Panel Session on Frequency Lowering Technology

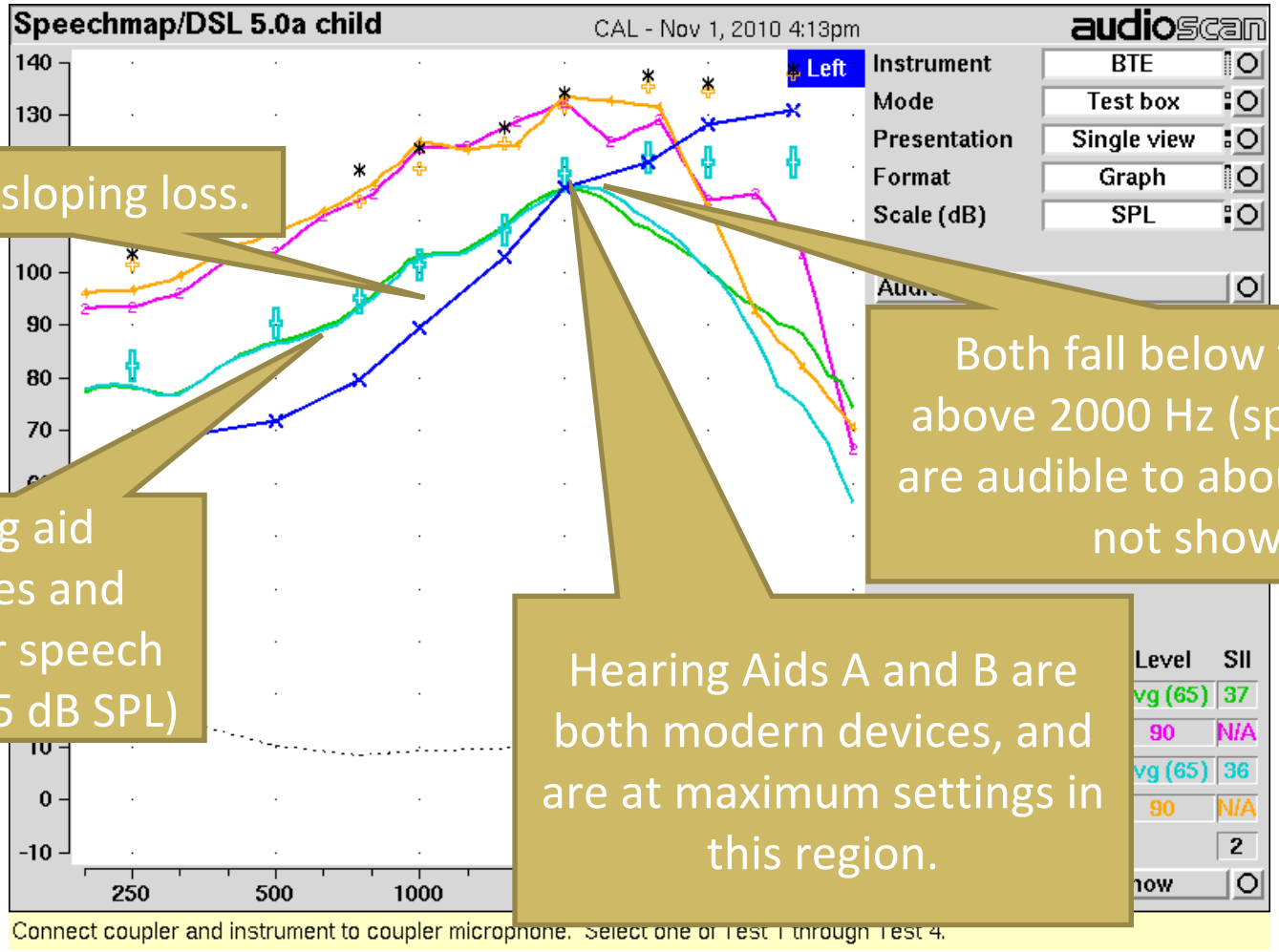
Panel chair:	Susan Scollie
Panel members:	Jace Wolfe
	Andrea Bohnert
	Danielle Glista
	Michael Boretzki

Clinical rationale for frequency lowering:

- Bandwidth matters:
  - Children need access to the high frequency sounds of speech, to understand and monitor:
    - See: Moeller et al, 2007, a review article by Stelmachowicz et al (2004), previous proceedings from this meeting, and this conference's presentation by Andrea Pittman.
- But:

  If audibility cannot be provided via the available bandwidth and gain/output, is it beneficial to lower the cues to an audible frequency range?

Bandwidth limitations in current-era devices:



A severe sloping loss.

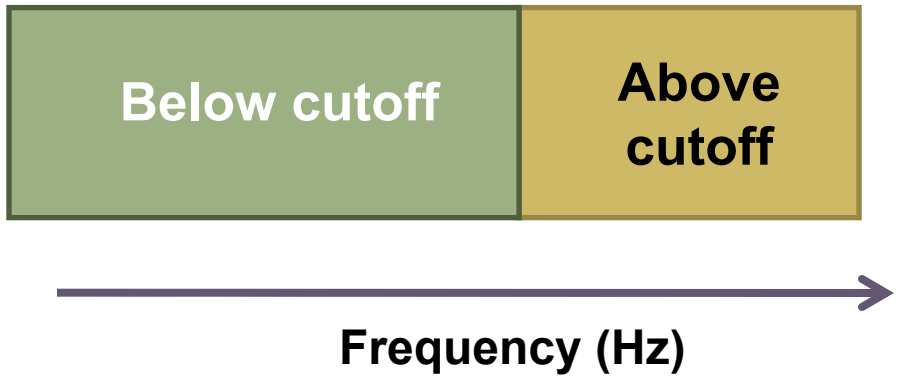
Hearing aid responses and targets for speech (input at 65 dB SPL)

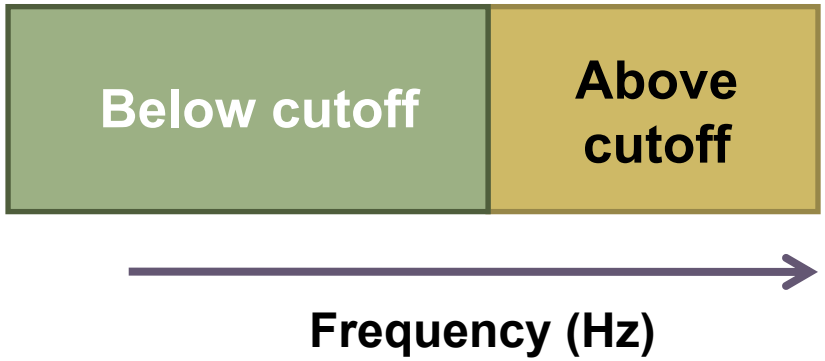
Hearing Aids A and B are both modern devices, and are at maximum settings in this region.

Both fall below threshold above 2000 Hz (speech peaks are audible to about 2500 Hz – not shown).

Frequency Lowering (FL): two types

- Frequency Compression (FC)
  - E.g.: Phonak SoundRecover
- Frequency Transposition (FT)
  - E.g.: Widex AudibilityExtender
- Review: Simpson (2009), Trends in Amplification





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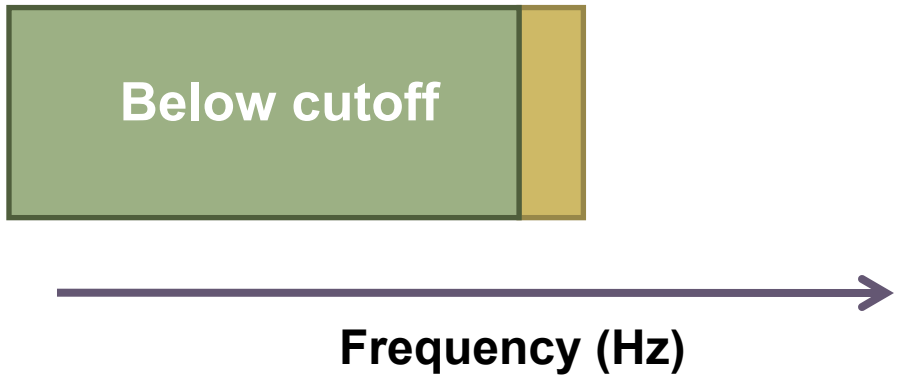
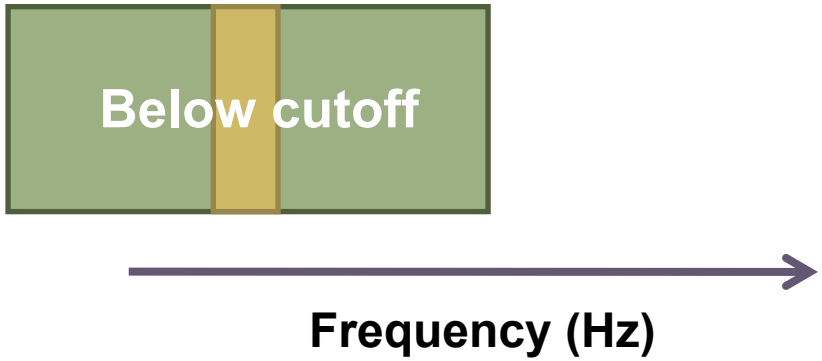




