Frequency compression: clinical trials and lab studies

Susan Scollie, Ph.D.
Child Amplification Laboratory
University of Western Ontario

Why use it?

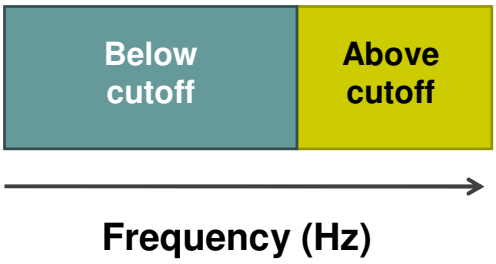
- Hearing loss is typically greatest in the highest frequencies.
- Hearing aids typically have less gain, less output in the very high frequencies.
- The high frequency output of the hearing aid may be further limited if it cannot be worn without feedback.

A little background…

- Frequency lowering…
  - Uses dsp to shift, in frequency, an incoming signal to a lower output frequency.
  - This can be done in various ways:
    - To all of the signal, or just the upper band
    - All of the time or some of the time.
    - Using transposition or compression

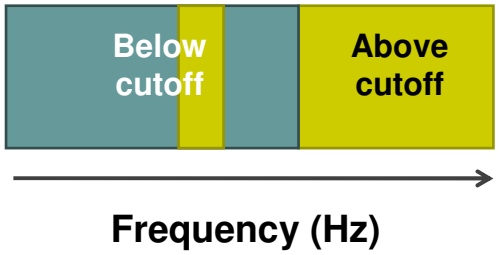
Compression or transposition?

- Frequency compression



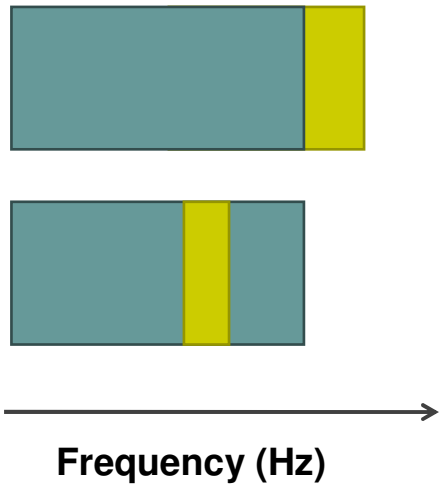
Compression or transposition?

- Frequency transposition



Compression or transposition?

- Compression
  - Alters formant relationships, does not mix channels.
- Transposition
  - Mixes channels, does not alter formant relationships in the lower channel.



Our Fitting Philosophy

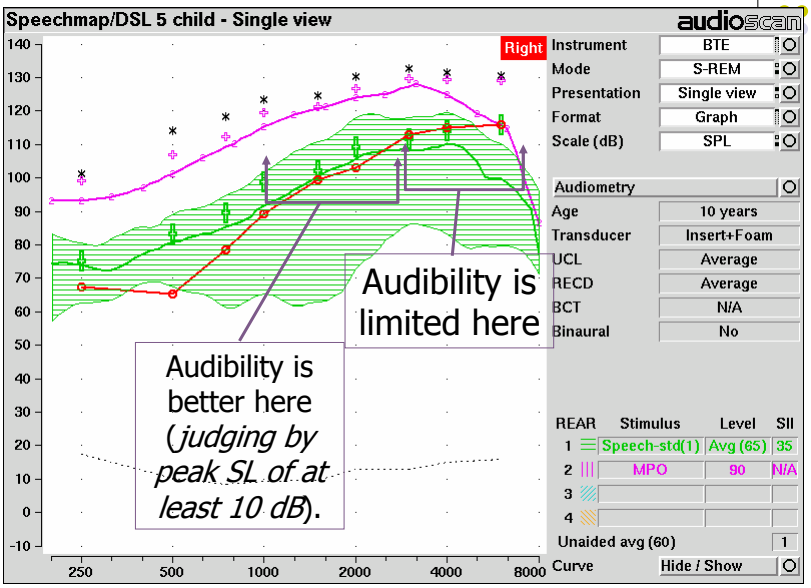
NFC fittings should:

1) …provide more audibility for high frequencies than is available with a non-NFC fitting.
2) … should not cause lisping of the phonemes S.
3) … should preserve normal formant relationships as much as possible.
4) … should maintain sound quality for both speech and music, as perceived by the wearer.

