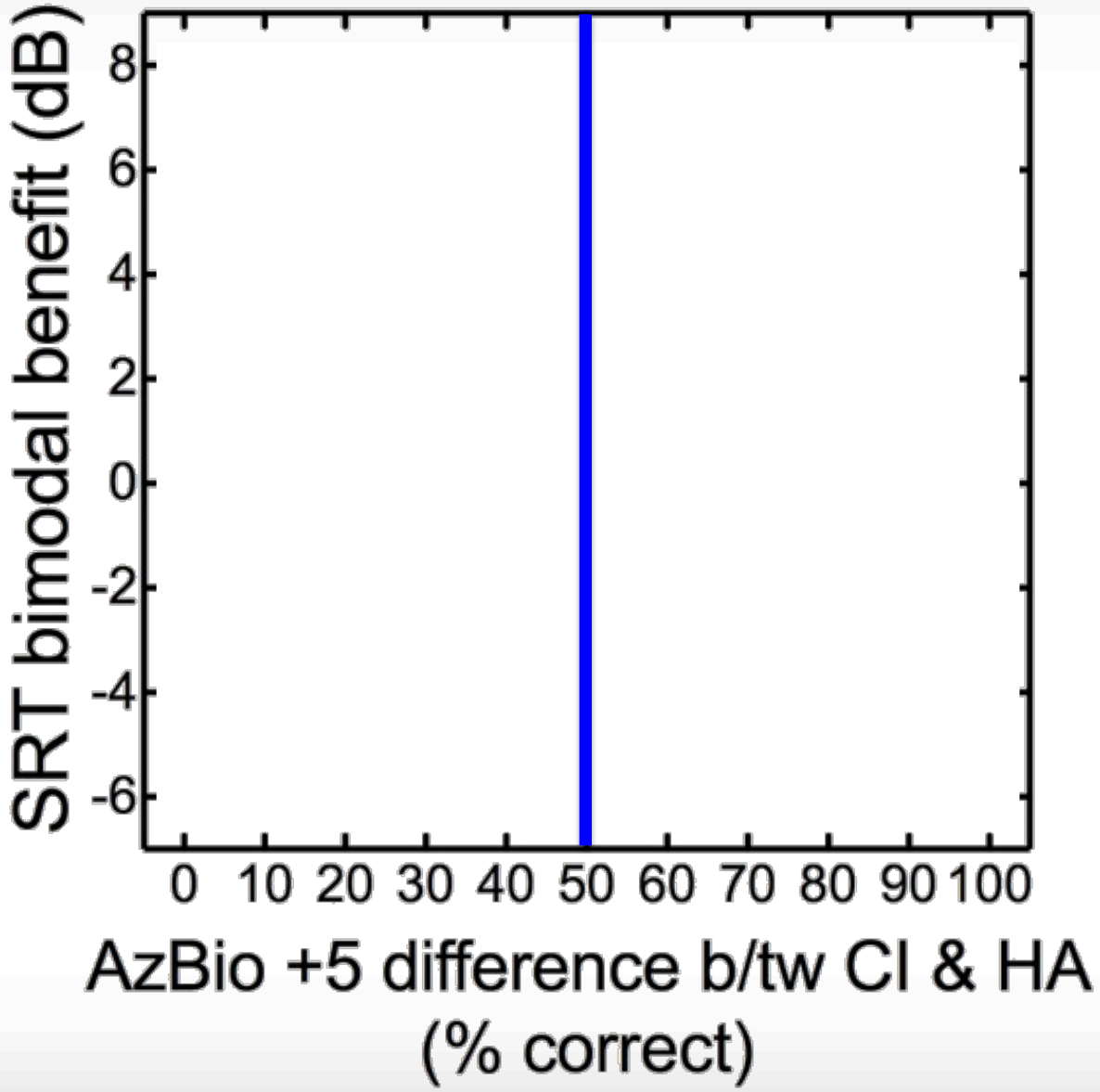

r = -0.036
p = 0.82
SRT bimodal benefit (dB)
8
6
4
2
0
-2
-4
-6
0 10 20 30 40 50 60 70 80 90 100
LF PTA (dB HL)
125, 250, & 500 Hz

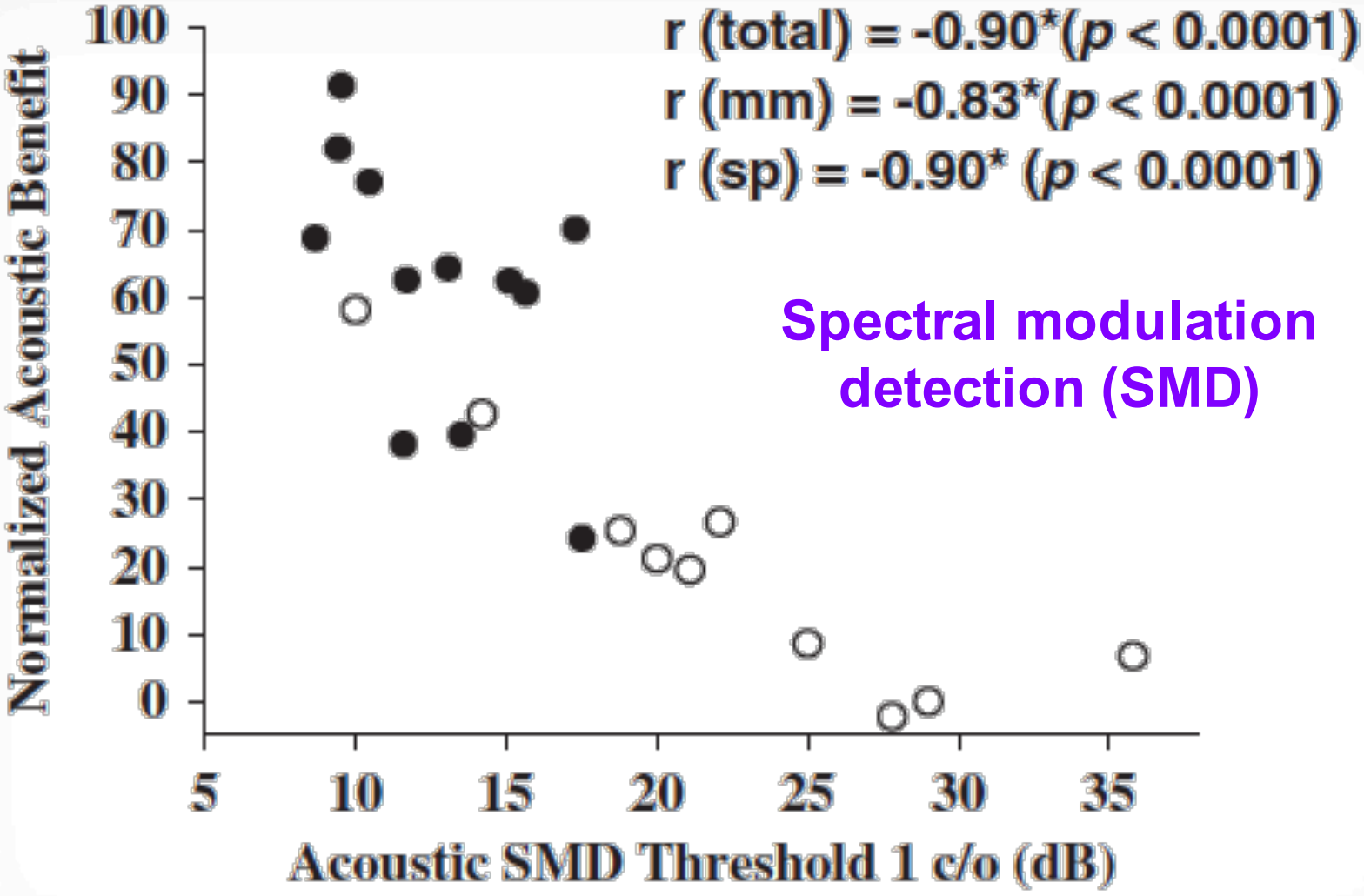


Gifford et al. (in prep).

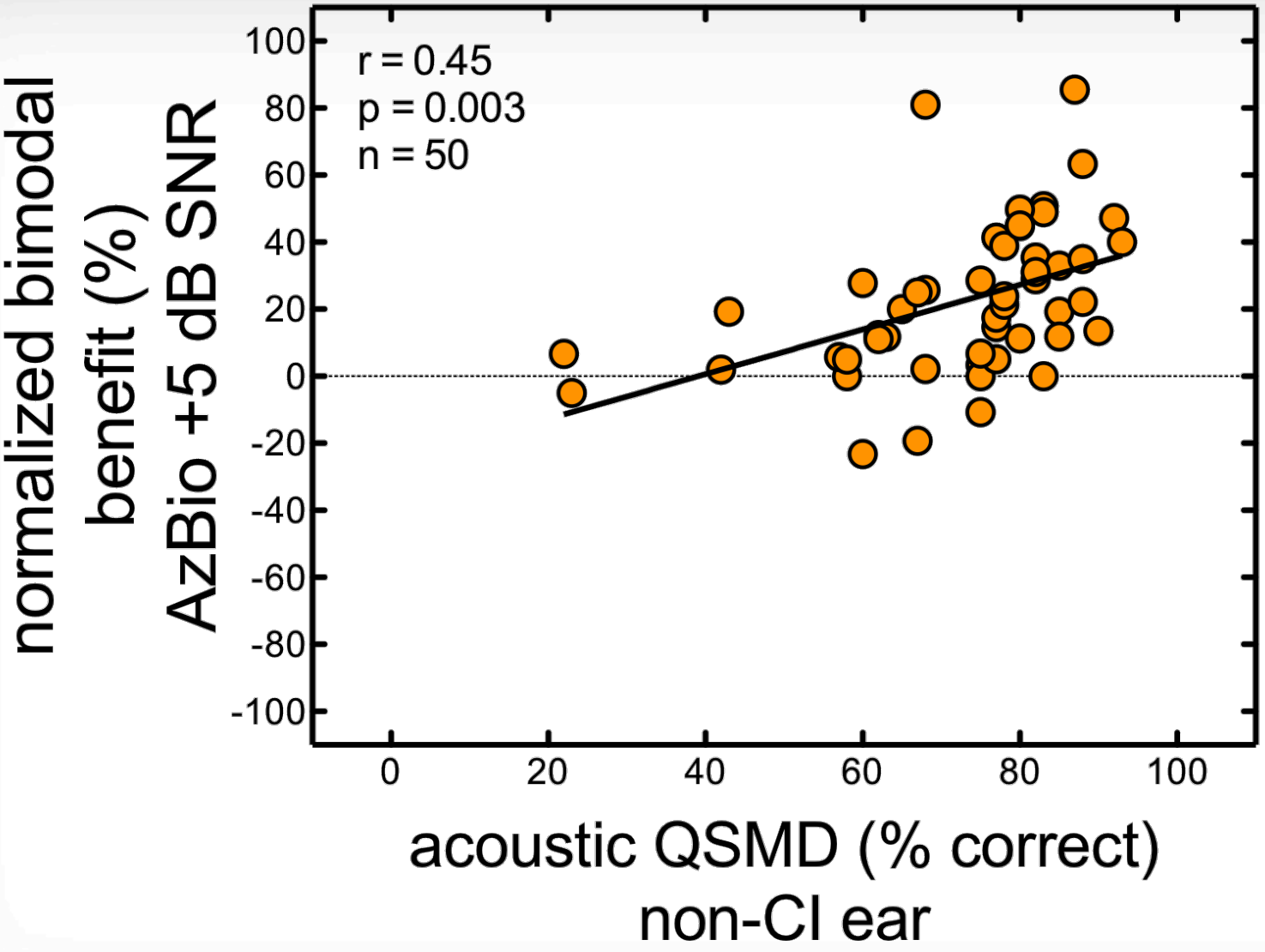
Functional or comparative measures that might predict bimodal benefit


bimodal benefit (dB)
8
6
4
2
0
-2
-4
-6
0
5
10
15
20
25
SRT difference b/tw CI & HA (dB)
degree of interaural symmetry re: speech understanding


SRT bimodal benefit (dB)
8
6
4
2
0
-2
-4
-6
0 10 20 30 40 50 60 70 80 90 100
AzBio +5 difference b/tw CI & HA
(% correct)

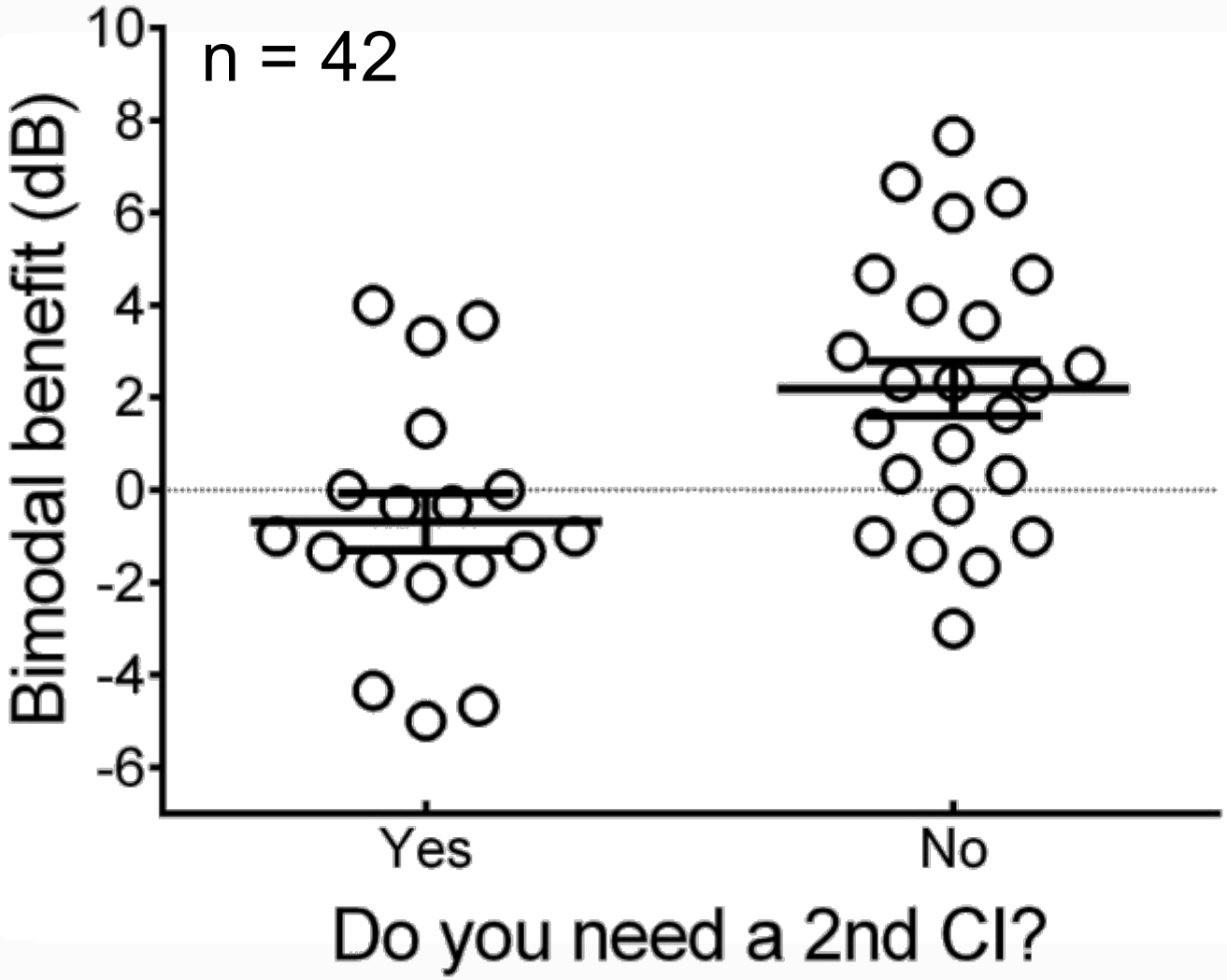


Zhang et al. (2013). Ear Hear, 34:133-141



Gifford et al. (in prep).

Ask a question:
Do you think you need a 2nd CI?


n = 42
Bimodal benefit (dB)
10
8
6
4
2
0
-2
-4
-6
Yes
No
Do you need a 2nd CI?