Some studies of frequency lowering:

(other studies have been done in adults, plus other non-peer reviewed in kids)

- FC in children:
  - Glista et al., 2009a
    - FC improves detection/recognition (group vs individual)
    - Significant candidacy factors (hearing loss, age group)
- FT (various types) in children:
  - Miller-Hansen et al, 2003, MacArdle et al, 2001
    - FT improves detection & recognition (group vs individual)
  - Auriemmo et al, 2009
    - FT + training improved consonant recognition (other outcomes)
  - Smith et al, 2009
    - FT improved consonant recognition

Efficacy? Experimental design factors…

Baseline	Aid	Fitting	Time	Measures
• FC should be compared to the best possible fitting. • Does this change over time as the fittable bandwidth extends? Candidacy?	• FC is best evaluated within-devices. • Allows us to hold all other device variables constant.	• FC settings should be appropriate to the individual. • Optimal settings are not yet known, but fitting, tuning, and verification are possible.	• An acclimatization period may be necessary. • What does this mean for studies comparing FL strategies?	• As with all hearing aid research, blinding is needed for subjective measures. • Sensitive tests are needed but may not test all speech sounds – a test battery?

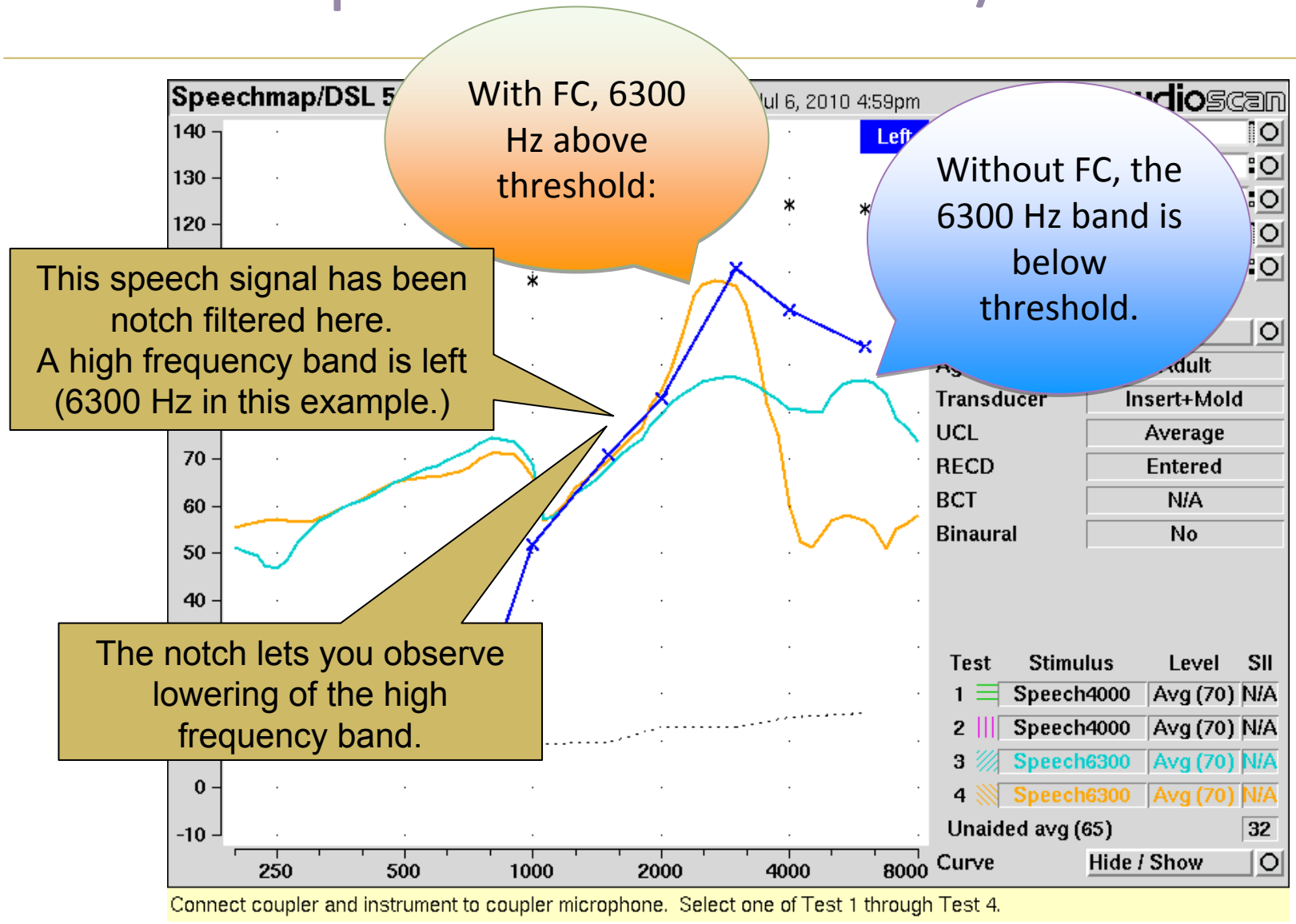
Fitting Method (pediatric):

1) Provide more audibility of high frequency cues than is possible with a well-fitted device. The frequency response is based on DSL5 child.

2) We verify using measures that show us audibility of specific high frequency speech bands (see Glista & Scollie, AudiologyOnline 2009)

UWO, and Hearts for Hearing, and University Mainz are all following this method.

Verifit “Speech Bands” with/without:



Today's panel:

- Jace Wolfe, Oklahoma, USA:

  Evaluation of FC for moderate hearing losses.

- Andrea Bonhert, Mainz, Germany:

  Evaluation of FC for moderate to profound losses.

- Danielle Glista, London, Canada:

  Do children need an acclimatization period after FC fitting?

- Michael Boretzki, Staefa, Switerland:

  Future directions in evaluating SoundRecover.

Evaluation of frequency compression for moderate hearing losses

Audiologists

Jace Wolfe, Ph.D., CCC-A
Kimberly Fox, AuD., CCC-A
Heather Kasulis, AuD, CCC-A
Brooke Shoemaker, Au.D., CCC-A

Speech-Language Pathologists

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Teresa H. Caraway, Ph.D., CCC-SLP, LSLS Cert. AVT
Wendy DeMoss, M.S., CCC-SLP, LSLS Cert. AVT
Tamara Elder, M.S. CCC-SLP, LSLS Cert. AVT
Darcy Stowe, M.S. CCC-SLP, LSLS Cert. AVT
Natalie O'Halloran, M.S. CCC-SLP, LSLS Cert. AVT
Lindsay Steuart, M.S., CCC-SLP, LSLS Cert. AVT
Krissa Cummins, M.S., CCC-SLP

Support Staff

Kris Taylor
Pati Burns
Kristy Murphy
June Cashion
Susan LeFleuer
Megan Miller
Kerri Brumley
Sherry Edwards
Katie Edwards

What about children with moderate hearing loss?

- Stelmachowicz and colleagues (2000, 2001, 2002, 2004) have shown that children with moderate to moderately severe SNHL need a wider bandwidth for optimal speech recognition.
- Young children with moderate to moderately severe SNHL show delays in fricative production (Moeller et al., 2007; Stelmachowicz et al, 2004).
- Children with access to high-frequency information (i.e., >4K Hz) demonstrate better short-term word learning (Pittman, 2008).

Study Objectives

- Does non-linear frequency compression (SoundRecover in the Nios hearing aid) improve speech recognition for children with moderate SNHL?

