Frequency lowering technology

or…why it's all about audibility (and bandwidth)

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- Kathryn Arehart

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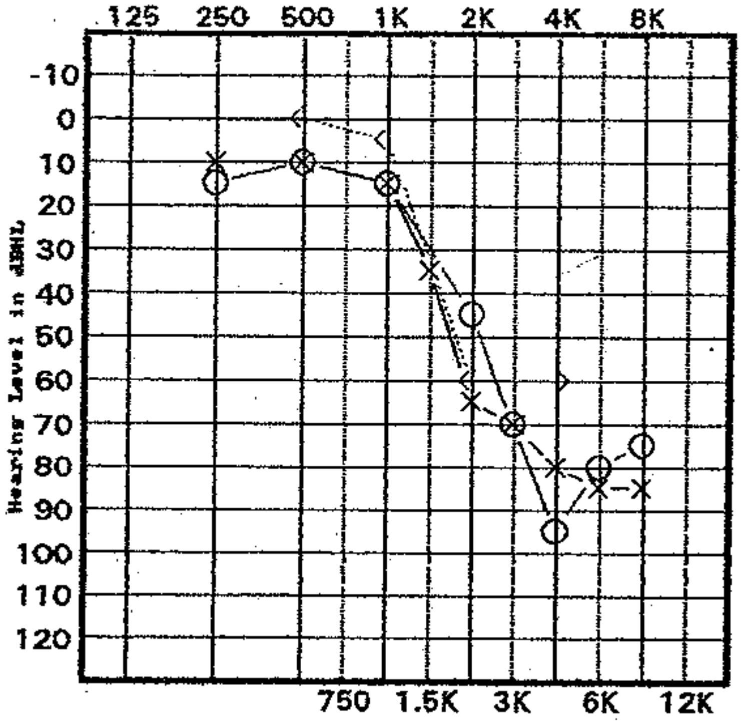
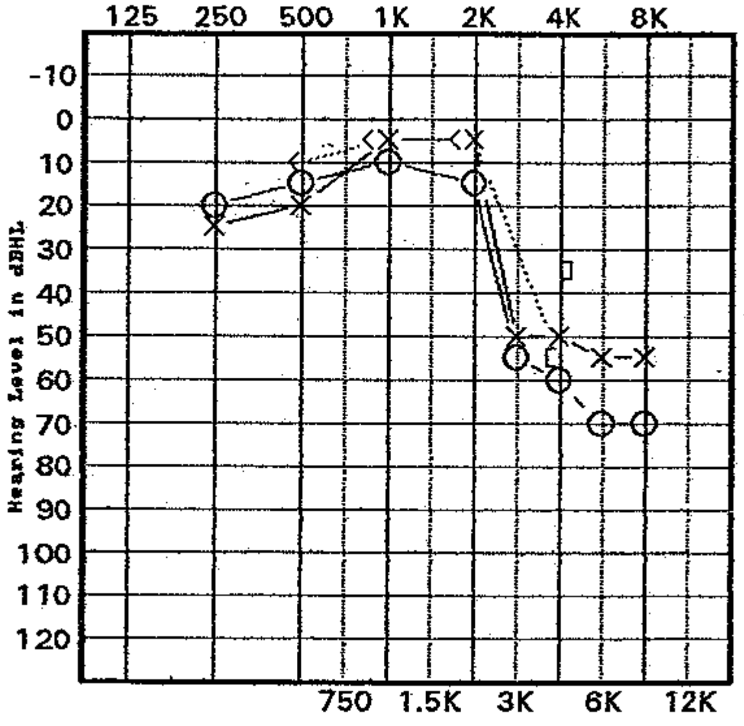
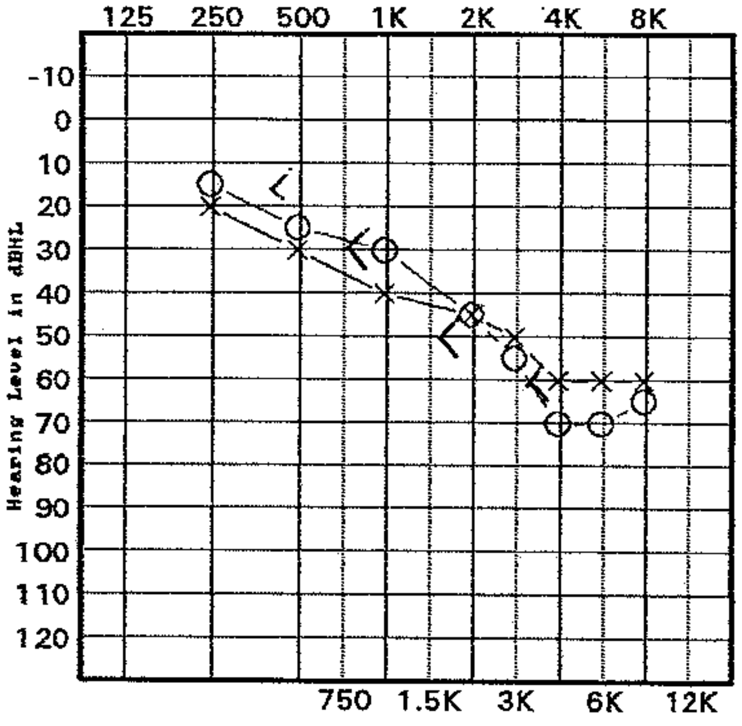
Frequency lowering: clinical intuition