Bimodal summary

- The majority of patients reporting for preop CI workup = bimodal candidates
- Underlying mechanism(s): jury still out
  - Regardless of mechanism, amplification through 250 Hz → significant benefit in quiet and noise, in adults & children
- Bimodal gain → greater benefit from a second ear with single speaker testing
  - two different signals with different (contrasting) information (van Hoesel, 2012)
- Bimodal listeners:
  - Report significantly better sound quality
  - Higher music perception and appreciation
  - Have some hearing even without technology

Bimodal summary

- There are valid reasons to promote and optimize bimodal hearing!
- How do we optimize bimodal hearing?
- Involves management of both HA & CI

Programming challenges for bimodal hearing

15:35

Acknowledgements

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Programming challenges in bimodal hearing

René H. Gifford, PhD

Department of Hearing and Speech Sciences
Department of Otolaryngology


HELLO
i'm back

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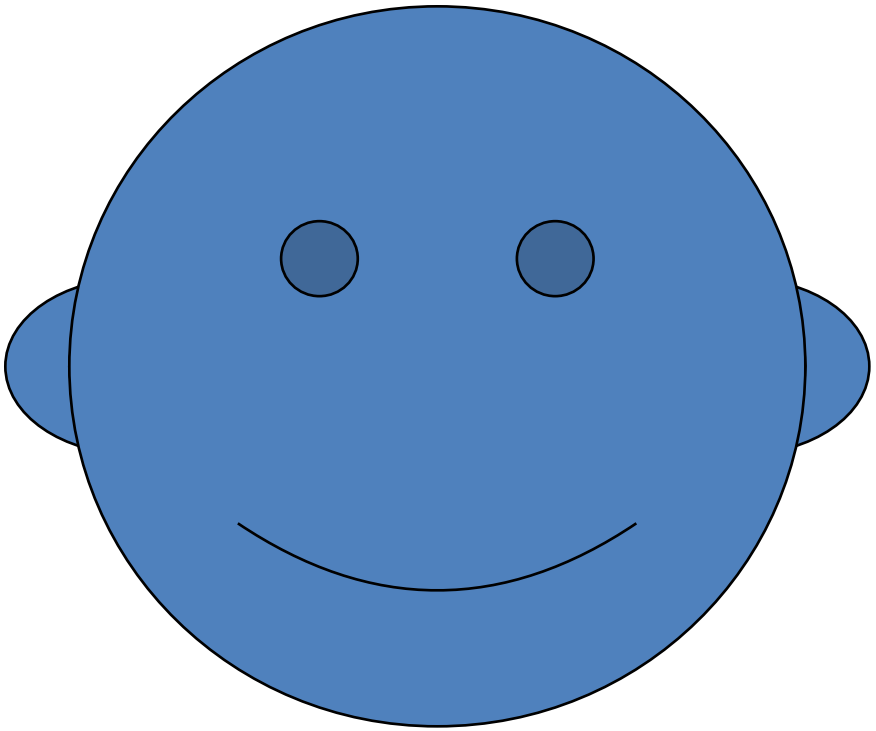
- Cochlear Americas
- MED-EL

Audiologic management

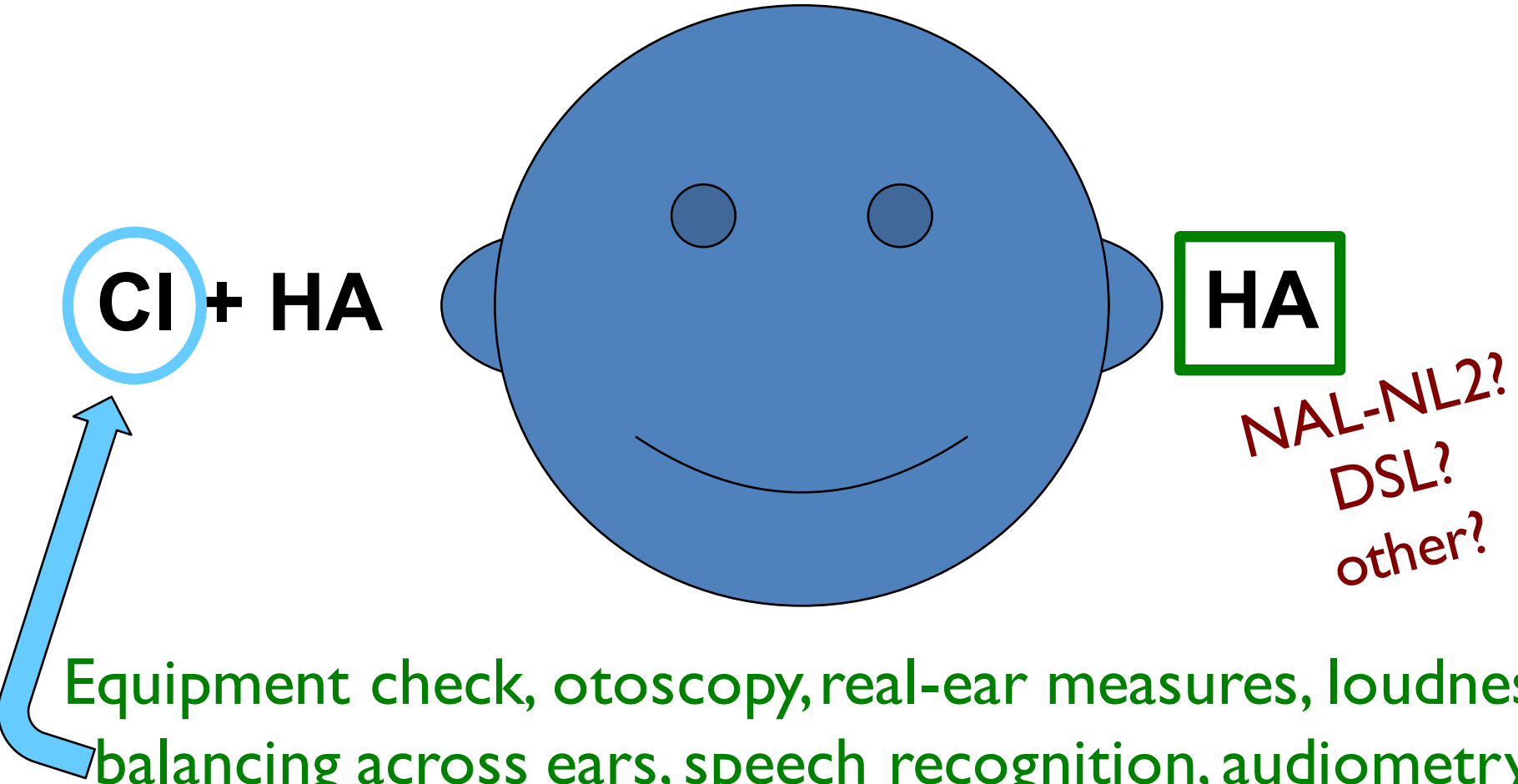
CI + HA



HA

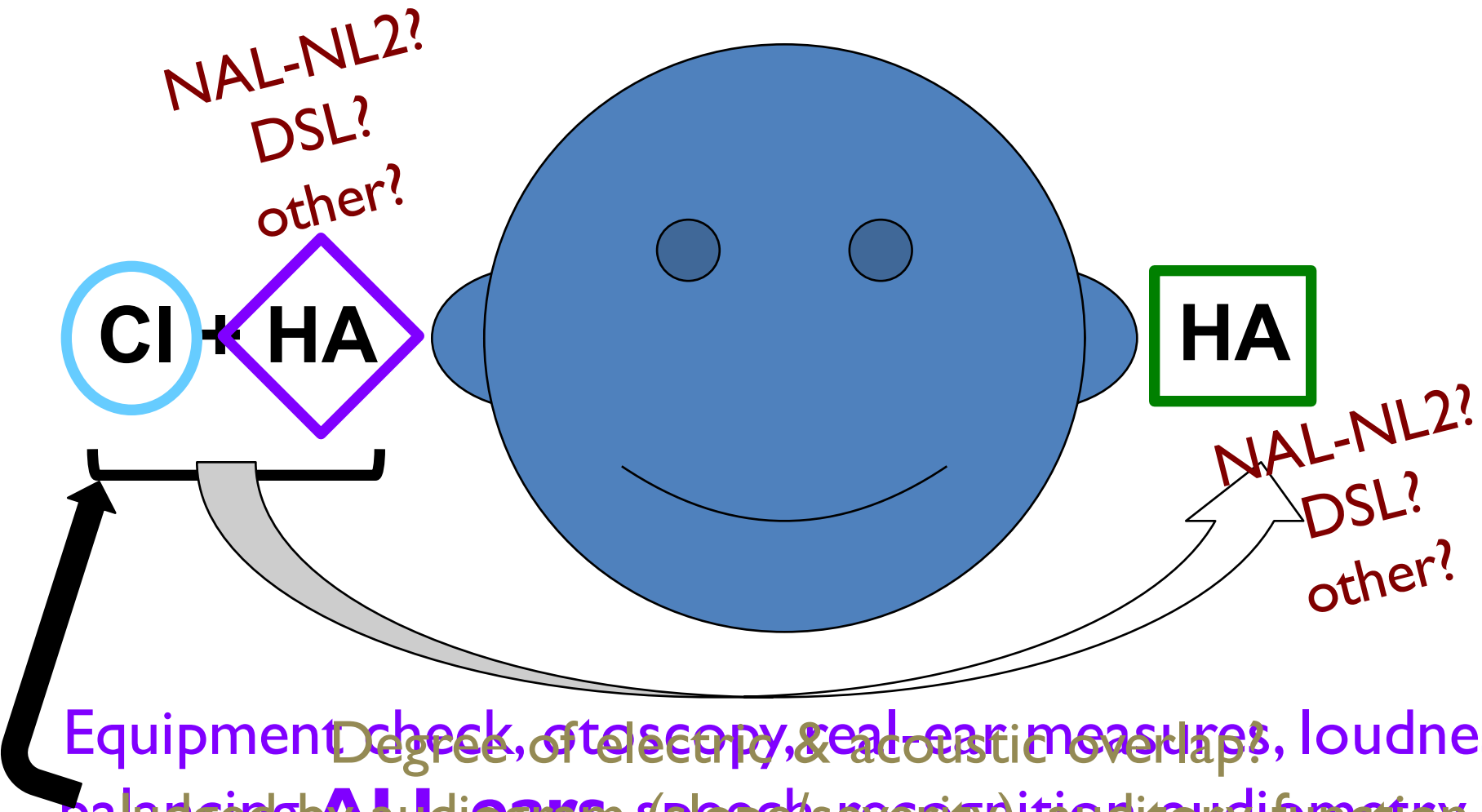
Listening/equipment/magnet check, otoscopy, telemetry, psychophysics, sweeping and balancing, soundfield thresholds, speech recognition, equipment orientation, counseling

Audiologic management



Equipment check, otoscopy, real-ear measures, loudness balancing across ears, speech recognition, audiometry (if needed), conductive overlay?, device orientation counseling

Audiologic management



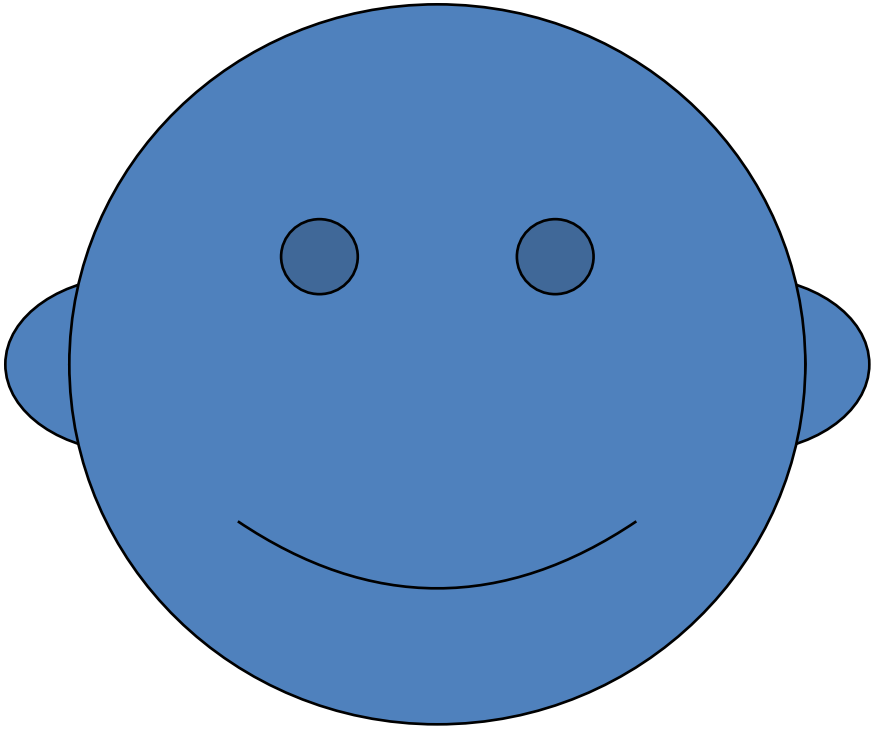
Equipment check, otoscopy, real-ear measures, loudness balancing by audiogram, speech recognition, tympanometry, (if needed), device orientation counseling?

Degree of electric & acoustic overlap? Judged by audiogram, speech recognition, audiometry, (if performed), device orientation counseling?

ALL ears

Audiologic management

CI + HA

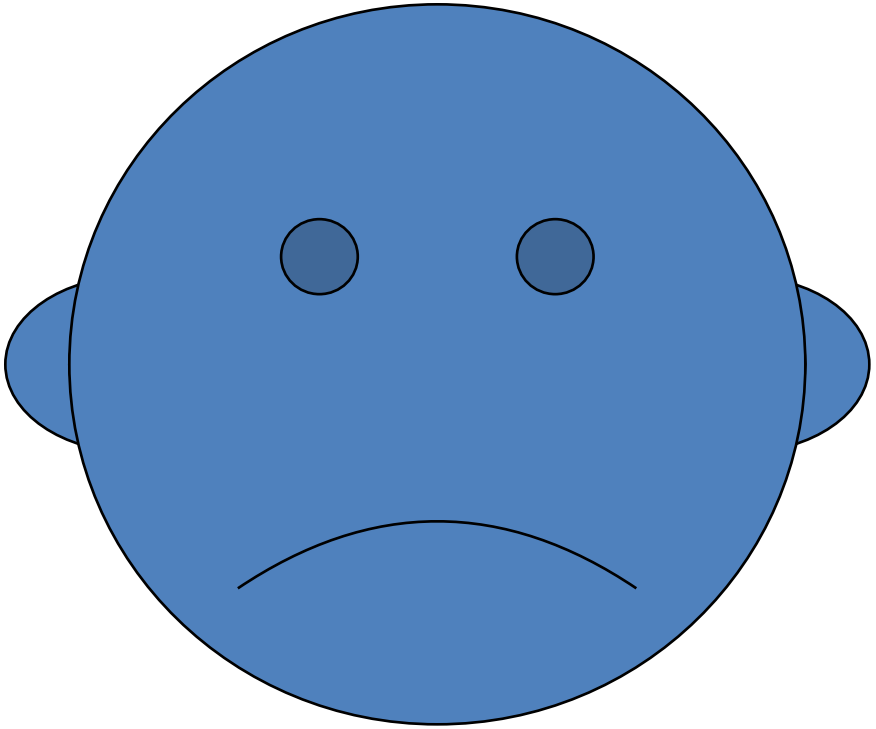


HA + CI

Without practice consensus guidelines
or EBP recommendations

Audiologic management

CI + HA



HA + CI

Without practice consensus guidelines
or EBP recommendations


SURELY A RESPONSE WILL COME
I JUST HAVE TO WAIT PATIENTLY...
quickmeme.com

Bimodal Optimization
Multiple combinations of parameters

HA related

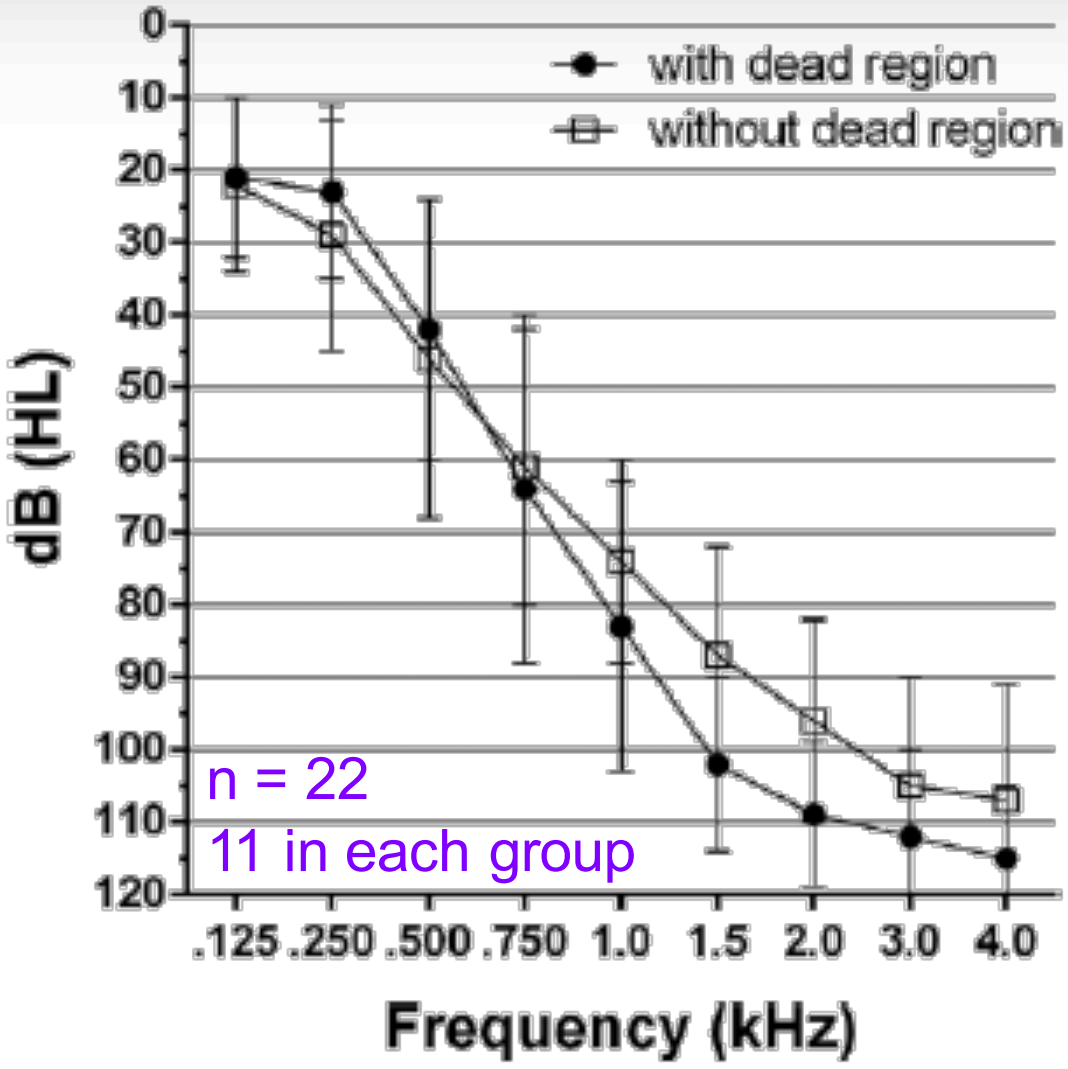
- Bandwidth
  - Minimal acoustic BW needed in non-CI ear
    - But how much should we amplify?
    - Dead regions?
- Gain
  - More gain yielded better EAS outcomes with hearing preservation patients → Vermeire et al., 2008; Dillon et al., 2014.
  - Many bimodal patients are underfit → Harris & Hay-McCuthcheon, 2010
- Output
- AGC characteristics (co-variant of gain)
- Frequency lowering technology
- Symmetry with HA in non-CI ear (timing & phase)