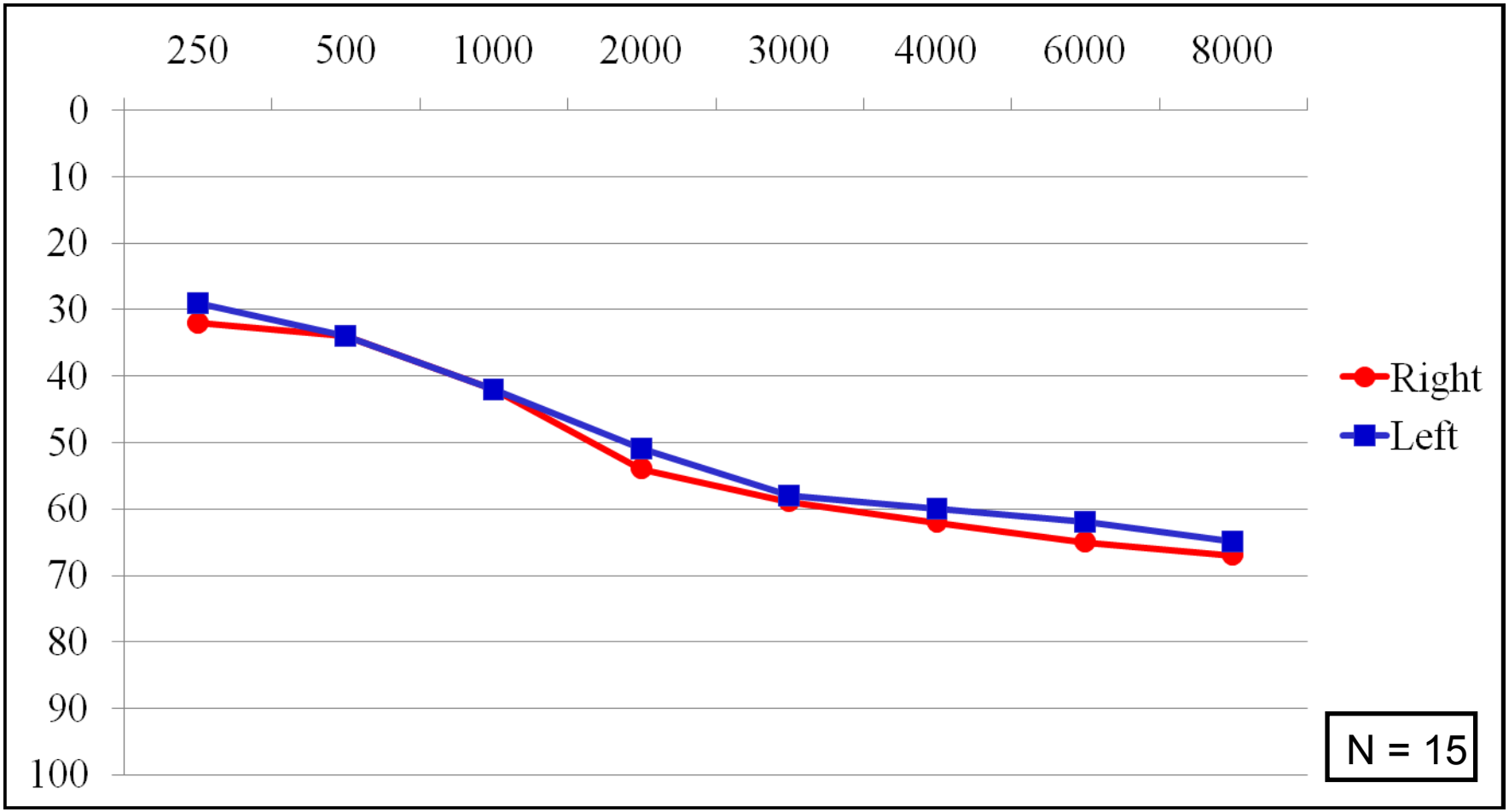
- Does non-linear frequency compression (SoundRecover in the Nios hearing aid) improve speech production for children with moderate SNHL?

Methods

- 18 children with moderate to moderately severe high-frequency SNHL fitted with Phonak Nios micro-sized behind-the-ear hearing aids.

- Today, we will be reporting on results for 15 children.

Mean Audiogram



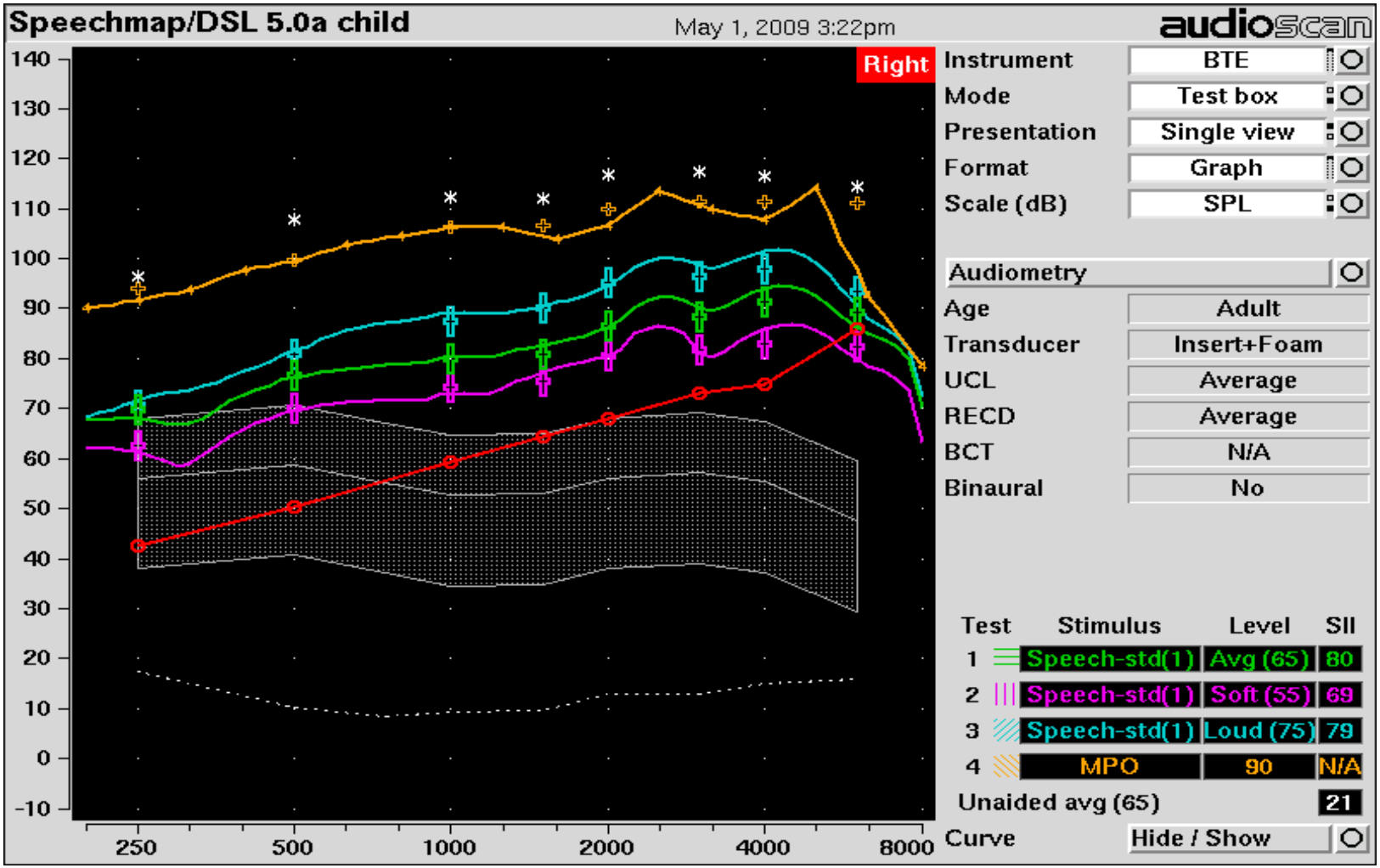
Subject Characteristics

- Full-time users of digital behind-the-ear hearing aids.
- No ANSD
- No previous experience with frequency lowering technology
- Oral-Aural communicators with English as primary language
- 5-13 years of age (Mean Age: 10 years, 6 mths)

