A FEW HEARING AID FEATURES: HOW EFFECTIVE ARE THEY AND ARE THERE MANUFACTURER DIFFERENCES?

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Disclosures

- Some of the research in this presentation was supported by investigator initiated research grants provided by the Dan and Margaret Maddox Charitable Fund, Phonak AG, GN Resound, Sivantos, Starkey, Oticon, Widex, the Department of Veterans Affairs, the National Science Foundation (NSF), the National Institute on Deafness and Other Communication Disorders (NIDCD) and the National Institute of Disabilities and Rehabilitative Research (NIDRR - DOE)

How do we help ensure satisfied patients in as many important environments as possible?

- Examine the **patient's communication and listening needs** and **based on the evidence** select and adjust **features and processing** to best address those needs.
- Counsel regarding use and benefit from technologies to make sure the patients expectations are met.
- Satisfaction = Expectations Met!

Polling Question…

- There is a single hearing aid that is best for everyone? (True/False)

Take Home Points for The 6 Features That Didn't Make the Cut

- **Common Directional Technology**
  - It improves speech rec in noise, but in very specific environments. Overhearing issues?
- **Extended High Frequencies**
  - Slight benefit and preference in listeners with flatter high frequency loss, hard to provide enough gain.
- **Trainable hearing aids and Automatic Gain Increase (AGI)**
  - Trainable hearing aids can improve patient connection to the process, but many patients can not reliably train. It can be useful for patients who want to do it, but requires follow-up.
  - AGI can be useful for some/many new patients, depending in part on clinician personality and style.
- **Bilateral Shared Information**
  - Can be useful for better signal identification and patient convenience.
  - Potential benefits related to localization are unclear, but enhancement is unlikely.
- **Wireless streaming**
  - Bilateral telephone streaming improves performance.
  - Streaming from remote mics and tv provides benefits, not all manufacturers work the same, (delay, intermediary devices and distance).
- **Advanced directional**
  - Improved speech recognition and listening effort for cue preserving bilateral beamformers with slight decrease in localization.
  - Sound steering technologies have benefits, but not all work the same way.

What Do The Data Say? Traditional Techniques

- Linear processing can maintain natural amplitude dynamics, but at the cost of limiting audibility, particularly for soft speech (e.g. Ricketts and Bentler, 1996).
- Little if any **average** differences in speech recognition across compression types are typically measured in quiet.
- Faster time constants appear to help some post-lingually impaired listeners **in noise**, for those with better gap detection (cognitive skills?) (Gatehouse et al., 2006; Yund & Buckles, 1995).
- Slower time constants/less compression is sometimes preferred for improved sound quality, (Moore, 2012) and for reception of low context speech in listeners with limited cognitive abilities (Gatehouse et al., 2006; Lunner & Sundewall-Thorén, 2007; Cox & Xu, 2010).

Speech Recognition in Noise as a Function of Time Constants: Predicting Individual Differences

- Previous work suggests that working memory may influence speech recognition performance as a function of compression speed in very controlled (laboratory) conditions, typically using very simple compression schemes (Foo, Rudner, Ronnberg, & Lunner, 2007; Gatehouse, Naylor, & Elberling, 2006; Lunner & Sundewall-Thoren, 2007; Ohlenforst, Souza, & Macdonald, 2014).
- Does this translate to real patients with modern hearing aids?

Souza and Sirow (2014)

- 27 older adults who were patients in a private practice audiology clinic served as participants.
- Fitted with mini-BTE instruments (RIC) via DSL v5 and appropriate real ear verification.
- Working memory was assessed using a reading span test (Daneman & Carpenter, 1980; Ronnberg, Arlinger, Lyxell, & Kinnefors, 1989)
  - Did the sentence make sense (half do not) – usually reaches ceiling performance.
  - Measure is recall of the first or last words in percentage correct as the number of words is increased.
- Two Quick-SIN list for each condition presented at 83 dB SPL (70 dB HL) – Loud but OK.

A range of compression parameters in commercial instruments (Mini-BTEs)

17 tested with 3 instruments, 10 with 4 instrument

Table 1. Compression parameters for tested aids.

Hearing aid	A	B-slow	B-fast	C
Release time	≤ 20 sec	1000	75	< 50 ms
Attack time	≤ 2 sec	5 ms	10 ms	< 5 ms

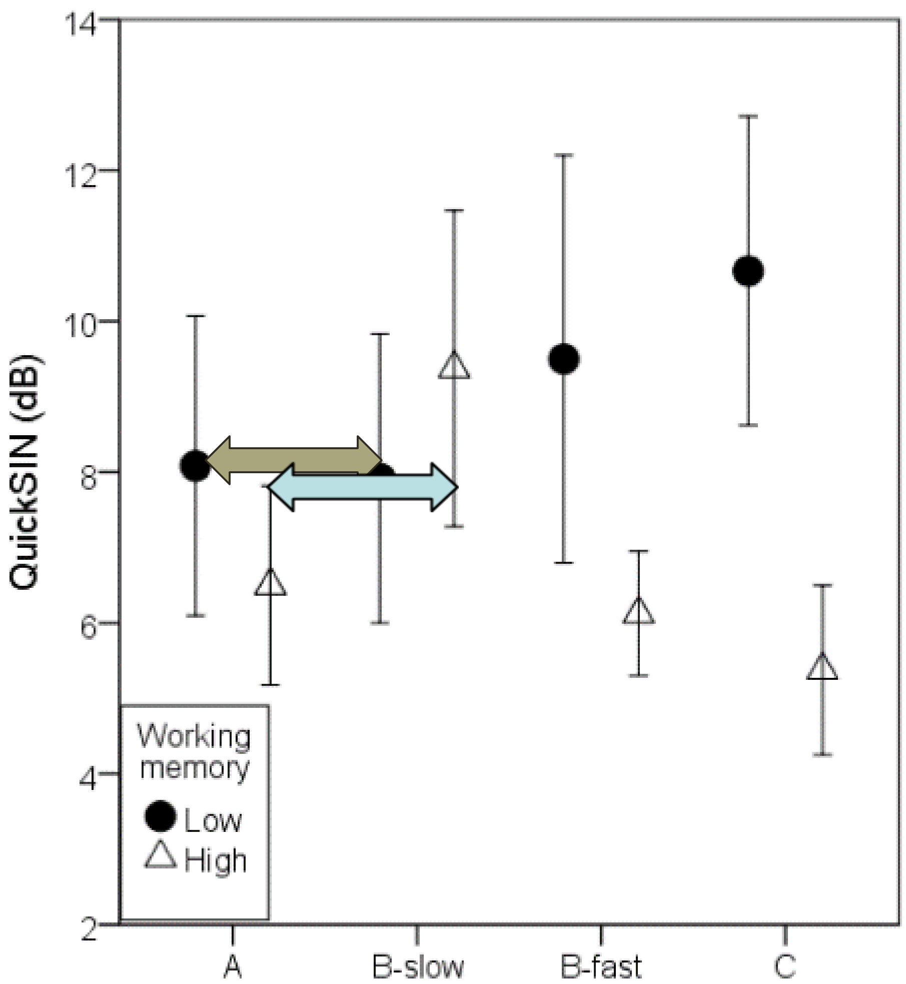
Very Slow Slow Fast Faster

What they found. . .

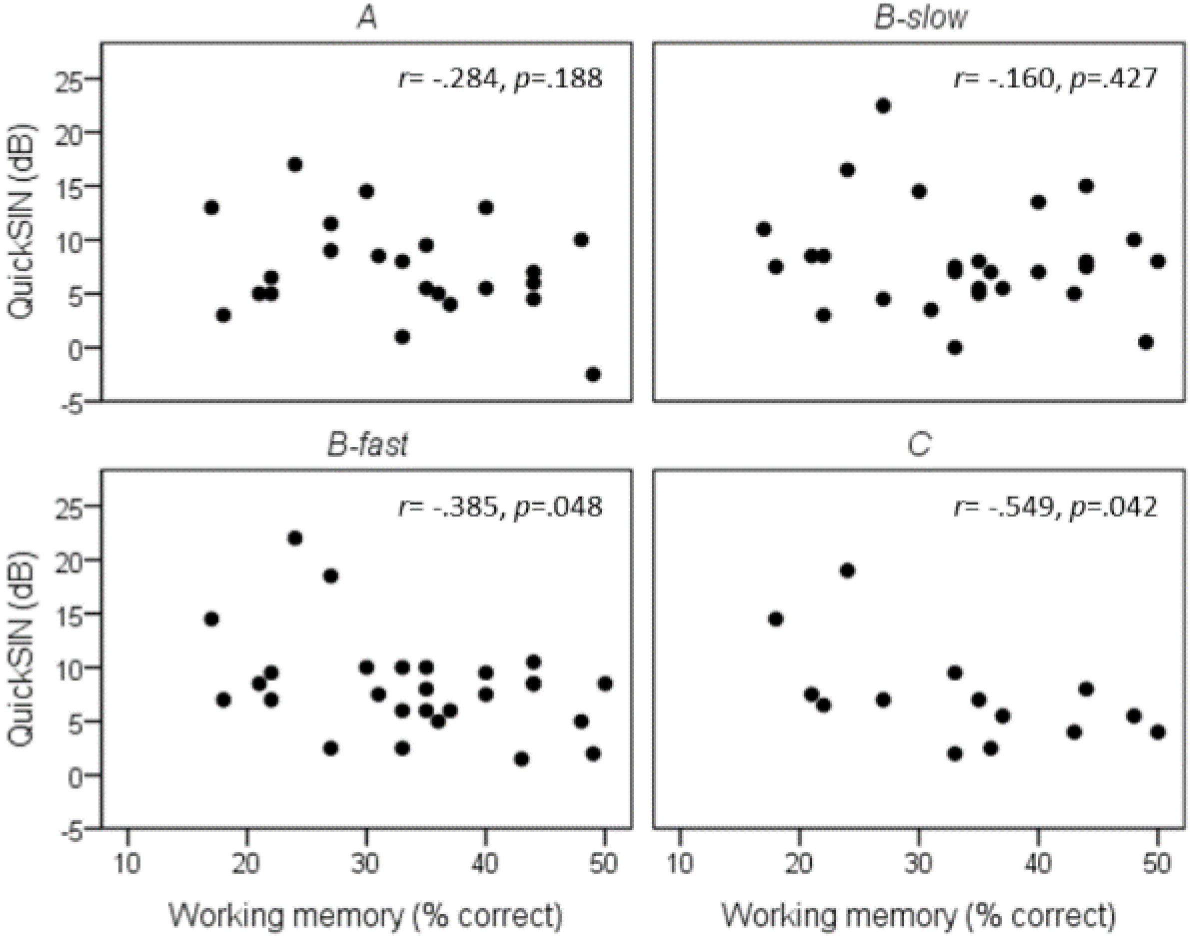
Both groups are similar for slow

-Those with low working memory perform significantly worse with fast.

-Those with high working memory performed significantly better with fast.



What about Individuals?



The bottom line? Working memory was not a good predictor for slow (instead hearing loss and age).

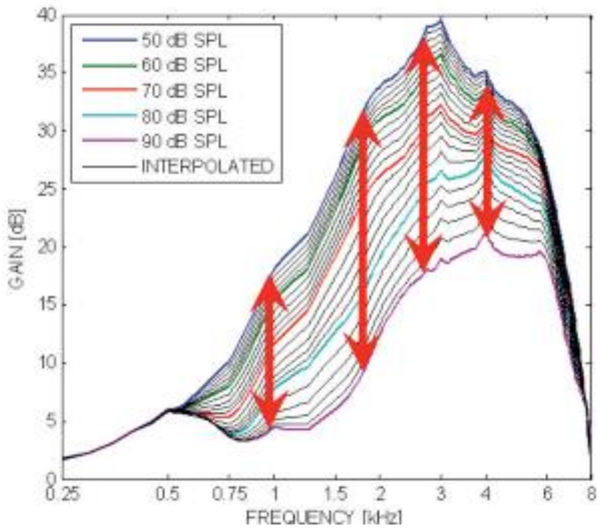
Working memory (alone 30%) + hearing loss (combined 70% of the variance) were significant predictors for fast.

Why is this important?…

- Younger patients with less hearing loss and high working memory may benefit from faster compression time constants (rich get richer).
    - While older patients with more hearing loss may perform more poorly with faster compression

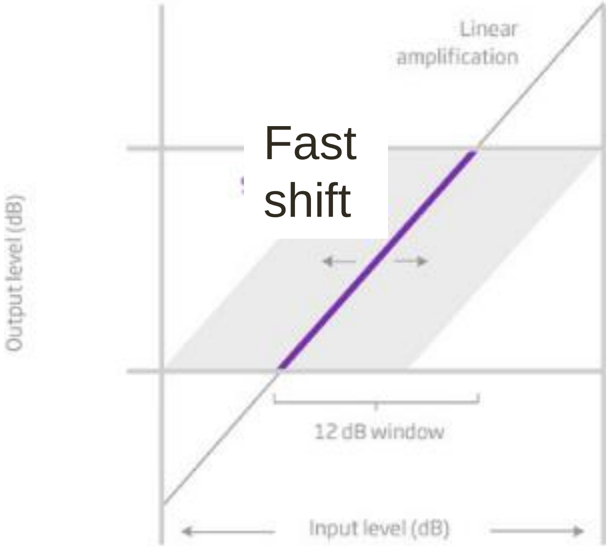
- “The use of cognitive testing in a real-world setting may contribute to an evidence-based method of prescribing appropriate compression parameters”

What Do The Data Say? Non-Traditional Compression Techniques

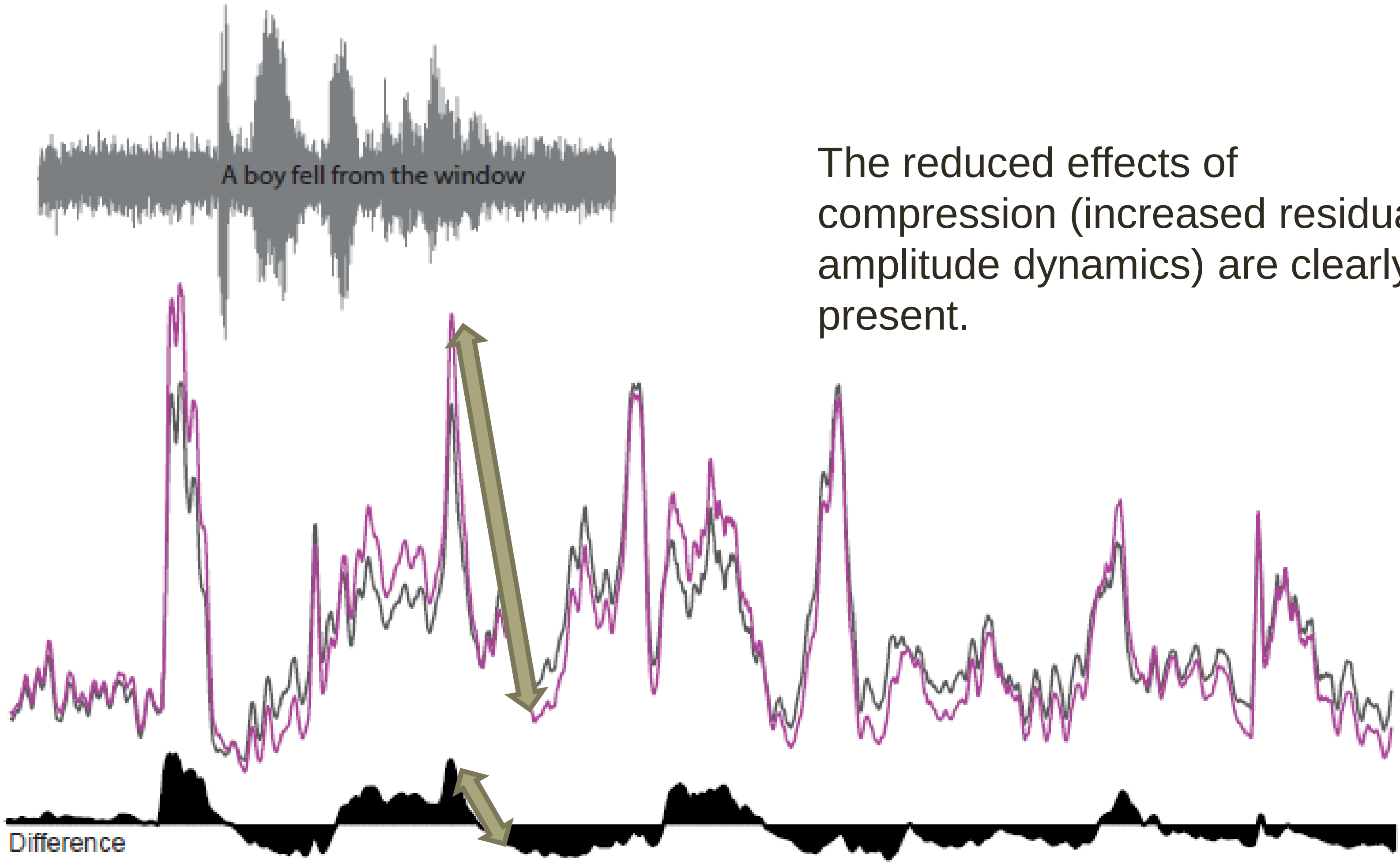


- FFT based compression
  - "ChannelFree" processing
  - Similar average benefits/preferences to traditional compression (e.g. Plyer et al., 2013).