Bimodal Optimization
Multiple combinations of parameters

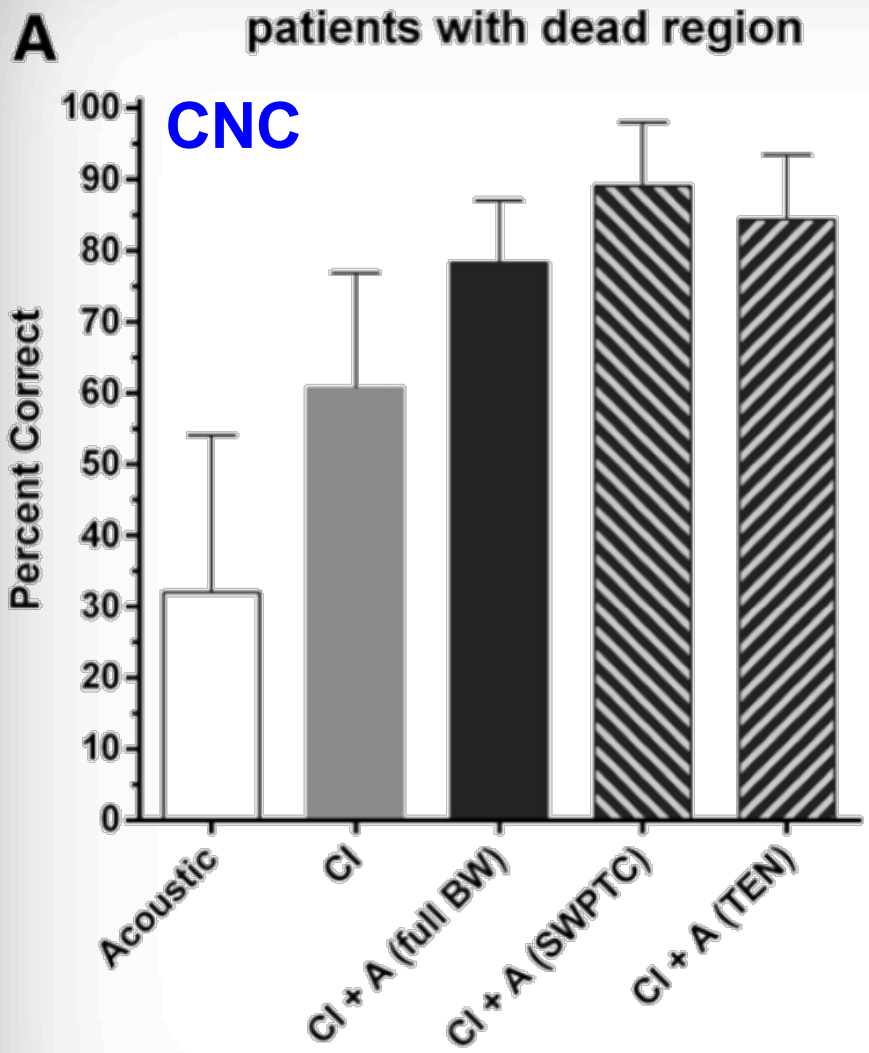
CI related

- CI frequency allocation
  - Do we want to provide EAS overlap across ears? Minimal overlap? No overlap? Full BW?
- Stimulation strategy (CIS/HiRes, Fidelity120, Optima)
  - Do we need strategies attempting to improve spectral resolution if we are providing fine structure via acoustic hearing?
- AGC characteristics
- Degree of symmetry with HA parameters in both ears
- Should we program bimodal patients in the same manner than we program those that have only CI stimulation?
  - Loudness matching? Pitch matching?

HA considerations

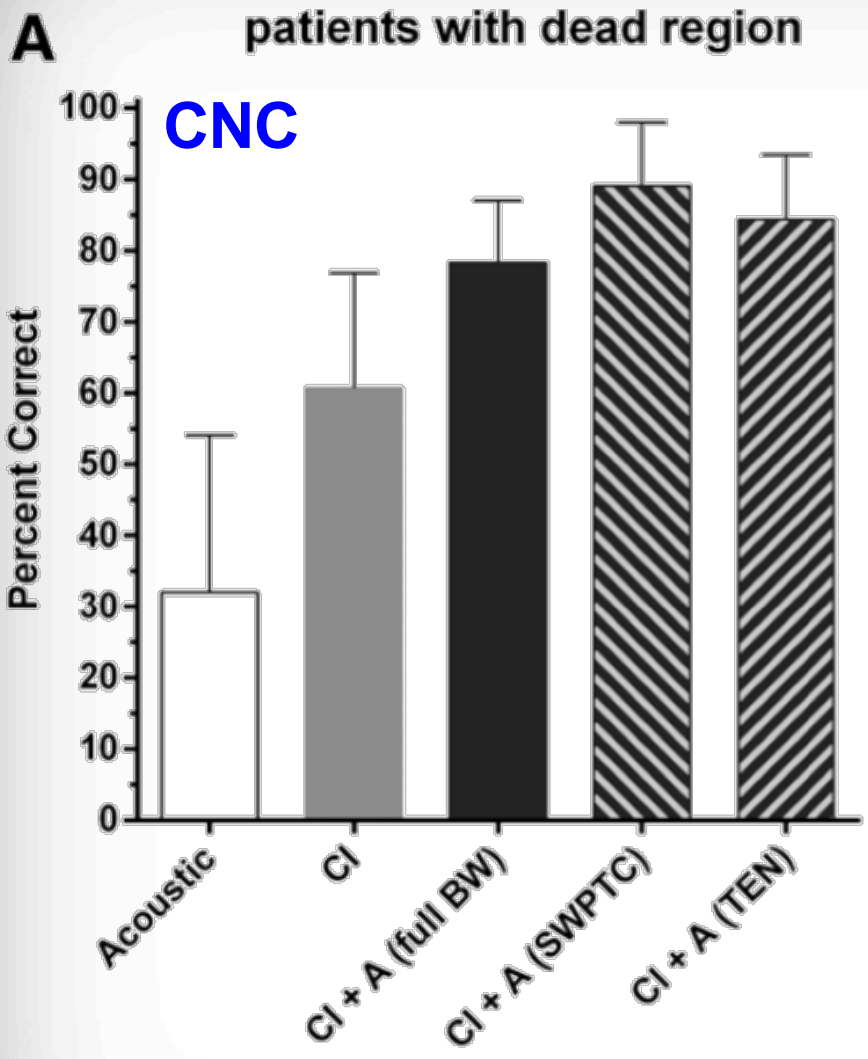


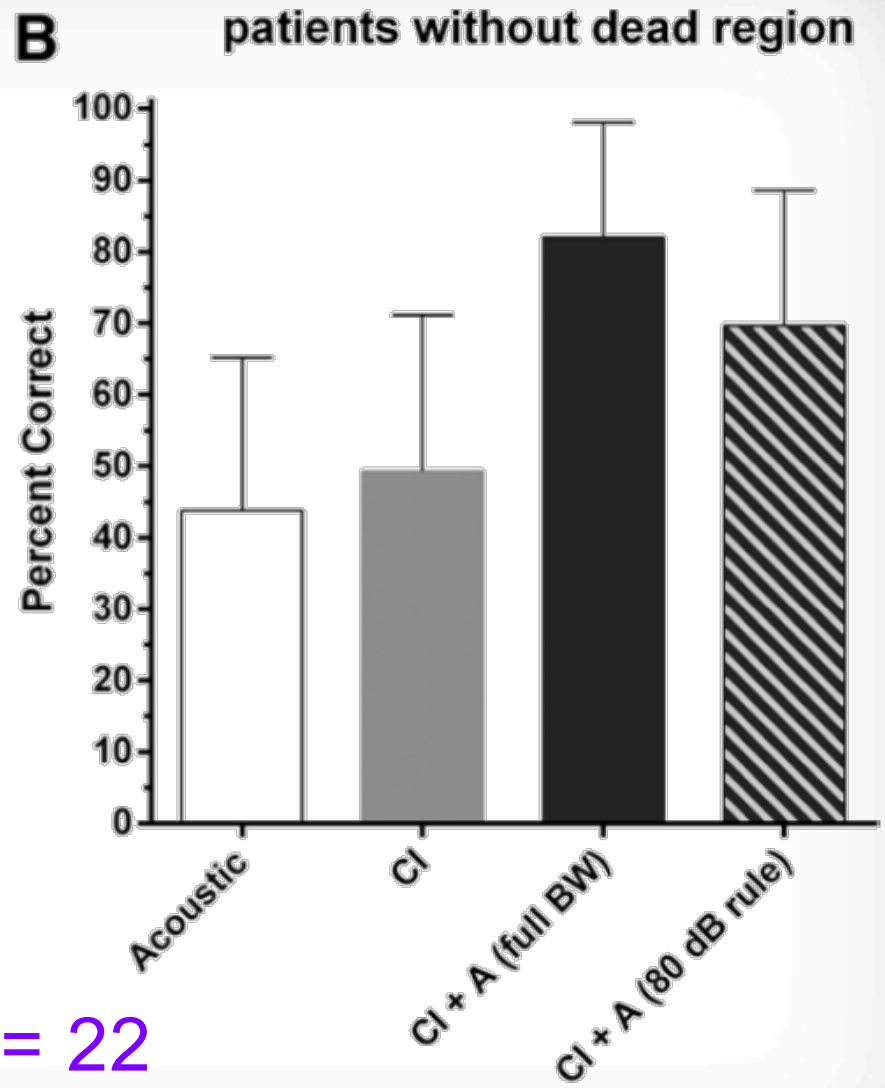
Zhang et al. (2014). Ear Hear, 35:410–417



n = 22

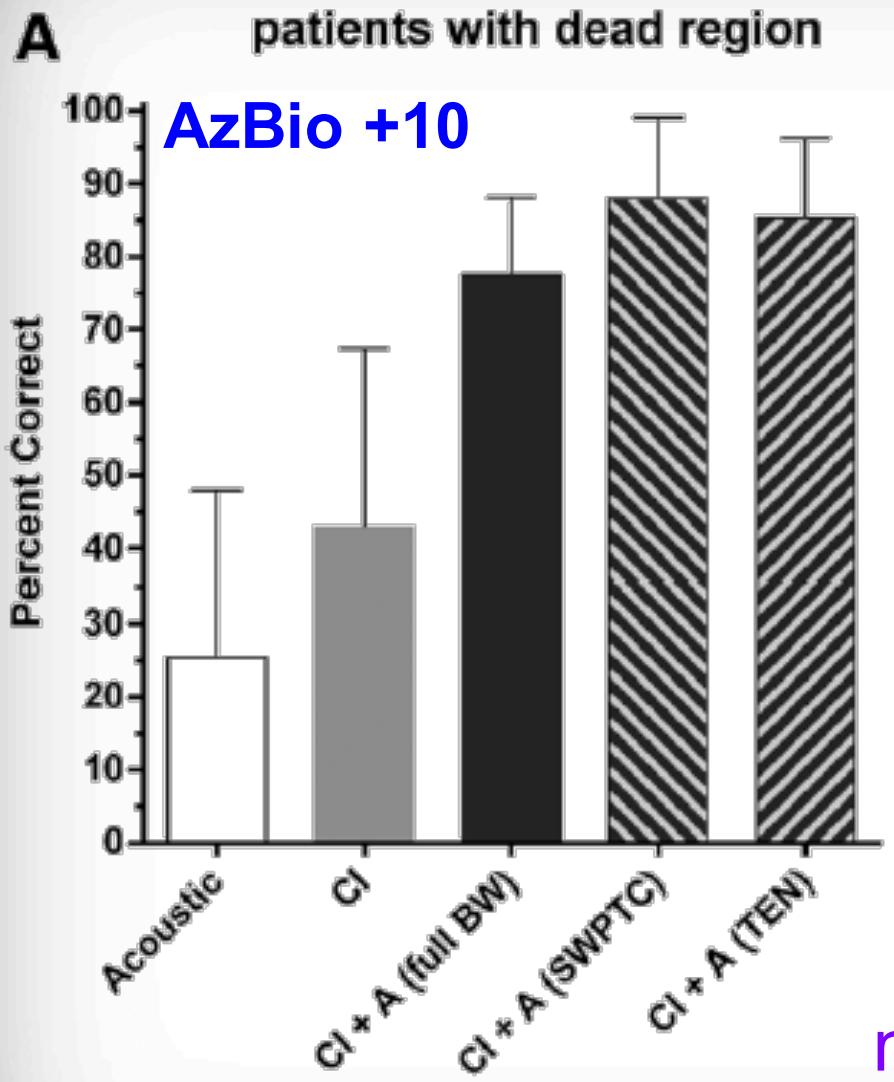
Zhang et al. (2014). Ear Hear, 35:410–417