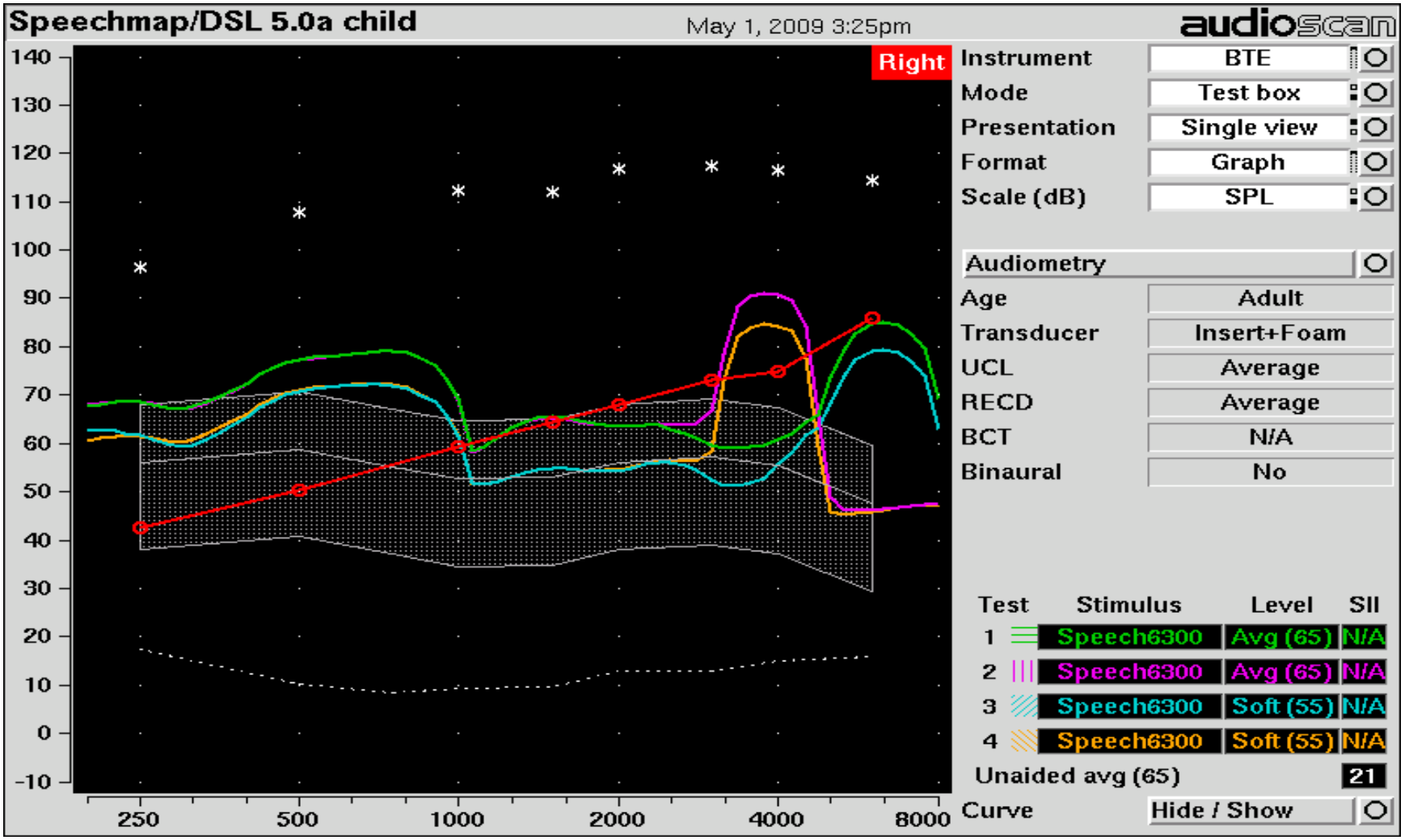
Procedures

- Measured unaided audiometric thresholds with insert earphones coupled to foam eartips.
- Measured RECD with same foam eartip.
- Used Audioscan Verifit to calculate threshold at TM in dB SPL.
- Fit hearing aid to appropriate earmold.
- Entered thresholds (dB HL) into Phonak iPFG fitting software.

Step 1: Fit to target without frequency compression



Step 2: Ensure that high-frequency sounds are audible



Procedures

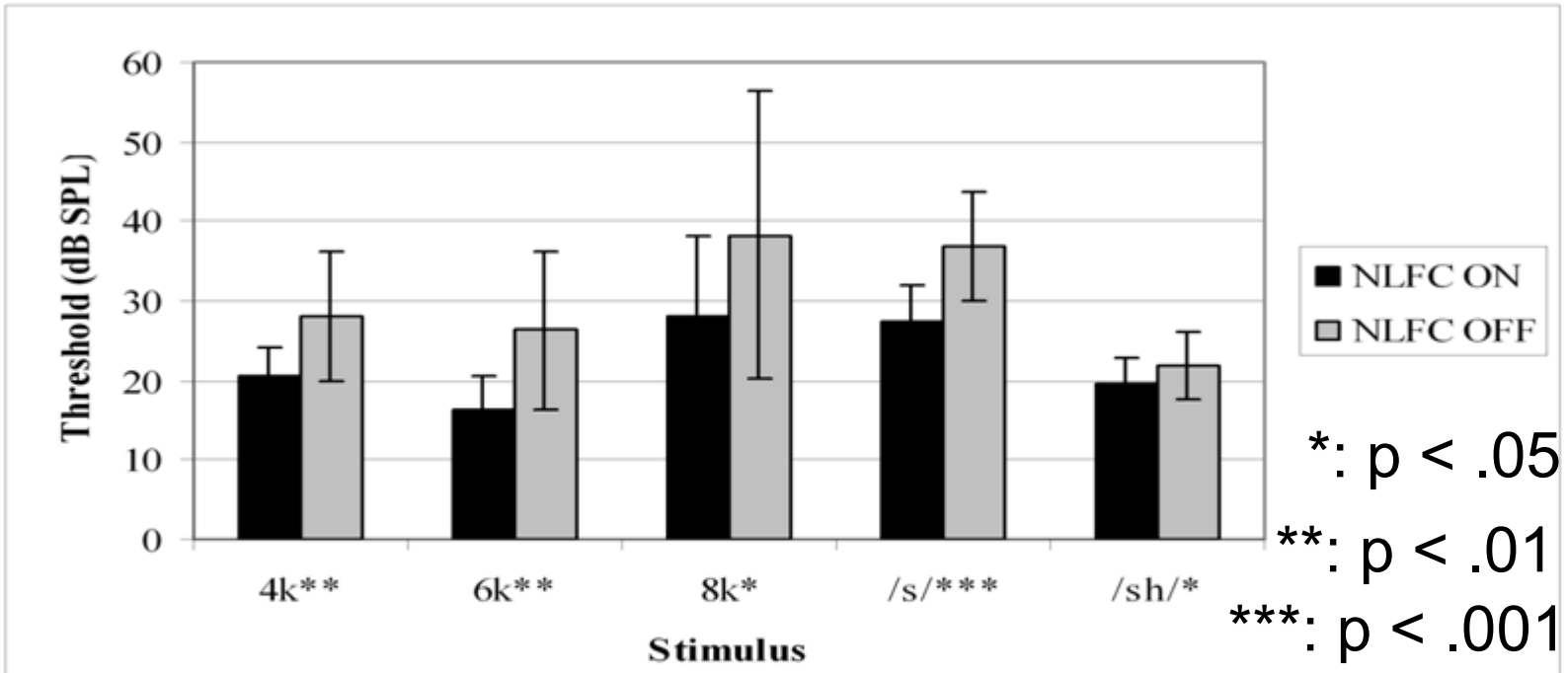
- Evaluated speech production, speech recognition, and aided thresholds with subjects' own hearing aids and Phonak Nios BTE hearing aids.
- Subjects wore Phonak Nios BTE hearing aids for two 6-week periods:
  - NLFC Off
  - NLFC On
- Order in which NLFC was used was counter-balanced across subjects.
- After completion of the two 6-week trials, the subjects wore the hearing aids with NLFC enabled for 6 months.