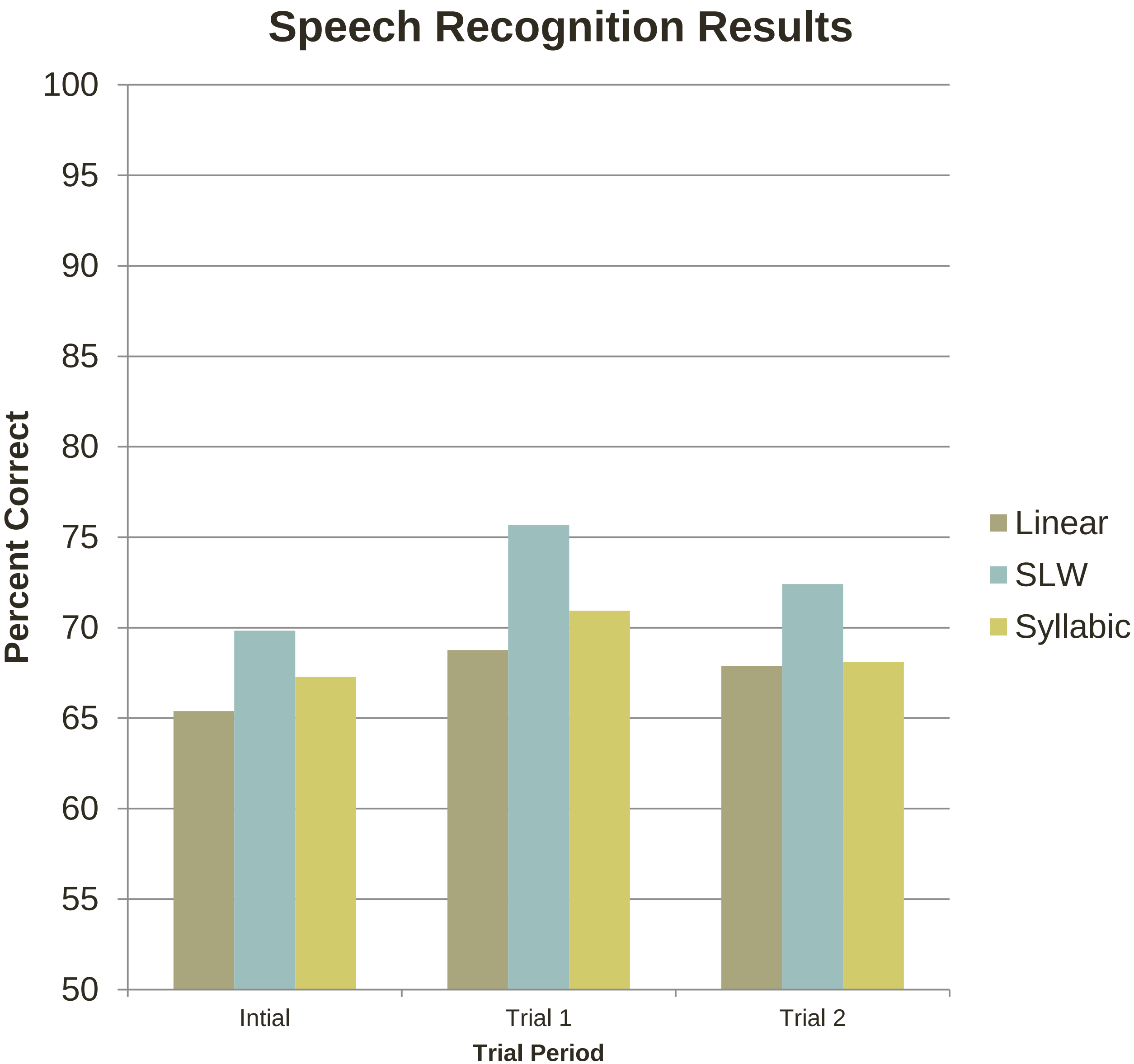
- Sliding "linear window"
  - Statistically based (e.g. Adaptive Dynamic Range Optimization - ADRO)
  - Level based with rule sets - different time constants can be applied based on signal classification (e.g. Speech Guard)



Dynamic output: Sliding Linear Window versus Syllabic Compression



The reduced effects of compression (increased residual amplitude dynamics) are clearly present.

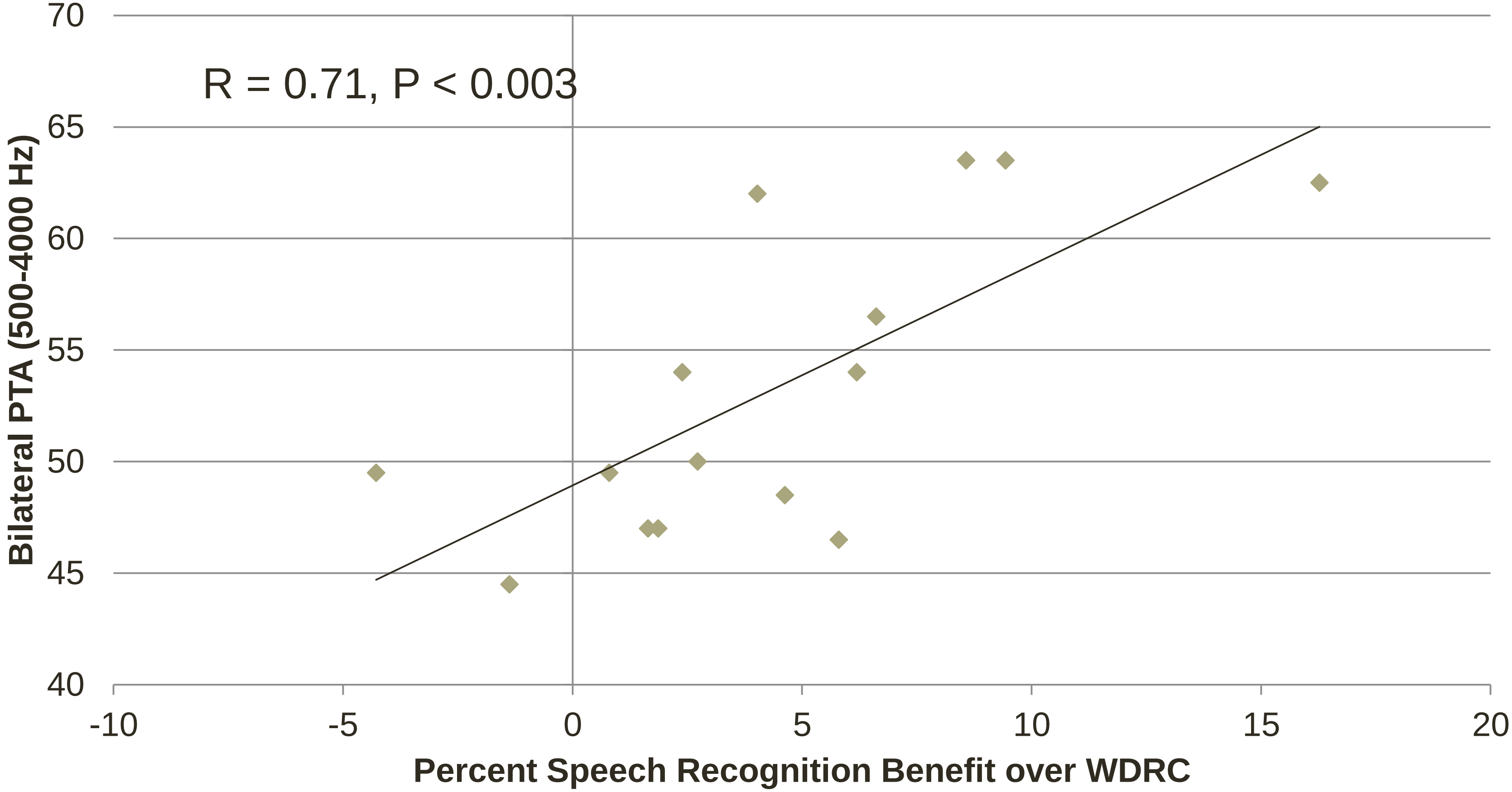


Results of a 3 (trial) X 3 (gain processing) within subjects ANOVA revealed a significant effect of gain processing ($F = 6.9$, $P < 0.004$). No other significant effects or interactions were present.

Follow-up testing (LSD) revealed that performance on the SLW was significantly higher than either Syllabic WDRC ($P < 0.018$) or linear processing ($p < 0.009$).

Advantage over linear support this advantage is NOT simply from maintaining more natural amplitude dynamics .

Significantly greater average benefit for listeners with the poorest hearing



Conclusions?

- Small (~5%) average speech recognition benefit present, although there were large differences across children.
- Those with greatest hearing loss and age equivalent PPVT scores (vocabulary) within 2 years of their actual age demonstrate the greatest benefits.
- PPVT score alone was unrelated to benefit.

PREFERRED COMPRESSION SPEED FOR SPEECH AND MUSIC AND ITS RELATIONSHIP TO SENSITIVITY TO TEMPORAL FINE STRUCTURE

UNIVERSITY OF CAMBRIDGE

Brian C.J. Moore and Aleksander Sek

(2016) *Trends in Hearing, 20,* 1–15

VANDERBILT UNIVERSITY MEDICAL CENTER

Why it matters…

- Individualizing processing for individual differences is expected to lead to better clinical outcomes.
- Optimizing sound quality through hearing aids is one important factor affecting the usefulness and acceptability of hearing aids.
- Poor sound quality is a major reason for rejection of hearing aids (Kochkin, 1996, 2010).

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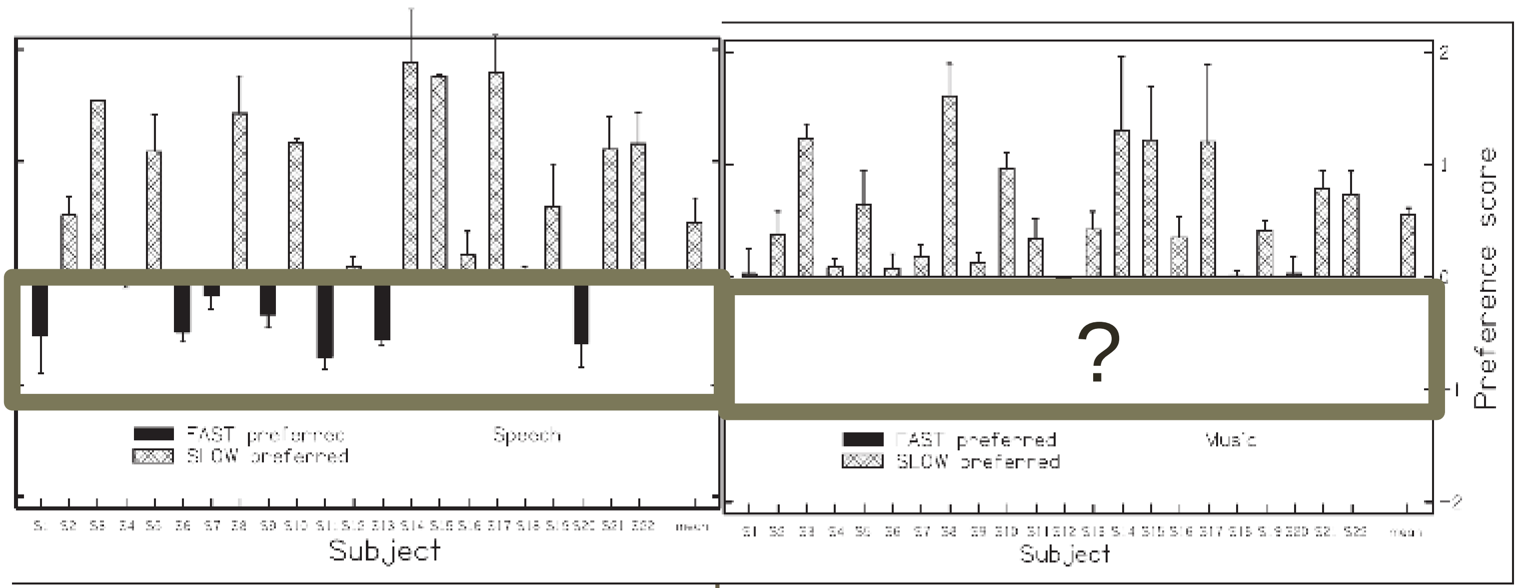
What they did…

- Twenty-two hearing-impaired subjects were tested (56-87 yo). A simulated hearing aid was fitted individually using the CAM2A method. On each trial, a given segment of speech or music was presented twice.
- Five channel simulated compression hearing aid - (CTs) 49, 41, 40, 34, and 28 dB SPL – presented through HDA 200 headphones.
- Attack and release times set to 10 and 100 ms (fast) or 50 and 3000 ms (slow).
- CR limited to 3:1 (fast) and 10:1 (slow).

What they found…

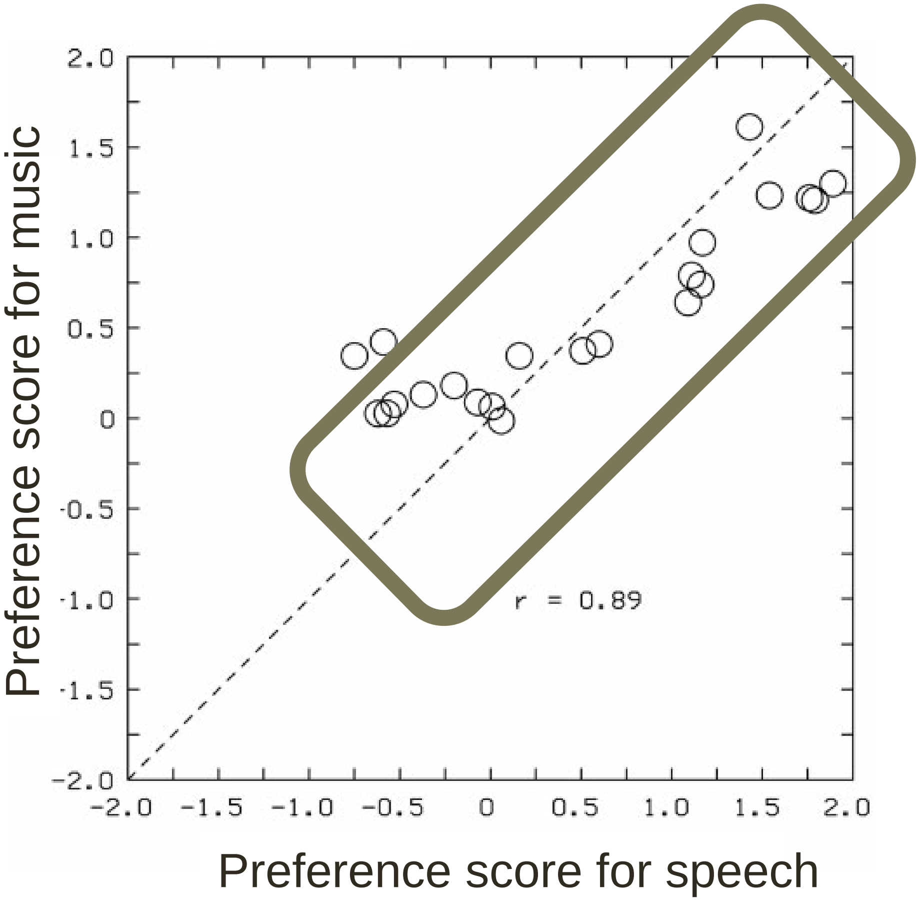
Speech | Music

Moderate
Slight
None
Slight
Moderate



More preference for slow acting, but a lot of inter-subject variability

What they found…



- Preference for slow compression was stronger for music, but similar preferences within subjects.
- No significant main effect of presentation level.
- Weak correlation between preference and one of the three TFS measures (Difference limens for frequency).

Does it matter clinically?

- Some evidence that TFS may be related to time constant preference, but not strong enough to warrant clinical testing, but some interesting findings related to preference. Specifically, slow time constants generally provided similar or better sound quality for music and speech for the majority of listeners.