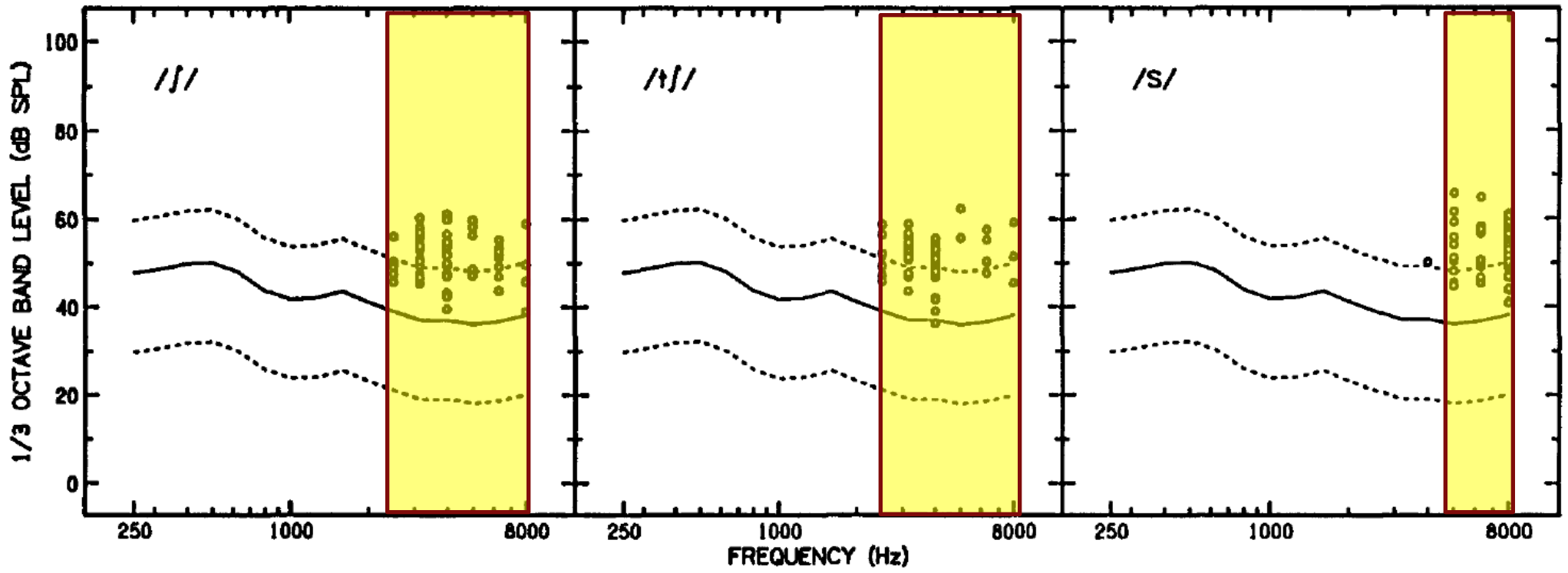




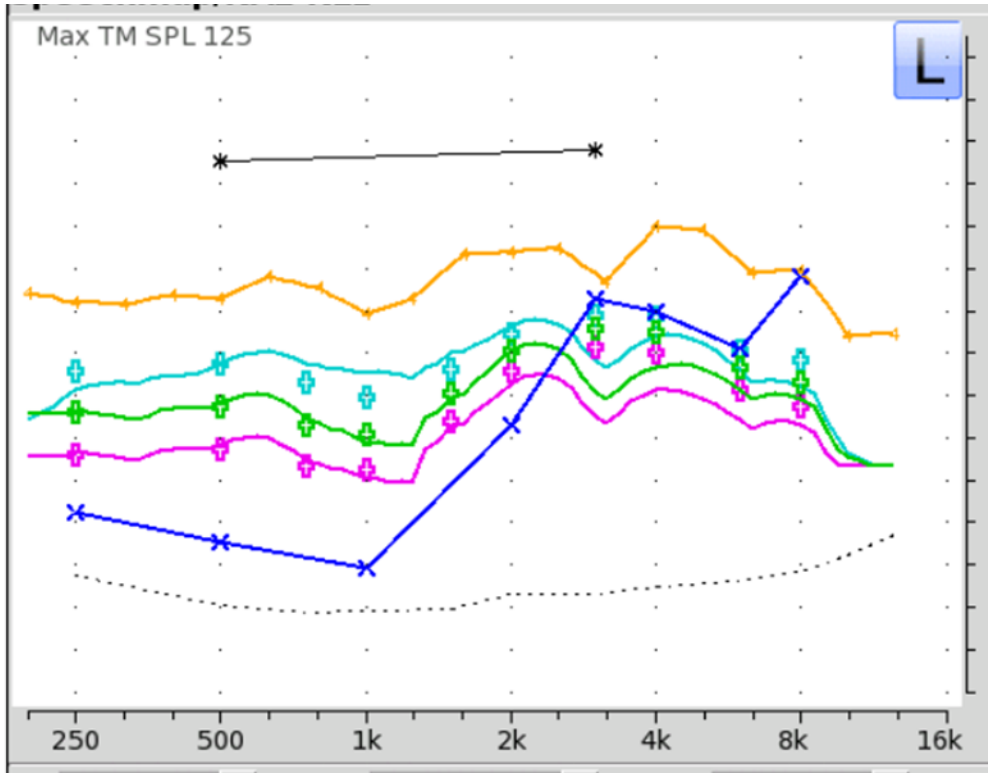


If you fit frequency lowering…

The problem part 1: high-frequency speech



The problem part 2: gain and audibility



- Even with a well-fit hearing aid and good match to NAL-NL2 targets, some higher-frequency information is inaudible
- Fitting range may limit greater gain (above targets)
- High-frequency sounds may not be usable by listener

A potential solution: frequency lowering

- Move high-frequency (inaudible) information to a lower-frequency range (where listener has better hearing thresholds)
- Frequency **compression** reduces the frequency range above a specified cutoff frequency
- Frequency **transposition** maintains frequency spacing and shifts the information to (overlap) in a lower frequency region

With focus on adult data

Some examples

- Phonak SoundRecover
- Widex Audibility Extender
- Starkey SpectralIQ
- Oticon Speech Rescue
- Siemens micon FCo

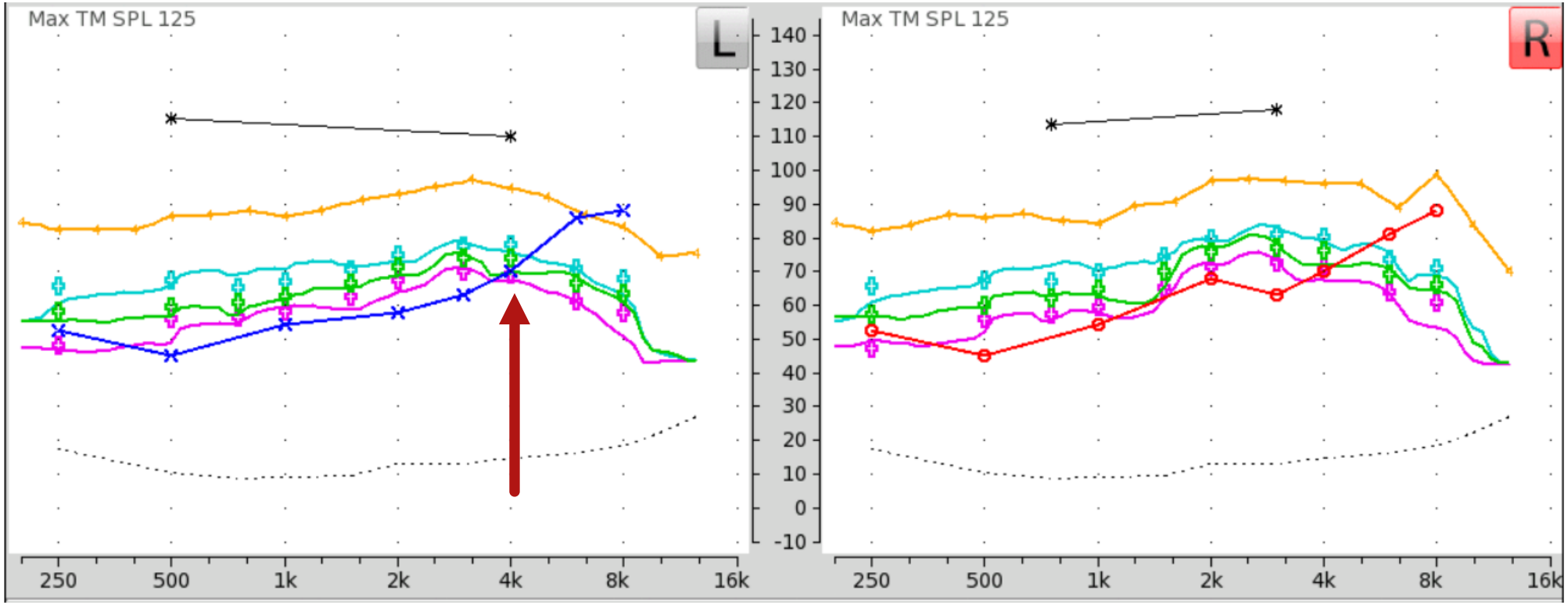
What clinicians want to know

- Who is a candidate for frequency lowering?
- How should parameters be set?
- What are expected benefits of frequency lowering?
- Do listeners fit with frequency lowering need to "get used to it"?