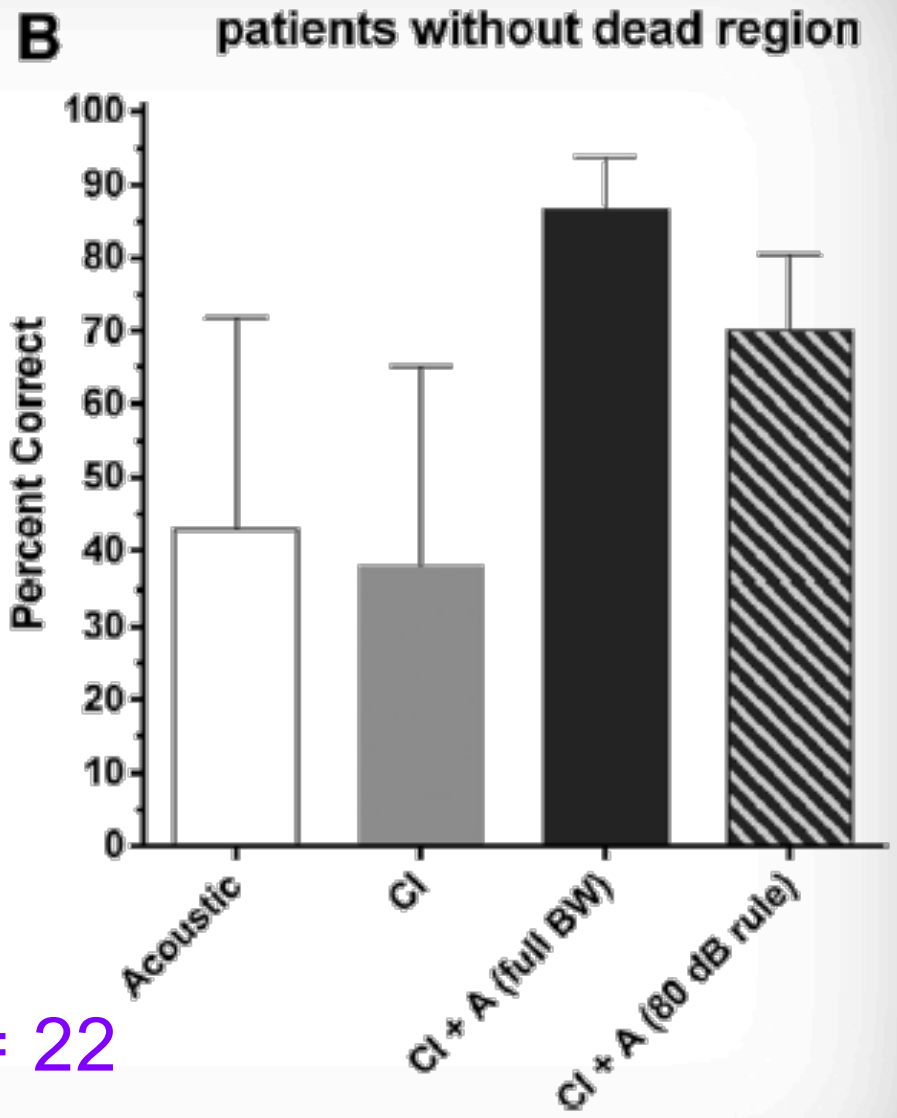




n = 22

Zhang et al. (2014). Ear Hear, 35:410–417





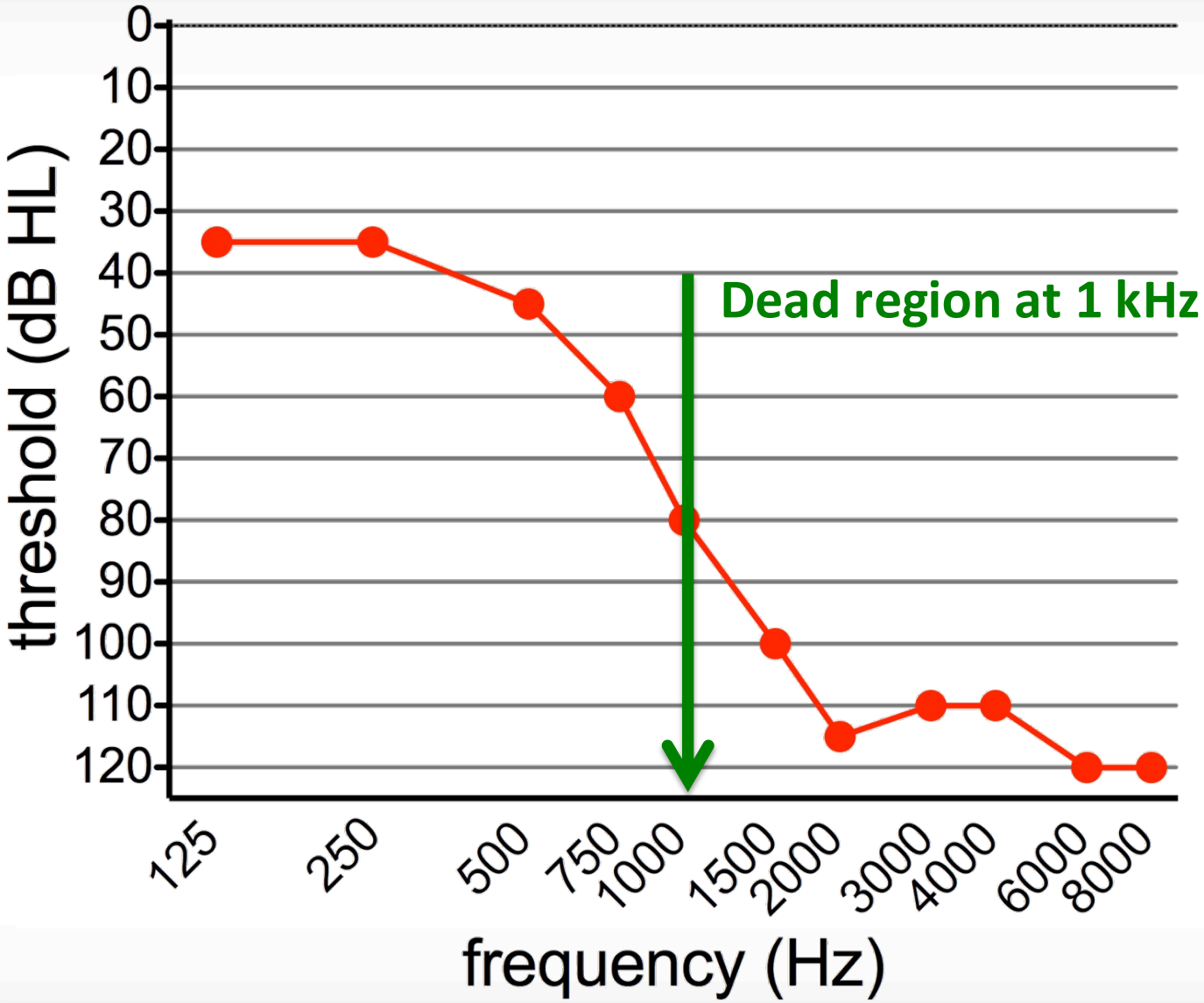
n = 22

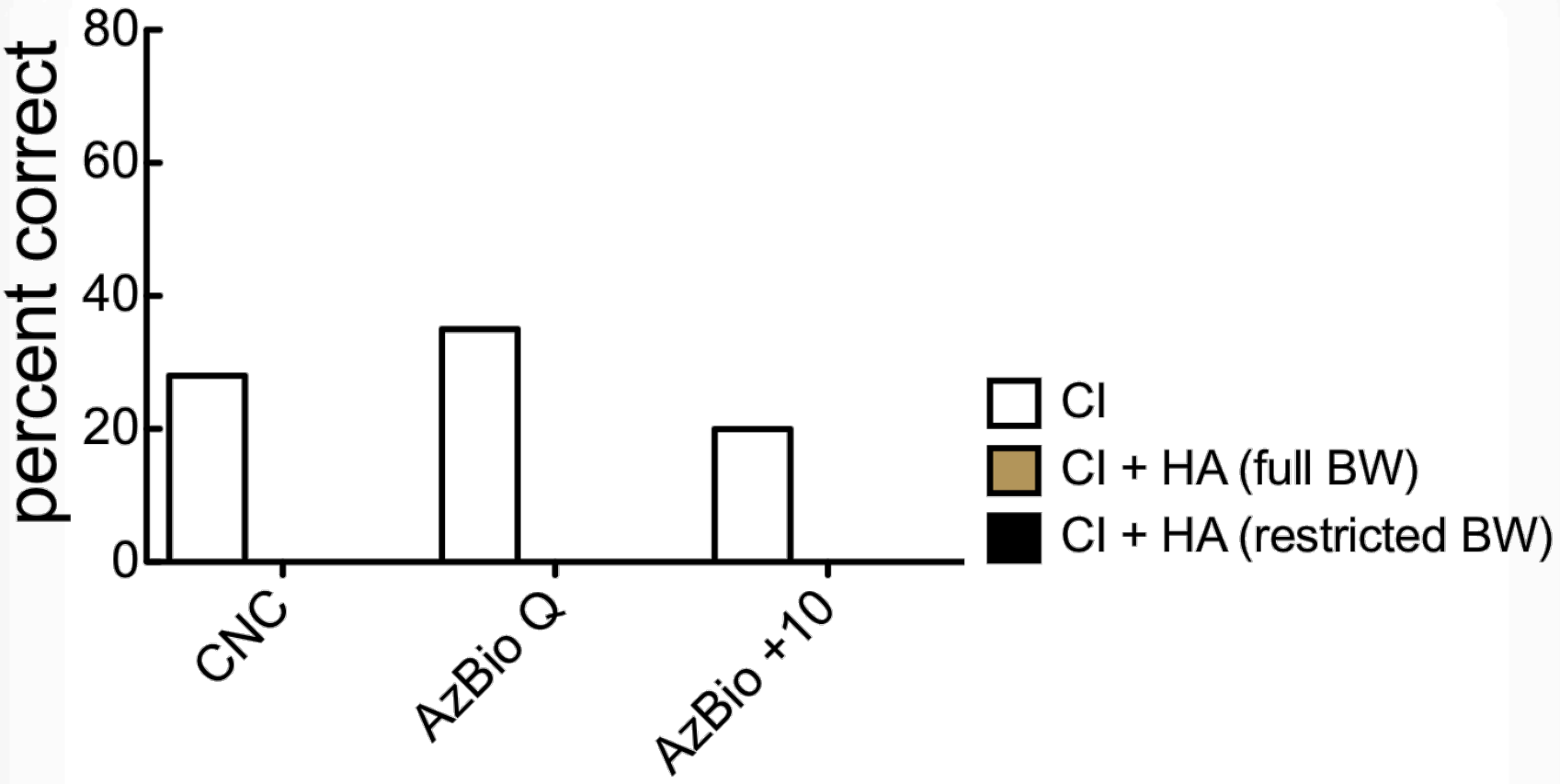
Zhang et al. (2014). Ear Hear, 35:410–417

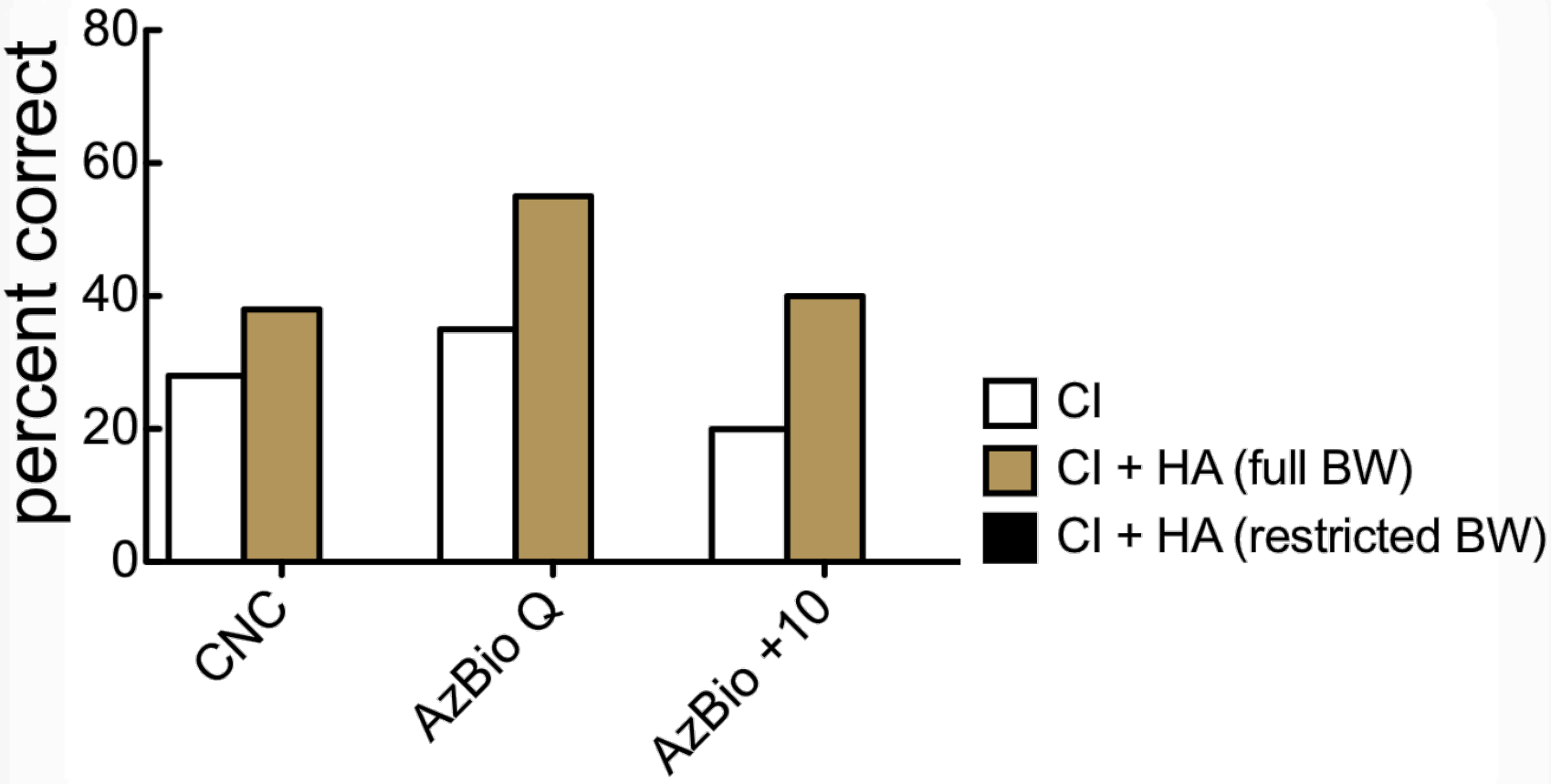
Case study

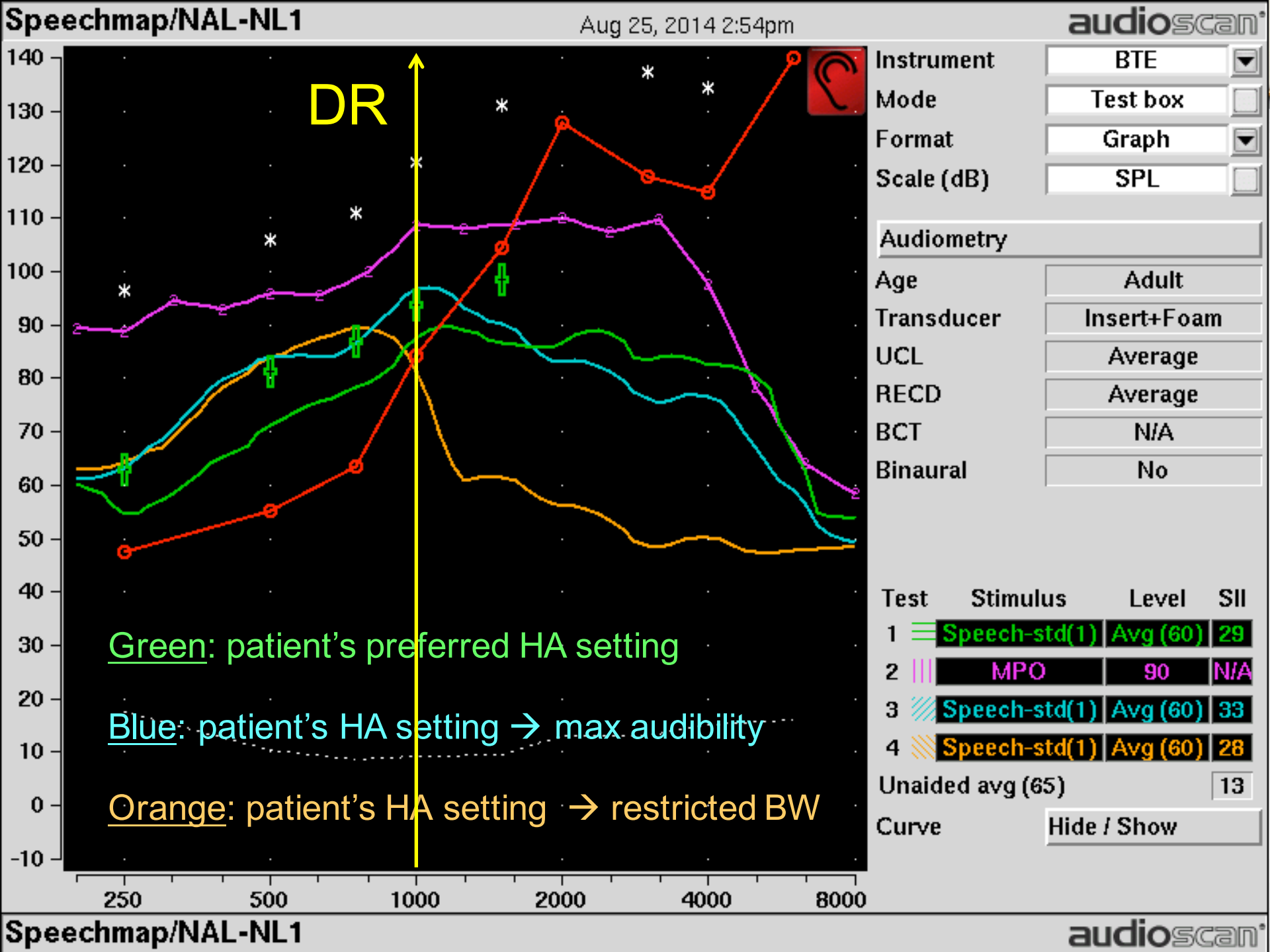
BIMODAL CASE STUDY

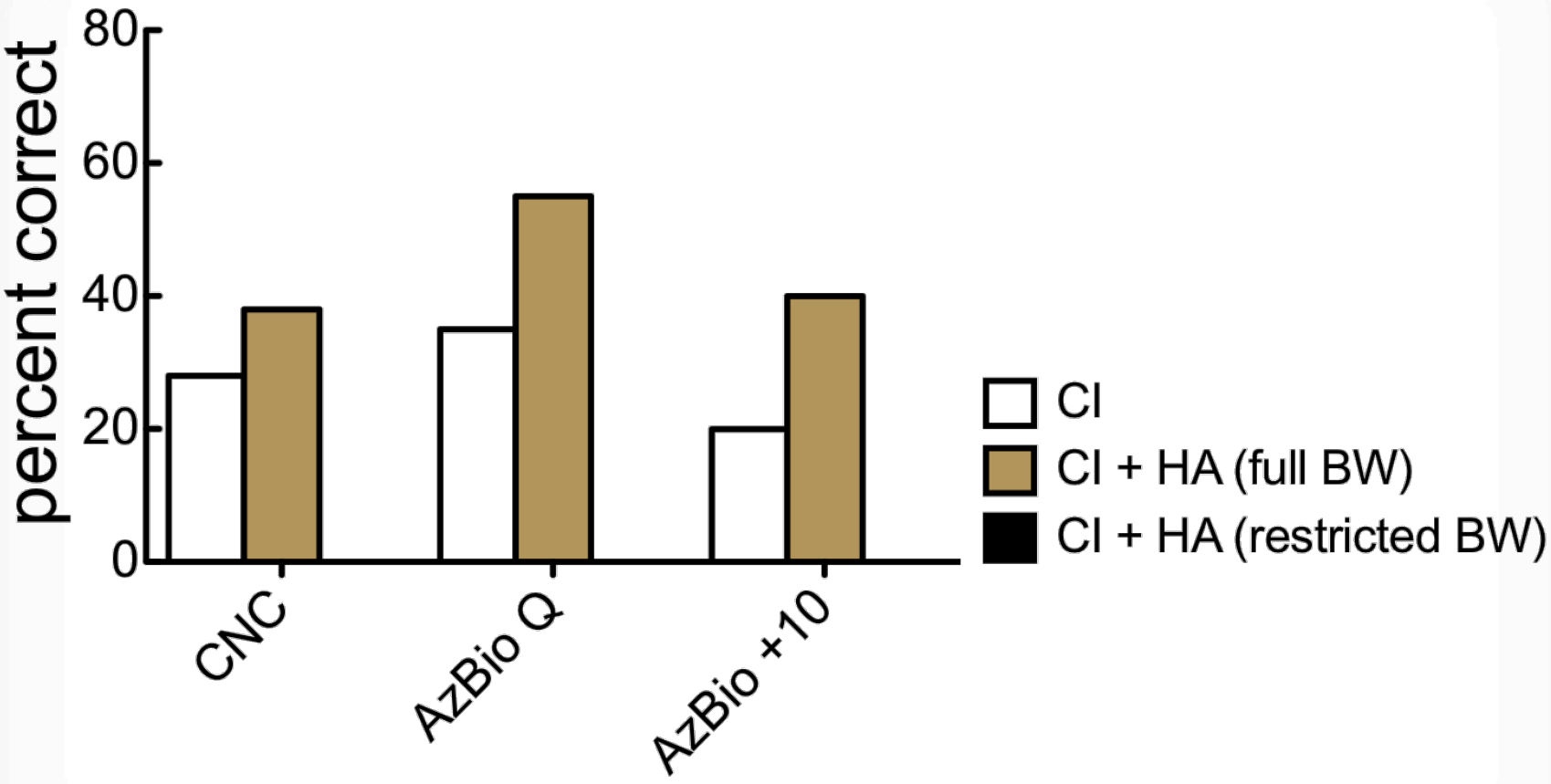
- 75-year old male
- Left CI: 18 months experience
- Considerable health problems
- Struggling with CI
  - Despite bimodal benefit, very frustrated with HA