- Although not 100% accurate, choosing slow time constants may therefore be the “safest” choice when considering sound quality for music.

What's it all Mean?

- Differences in <u>average</u> speech recognition and sound quality across different gain processing schemes are generally small.

- Significant <u>individual</u> differences are sometimes present and appear to relate mostly to compression speed.

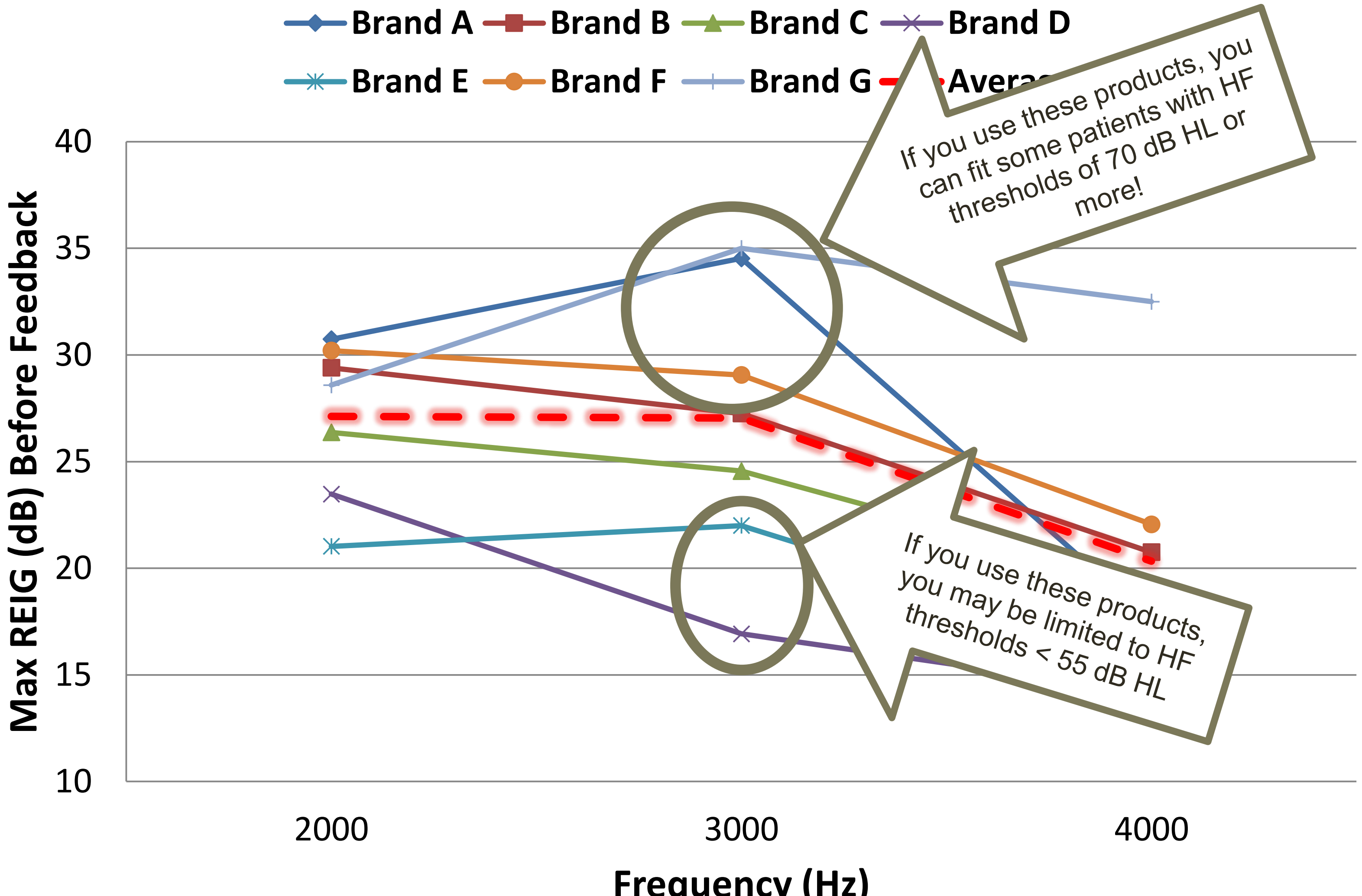
- When there are individual differences the best predictors for candidacy relate to degree of hearing loss and age. Cognitive ability is also a limited predictor.
  - Those with greater degrees of hearing loss typically and adults who are older and children who are younger perform better with more linear processing/slower time constants
  - Sliding linear window may be advantages for kids, particularly with more hearing loss (and perhaps **<u>better</u>** cognitive abilities?)

Digital Feedback Suppression: How Does It Work?

- **First, the feedback path is acoustically modeled in some cases for the individual patient.**

- **Ongoing cancellation within the feedback path is accomplished in a variety of ways including cancelation and frequency shifting.**

The magnitude of hearing loss you can fit with open venting depends greatly on DFS performance (Important to listen for artifacts too!)



Ricketts, Picou & Marcrum (2013) – Newest systems also better with dynamic feedback

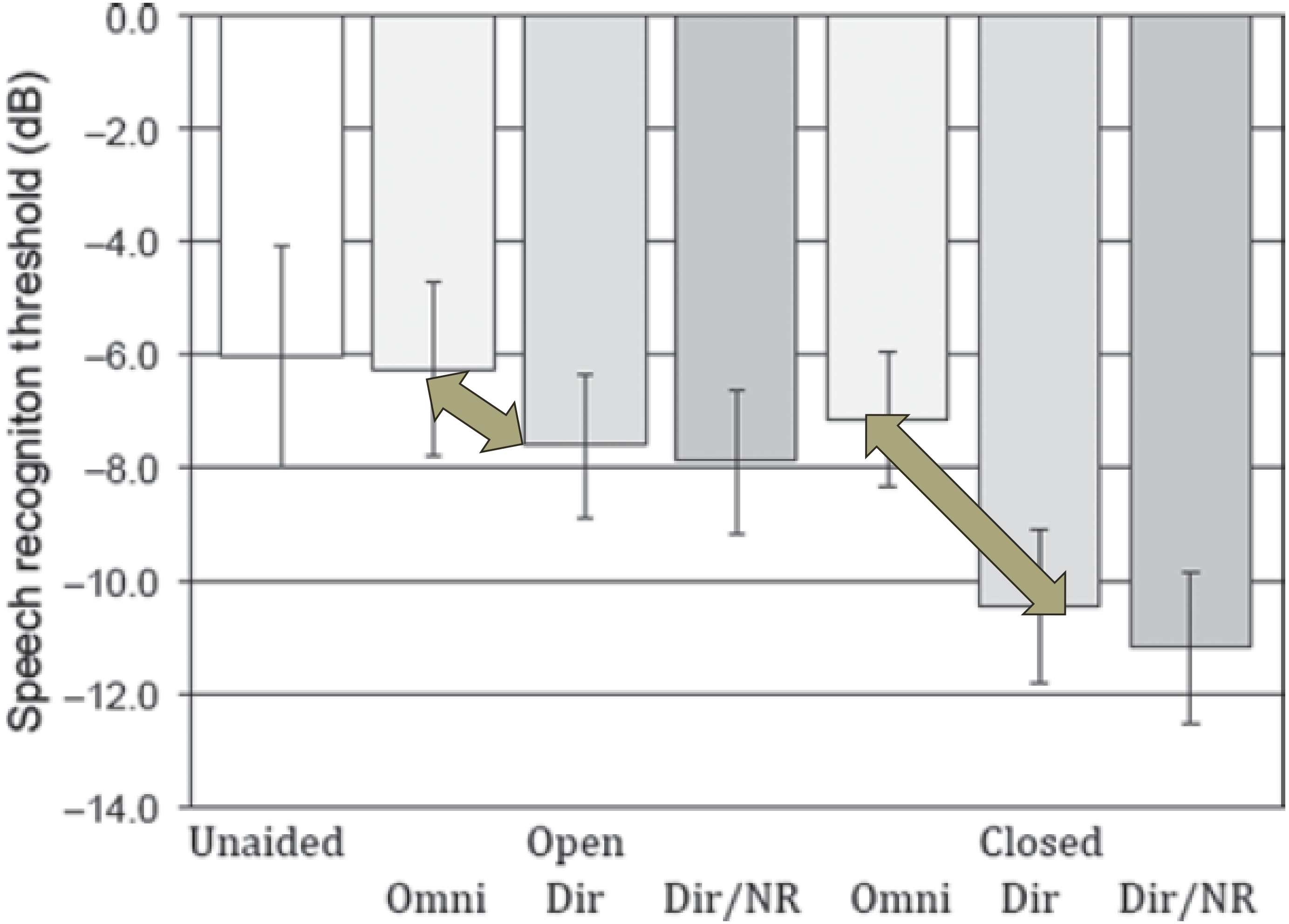
Polling Question…

- Approximately what is the range of Additional Gain Before Feedback (AGBF) across the Digital Feedback Suppression (DFS) used in the best state-of-the-art models of mini-BTE hearing aids?
- a. 15-30 dB
- b. 1-5 dB
- c. 5-25 dB
- d. 5-10Hz

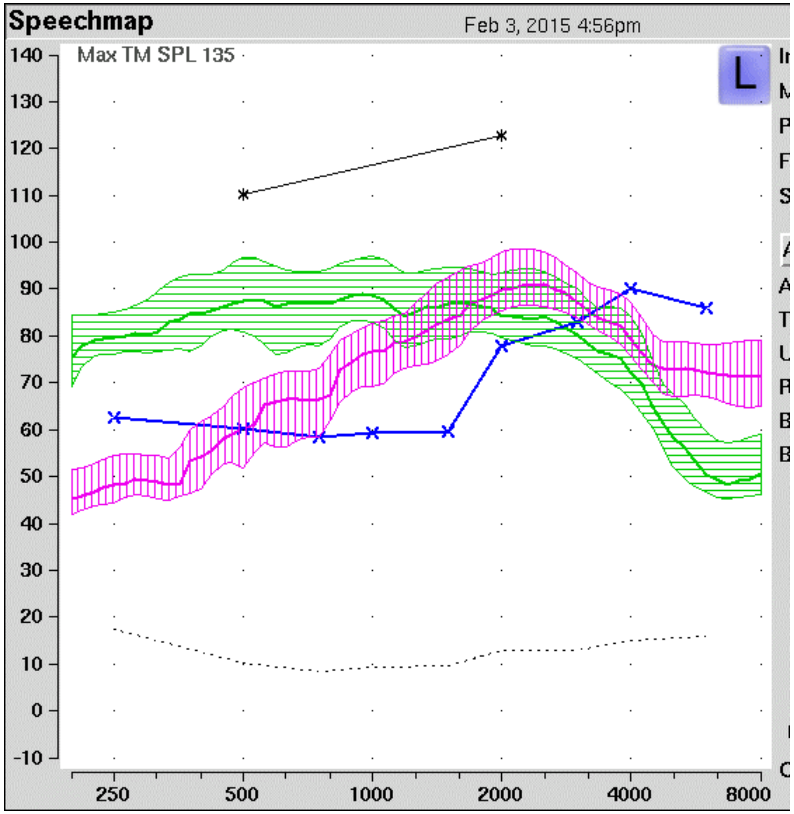
Open Eartips: There is no occlusion greatly improving sound quality when chewing and for own voice, but…

- Reduced directional/beamformer benefits
- Poor sound quality for streamed music and telephone.

There is a downside to open fittings for some listeners though (Magnusson, Claesson, Persson & Tengstrand, IJA 2013; 52: 29–36)



When considering remote microphone/ telephone and music streaming remember: Coupling/Venting matters!



Sometimes a closed dome is a good compromise when streaming!

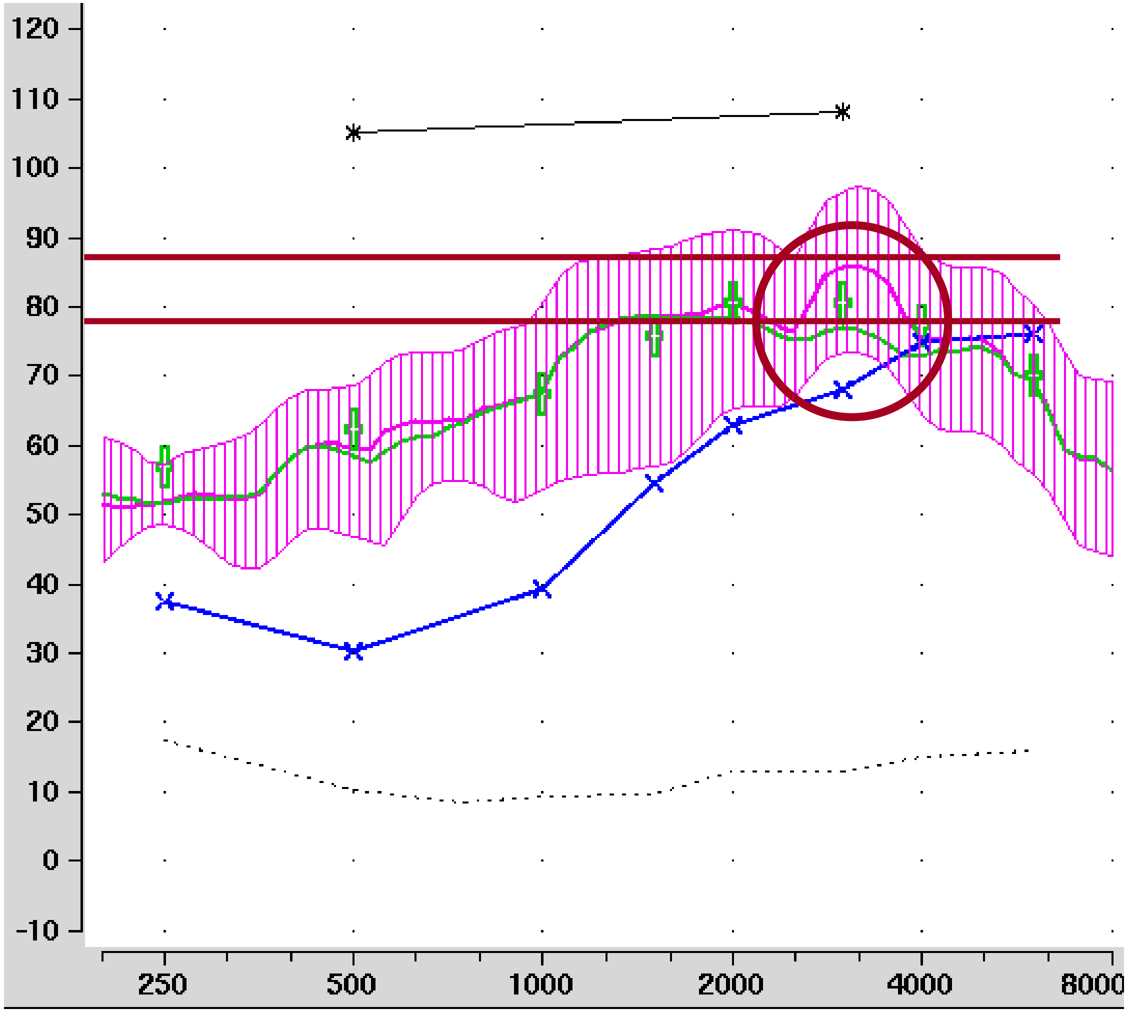
Polling Question…

- Any standard probe microphone fitting technique works fine for open canal fittings? (True/False).

Potential Equalization Problem With OC Fittings

- Sound leaking out of ear is picked up by reference mic
- Sound leaking out of ear may be greater than the input to reference mic from loudspeaker
- Reference mic thinks it is output from loudspeaker, and so loudspeaker output to ear is then turned down
- The result will be less measured hearing aid output (and gain) than is actually present.
- Complaint? When I match targets with OC, patients complain that is too sharp/harsh.
- Solution? Disable the reference microphone (in most systems, select "open" and calibrate.