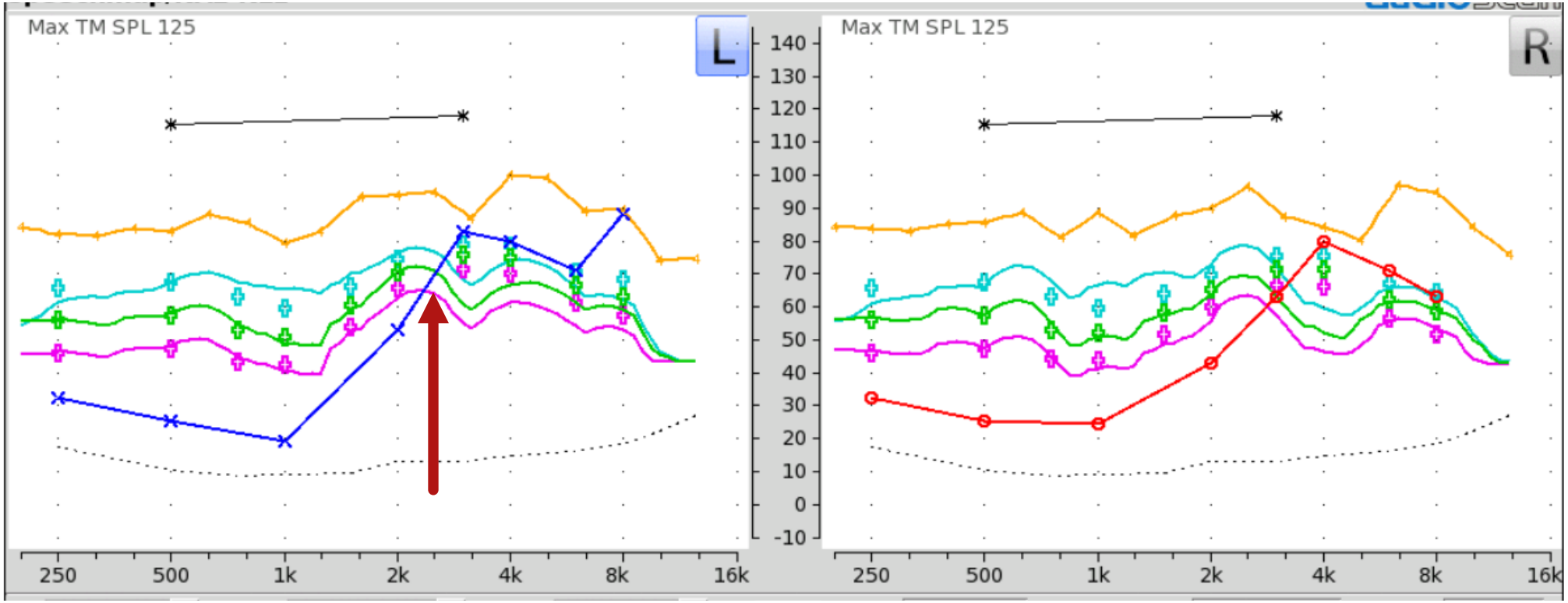
Who is a candidate?

- Consider **audible bandwidth** without FC (via real ear if possible)
- Evaluate whether non-FC gain will result in adequate bandwidth
  - Listening needs (COSI?)
- Availability of frequency compression in devices being considered