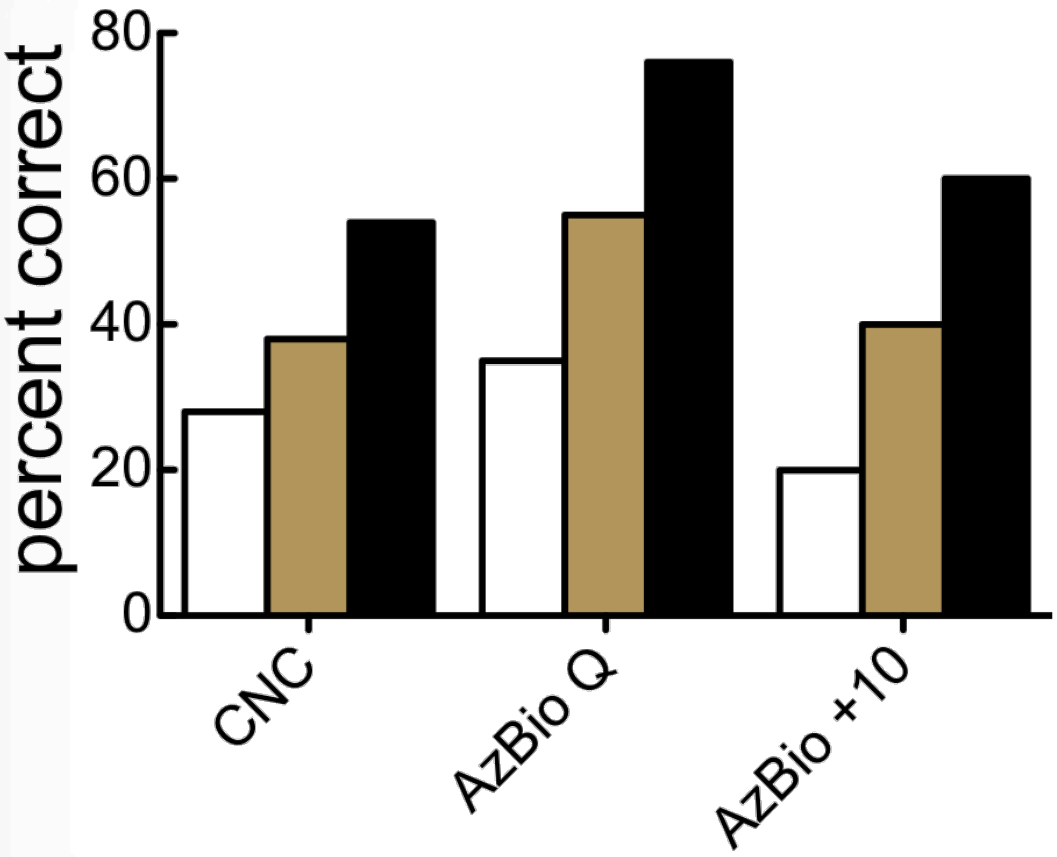

threshold (dB HL)
0
10
20
30
40
50
60
70
80
90
100
110
120
125
250
500
750
1000
1500
2000
3000
4000
6000
8000
frequency (Hz)
Dead region at 1 kHz


percent correct
80
60
40
20
0
CNC
AzBio Q
AzBio +10
CI
CI + HA (full BW)
CI + HA (restricted BW)


percent correct
80
60
40
20
0
CNC
AzBio Q
AzBio +10
CI
CI + HA (full BW)
CI + HA (restricted BW)


Speechmap/NAL-NL1
Aug 25, 2014 2:54pm
audioscan
DR
Green: patient's preferred HA setting
Blue: patient's HA setting → max audibility
Orange: patient's HA setting → restricted BW
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
250
500
1000
2000
4000
8000
Instrument
BTE
Mode
Test box
Format
Graph
Scale (dB)
SPL
Audiometry
Age
Adult
Transducer
Insert+Foam
UCL
Average
RECD
Average
BCT
N/A
Binaural
No
Test
Stimulus
Level
SII
1
Speech-std(1)
Avg (60)
29
2
MPO
90
N/A
3
Speech-std(1)
Avg (60)
33
4
Speech-std(1)
Avg (60)
28
Unaided avg (65)
13
Curve
Hide / Show
Speechmap/NAL-NL1
audioscan


percent correct
80
60
40
20
0
CNC
AzBio Q
AzBio +10
CI
CI + HA (full BW)
CI + HA (restricted BW)

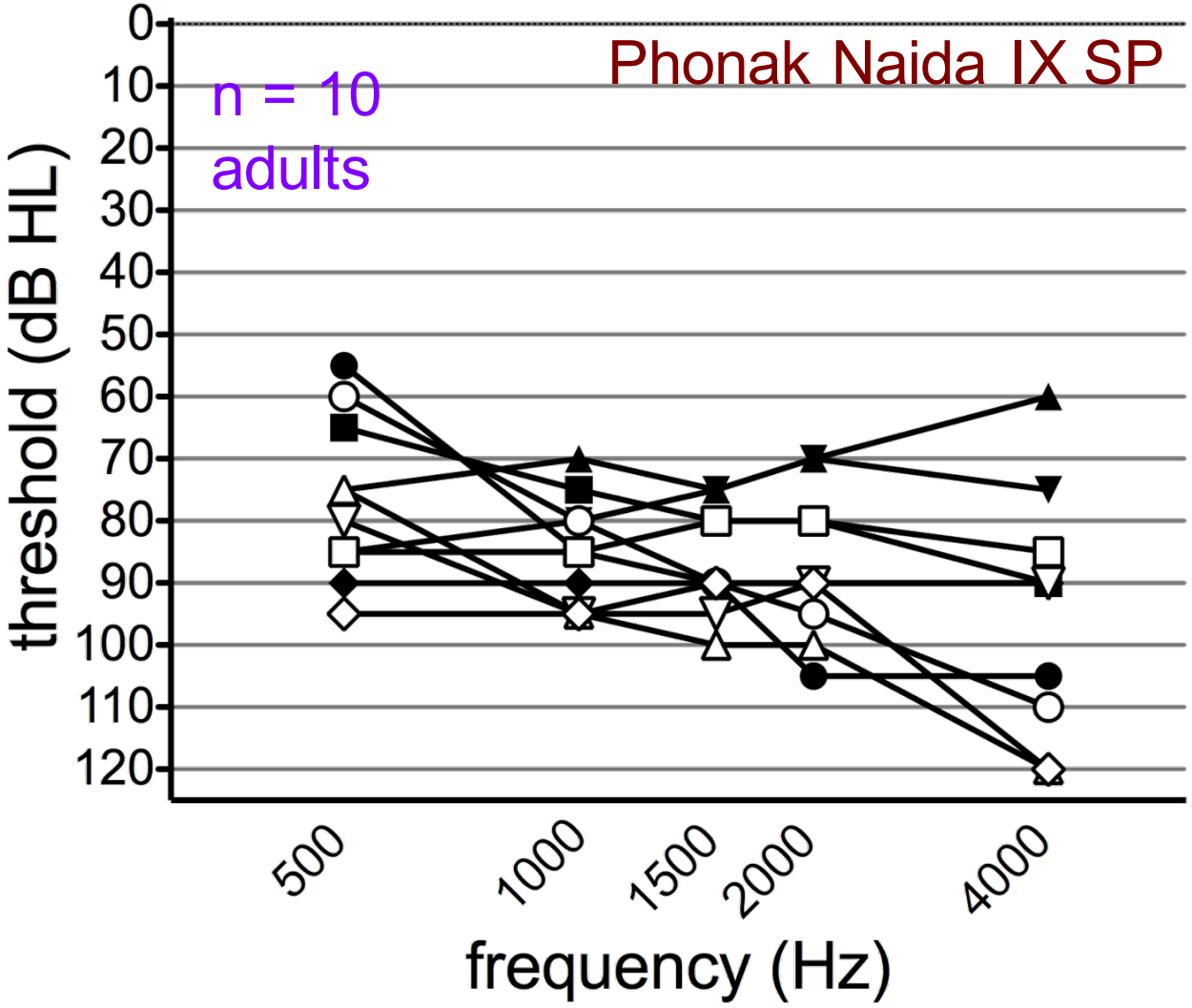


CI
CI + HA (full BW)
CI + HA (restricted BW)

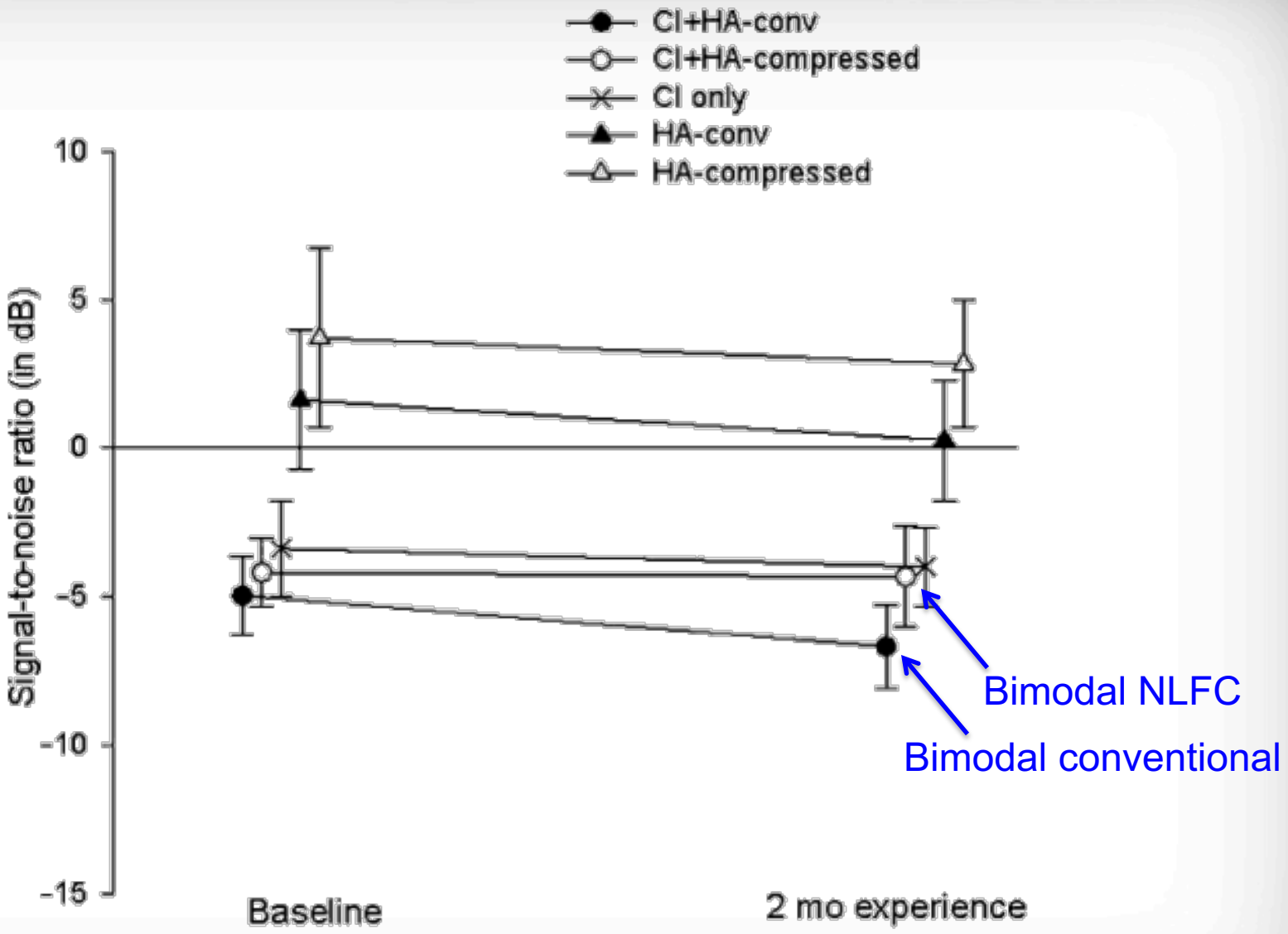
Bimodal hearing with non-linear frequency compression (NLFC)

Adults

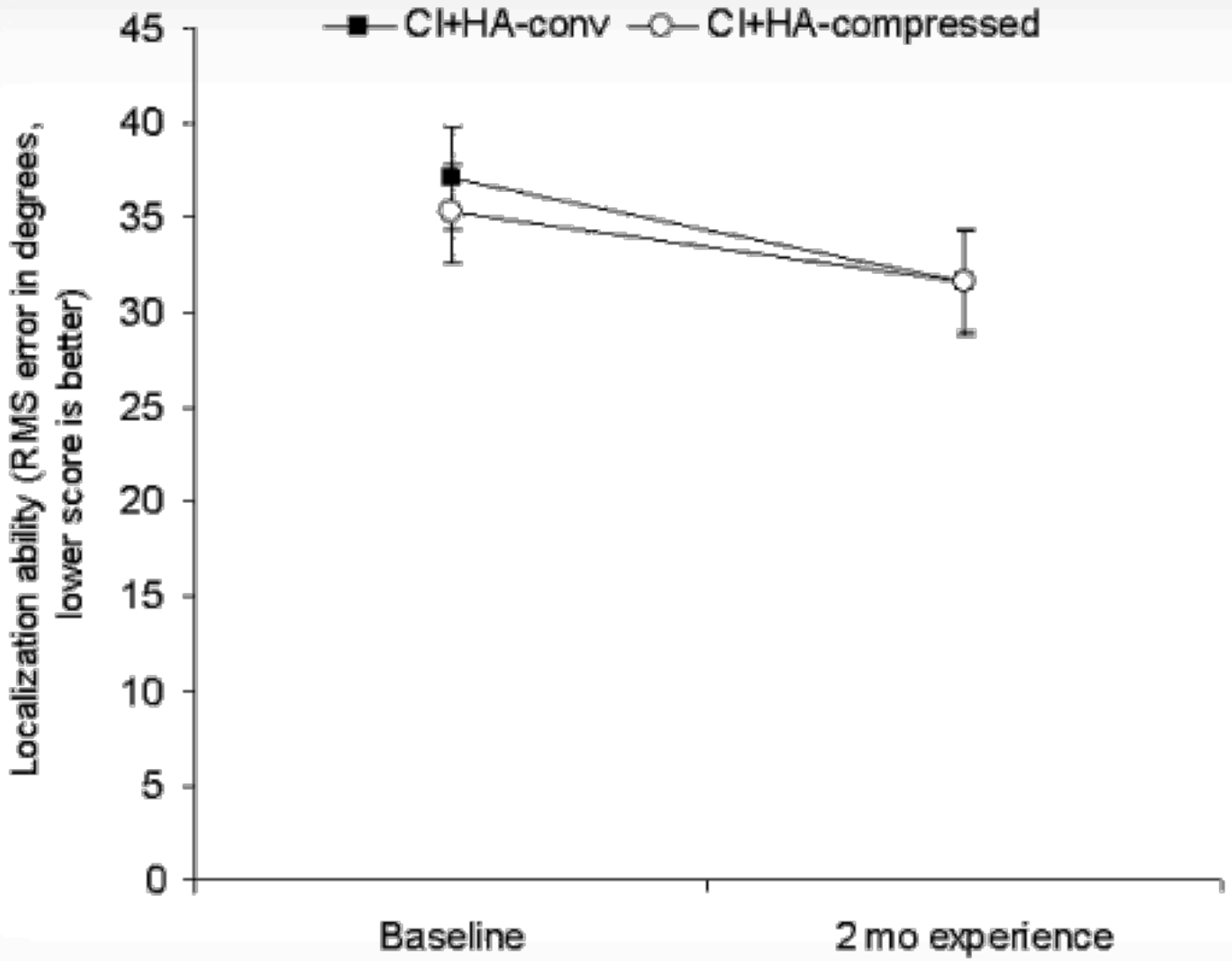
Nonlinear frequency compression: non-CI ear