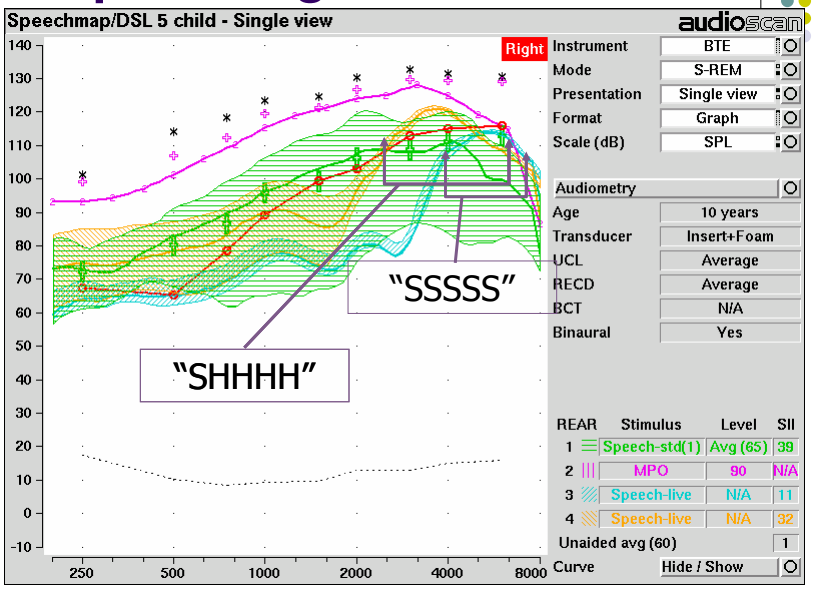
How did we fit NFC?

- We used the DSL Method, version 5 to provide a broad bandwidth of amplified speech without frequency compression.
- We then activated & varied the frequency compression algorithm & measured to see if things improved. We listened to evaluate overall speech quality and s/sh distinction.
  - Programmable cutoff frequency
  - Programmable compression ratio
- An example…

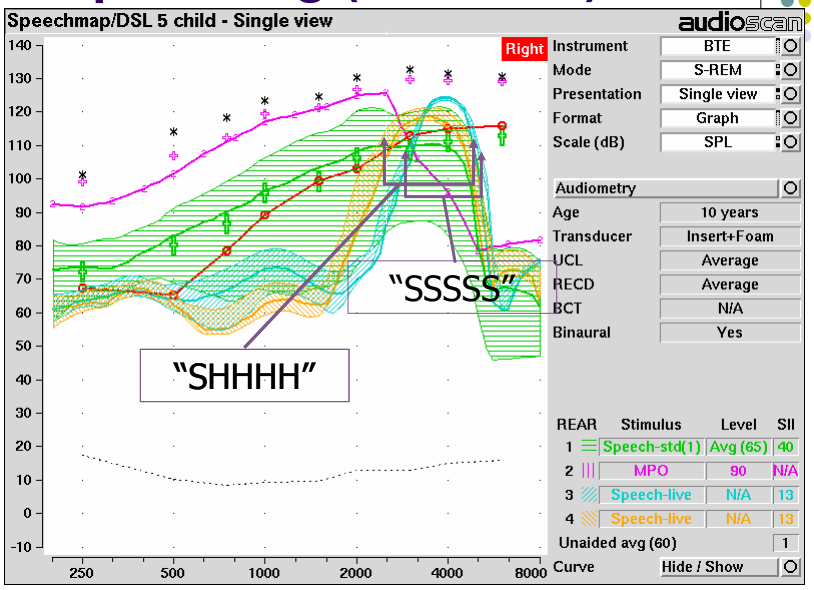
Sample fitting:



Sample fitting:



Sample fitting (with NFC):

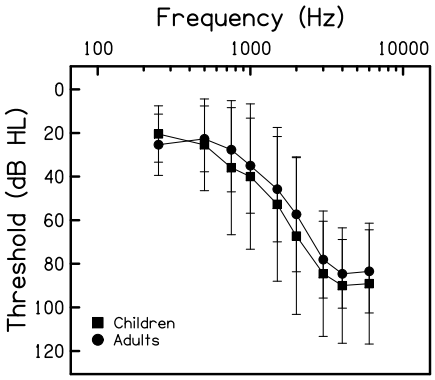


Fine tuning

- If too much frequency lowering is provided:
  - Speech may sound slurred
  - High frequency environmental sounds may be too harsh and interfere with device acceptance
- If too little frequency lowering is provided:
  - There may not be any noticeable benefit. (Note that people can benefit without noticing though, so this is a tricky one).