Example: audible bandwidth ≤ 4 kHz

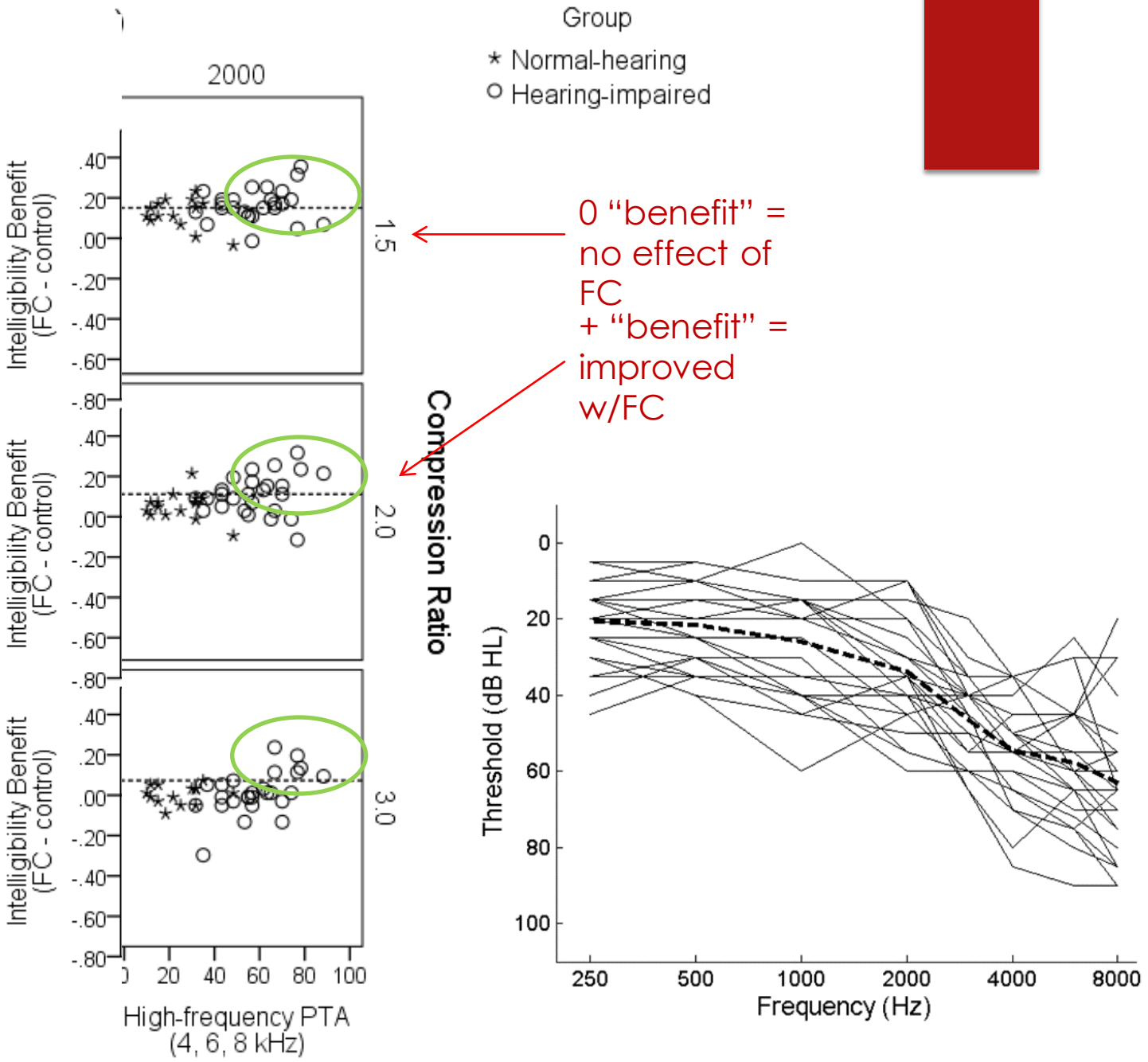


Example: audible bandwidth ≤ 2.5 kHz



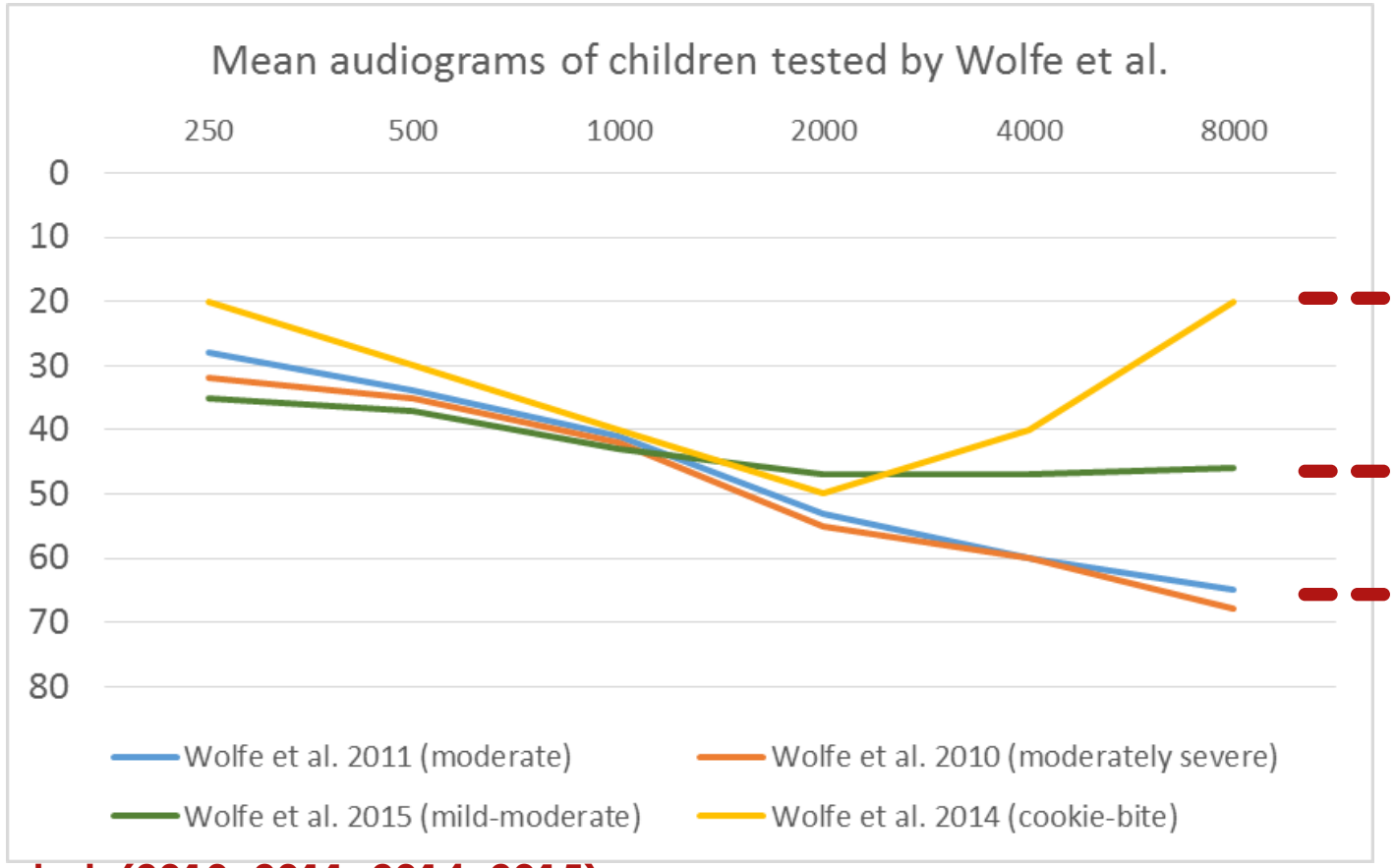
FC is beneficial if it improves audible bandwidth

With simulated FC, listeners with more high-frequency loss (and less audible bandwidth) had better sentence intelligibility



Souza et al. (2013); similar conclusions by Hopkins et al., 2014 for high-frequency consonants

FC is beneficial if audible bandwidth improves



No FC benefit

No FC benefit

+ FC benefit

Wolfe et al. (2010, 2011, 2014, 2015)

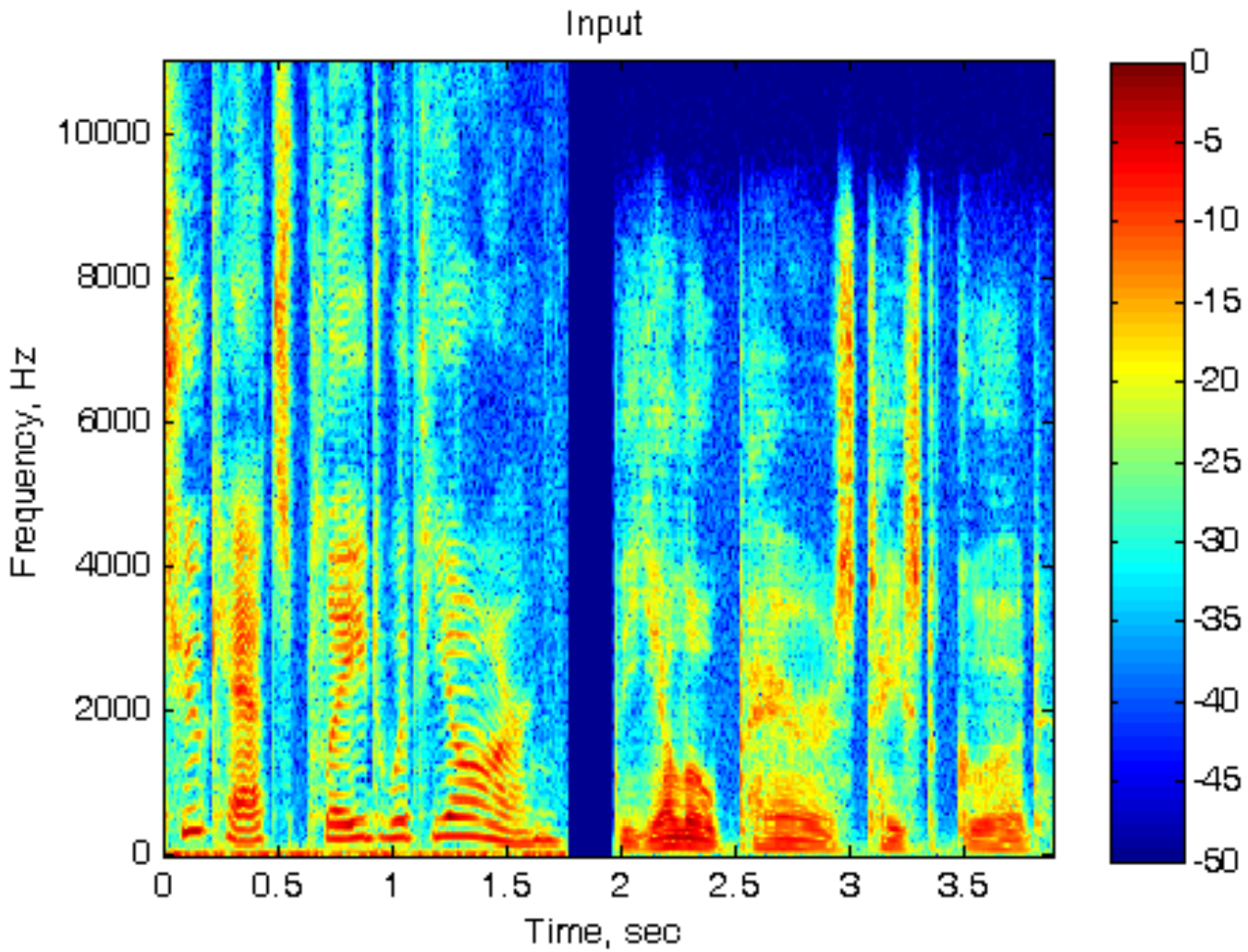
Who is a candidate? Other considerations