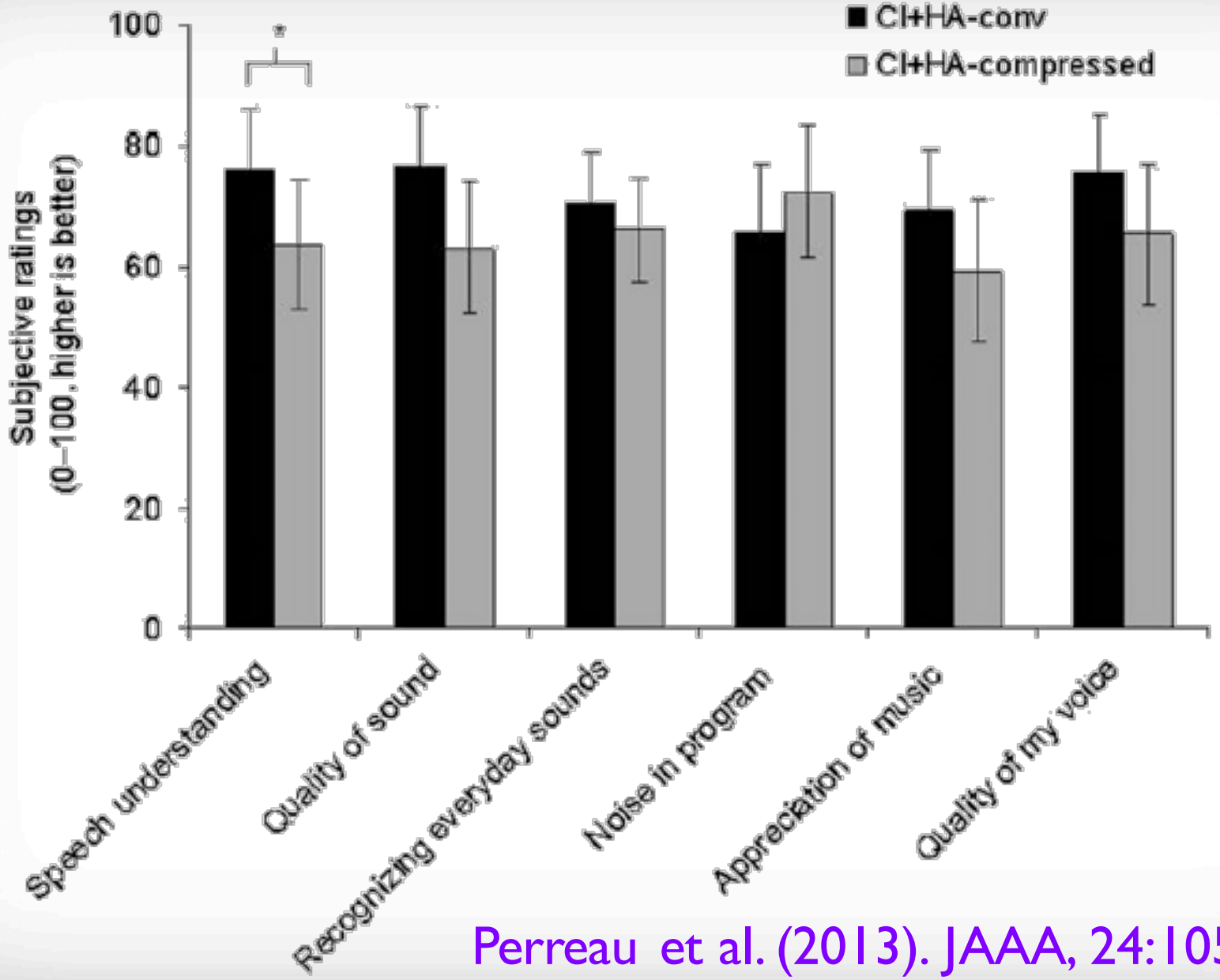
Perreau et al. (2013). JAAA, 24:105–120.



Perreau et al. (2013). JAAA, 24:105–120.



Perreau et al. (2013). JAAA, 24:105–120.

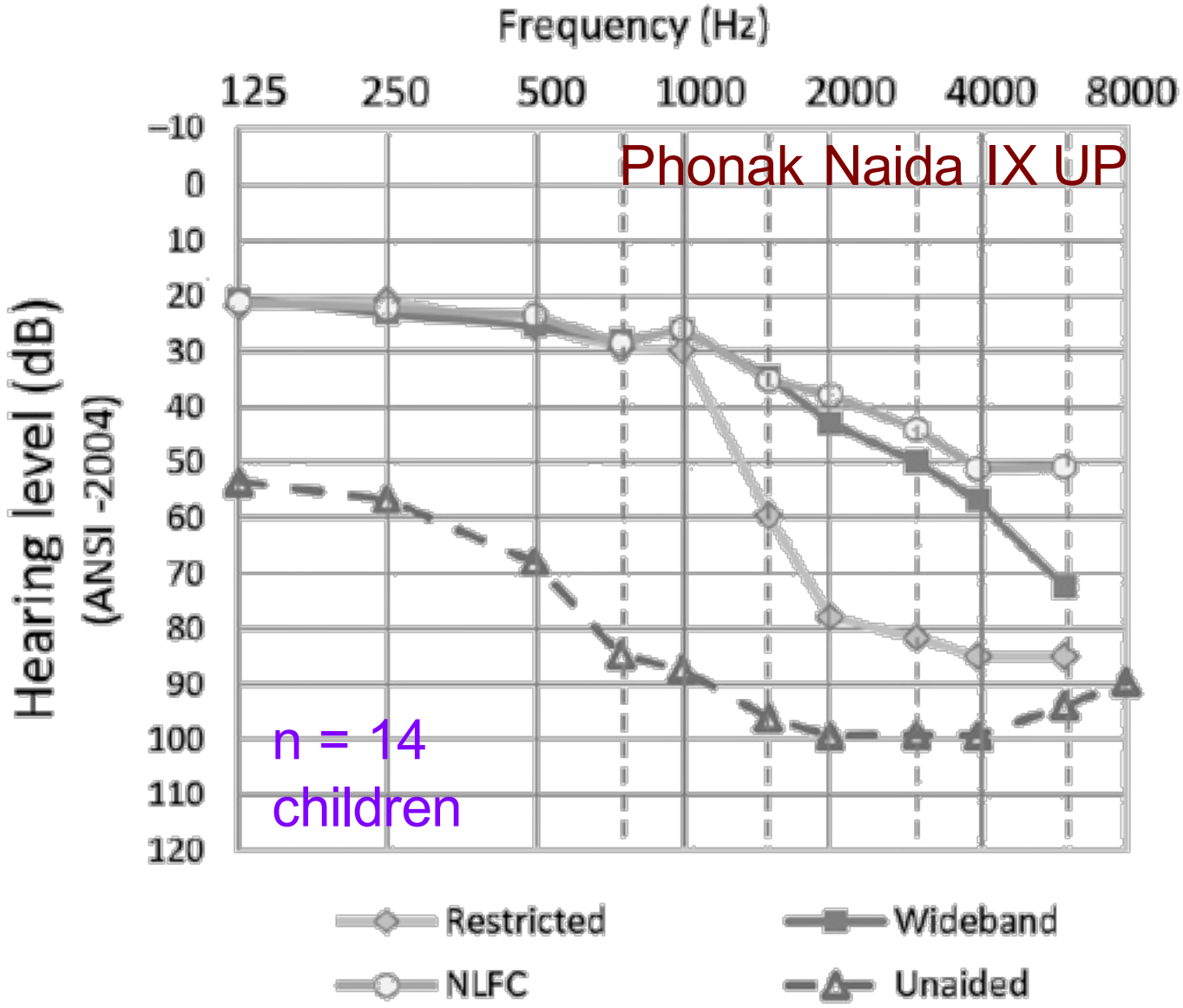


Perreau et al. (2013). JAAA, 24:105–120.

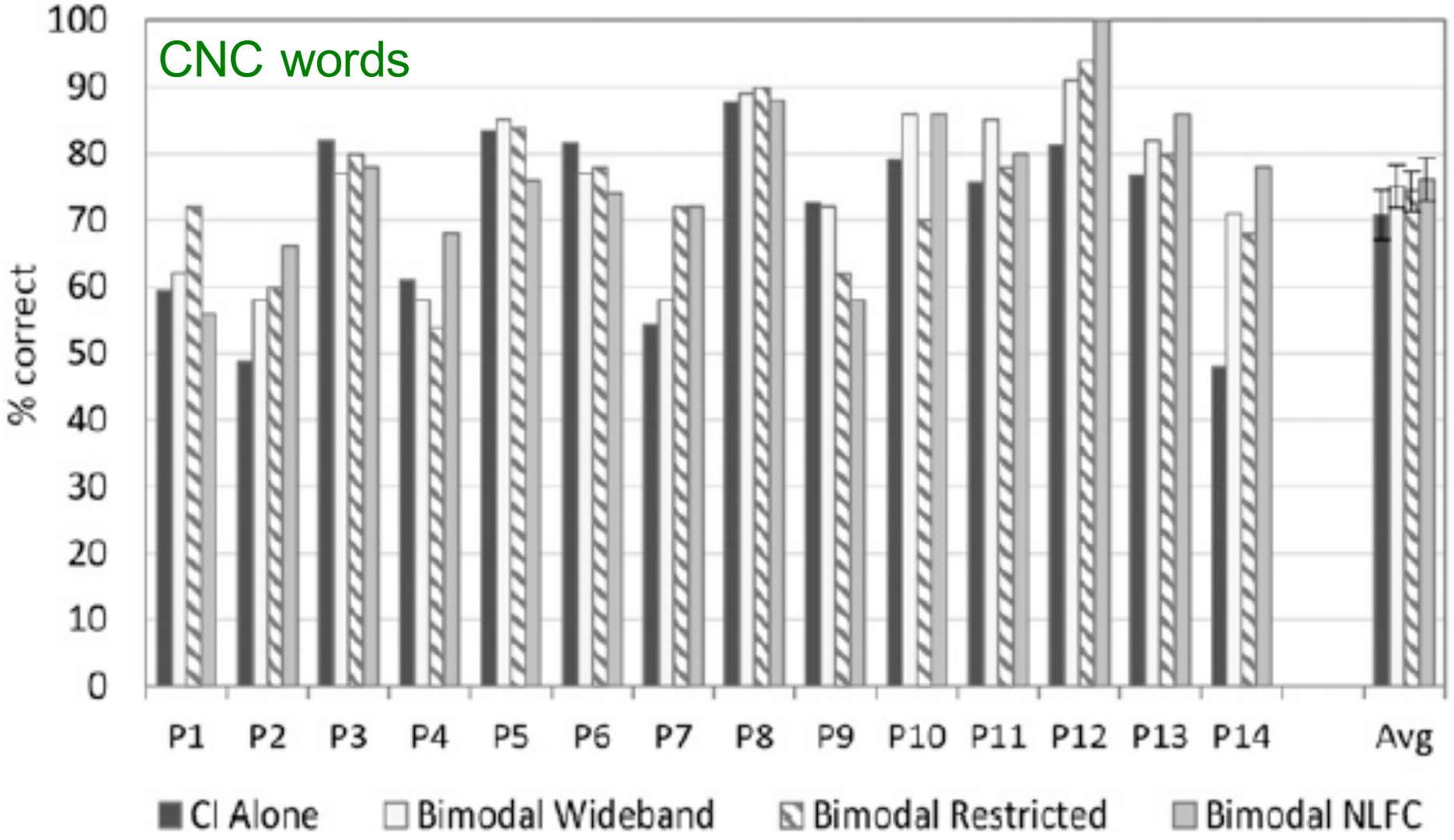
Bimodal hearing with non-linear frequency compression (NLFC)

Children

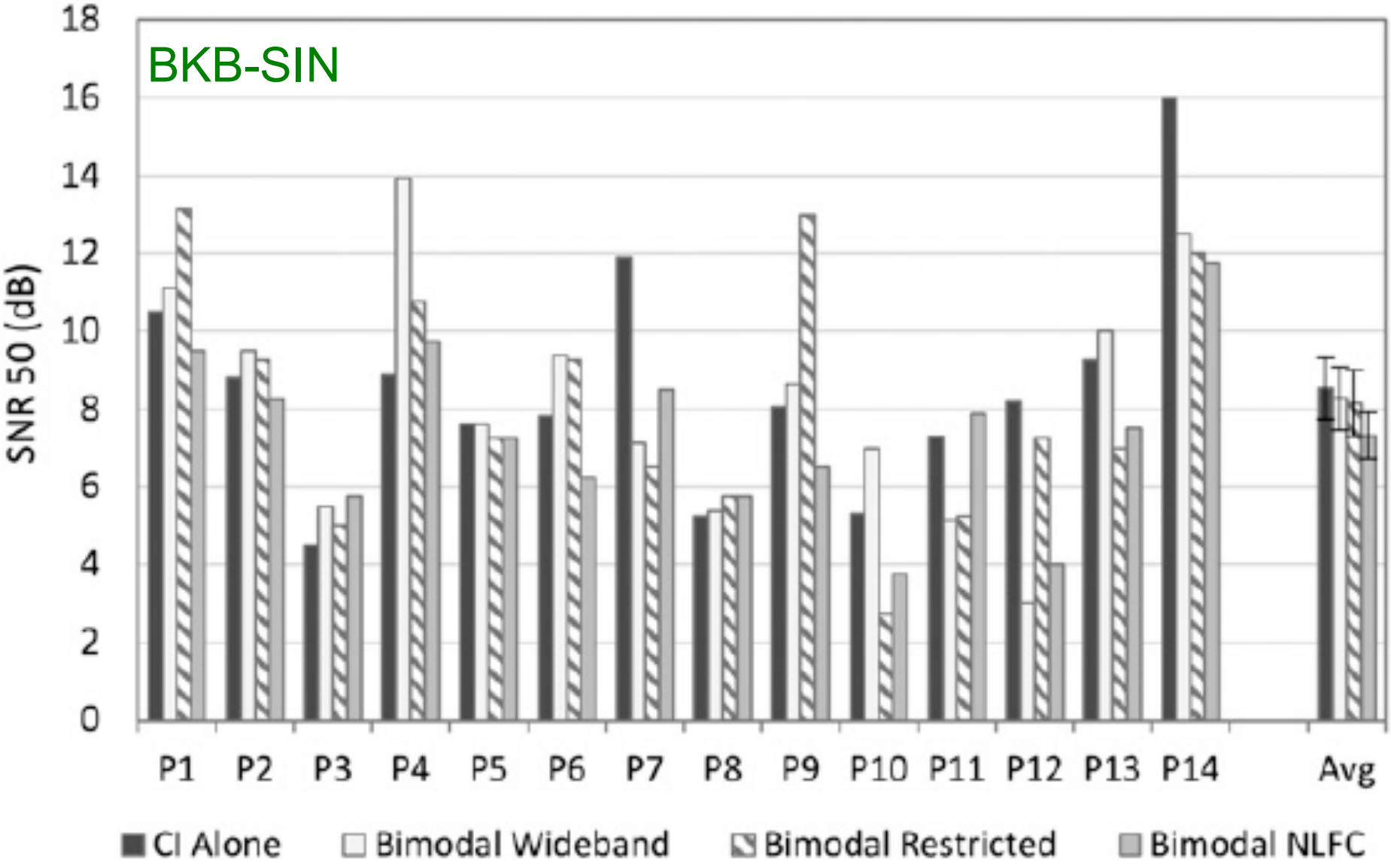
Nonlinear frequency compression: non-CI ear



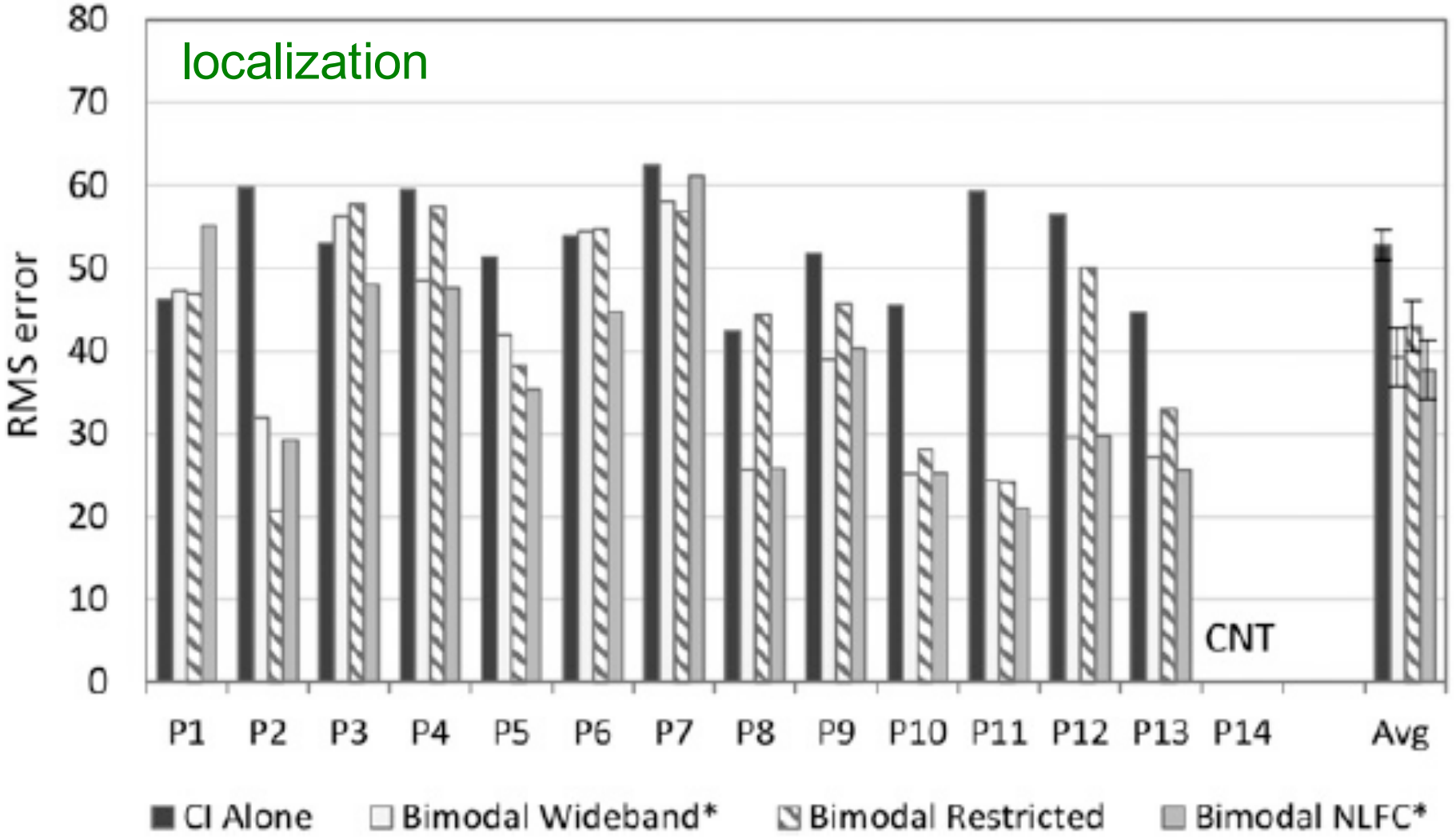
Davidson et al. (2015). JAAA, 26:393–407.