Field trial

- 24 patients: 11 children and 13 adults
  - A wide range of hearing losses from mild through profound.



Glista, D., Scollie, S., Bagatto, M. Seewald, R., Parsa, V., Johnson. A. (2009). Evaluation of nonlinear frequency compression: Clinical outcomes. International Journal of Audiology. 48(9), 632-644.

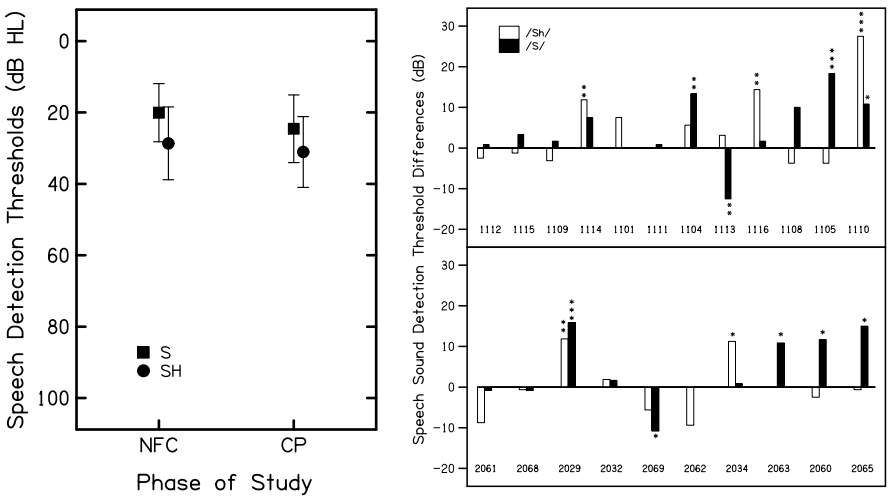
Study design:

Time course	Objective	Duration
Participant intake	Audiometric evaluation. Hearing aid fitting (CP).	Range: 2 weeks to 3 months Mean: 4.17 weeks
Acclimatization phase	Real world trial with CP. Practice tests.	
NFC phase	Real world trial with NFC. Outcome evaluation with NFC.	Range: 3 weeks to 1.3 years Mean: 10.75 weeks
Multimemory phase	Real world trial with user selectable NFC. Evaluation of real world preferences.	Range: 2 weeks to 5 months Mean: 5.58 weeks
Withdrawal testing	Outcome evaluation without NFC.	

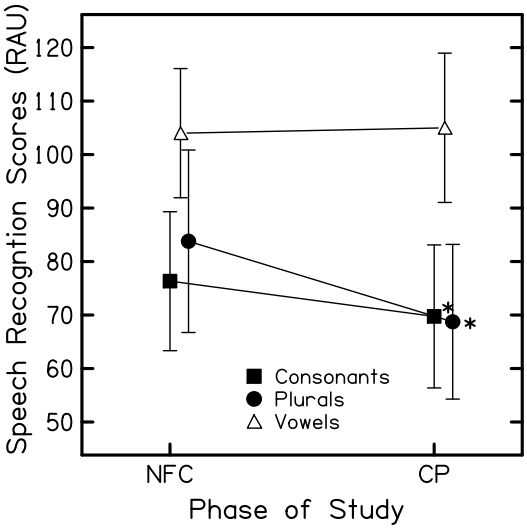
Outcomes battery:

- Aided detection thresholds of the phonemes s, ʃ
- Recognition of high frequency consonants:
  - /ʧ, d, f, ʤ, k, s, ʃ, t, d, z/ spoken by two female talkers
- Identification of word-final plurals on 15 words:
  - ant, balloon, book, butterfly, crab, crayon, cup, dog, fly, flower, frog, pig, skunk, sock and shoe
- Double blind subjective preference.
- Speech production.