Procedures

- Aided Thresholds
  - 4000, 6000, & 8000 Hz
  - Recorded /sh/ & /s/, Univ Western Ontario
- Speech Recognition
  - University of Western Ontario Plural Test
  - Phonak Logatome Test
  - BKB-SIN

- Results

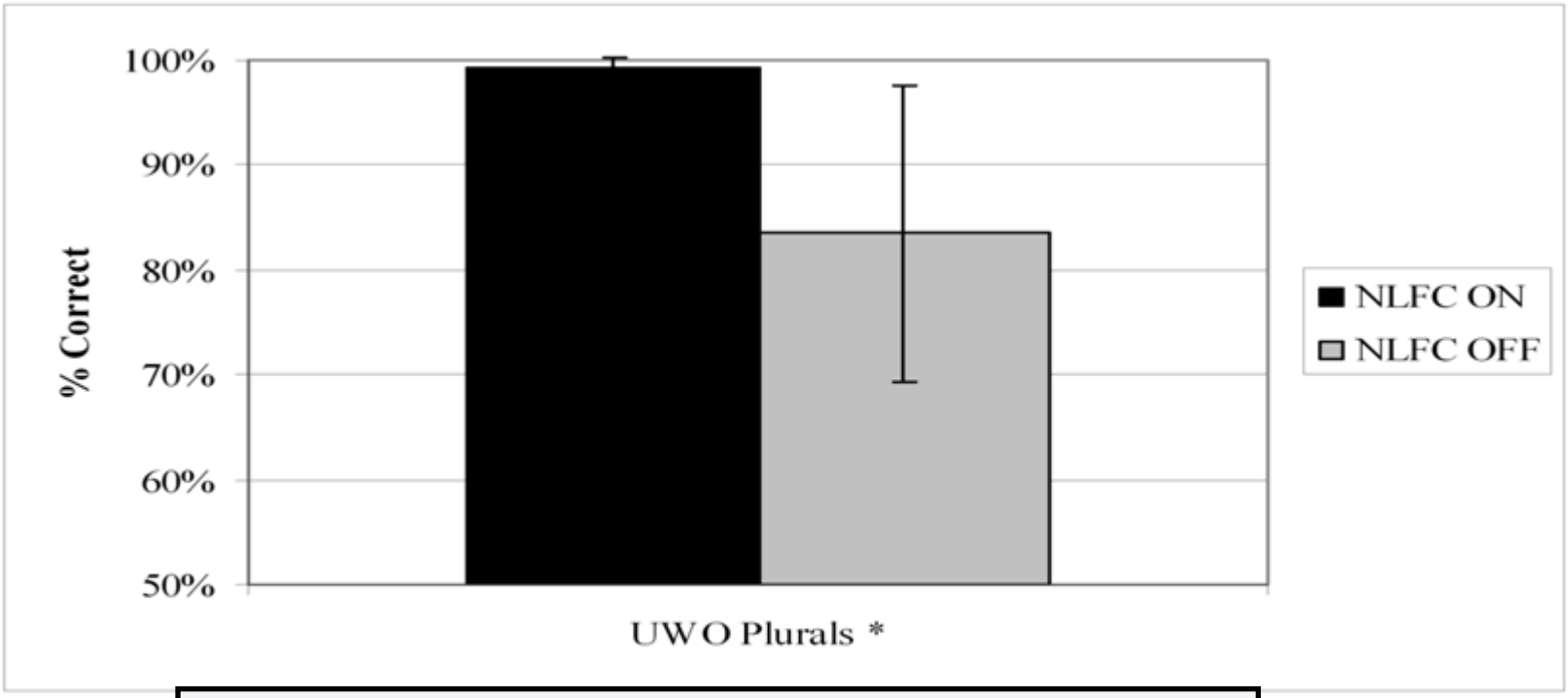
Aided Thresholds (dB HL)
NLFC Off vs. NLFC On



NLFC provides a statistically significant improvement in aided thresholds.

Wolfe et al. (in press), J Am Acad of Audiol

UWO Plural Test
NLFC Off vs. NLFC On

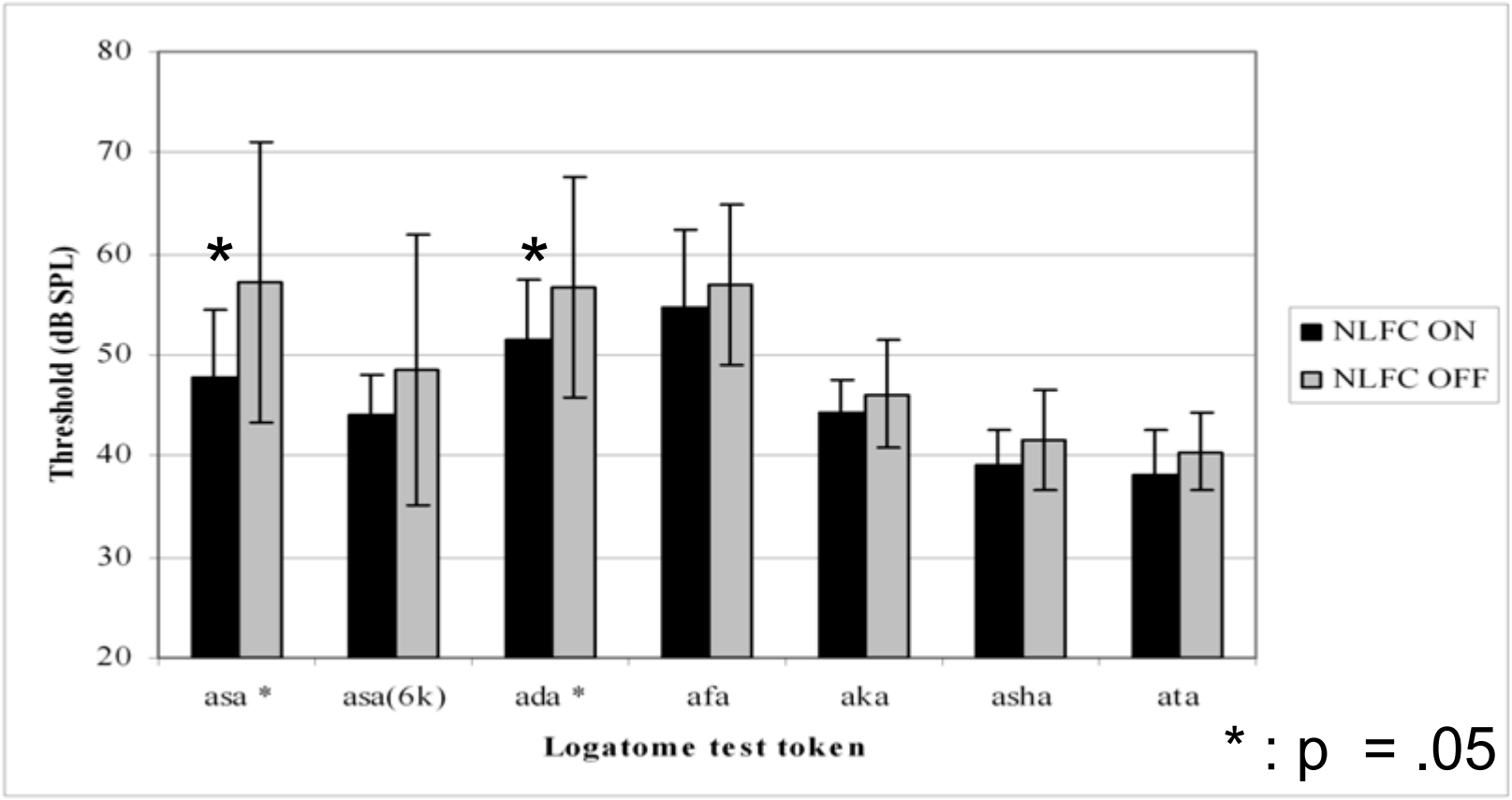


NLFC improves speech recognition on UWO Plural Test by 16% points.