Davidson et al. (2015). JAAA, 26:393–407.



Davidson et al. (2015). JAAA, 26:393–407.



Davidson et al. (2015). JAAA, 26:393–407.

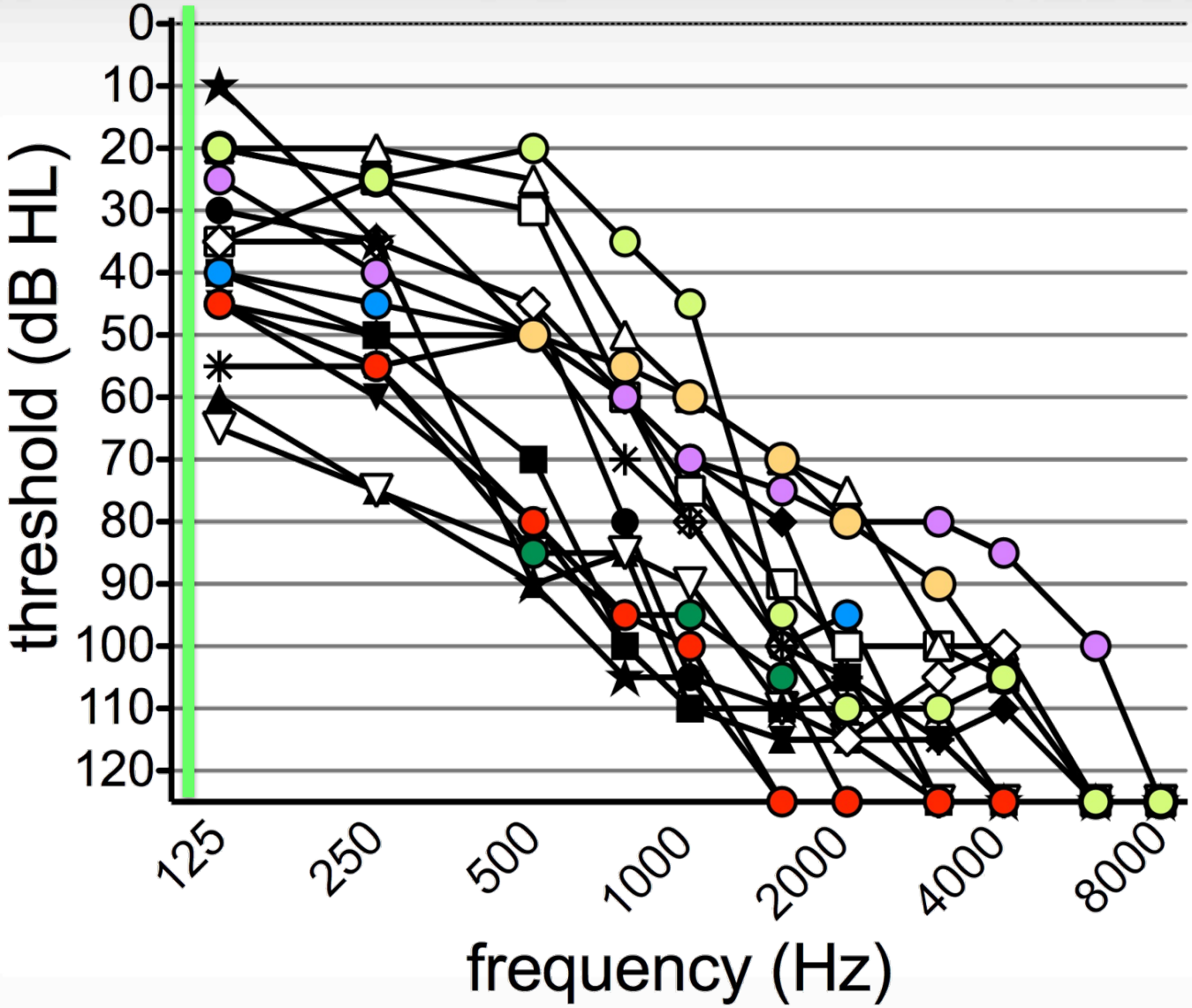
CI considerations

Gifford et al. (submitted)

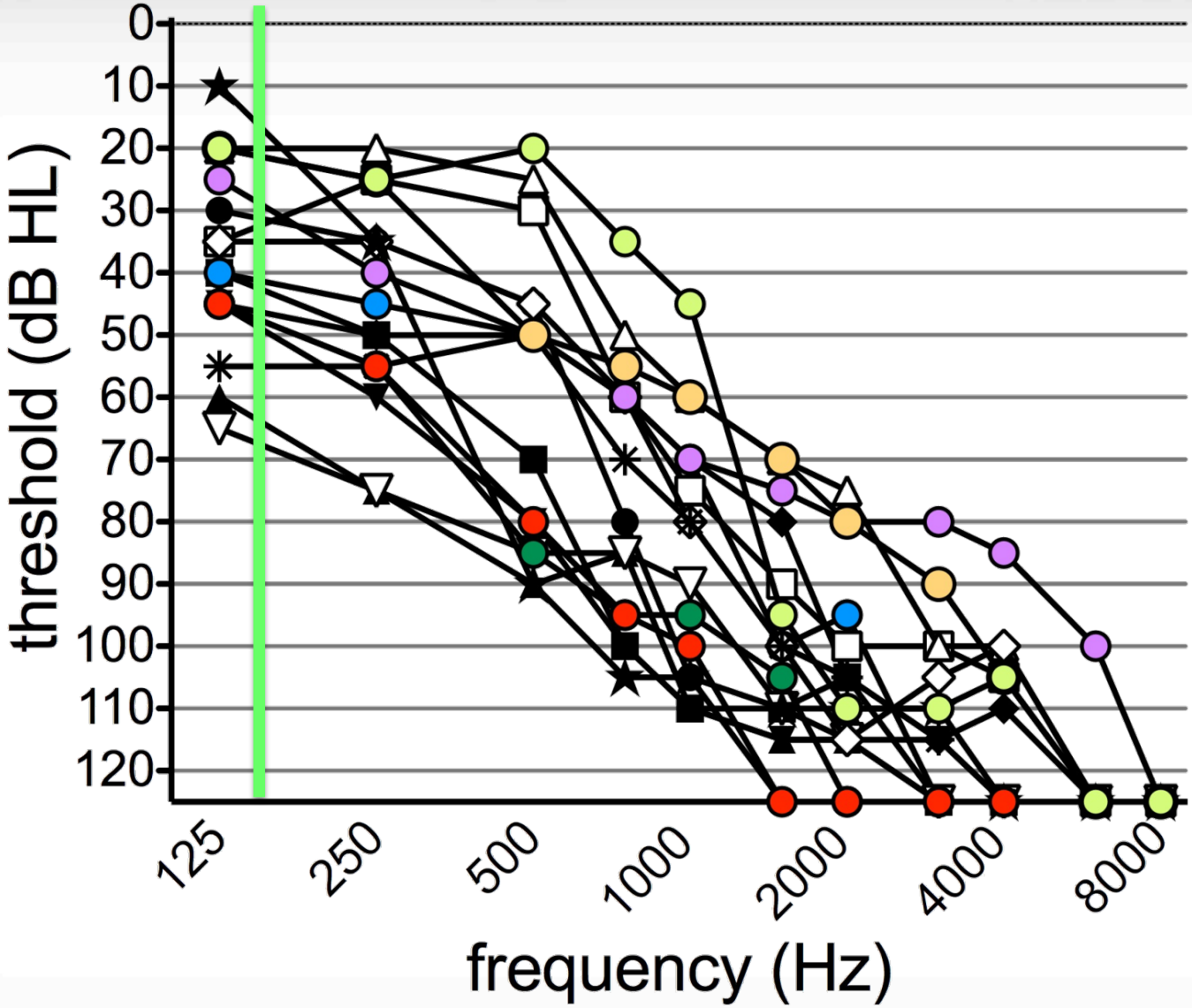
- n = 17
- Adult CI recipients w/ hearing preservation
  - Mean age = 63 years
- Experienced users (6+ months with CI)
- Cochlear & MED-EL recipients

Gifford et al. (submitted)

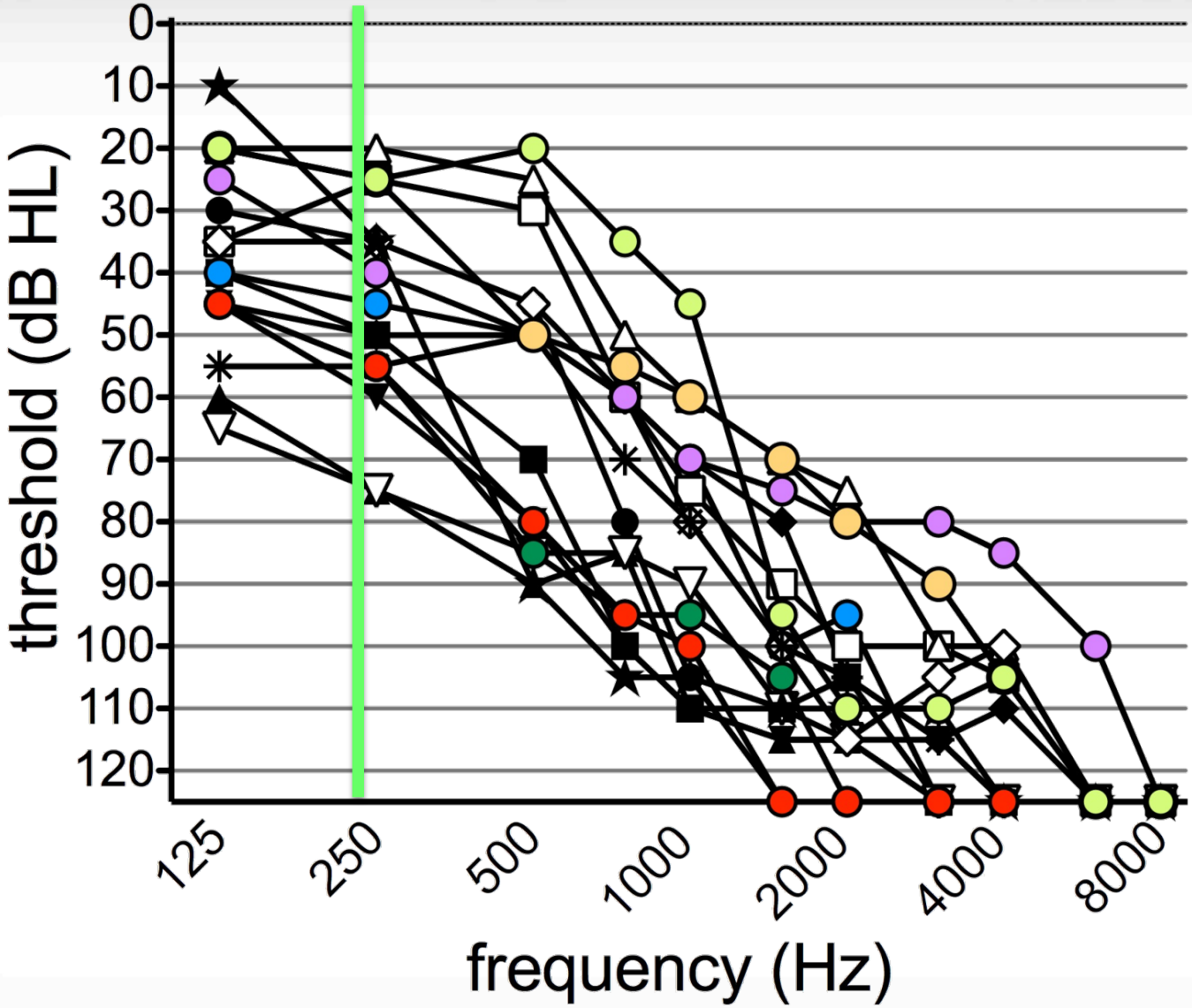
- Fit acoustic amplification in non-CI ear to limits of hearing loss (no NLFC)
- Varied the starting frequency of the CI
  - Nucleus: 188, 313, 438, 563, 688, and 813 Hz
  - MED-EL: 70, 150, 250, 350 Hz
- Speech understanding in semi-diffuse noise (R-SPACE™)
  - restaurant noise = 62 dBA
  - AzBio sentences = 67 dBA



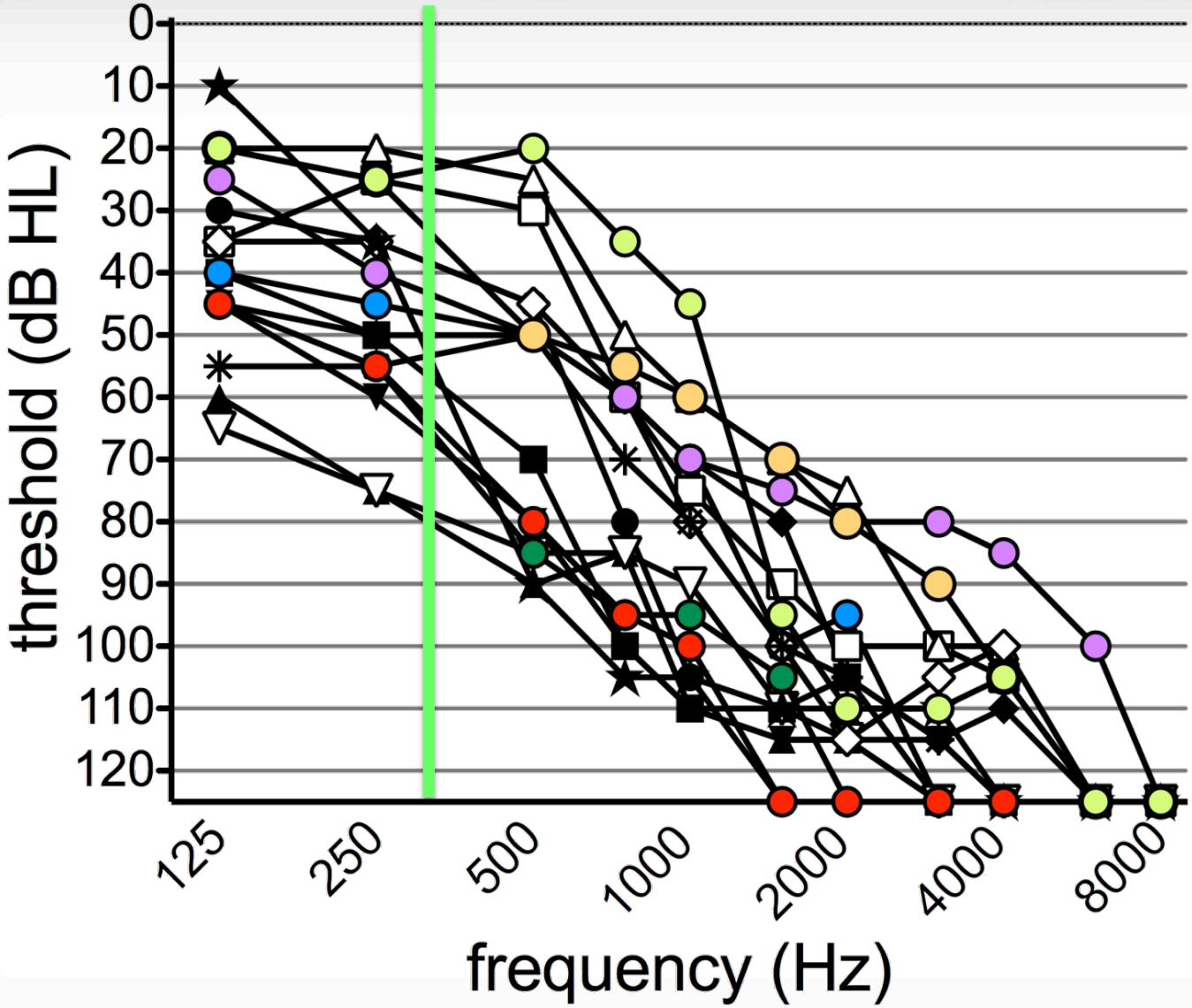
Gifford et al. (submitted).