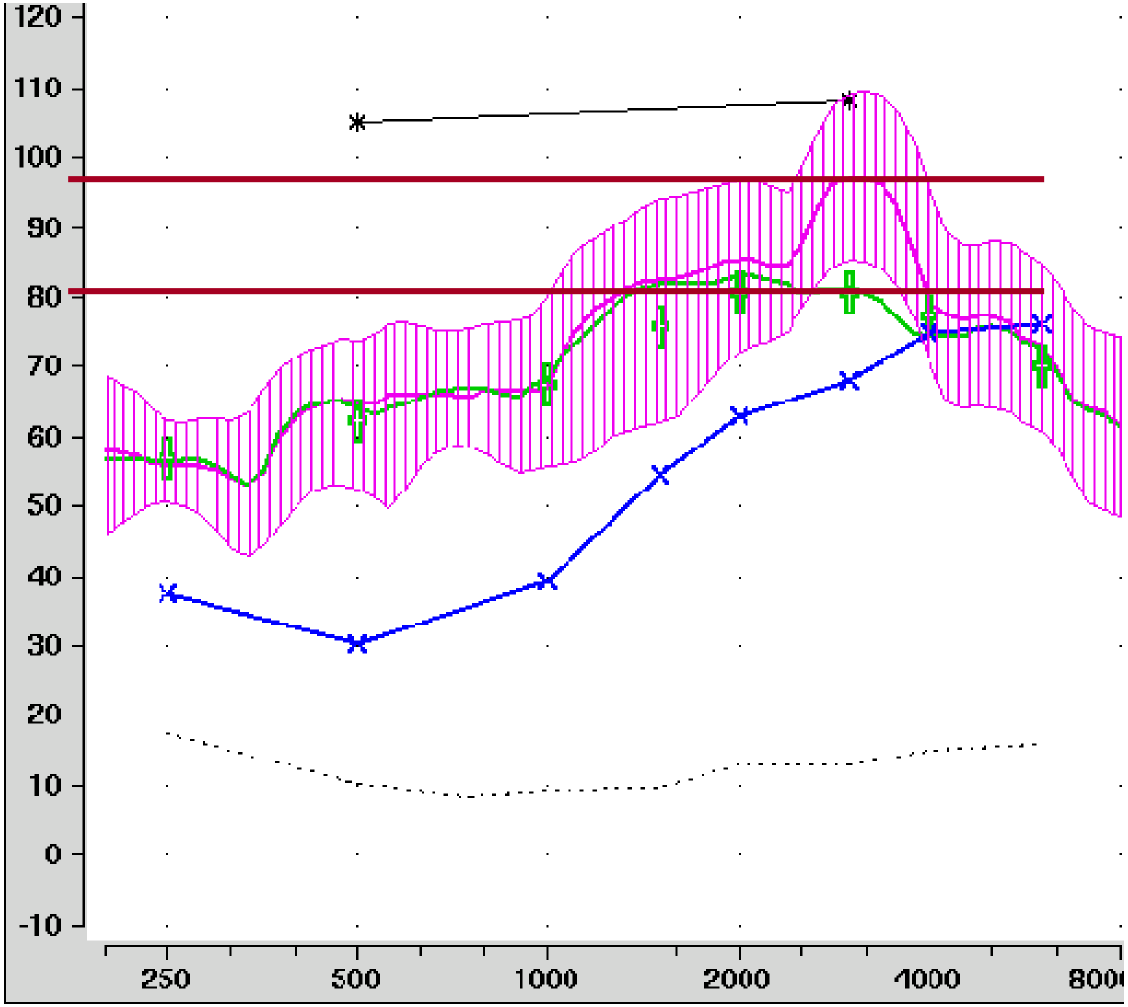
Concurrent vs. Stored equalization (input = real speech @ 65 dB SPL; hearing aid gain ~26 dB)



8 dB

Note what happens when you increase gain in the highs!

(input = real speech @ 65 dB SPL; hearing aid gain ~34 dB)



16 dB

PROBE MICROPHONE VERIFICATION OF OPEN FITTINGS: STEP BY STEP

How Open Does the Fitting Really Need to Be?

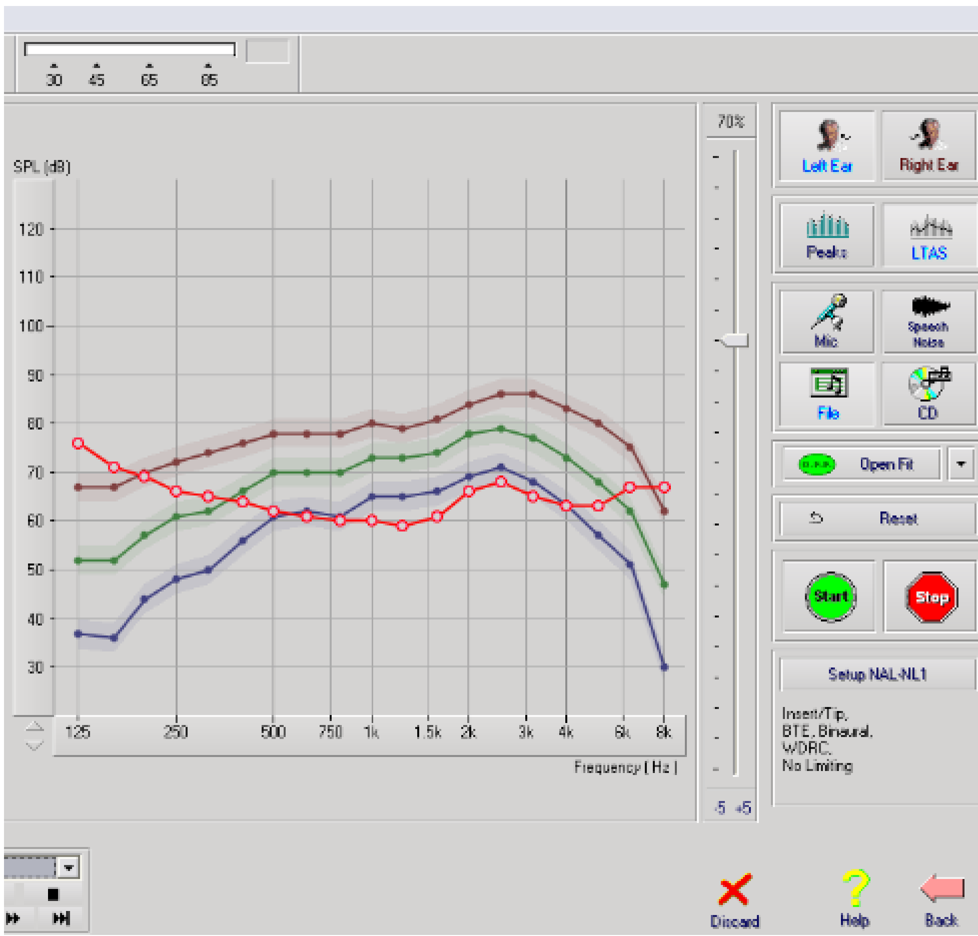
ISSUES RELATED TO CLINICAL ASSESSMENT OF FEEDBACK SUPPRESSION

How important are:

1) The specific gain configuration?
2) Other feature settings?
3) Style?

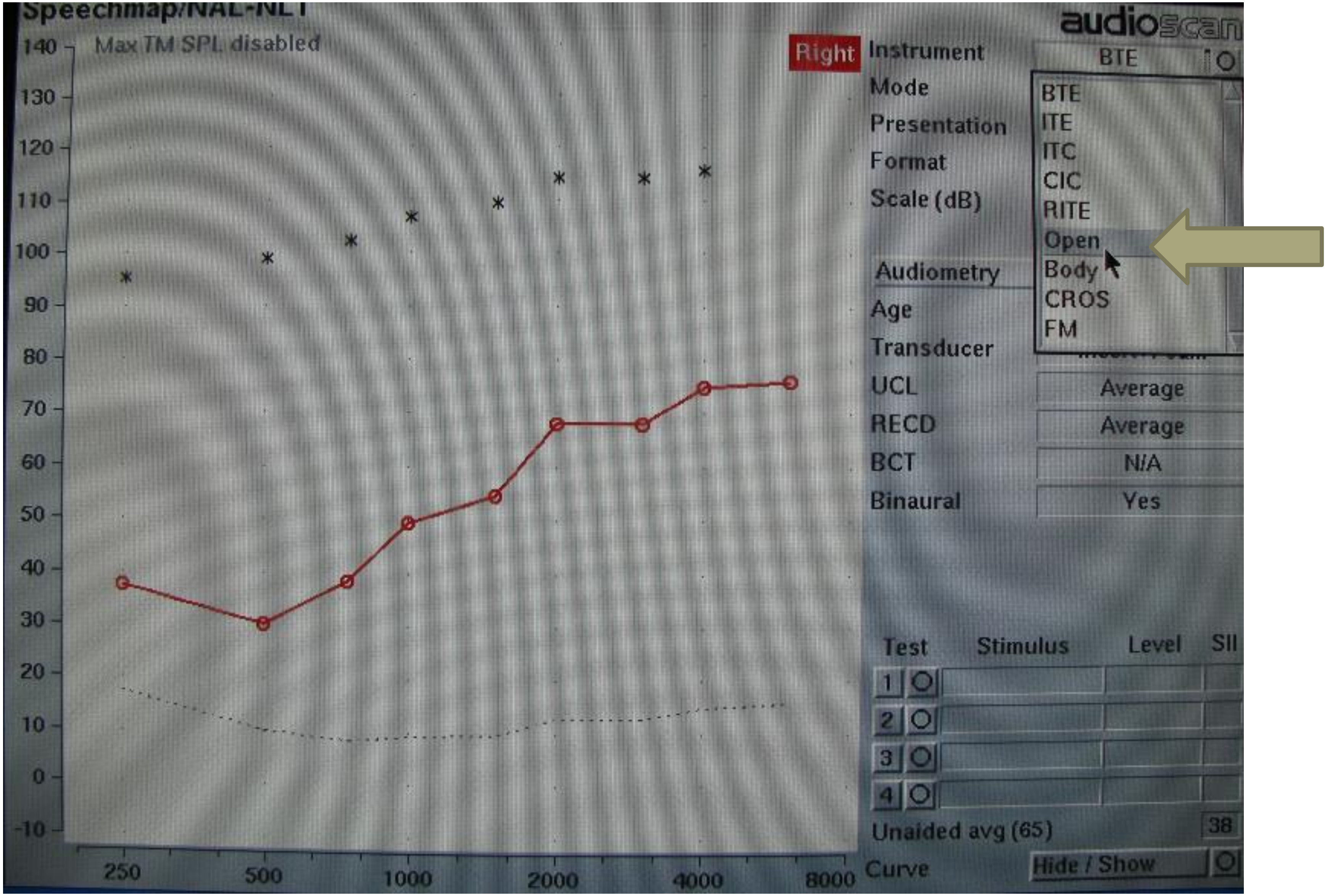
Disable Reference Microphone (Frye 8000)

Disable Reference Microphone (MedRx Avant)

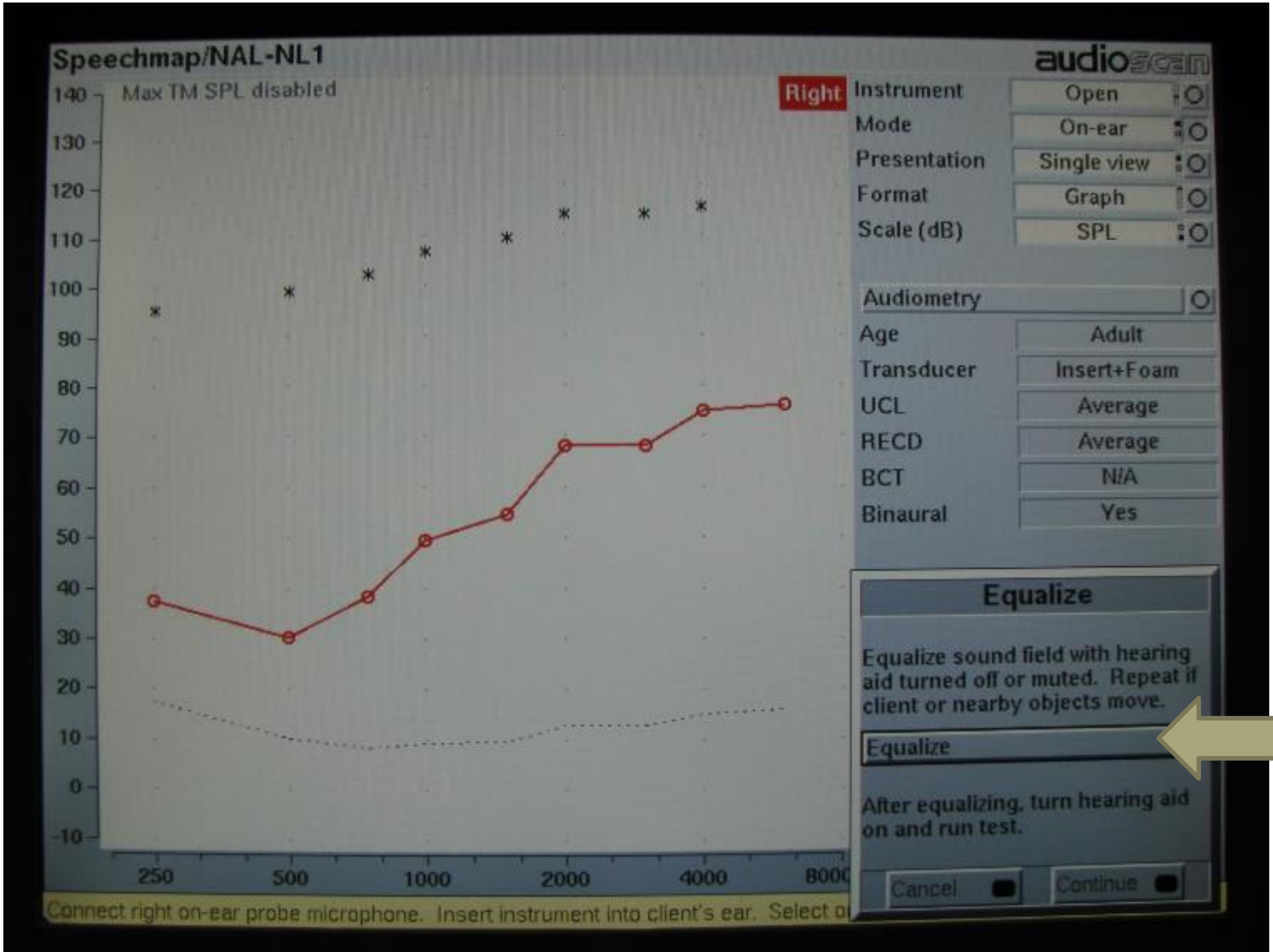


Click Open Fit and Select Calibrate

Disable Reference Microphone (Audioscan)

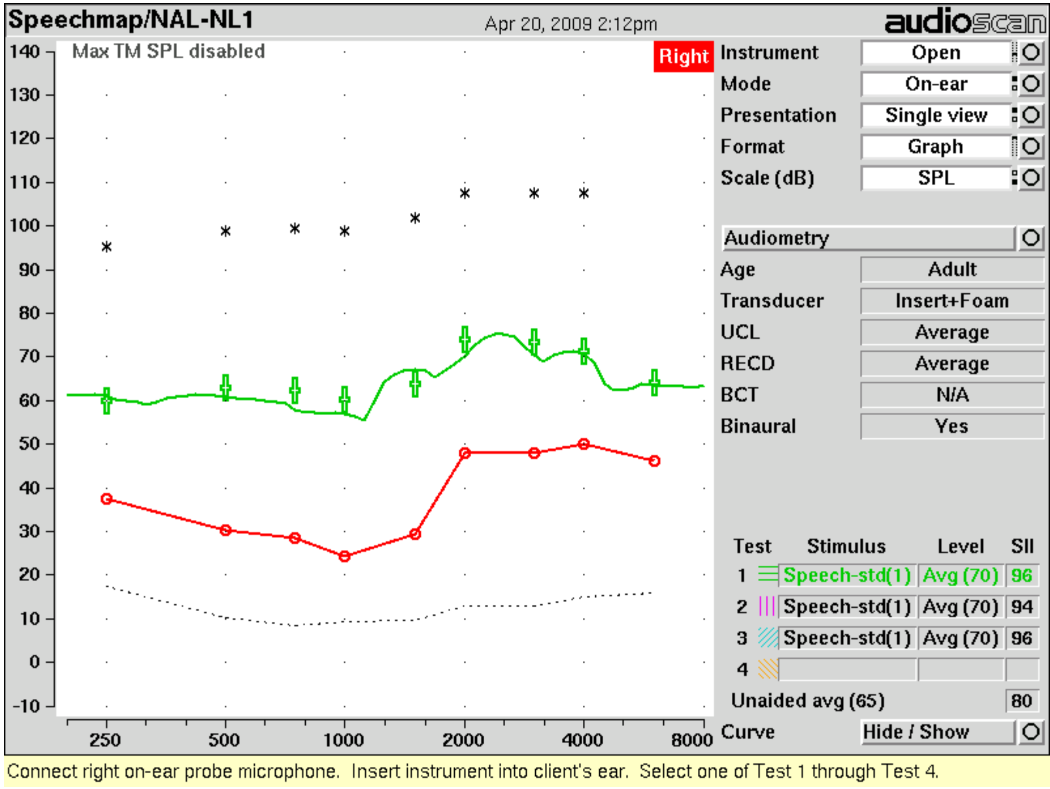


Equalize, Level or Calibrate (Depending on the System)