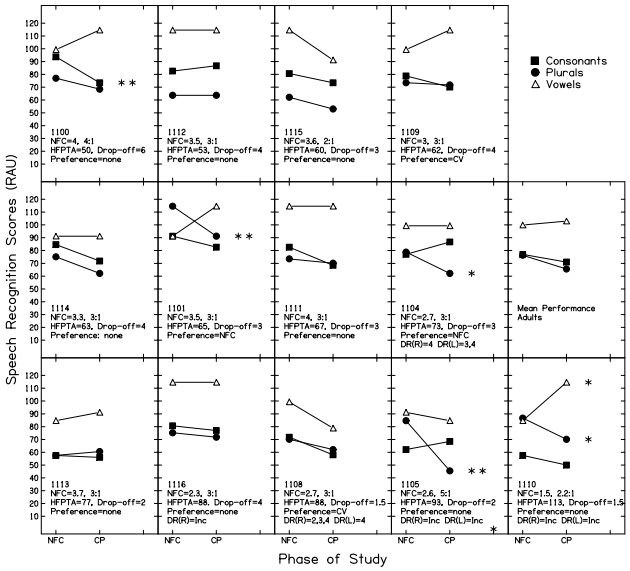
Speech sound detection improved.



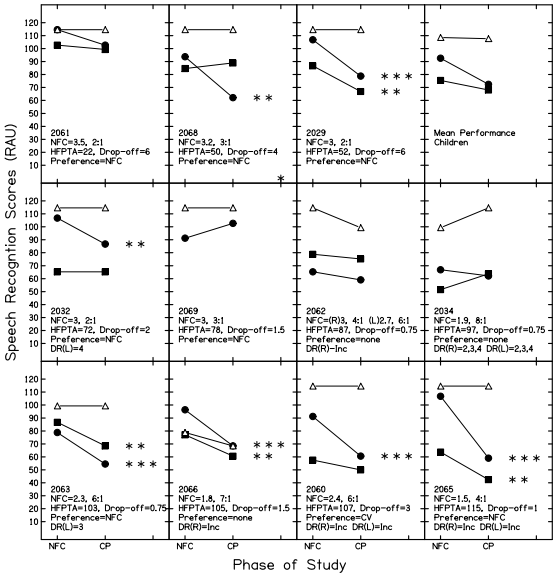
Consonant & word-final plural recognition improved.



Some adults benefit more.

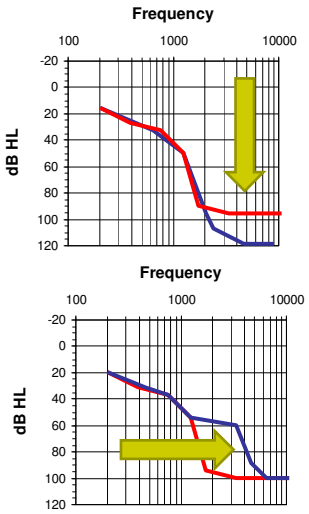


Children's results look better.



Audiometric & age candidacy.

- Significant predictors of outcome:
  - Age group (adult versus child)
  - Better ear high frequency pure tone average
  - The lowest frequency at which the audiogram had a severe loss (drop off frequency)



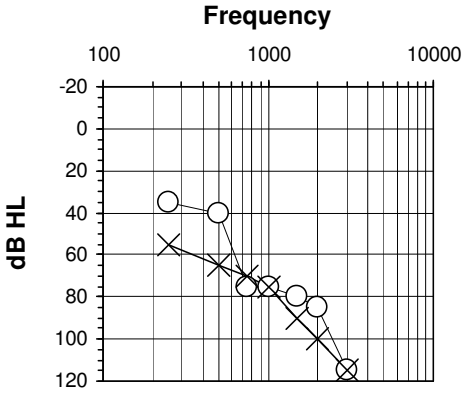
Summary of outcomes

- On average, the NFC processor improved speech sound **detection thresholds**, as well as consonant and plural **recognition scores**; vowel perception was not significantly changed.
- Individual results indicated that age group and degree and configuration of hearing loss were related to NFC benefit and to preference.
- Variance in individual outcome results was considerable. Individual determination of candidacy is warranted when considering NFC use in clinical application.