* P < .001

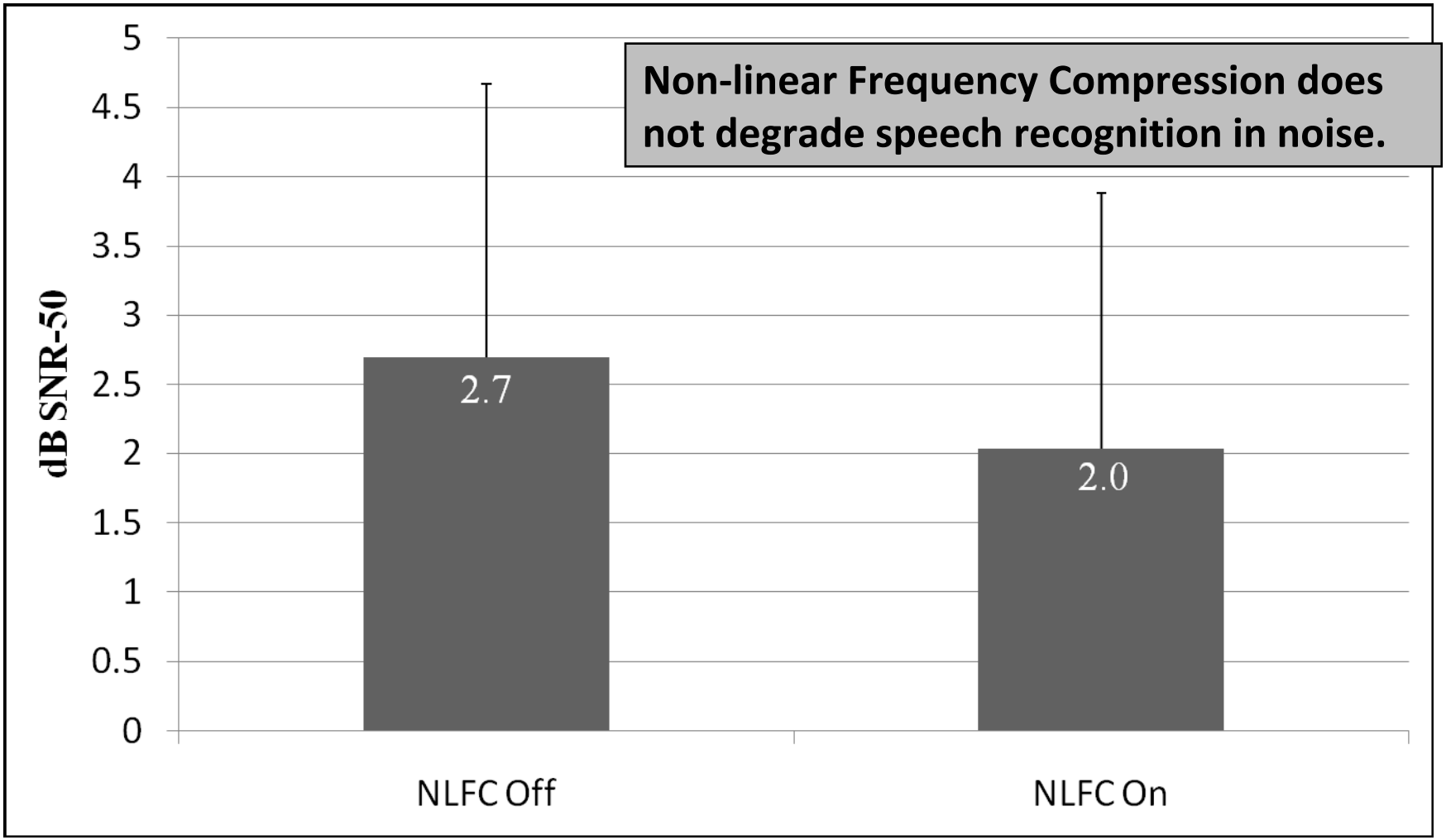
Wolfe et al. (in press), J Am Acad of Audiol

Speech Recognition Threshold (dB SPL) for 7 VCV Tokens



Wolfe et al. (in press), J Am Acad of Audiol

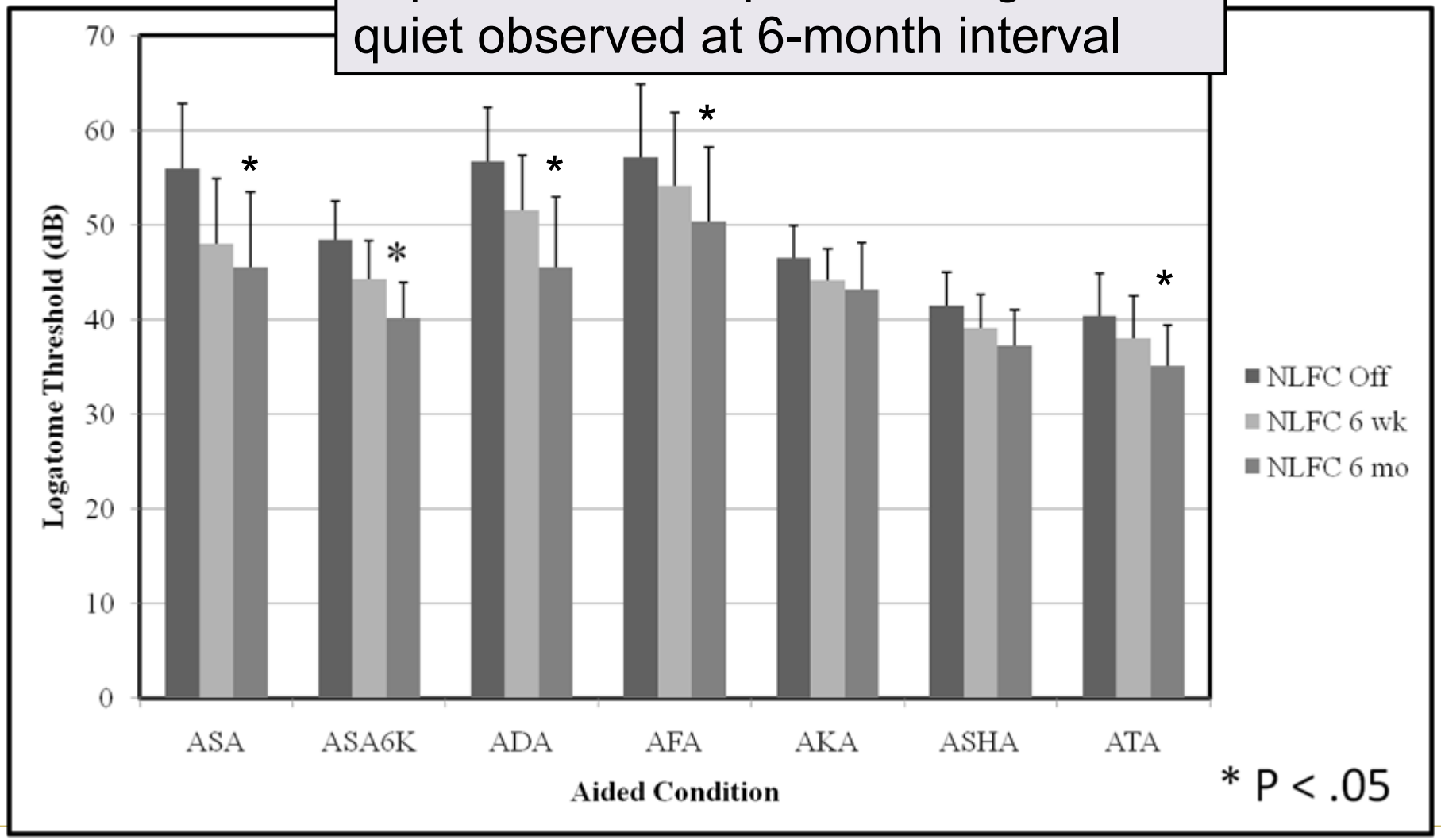
Speech Recognition in Noise
NLFC Off vs NLFC On