After Equalization the reference mic is disabled

Then Present the Signal and Measure REAR (Or REAG for calculation of REIG)



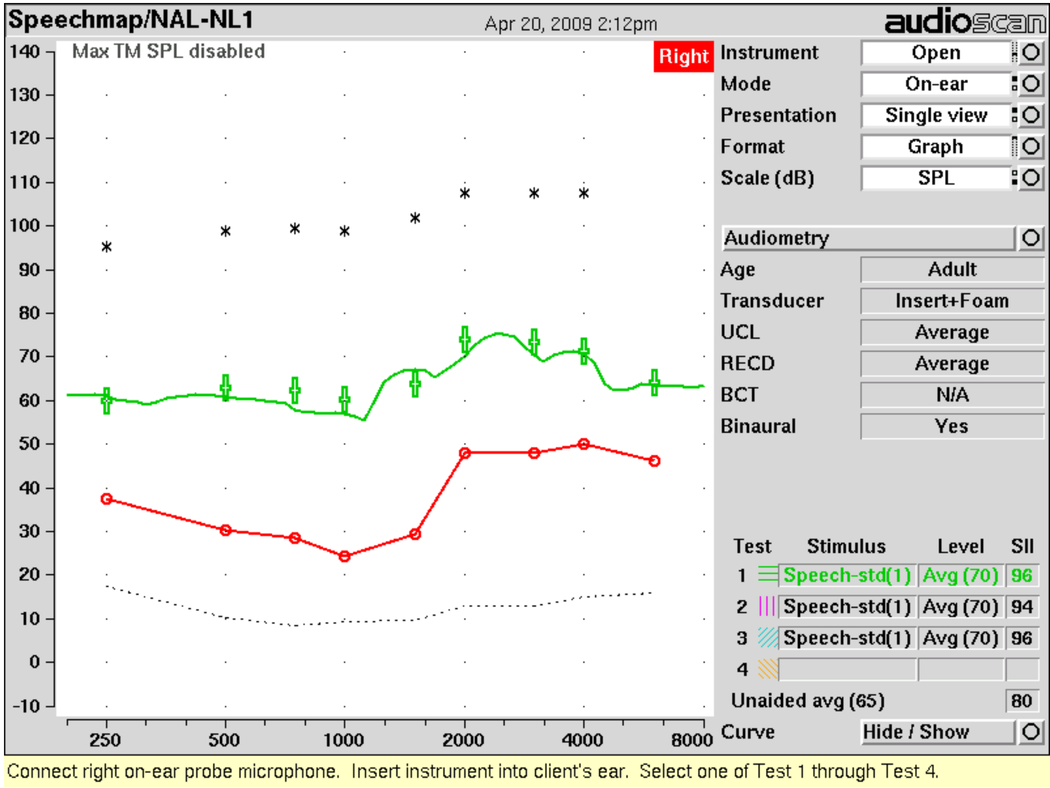
After Equalization the Patient Cannot Move!

The Curious Engineer

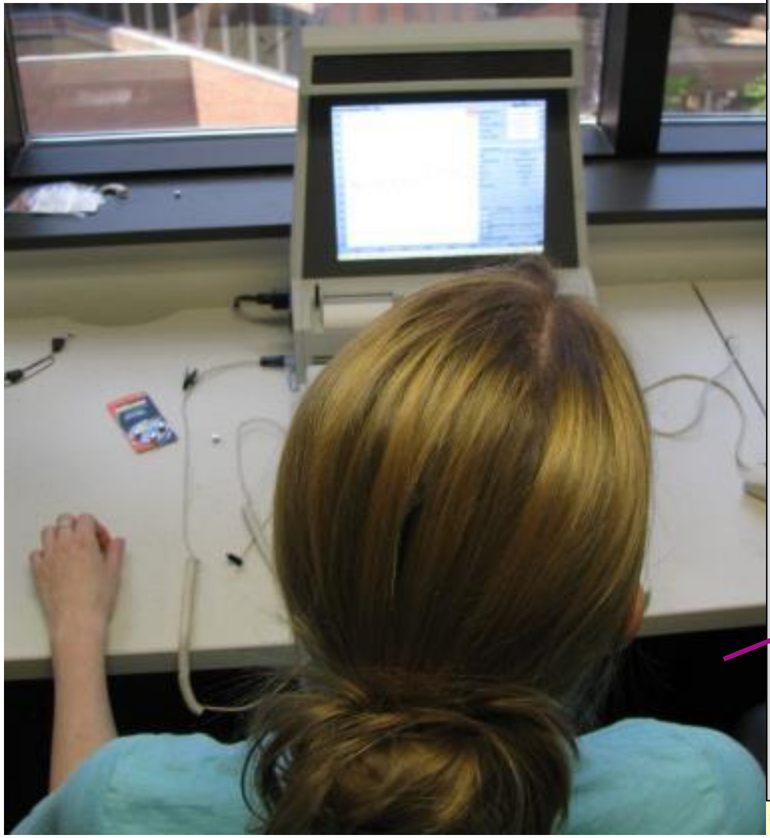
The Slacker

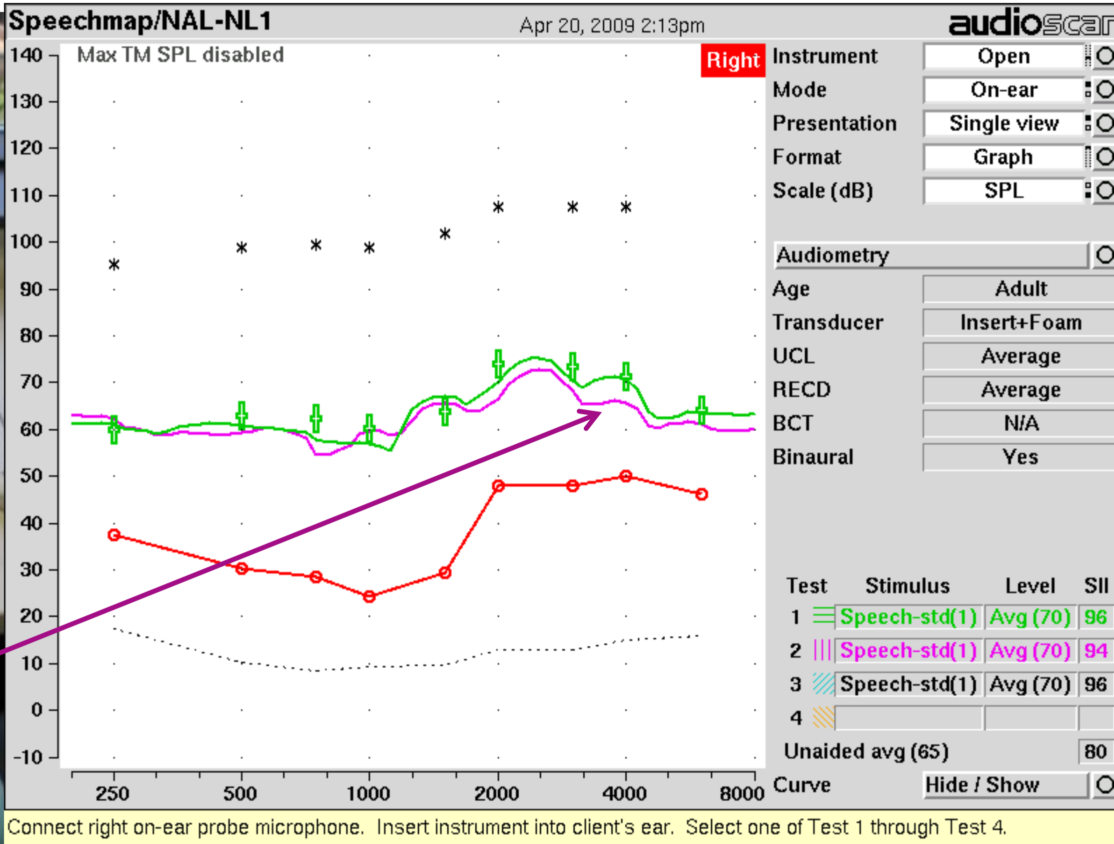
How Much of A Problem Is Movement?

A Pretty Good Fit

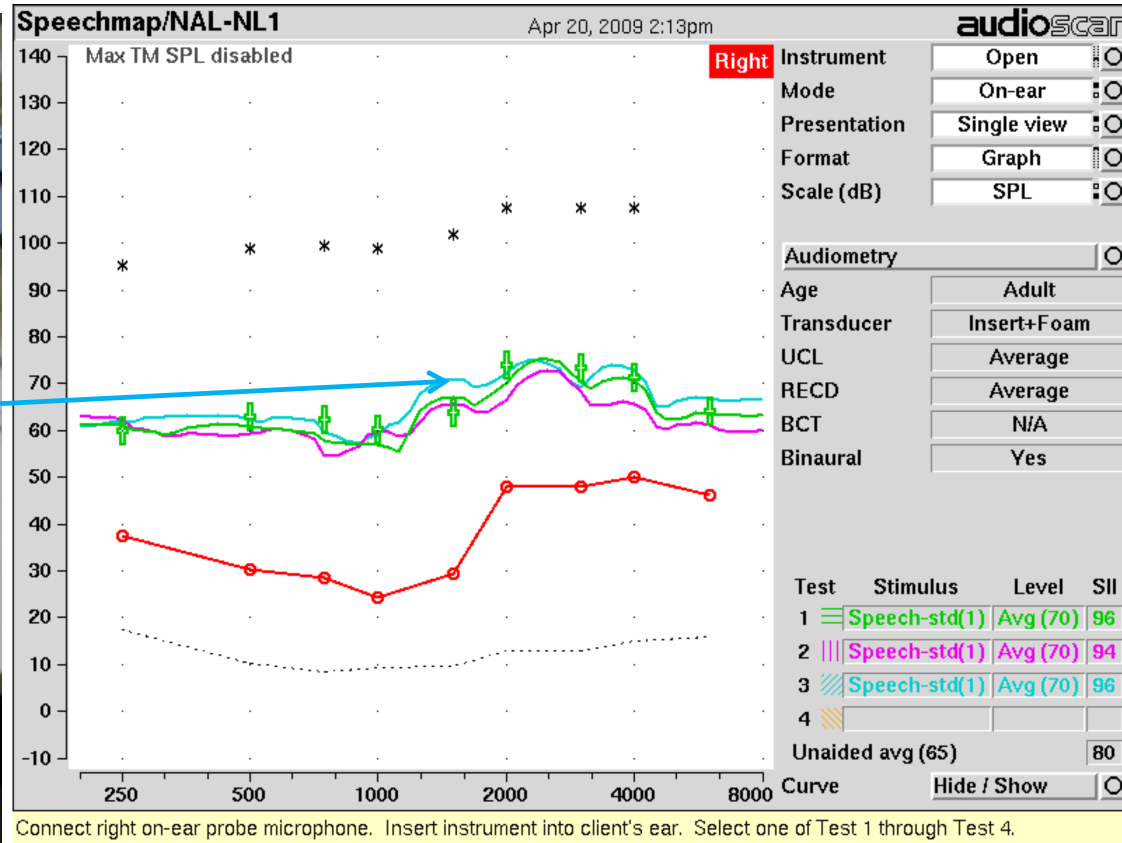


A Little Head Movement

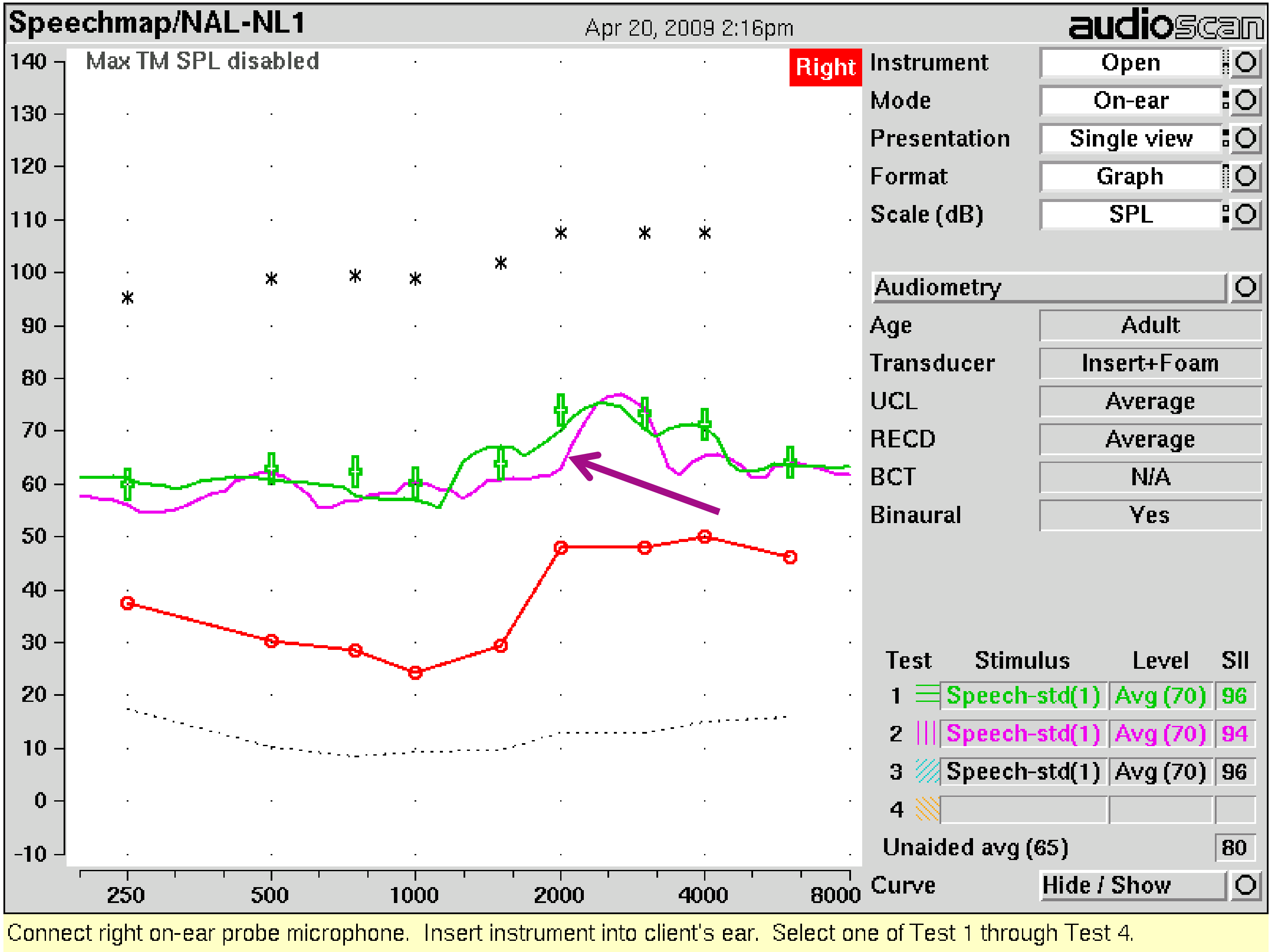




A Little Head Movement: The Other Direction



A Little Head Movement: Leaning In



Individualization of Feedback Suppression/ Open Fit: Current Clinical Thoughts

- If you truly want an open fit ensure that the DFS provides enough gain before feedback with limited audible distortion for the target patient.
  - Seems simple – but consider – “Should I change brands or use a more closed tip?” Not as simple as it may at first seem…
- For patients who struggle the most with speech recognition in noise, less venting will (slightly) improve performance with directional, omnidirectional, and FM/remote microphone.
- Kids can benefit from open too - but REAR is required for a good fit.
- Open fittings will greatly affect sound quality for streamed signals.