- Consider audible bandwidth without frequency compression (via real ear if possible)
- Evaluate whether gain (but no frequency compression) will result in adequate bandwidth
- Other considerations
  - Ability to resolve compressed spectral information
  - Working memory may affect benefit of improved audibility, when that audibility comes at expense of altered speech cues

Kates, Arehart, Souza (2013)

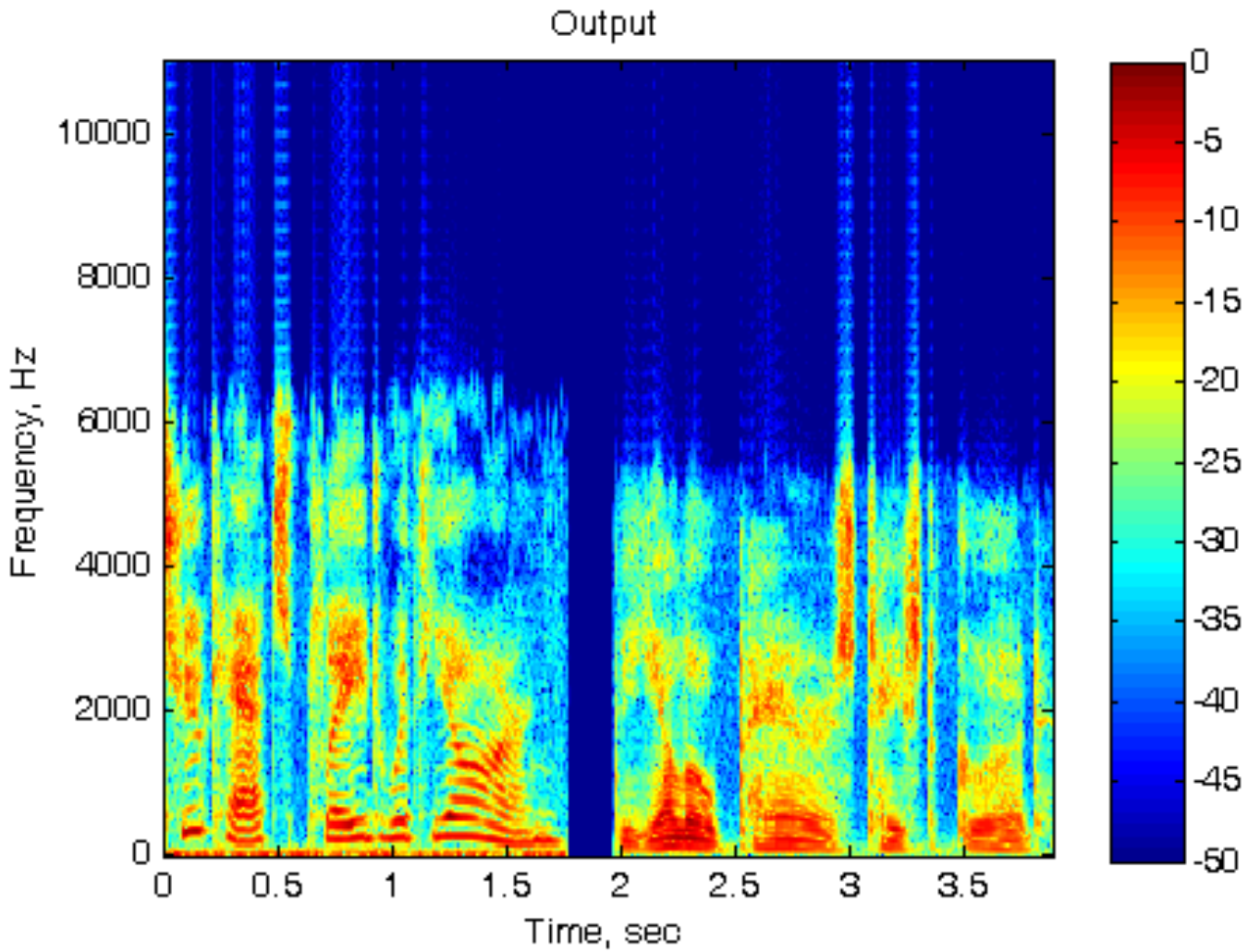
Ability to resolve spectral information

In non-frequency-compressed speech, listeners can use formant spacing and overall spectral shape for phoneme discrimination



Ability to resolve spectral information

With frequency compression, spectral detail is reduced. This may be detrimental for listeners with poor spectral resolution (but we need more data)



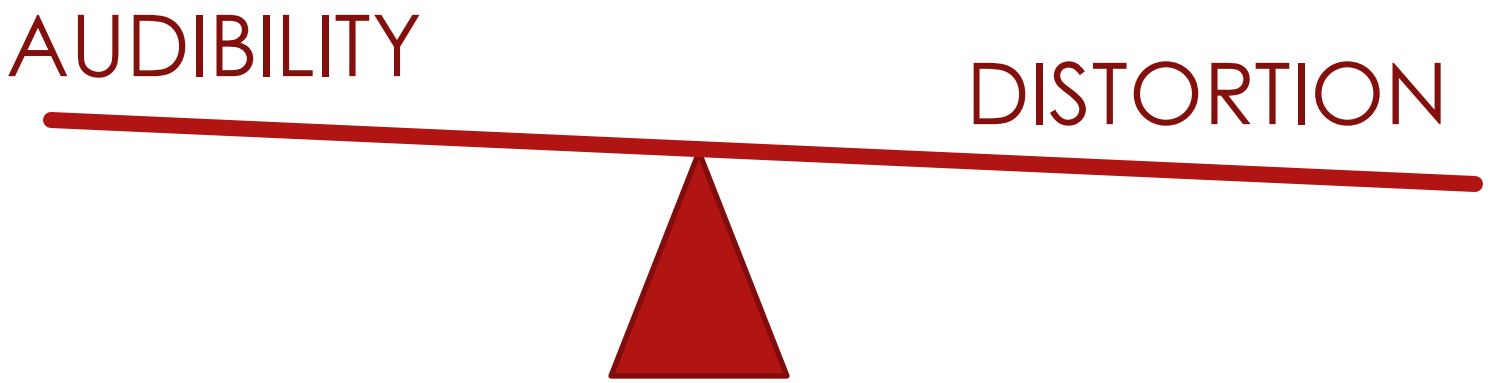
Cognitive ability and frequency compression

- Two studies showed reduced benefit from frequency compression with lower working memory capacity
  - Simulation study, no acclimatization
  - FC above 1000 Hz-2000 Hz, at CRs 1.5:1-3:1
- One study showed no relationship between frequency compression and working memory
  - 6 weeks experience with FC
  - FC above 2000-3700 Hz, at CRs 1.8:1-2.6-1

Arehart et al. (2013); Souza et al. (2015); Ellis & Munro (2015)

Net benefit from frequency compression

- Improved audibility of high-frequency speech cues…
- …leading to improved speech recognition
- But: also altered acoustic cues (frequency spectra)



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Avoiding distortion/degradation

- Least aggressive FC needed to improve audibility and bandwidth (assessed via real ear)
- Low cutoff frequencies degrade sound quality more than high compression ratios
- If listeners reject FC on basis of sound quality, try adjusting parameters rather than turning it off

Alexander (2013); Parsa et al. (2013); Souza et al. (2013)

Tools for adjusting FC: FLassist

SoundRecover Fitting Assistant v2.0c

(use with Spice and Quest products only)

Maximum Audible Output Freq. (Hz)