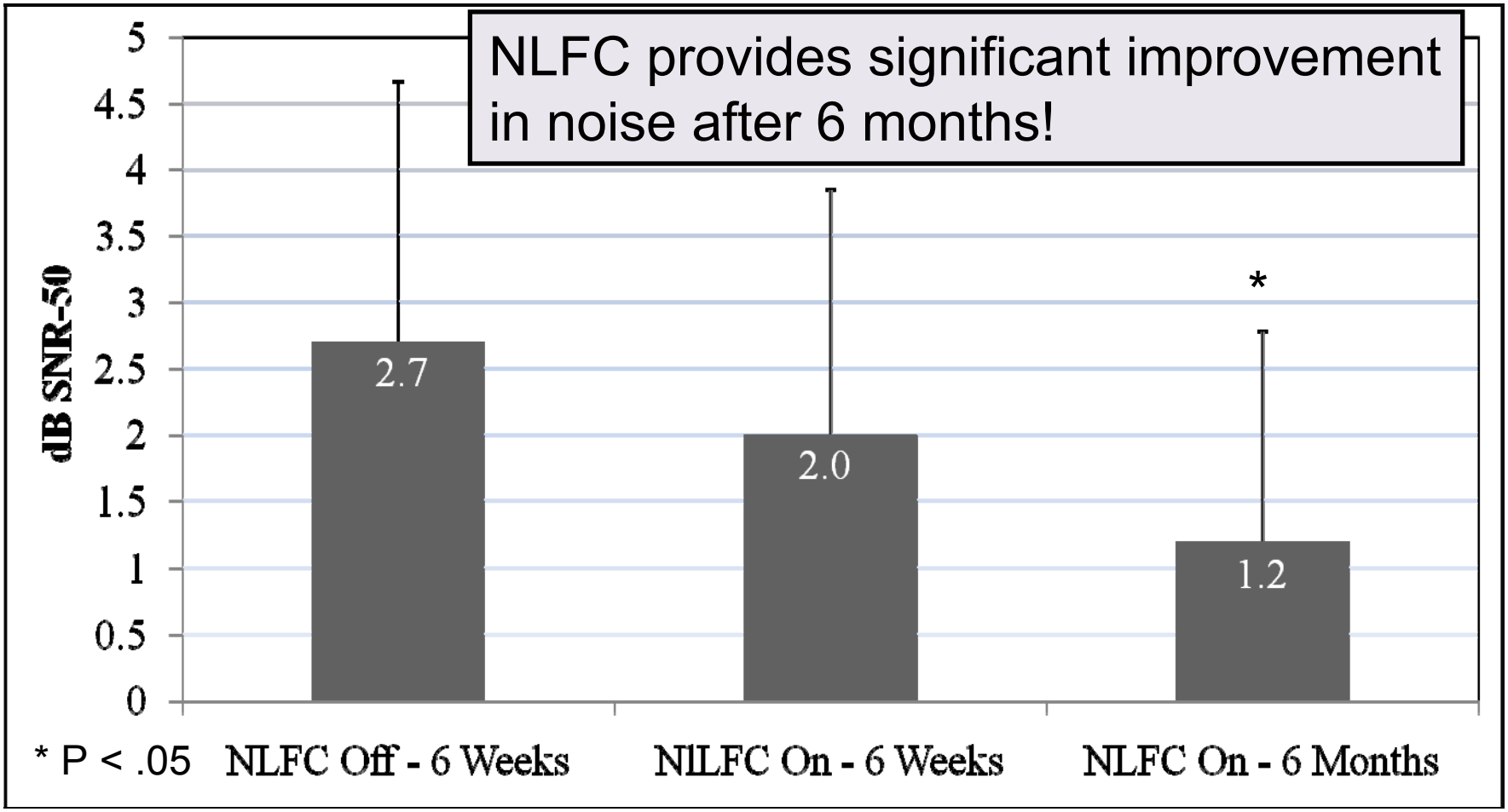
Wolfe et al. (in press), J Am Acad of Audiol

Logatome Thresholds

Improvement in speech recognition in quiet observed at 6-month interval

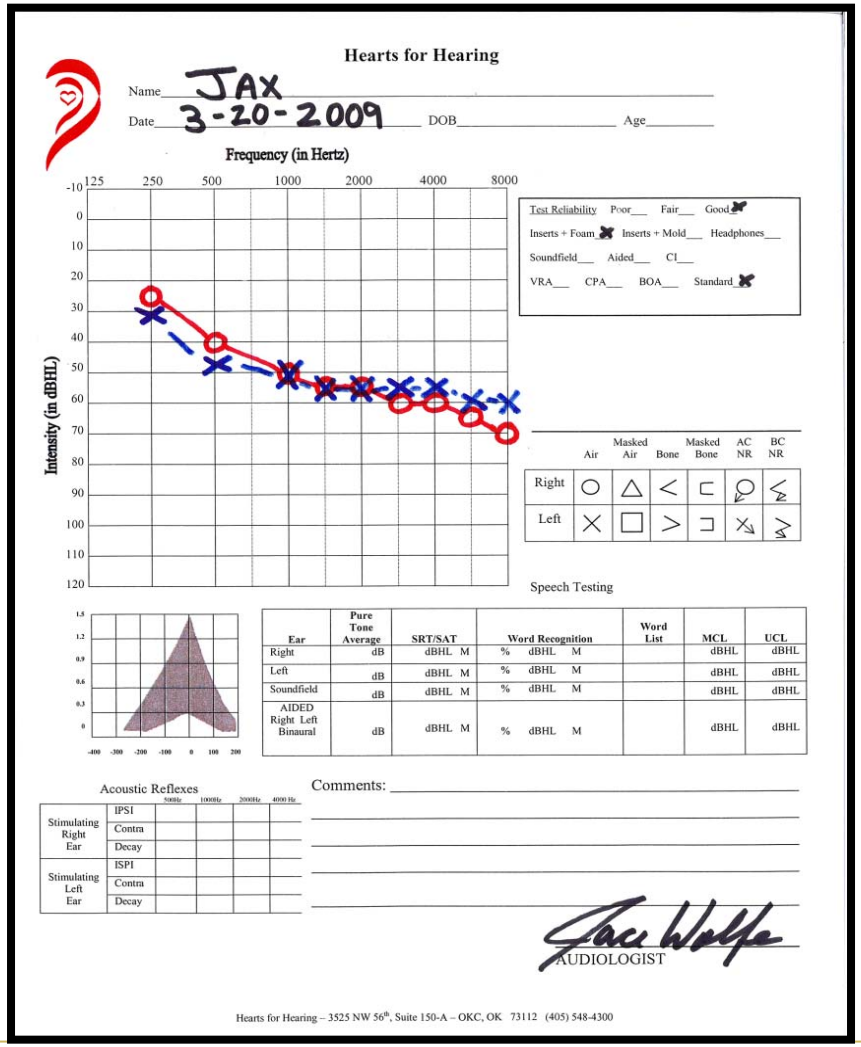


Speech Recognition in Noise on BKB-SIN



Jax

- 13-year old boy
- Congenital hearing loss of unknown etiology
- Previously wore Perseo 211 Behind-the-Ear hearing aids
- Excels in typical classroom placement



Summary

- NLFC improves speech recognition and speech production for children with moderate hearing loss.
- Research needed to examine pros and cons of mild losses!
- Verification is key
  - Probe microphone measures with calibrated stimuli designed for verification of frequency lowering hearing aids or with live voice stimuli (/sh/, /s/).
  - Ensure adequate sound quality
  - Aided speech recognition
- Remember earmold acoustics!
- Children may need to acclimate
  - May require time to develop speech recognition and production.

Acknowledgements

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- Andrew John, Ph.D., University of Oklahoma Health Sciences Center
- Erin Schafer, Ph.D., University of North Texas
- Myriel Nyffeler, Ph.D., Michael Boretzki, Ph.D., and Christine Jones, Au.D., Phonak

- Thank you for your attention

Evaluation of frequency compression for moderate to profound hearing losses

Andrea Bohnert

University Medical Center of the
Johannes Gutenberg-University Mainz

Department for Oto-Rhino-Laryngology,
Division for Communication Disorders

UNIVERSITÄTSmedizin.
MAINZ

Children with a severe to profound loss:

- Can we demonstrate speech recognition benefits?
- In quiet as well as in noise conditions?
- Can articulation be improved?

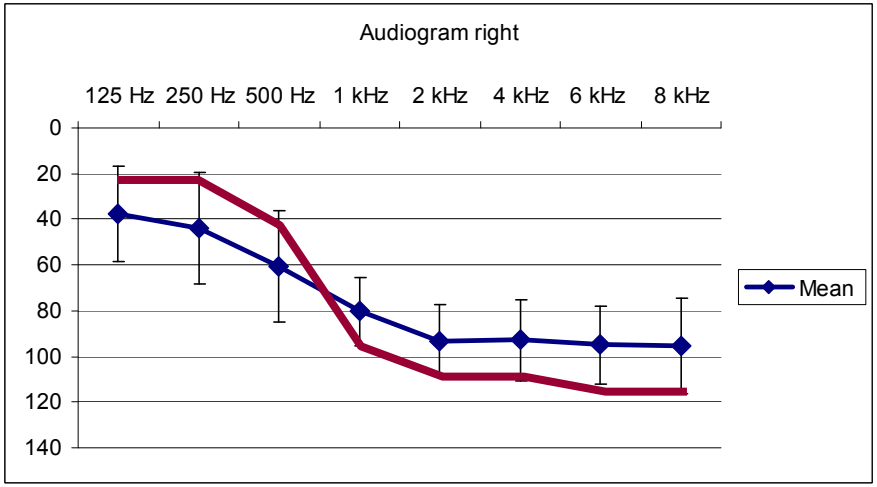
Which configurations of hearing loss will benefit….