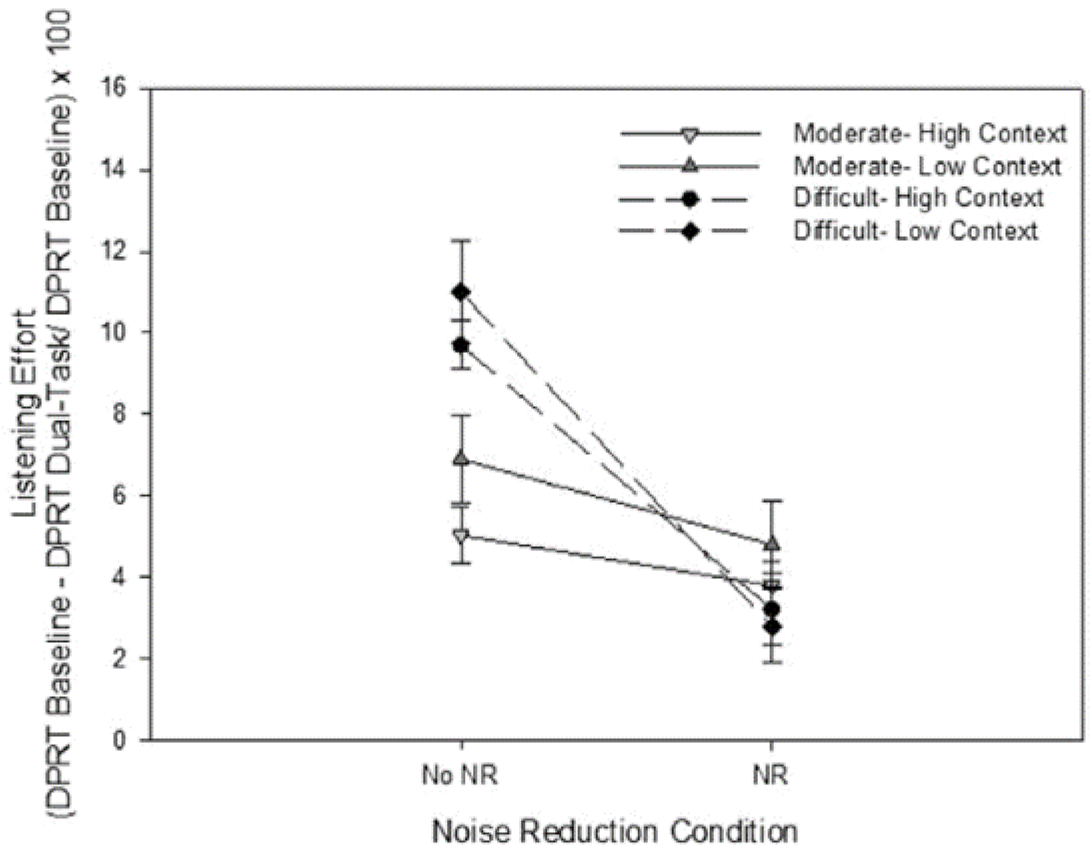
What we know from many years of DNR hearing aid research

- ***Numerous*** **lab studies have all found the same thing: No advantage for DNR for speech understanding in background noise.**
  - **Some systems will lead to decreased speech recognition especially at low levels and when speech follows periods of steady-state noise.**
  - **All will reduce audibility for signals identified as "noise" – this may be problematic for some types of music.**

- **There are data showing significant improvement for subjective ease of listening, reduced self reported aversiveness, improved listening comfort and preferred signal quality.**

- **Is there anything new?**

The Effect of Hearing Aid Noise Reduction on Listening Effort in Hearing-Impaired Adults (Desjardins & Doherty, 2014)



- No change in speech recognition.
- Significantly lower effort, but only in the more difficult environment (~1.6 dB SNR – compared to 4.4 dB SNR).
  - No interaction with context.

What they found (predictors) . . .

- Trend for individuals with faster processing speed to expend less listening effort with the NR activated in the more difficult listening condition.

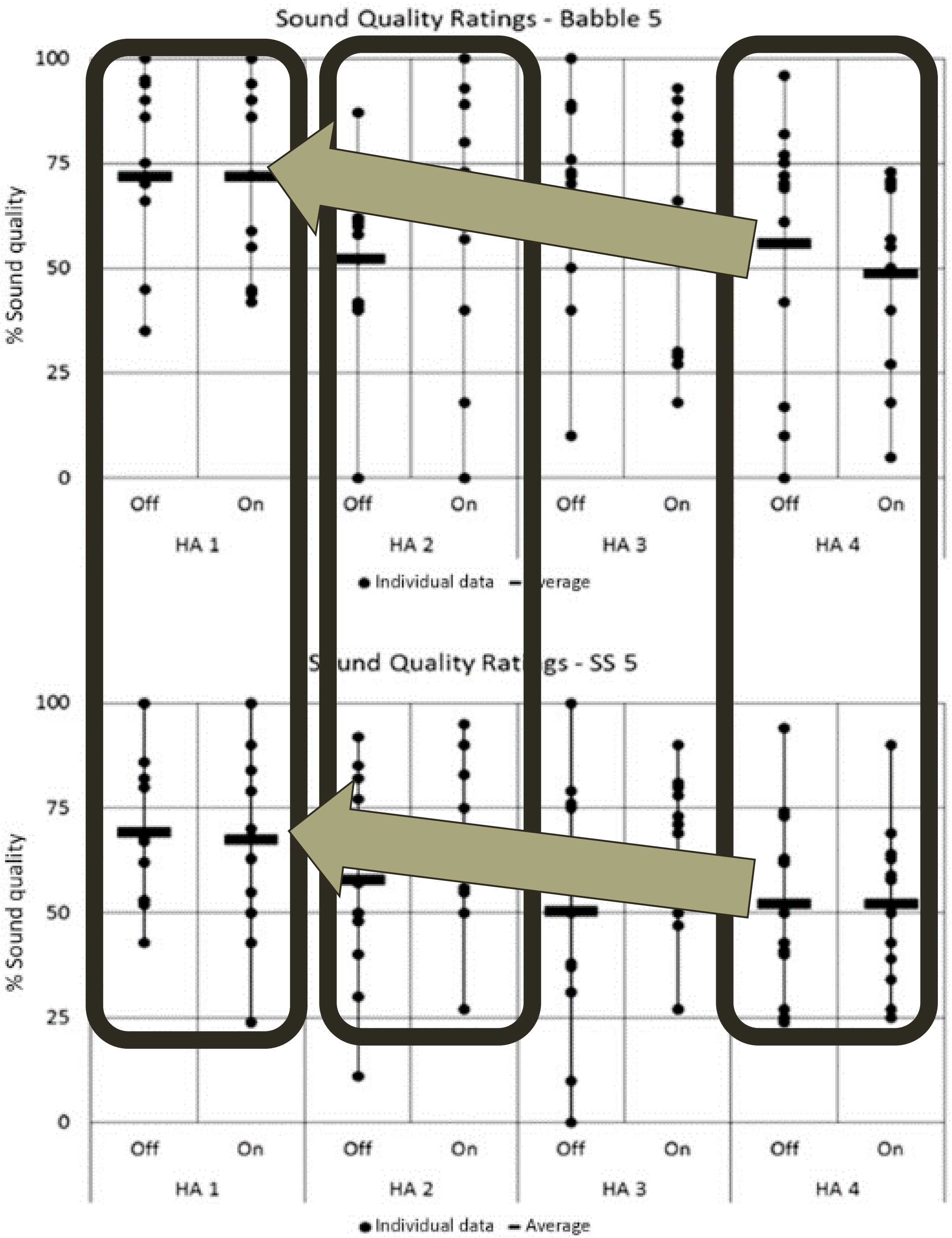
- Another example of the “rich get richer” those with best processing/cognitive functions/least hearing loss seem to benefit more from complex signal processing aimed at improving listening in noise.

SOME NEWER PEDIATRIC DNR DATA: FITTING NOISE MANAGEMENT SIGNAL PROCESSING APPLYING THE AMERICAN ACADEMY OF AUDIOLOGY PEDIATRIC AMPLIFICATION GUIDELINE: VERIFICATION PROTOCOLS

Susan Scollie, Charla Levy, Nazanin Pourmand, Parvaneh Abbasalipour, Marlene Bagatto, Frances Richert, Shane Moodie, Jeff Crukley and Vijay Parsa

Journal of the American Academy of Audiology (2016), 27:237–251

What they found (MUSHRA Sound Quality)



For some brands DNR activation had little to no average effect on sound quality.

For other brands DNR improved sound quality at least for some conditions.

Some brands generally resulted in higher sound quality ratings than other regardless of DNR status.

Why is this important?…

- These results are broadly consistent with those of Brons et al (2013) which demonstrated differences in annoyance, listening effort, and speech intelligibility across DNR systems in adults.
- As the author’s stated “Taken together, these results call into question the assumptions that noise reduction and hearing aid sound quality are equivalent across brands and types of hearing aids.”
- Considering the DNR function and how each individual reacts to the sound quality may be important for optimizing sound quality of hearing aids in noisy environments

Other considerations not discussed by the authors…

- The authors categorized DNR based on reduction in noise level and change in SNR, this does not really differentiate between Modulation Based DNR (gain reduction) and fast filtering (adaptive Weiner filtering/spectral subtraction) techniques.
- While these methods are commonly used in tandem, sound quality differences for speech in noise are typically attributed to the later (e.g. Ricketts and Hornsby, 2006). Further, depending on brand, fast filtering may be always active, or adjusted by the DNR control.
- Compression and other processing differences can also affect sound quality.
- It may not be straightforward to predict preference based only on test box measures of DNR function.

Potential Clinical Application?

- If results are generalizable and reliable, development of individualized fitting methods for DNR may lead to improved outcomes.

MAKING A CASE FOR HIGH FREQUENCY AUDIBILITY

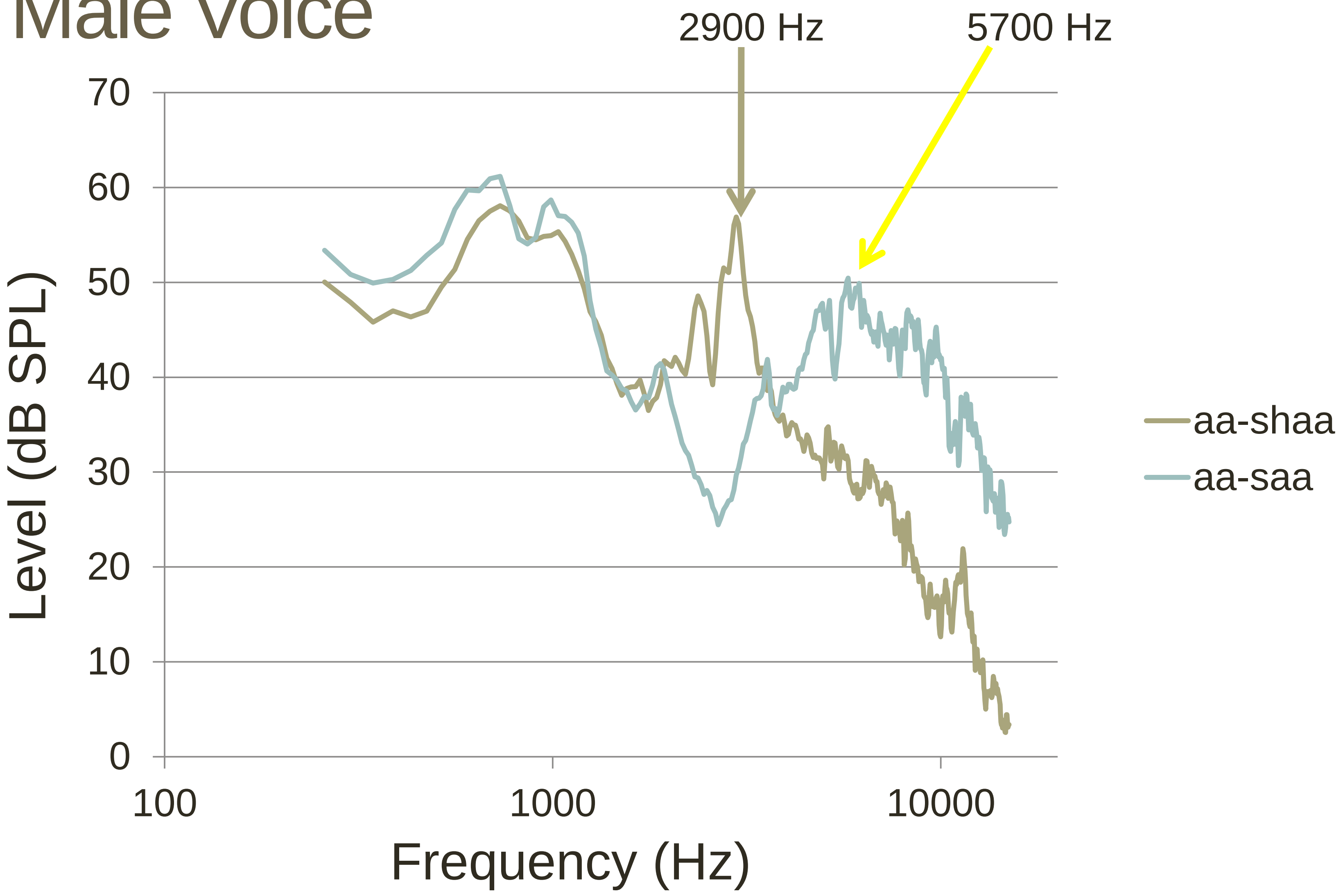
Importance of High Frequency Audibility

- Mis-articulation of affricates and fricatives common in children with hearing loss
- Both early- and late-identified children using hearing aids show delays in fricative production
- High frequency environmental sounds may be entirely missed by listeners with limited audibility in the highest frequencies.
- Some evidence that children with access to high-frequency information (i.e., >4K Hz) demonstrate better short-term word learning (Pittman, 2008).

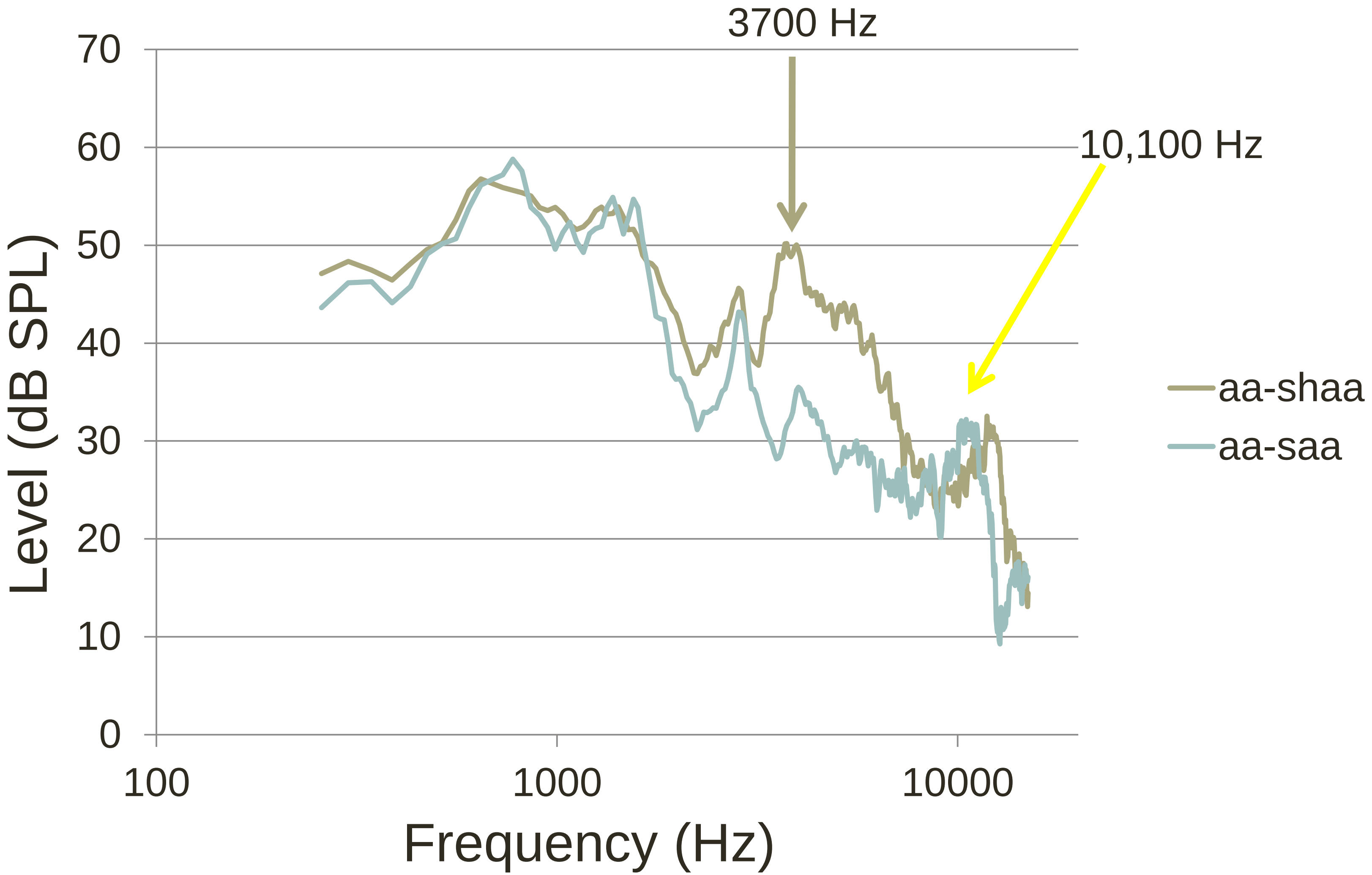
Importance of High Frequency Audibility

- Children with hearing loss need a 4-5 kHz bandwidth for male talkers and a 9 kHz bandwidth for female & child talkers to obtain maximum speech recognition performance for nonsense syllables containing the phoneme /*s*/
  - Perception of /*s*/, /*z*/, and /*ð*/ improved (and /*f*/ and /*v*/ decreased) when extended bandwidth from 5 kHz to 10 kHz (Stelmachowitz et al.,)
- Increasing BW up to approximately 7 kHz in hearing impaired adults (high frequency hearing thresholds as poor as 85 dB HL) may lead to small improvements in speech recognition performance (Hornsby and Ricketts, 2006).