2500

SETTING A

START (kHz)	CR	Max. Audible Input
3.0	3.0	2500

*Setting A: Recommend lower start or higher CR

SETTING B

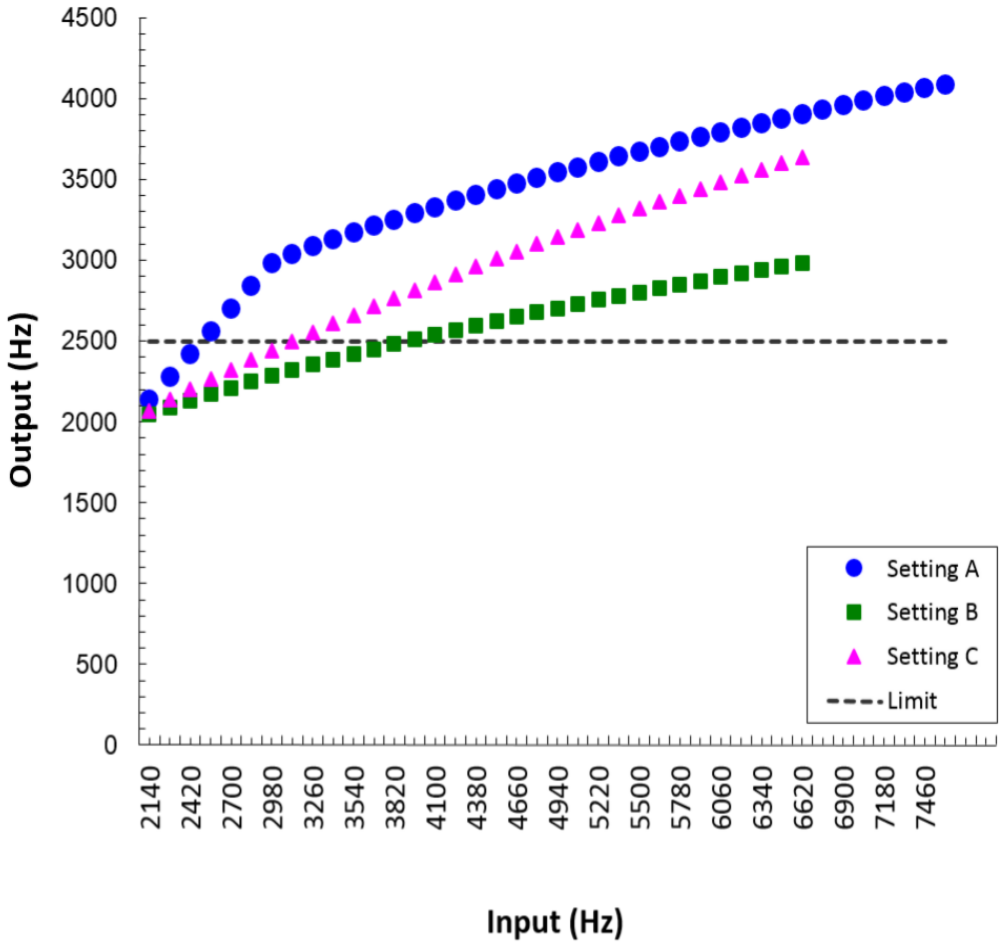
START (kHz)	CR	Max. Audible Input
2.0	3.0	3906

*Setting B: Recommend lower start or higher CR

SETTING C

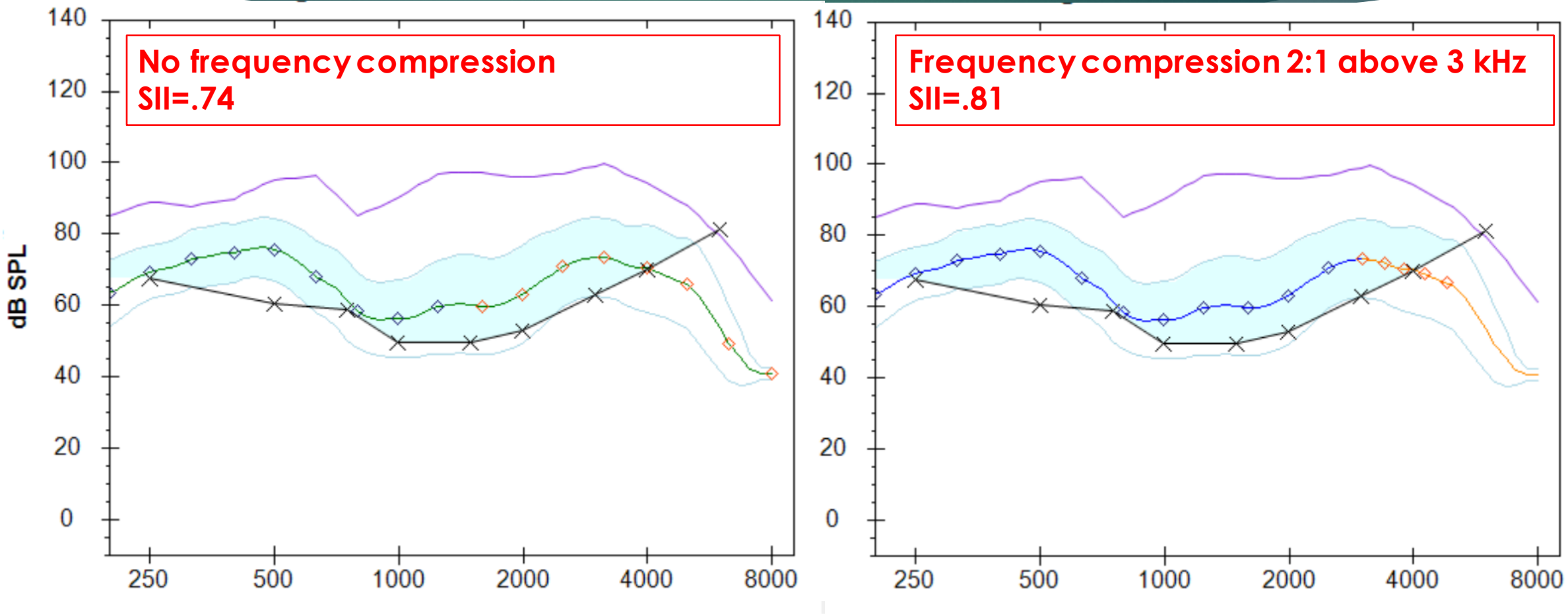
START (kHz)	CR	Max. Audible Input
2.0	2.0	3125