Speech production:

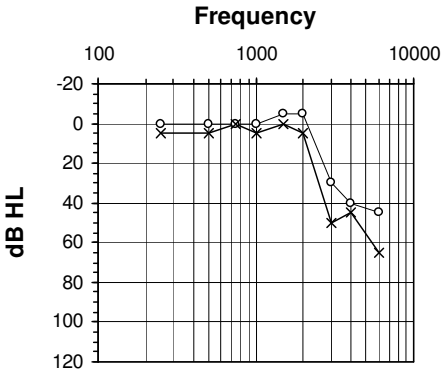
- Trial participants were recorded while repeating sentences:
  - Give me your **s**ocks.
  - **S**oup is good food.
  - I **s**ee the fox.
  - **Sh**e got a **sh**ot.
  - My **sh**oes are new.
- And while answering questions (e.g., Tell me how you would plant a seed.).
  - Before NFC and after 9.5 weeks mean acclimatization
    - Range: 6 to 14 weeks
- Electroacoustic and subjective analyses

“Can you tell me how to plant a seed?”



- 2400, 6:1
- Significant benefit with NFC
- “Now I hear /s/ where before there was only silence”
- Difficulty adjusting

“Can you tell me how to plant a seed?” and “… how to make a sandwich?”



- 3500 Hz, 2:1
- No objective benefit because at ceiling on all measures at baseline.
- Significant blinded preference

Speech production summary (at this point):

- These data are still under analysis.
- Not all children show changes:
  - Children who had good speech at the start of the project did not show these types of changes.
  - Some children needed a longer time frame.
  - Be cautious but reasonable about expectations: a child with absent /s/ in his or her speech, inaudible /s/ on previous fittings, and a frequency lowering fitting that makes /s/ audible may benefit in terms of speech production. Others may not. Blanket statements are not warranted.

Prototype versus commercial:

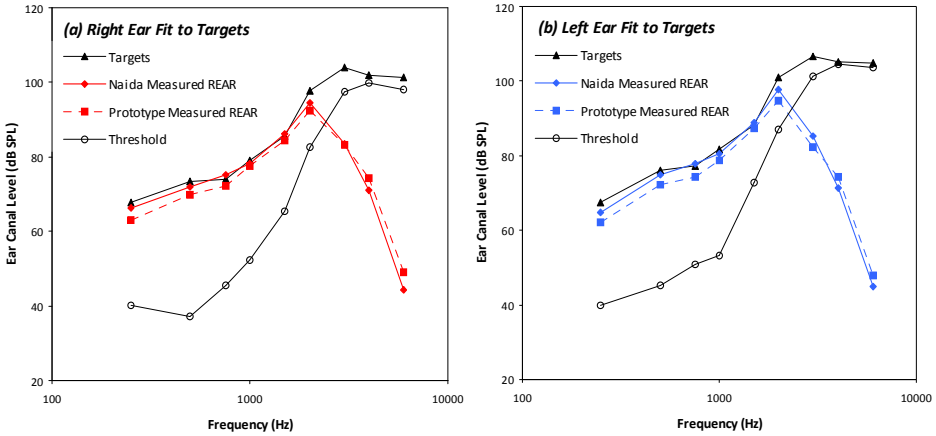
- 10 child participants from the Glista et al. (2009a) study

Devices:

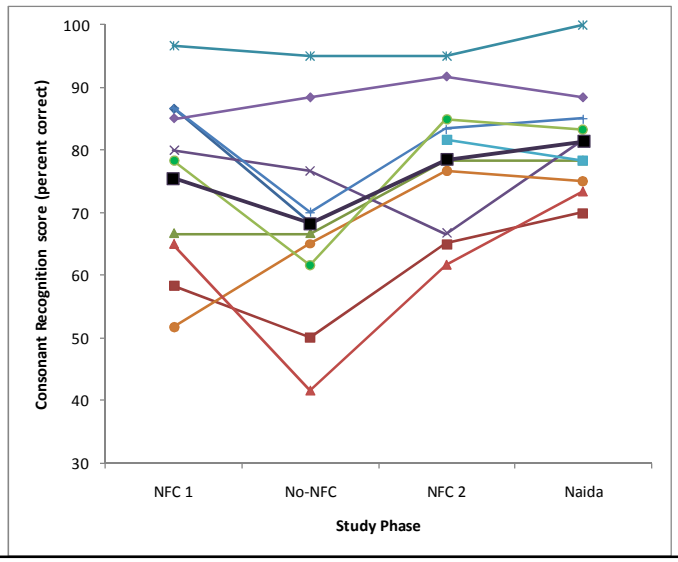
- Savia 311 and 411, modified to include prototype NFC
- Naida V SP and UP with SoundRecover® NFC