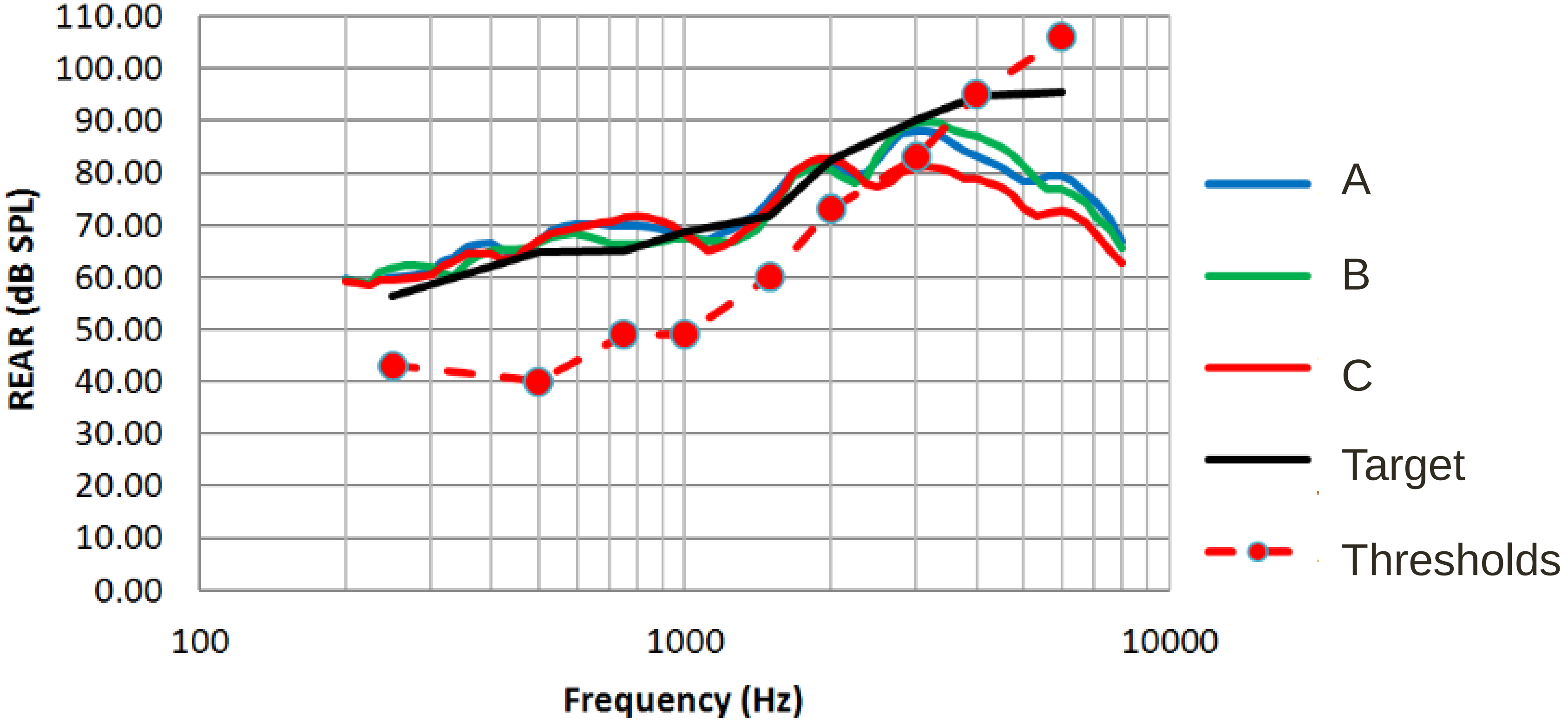
Making a Case for Extended Audibility: Male Voice



Making a Case for Extended Audibility: Female Voice



The Need - Limited Audibility in Real Fittings (Galster et al, 2012): N = 72



Three different Hearing Aid Brands/Models

Current and recent Frequency Lowering Technologies and manufacturer names (Modified from Josh Alexander)

Manufacturer	Feature Name	Frequency Lowering Method
Widex	Audibility Extender	Transposition (static)
	Enhanced Audibility Extender	Transposition (adaptive)
Phonak	SoundRecover	Compression (static)
	SoundRecover2	Compression (Adaptive)
Starkey	Spectral iQ	High Frequency Reinforcement (Spectral Envelope Warping)
Signia (Sivantos)	Frequency Compression	Compression
ReSound	Sound Shaper	Proportional Compression
Oticon	Speech Rescue	Multilayered Transposition

FREQUENCY LOWERING DATA TO DATE (ADULTS)?

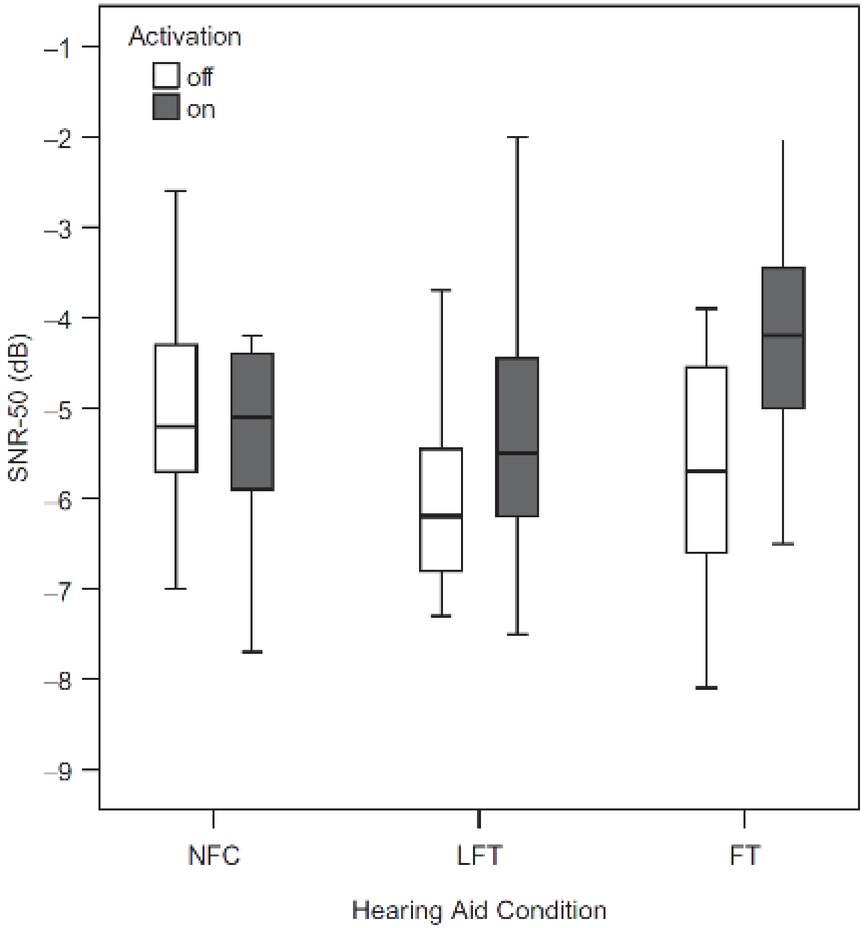
Mostly on Phonak, first generation, a little on Widex First Generation

NFC Research in Adults with Significant HF hearing loss?

- O'Brien et al, 2010
- Walden T, Block K, Cord M, Brungart D, Grant K, Sheffield B. (unpublished)
- Souza et al, 2013

- No **mean** difference for "FC-On" versus "FC-Off" for speech recognition at the time of the fitting or following training
- SSQ from field testing also showed no difference for FC-On versus FC-Off
- Decreased sound quality for FC-On

Miller, Bates & Brennan (2016)



- SNR-50 was not improved for any condition and decreased for some.
  - Role of experience particularly for LFT?
- <u>No difference in calculated SII despite documented improvements in audible bandwidth!</u>

Children and NFC …

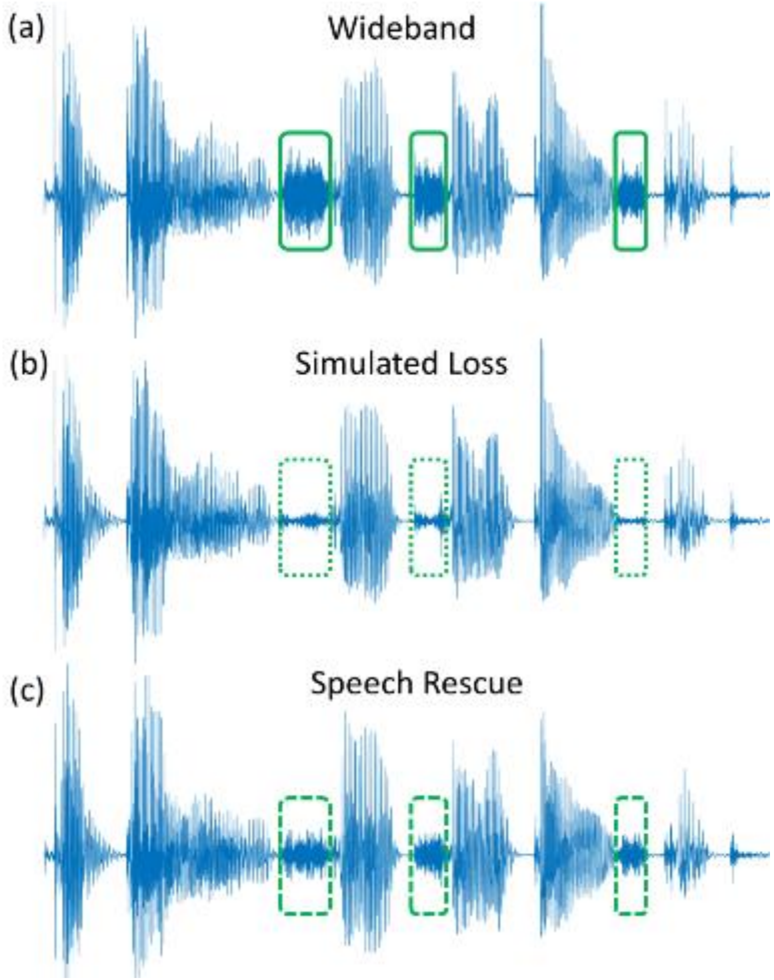
- A number of studies have generally shown positive short term outcomes in general for children, or at least for individual children.
- Newer large scale studies in children are less promising than hoped
  - Ching et al., 2013 - receptive and expressive language was better (but not significantly so except by parent self report) with NFC than conventional processing, but receptive vocabulary and consonant articulation scores were lower.
  - Bentler et al., 2014 - no differences in speech or language outcomes or speech perception between the NFC and conventional technologies (worn for at least 6 months) in 66 3-, 4-, and 5-year-old children with hearing loss.

A few things we know…

- There will be no benefit unless audibility is improved, and for many default fittings it may not be (Alexander, 2016; McCreery, 2016).
  - When improved audibility is assured, small average benefits have been shown in adults and children.
- Too much audibility distorts the signal and decreases outcomes therefore the weakest FL setting that is able to provide increased audibility is typically adovocated for (e.g. Scollie et al., 2016; McCreery et al., 2016).
- A hallmark of the FL outcomes is variability – some benefit, some do not, even when improved audibility is assured.
  - Benefits include improved awareness, speech recognition, speech production (particularly in pre-lingualy impaired children)

Potential For Benefits?

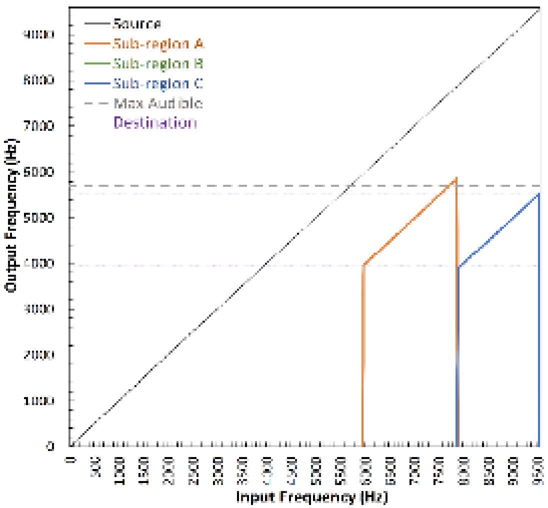
- What really get's lowered?
  - What is a high-frequency phoneme?
- Is audible frication a good thing from a wide-band standpoint?

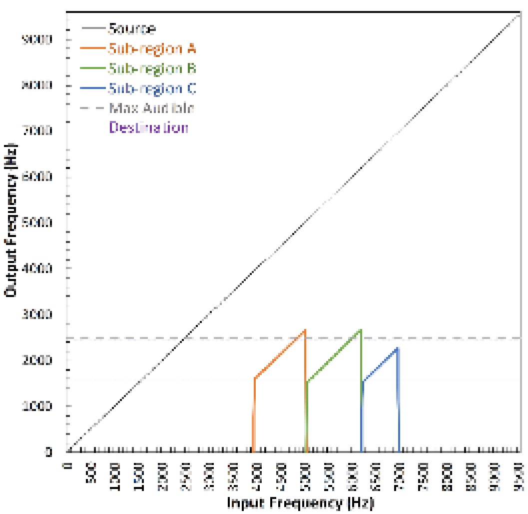


WILL THE CURRENT METHODS LEAD TO BETTER OUTCOMES?

Frequency Lowering: How Does it Work?

Multi-layered Frequency Transposition (Oticon Speech Rescue)



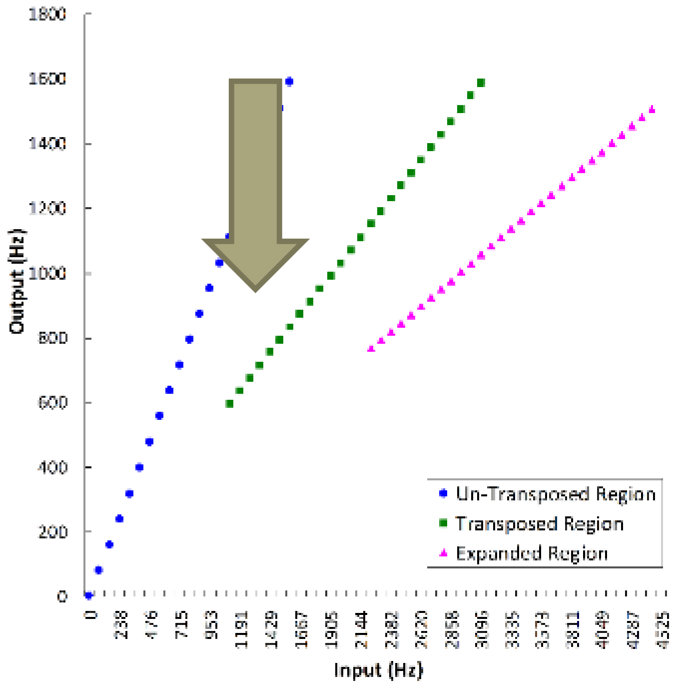


- Two or three source frequency regions are transposed down into narrower destination regions

- Energy and gain in the source region can be maintained, if desired, through programming.