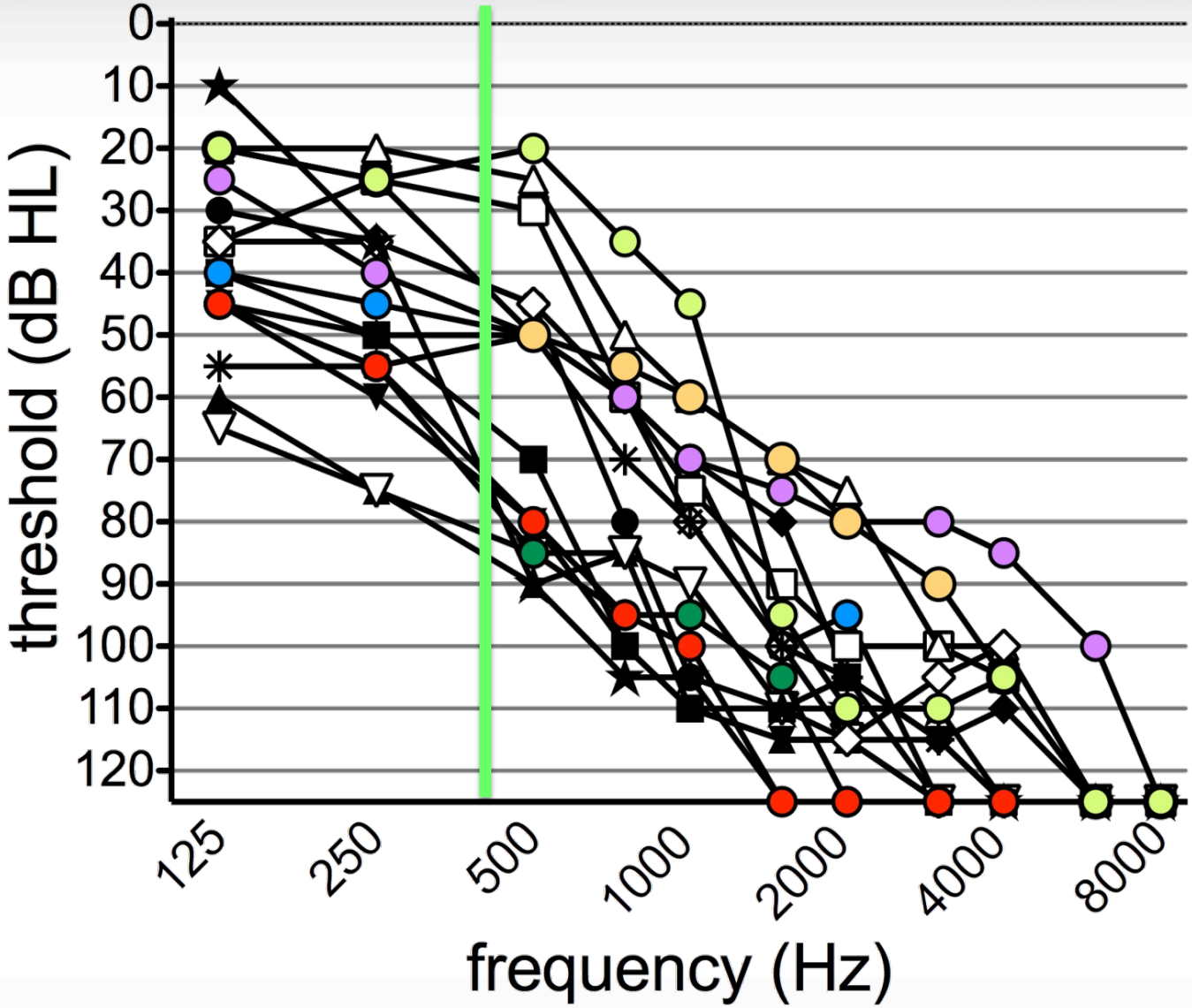
Gifford et al. (submitted).



Gifford et al. (submitted).

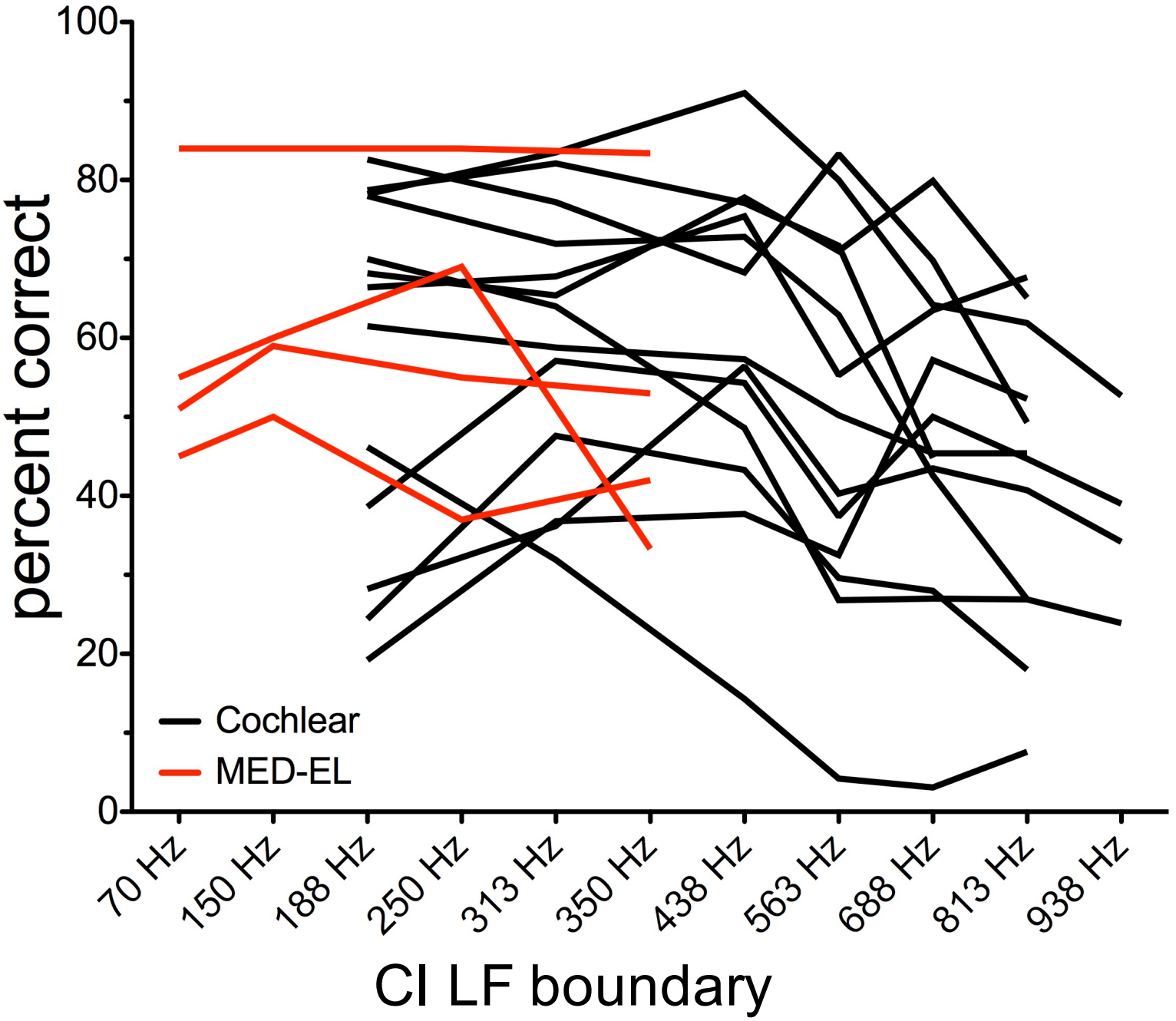


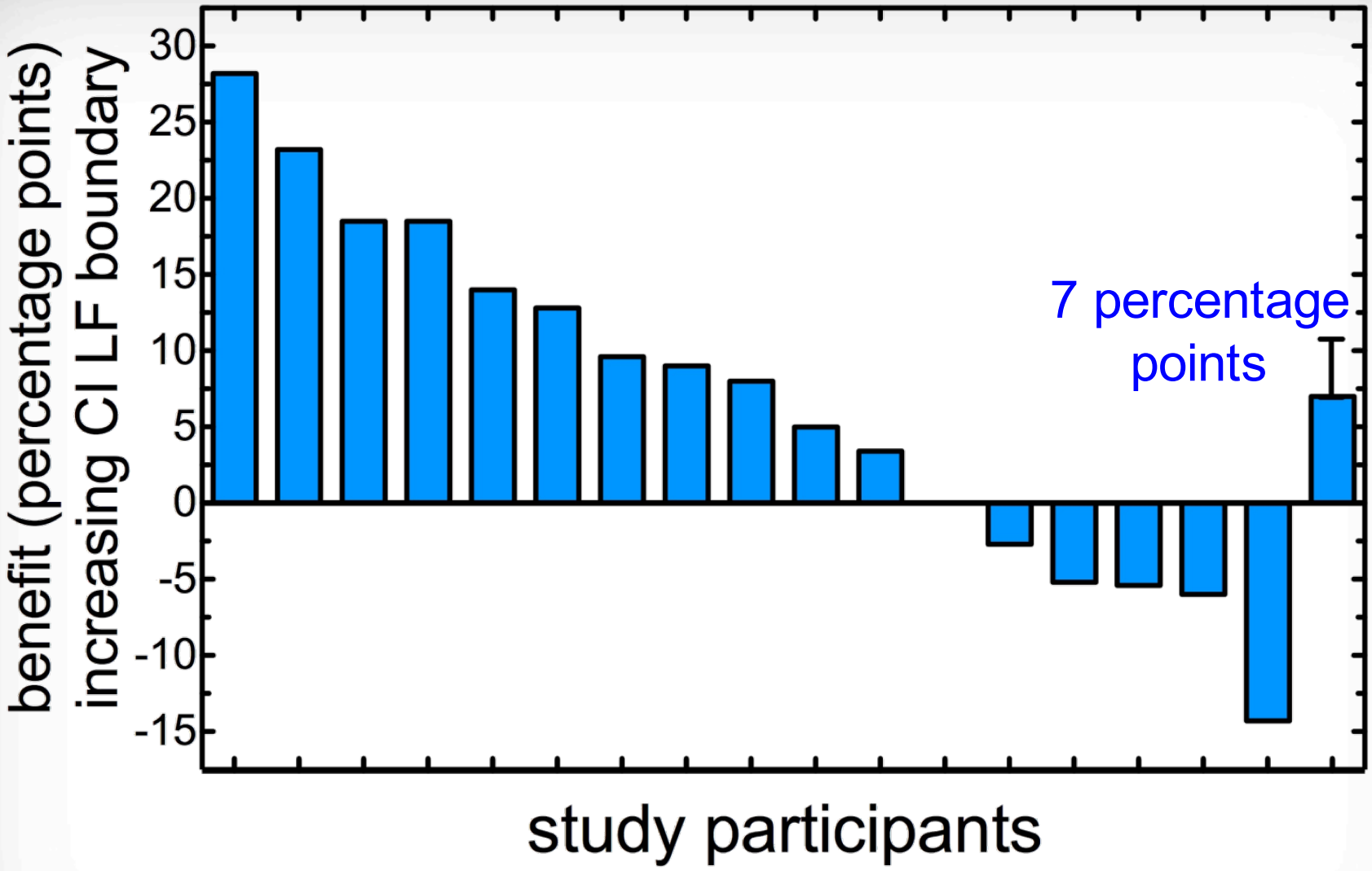
Gifford et al. (submitted).



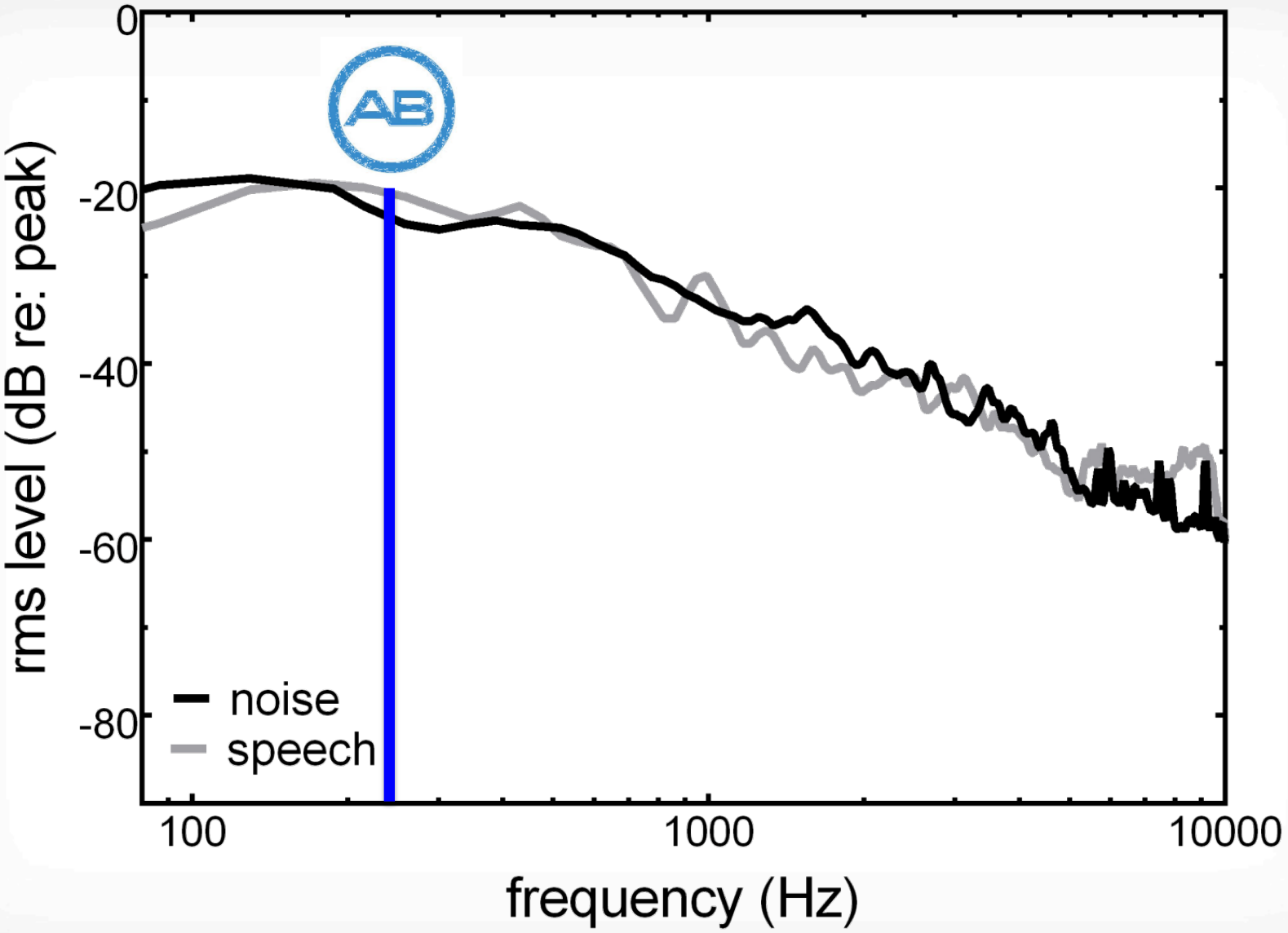
Gifford et al. (submitted).

Preliminary results


100
80
60
40
20
0
percent correct
Cochlear
MED-EL
70 Hz
150 Hz
188 Hz
250 Hz
313 Hz
350 Hz
438 Hz
563 Hz
688 Hz
813 Hz
938 Hz
CI LF boundary



See also Fowler et al. (2015). J Speech Lang Hear Res. Epub ahead of print


0
-20
-40
-60
-80
rms level (dB re: peak)
noise
speech
100
1000
10000
frequency (Hz)

CONCLUSIONS

- Bimodal/EAS patients are complex
- Audiologic management
  - time intensive
  - billing, reimbursement, scheduling
  - Programming and verification of CI + HA(s) is *not evidence based*
    - Studies with large samples are needed!
  - Prescriptive formulas? EAS overlap? Upper limit for amplification in CI ear? Limits for CI bandwidth?

CONCLUSIONS

- Bimodal/EAS patients are complex
- Increasing complexity → audiologists who are not HA & CI proficient?

Imagine if we saw two different optometrists…

BI-MONOCLES

...because any fool can wear glasses, but it takes skill to manage two monocles.

Thank you for your attention!
Questions? Comments?