Glista, D., Scollie, S., Polonenko, M., & Sulkers, J. (2009, November). Prototype nonlinear frequency compression versus SoundRecover®: A comparison of performance in children. *The Hearing Review.*

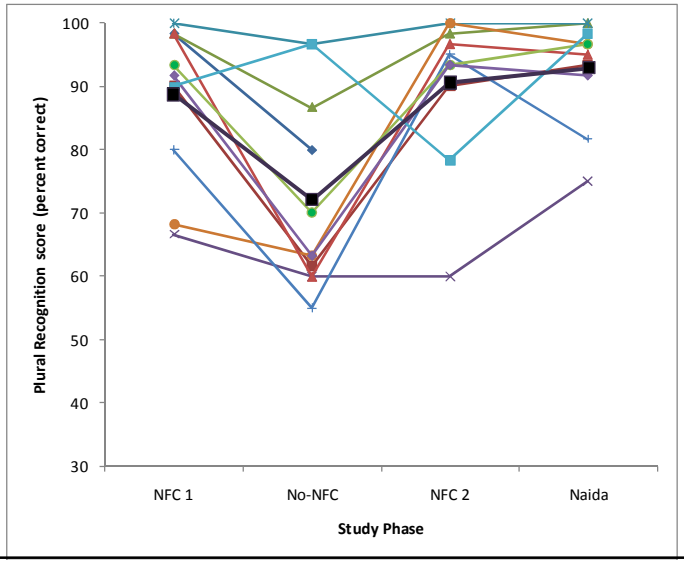
Devices were well matched.



Consonant Recognition: some children benefit from NFC.



Plural Recognition: most children benefit from NFC.

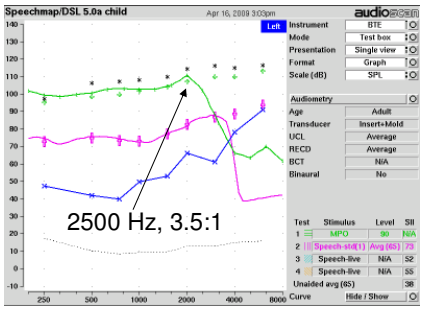


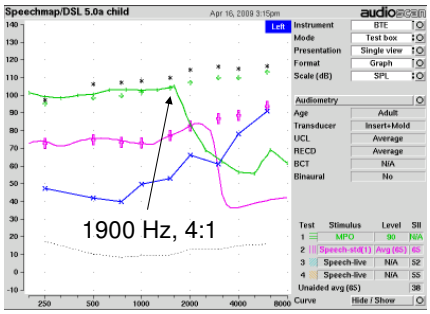
Fitting & Verifying

- Can electroacoustic tests tell us when too much frequency compression has been applied?
- In our trial, fittings that overlapped S and SH were typically rejected. So….

Clinical verification

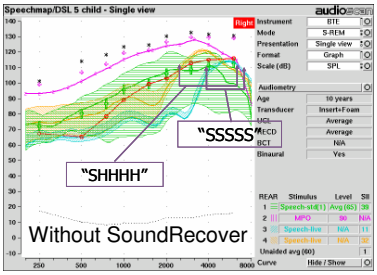
- MPO measures are invalid above the cutoff (shown).
- Pure tone sweeps are invalid above the cutoff (not shown).