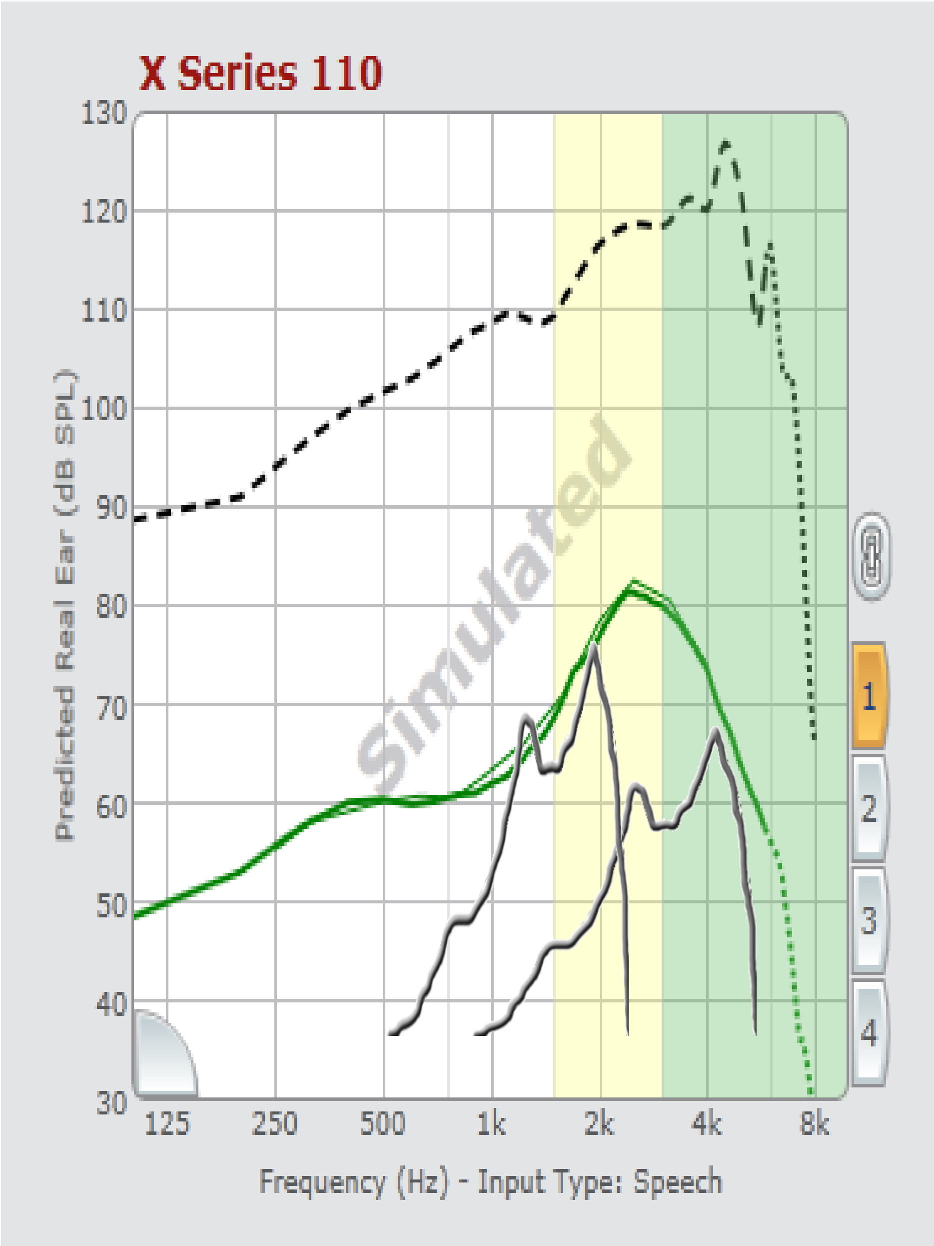
Frequency Lowering: How Does it Work?

Adaptive Linear Frequency Transposition (Widex- Enhanced Audibility Extender)



Overlapping ½ and 1/3 Octave Lowering

- More gain for sounds identified as voiceless than voiced phonemes.
- Alignment of lowered harmonics with harmonics already in the target region (voiced phonemes).
- Can set the bandwidth of the non-transposed signal higher than the cut-off.
  - Note the overlap



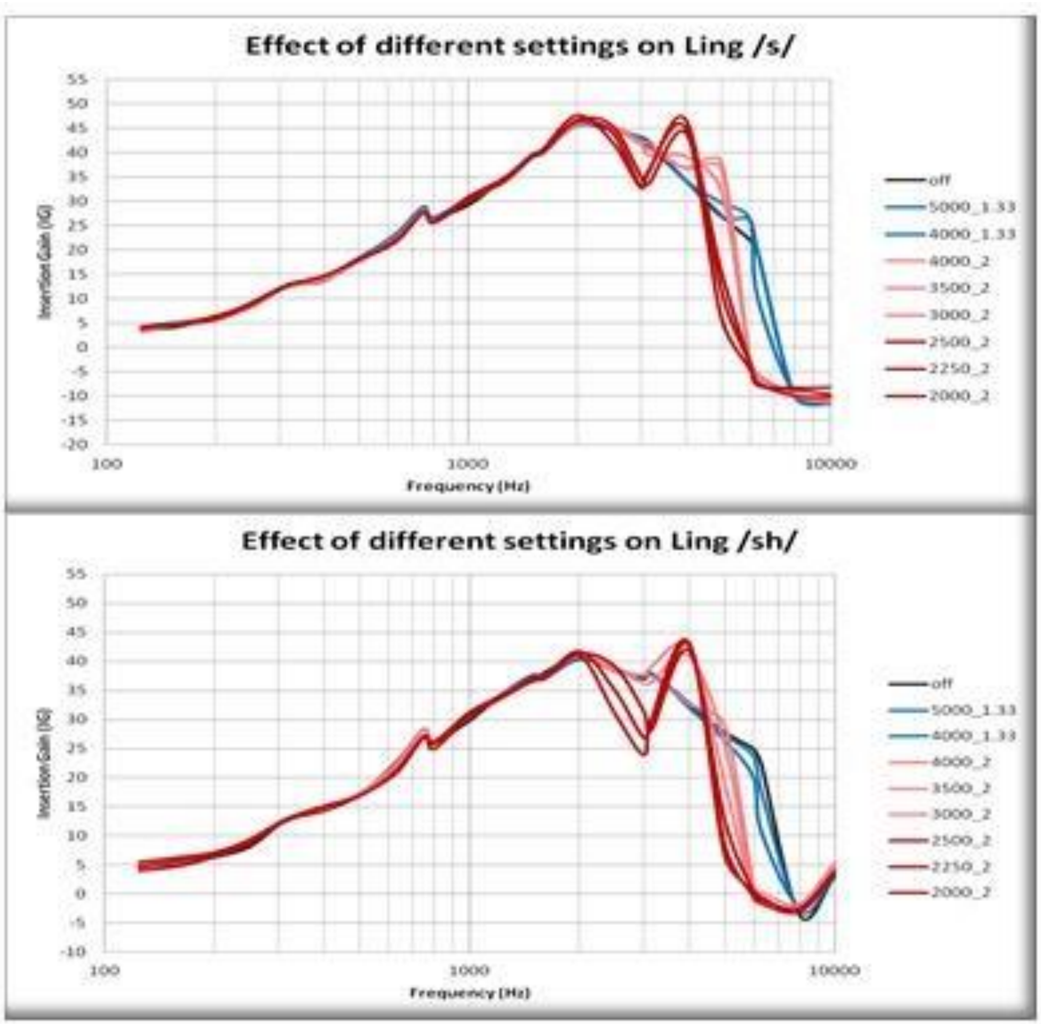
Frequency Lowering How Does it Work?

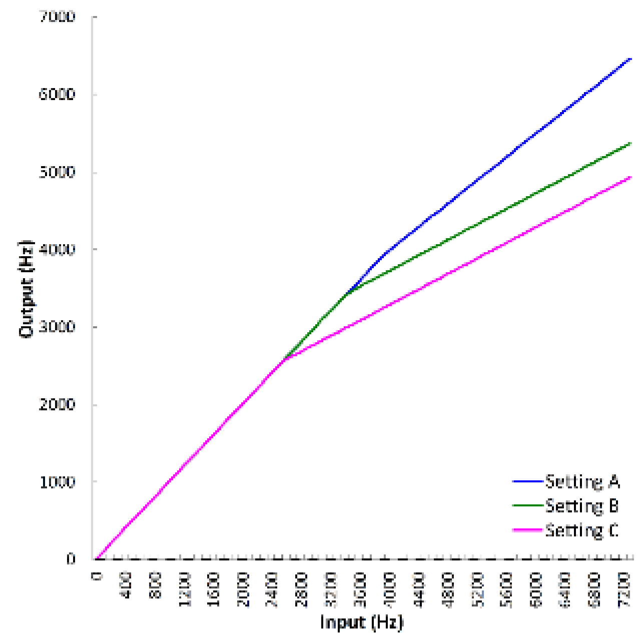
High Frequency Reinforcement: Starkey iQ

- High-frequency spectral peaks are identified by the algorithm; once identified the envelope of this high-frequency information is estimated and replicated around a lower target frequency.
  - E.g. more gain provided in the target region to existing signal
- The newly introduced spectral envelope is mixed with the amplified pathway. The replicated stimulus cue is only presented while the corresponding high-frequency energy is present; otherwise the amplified pathway is maintained.

Resound Proportional Frequency Compression

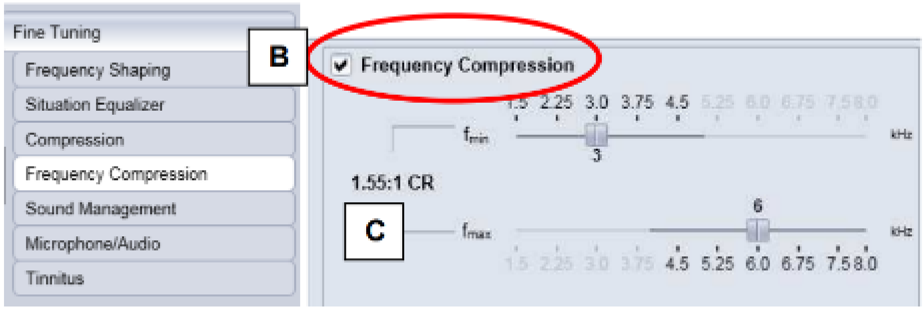
Linear compression ratio – e.g. 2:1 will place 3000 Hz at 1500 Hz

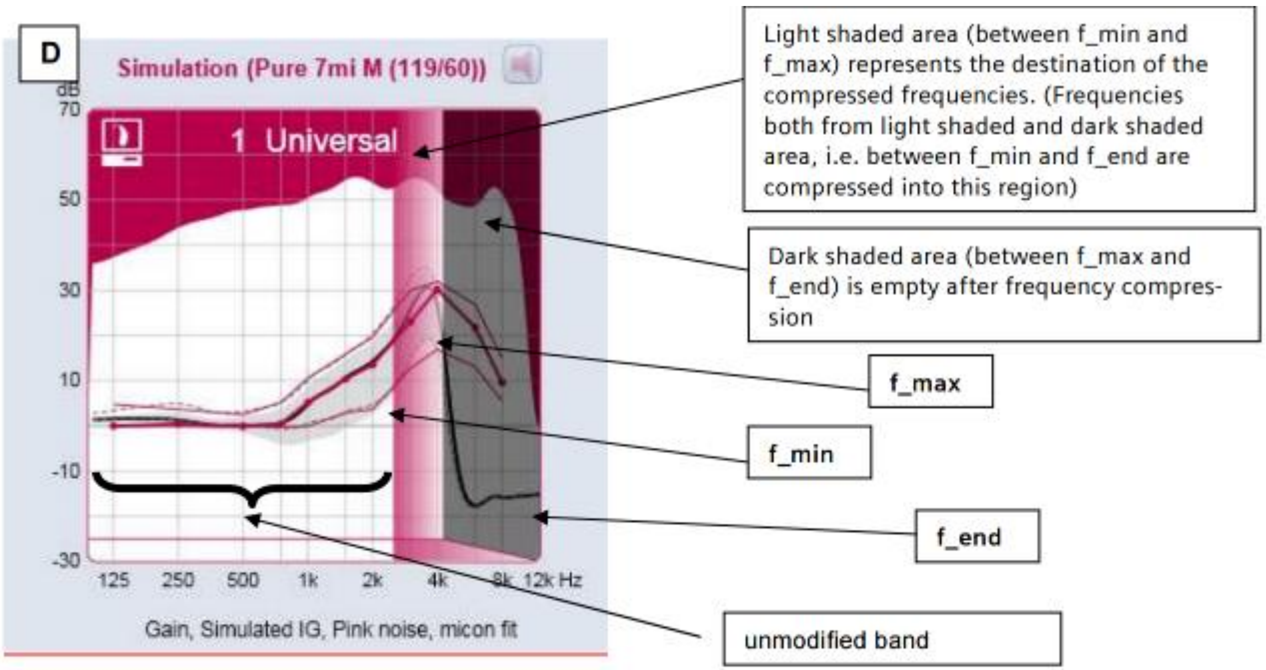




Choose from 3 settings

Signia (Sivantos) "Sound Shaper"





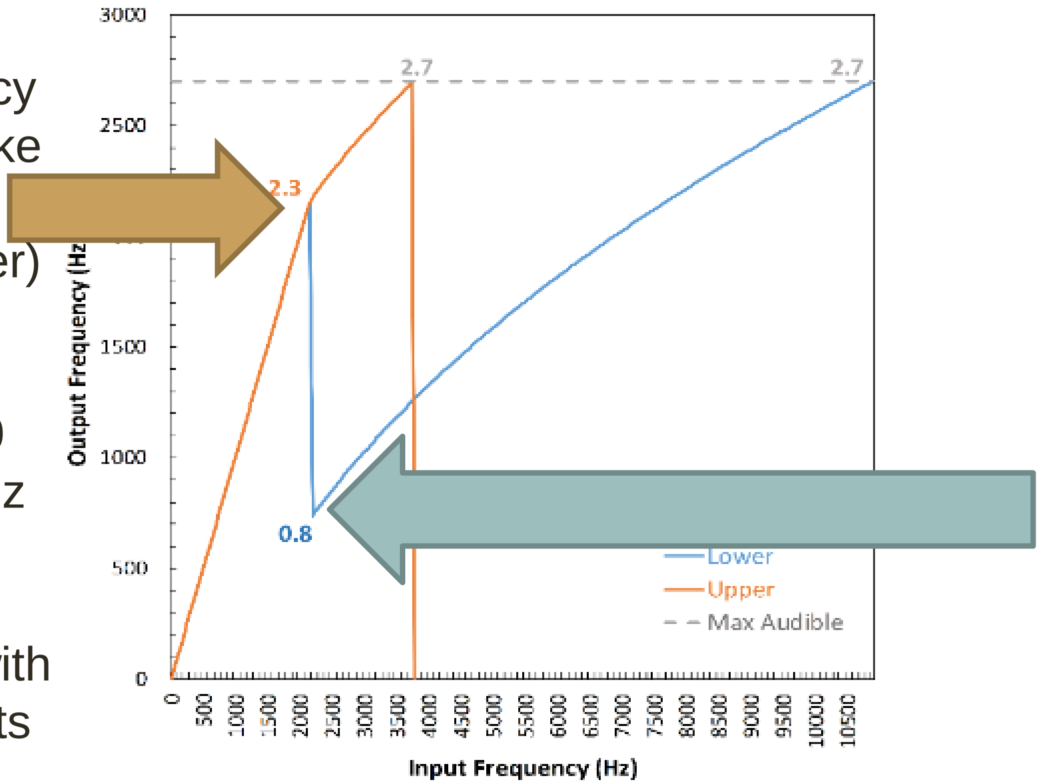
Frequency Lowering: How Does it Work?

Phonak Nonlinear Frequency Compression (Adaptive)

Low Frequency Dominated (like original SoundRecover)

Compressed output - 2,300 Hz to 2,700 Hz

Avoid competition with vowel formants



High Frequency Dominated Input

Compressed output - 800 Hz to 2,700 Hz

Better audibility for lowered sound and better resolution.

1. Upper cut-off controlled by Clarity-Comfort Slider: More comfort (c and d), the less compression for low frequency dominated sounds.
2. Audibility-Distinction” slider (1 to 20) progressively increases the lower cutoff and the maximum output frequency.

What does it all mean?

- What about updated algorithms, are they better?
- It may come down to better identification of individual candidacy.
- At least data shows no average harm in adults, even those with mild/moderate HL (Picou, Marcrum and Ricketts, 2015)

- Some recent work has demonstrated that the NFC settings that provide the best enhancement to speech recognition is dependent on the specific speech sound (Alexander, 2016).
  - The same setting leads to improvements or decrements depending on the target speech sound.
  - Would not surprise me if this was not also true for other types of frequency lowering.
- The optimal answer may be optimizing the setting based on the input speech – once we have more processing power that is!

Until then, a few tips…

- Some helpful tools to visualize audibility changes – Josh Alexander’s Fitting Assistants: http://web.ics.purdue.edu/~alexan14/fittingassistants.html

THANK YOU!