*Setting C: Recommend lower start or higher CR



Alexander, 2013; TinyURL.com/FLassist

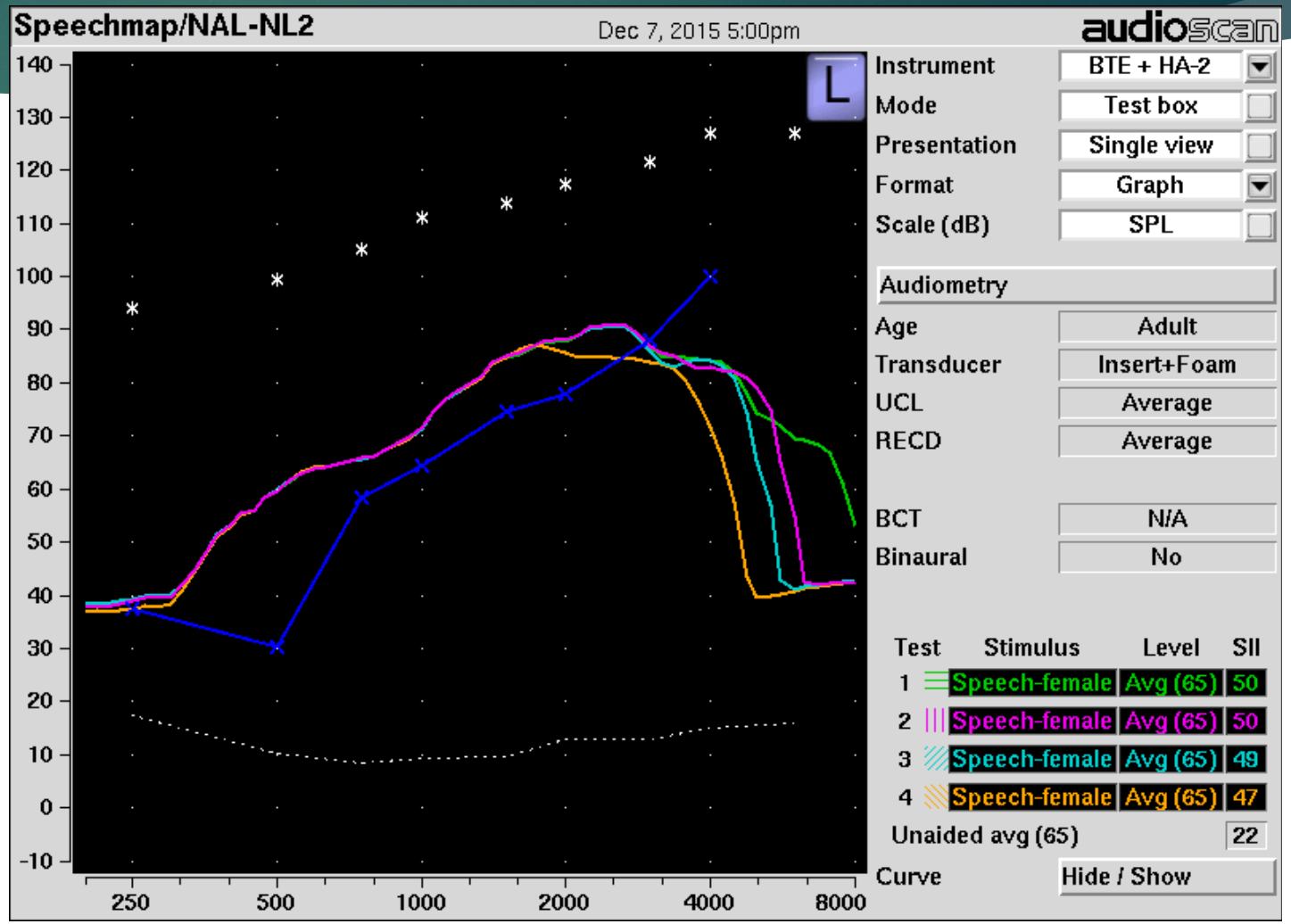
Tools for adjusting FC: SHARP



Brennan & McCreery 2015; http://audres.org/rc/sharp/

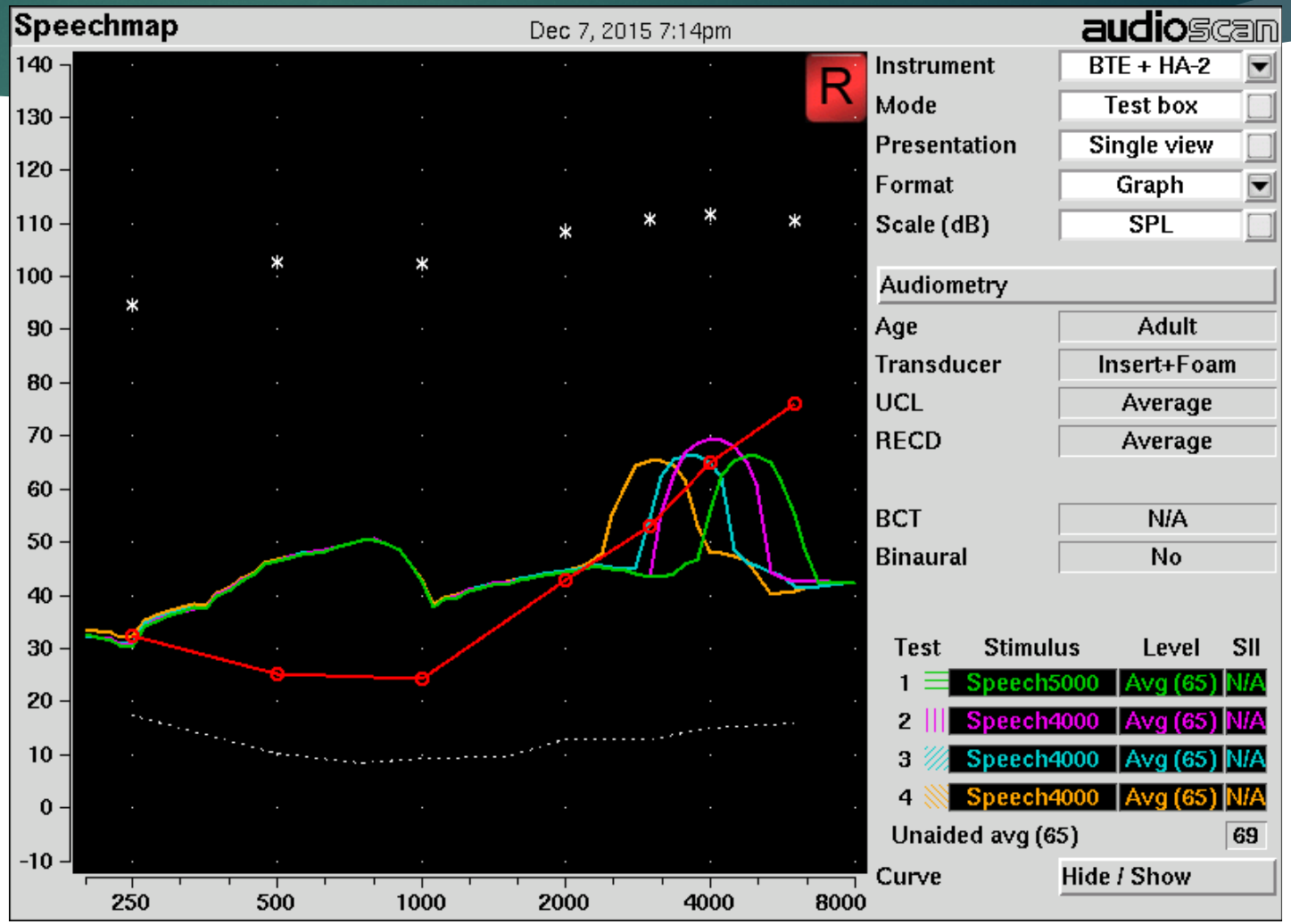
Verification tools: real ear?