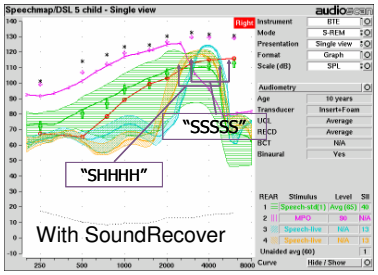




Clinical verification

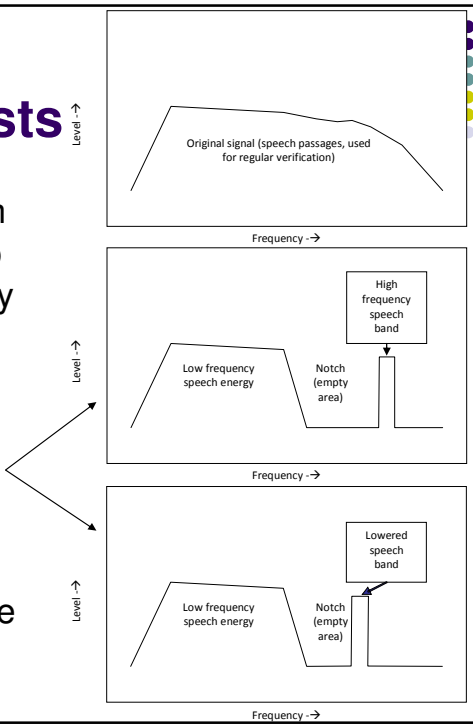
- Live speech productions of /s/ and /sh/ can be used.
- They are not calibrated, but provide an informal way to see change in the frequency location of speech sounds.





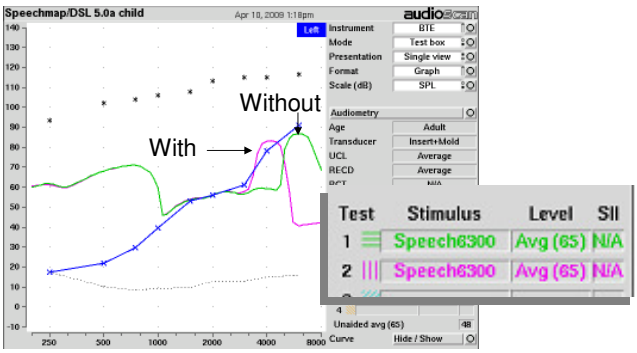
New clinical tests

- A new test signal from the Verifit allows us to see if a high frequency band is lowered.
- Run with & without SoundRecover.
- Test at 3.1, 4k, 5k or 6.3kHz.
- <u>May</u> offer a calibrated alternative to live voice /s/ and /sh/.



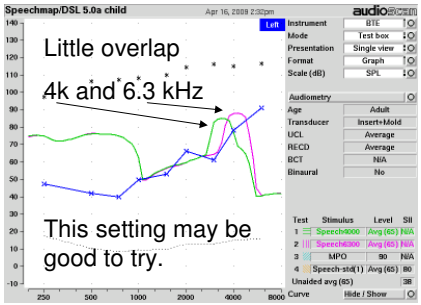
Our uses of this new test

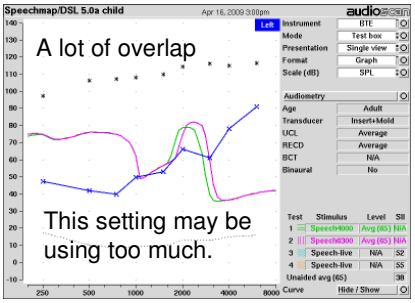
- Are the 4 and 6.3kHz bands audible with vs. without SoundRecover?



Our uses of this new test

- With SoundRecover on, are the 4kHz and 6kHz regions overlapping?
  - Our previous research tells us that overlapping /s/ and /sh/ using high SoundRecover settings led to rejection.
  - The 4kHz and 6.3kHz bands are similar to /s/ and /sh/.





In the clinic & the future…

- This is a viable technology for some losses. As with most technologies, it does need to be individually fitted. Working in the frequency domain is a new mindset!
- We still need to learn more, for example:
  - Candidacy (lowest versus highest loss limits, cochlear implant candidacy), best settings.
  - Asymmetry
  - Younger versus older populations

My colleagues in this work:

- Danielle Glista, Ph.D. Candidate
  - Collaborated in the development of the fitting method and field trial design, and conducted much of the data collection to date, along with Marlene Bagatto and Melissa Polonenko
- Vijay Parsa, Ph.D.
  - Spearheaded the sound quality projects and modelling, along with Guo Chen and Rainer Huber and Andreas Seelisch
- Fellow researchers Richard Seewald, Marilyn Kertoy, Marc Joanisse
- Support from Phonak AG and granting agencies: NSERC/CIHR CHRP, The Hearing Foundation of Canada, and the Help2Hear Foundation

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