- Conventional real ear measures may not emphasize improved high-frequency audibility



Verification tools: high-frequency speech

- High-frequency speech option on Verifit
- From right to left:
  - No FC
  - FC above 4500 Hz
  - FC above 3300 Hz
  - FC above 2500 Hz



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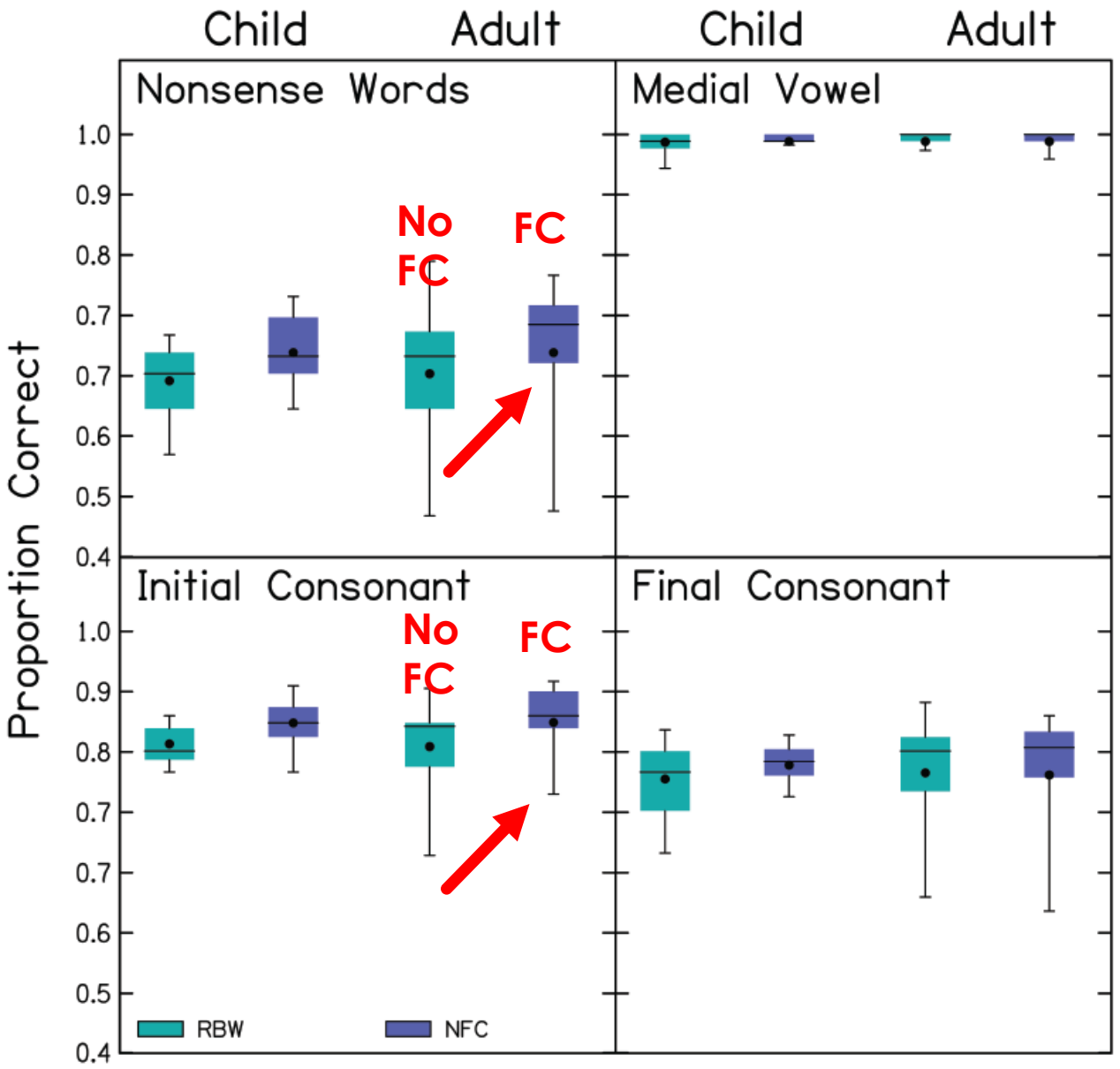
Comparing FC and no frequency compression

Small improvements in % correct for fricatives and affricates, or nonsense words that included those sounds



Brennan, McCreery, Kopun, & Lewis, 2015

Expected benefits of frequency compression

- Improved detection of high-frequency phonemes (especially fricatives and affricates)
- Improved perception of plurality
- Data suggest minimal to no improvement in sentence recognition (at least for adults)
- Reduced listening effort not yet demonstrated

Alexander et al., 2014; McCreery et al., 2014; Picou et al., 2015; Brennan et al., 2015; Ellis & Munro, 2015

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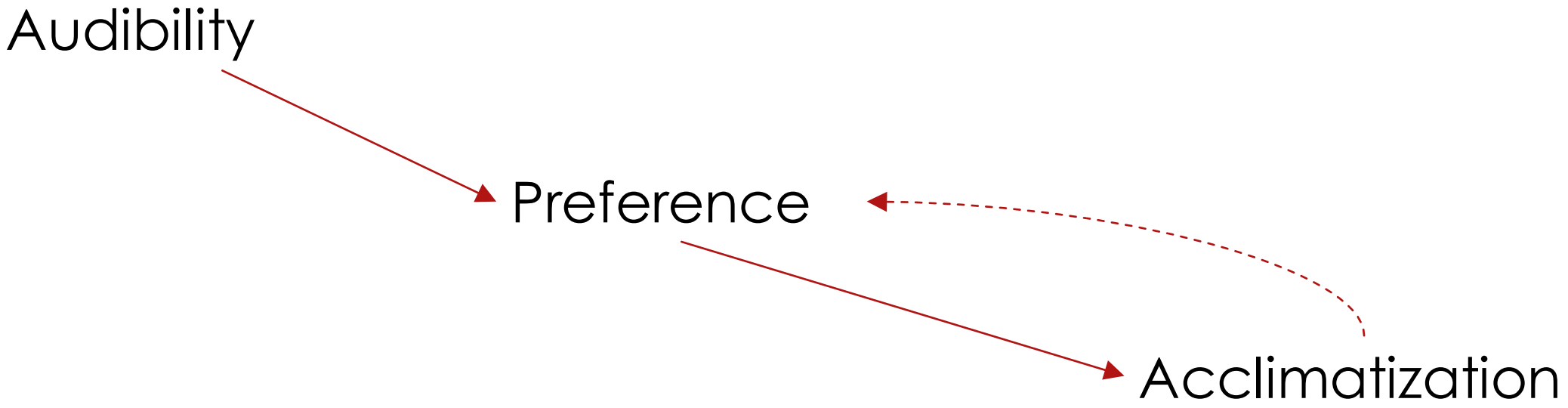
Is acclimatization needed?



Myths and facts

Myth

- All listeners benefit from FC
- Listeners will not accept the sound quality with FC
- Extensive experience needed to obtain benefit

Fact

- FC benefit likely related to improvements in audible bandwidth
- Acceptable quality with some FC parameters (especially with higher cutoff frequencies)
- While some studies showed acclimatization, unclear if related to FC or to use of amplification (no RCTs)

Take-home: the past (research)

- When FC improves audible bandwidth, it also improves perception of high-frequency phonemes (/s,ʃ)
- Little improvement in perception of sentences for adults with acquired hearing loss
- Aggressive FC (activated below 2 kHz, or with high compression ratios) may have undesirable sound quality, or distortion that is disruptive to listeners with lower working memory capacity

Take-home: the present (practice)

- Assess candidacy for FC by evaluating audible bandwidth
- Goal is minimum frequency compression needed to improve audible bandwidth
- To maintain sound quality, compression start frequency matters more than compression ratio

Take home: the future (??)

- Consensus on benefits of FC (use and satisfaction)
- Double-blind, randomized control trial to evaluate acclimatization
- More research on individual factors (such as spectral resolution and working memory) that may mediate frequency compression benefit
- It would be helpful to have built-in tools to set "best bandwidth" frequency compression

Resources

- FLassist program at TinyURL.com/FLassist
- SHARP program at http://audres.org/rc/sharp/
- Review papers
  - Simpson (2009) Trends in Amplification
  - McCreery et al. (2012) American Journal of Audiology
  - Alexander (2013) Seminars in Hearing and Audiology Online 20Q

Thank you

- Contact: p-souza@northwestern.edu.
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