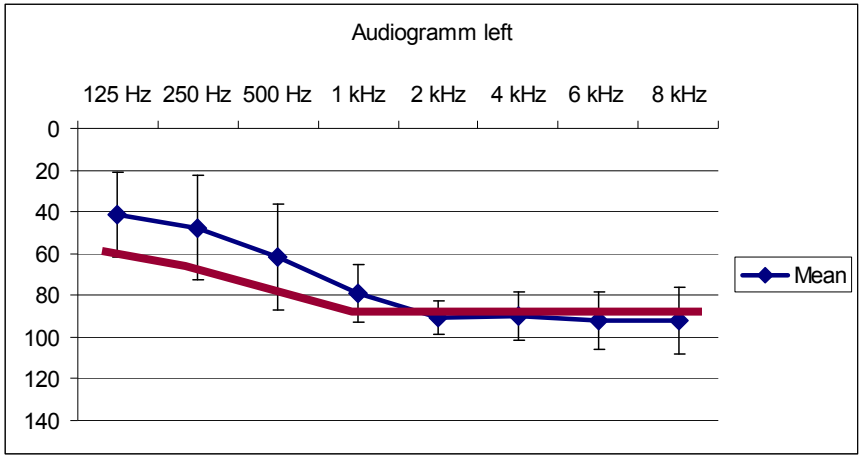
- *Steep or flat losses???*

Clinical field trial

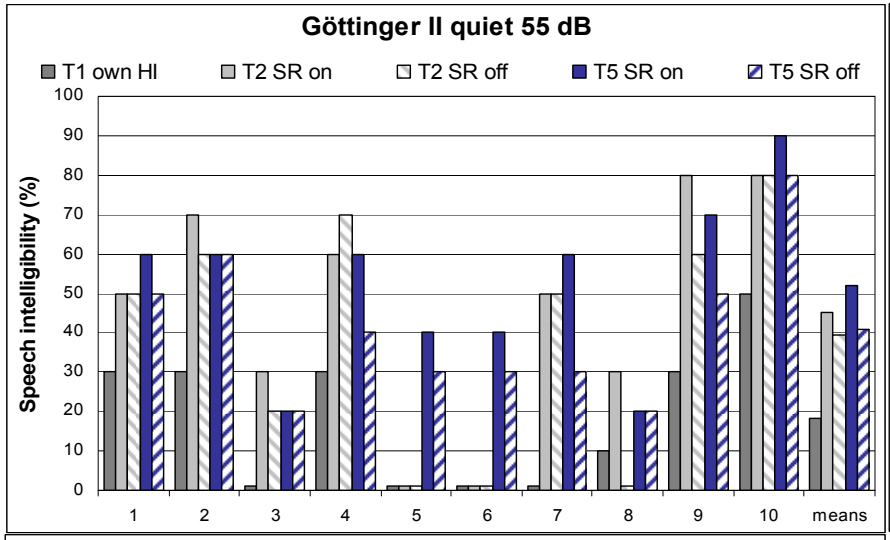
- 4 female, 9 male (6 – 15 years)
- Average age: 10,5 years
- All experienced HA users
- Fitted on DSL basis with high-quality HA
- 4 main stream school
- 9 school for HI

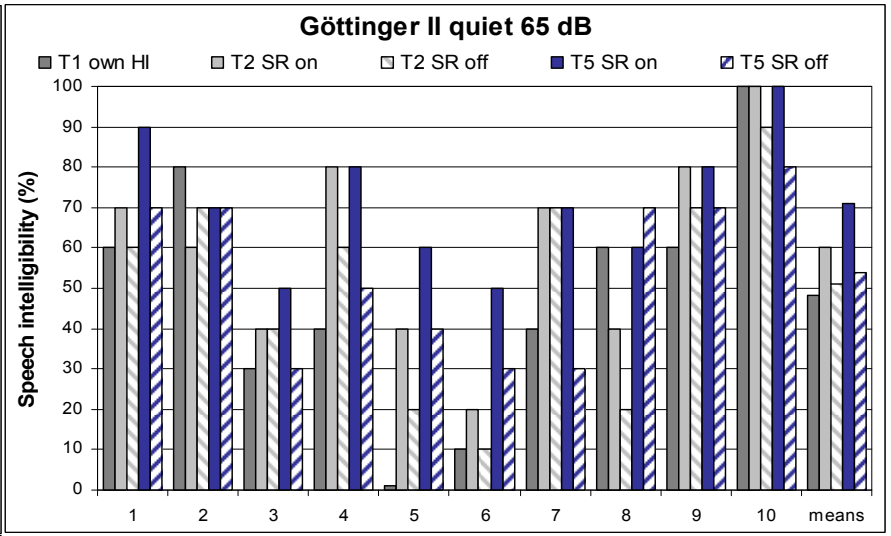
Audiogram right / left

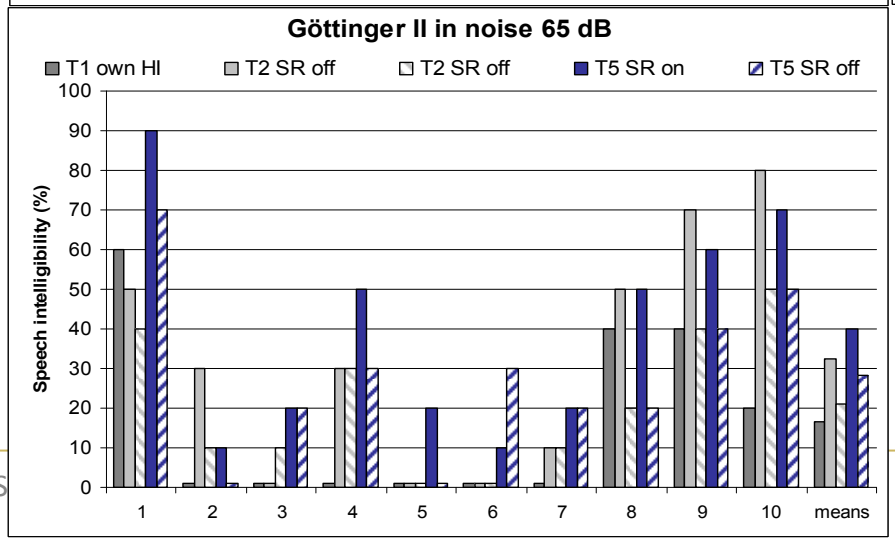




Study - Group results – GII T1 vs T5







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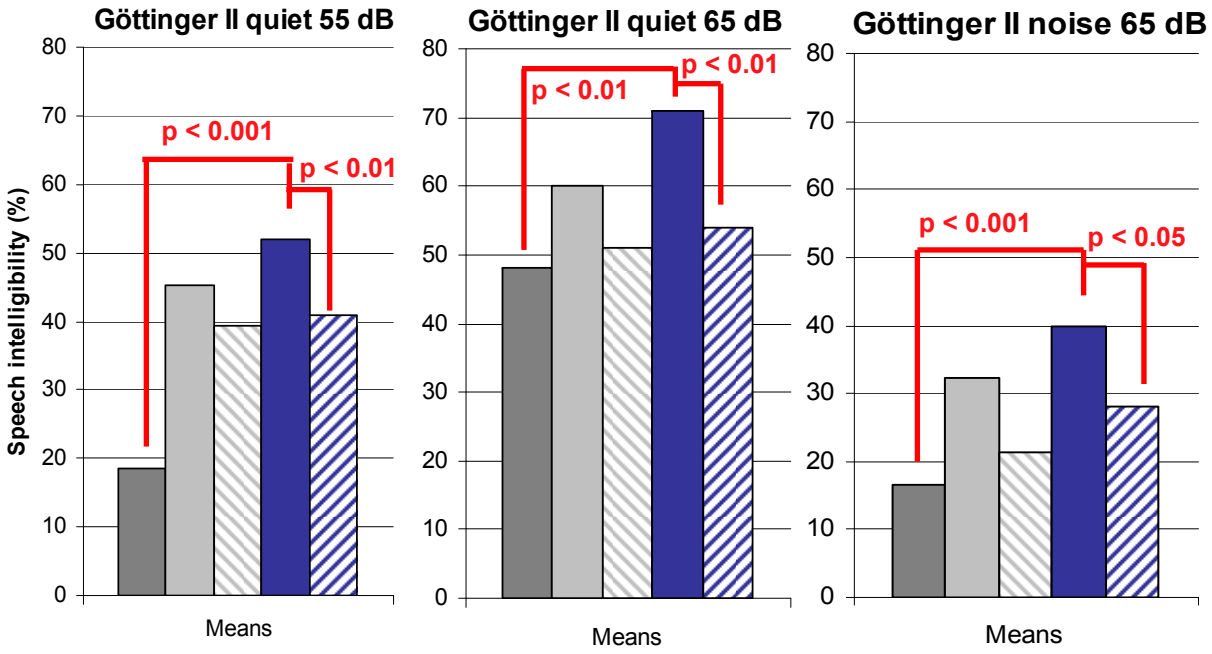
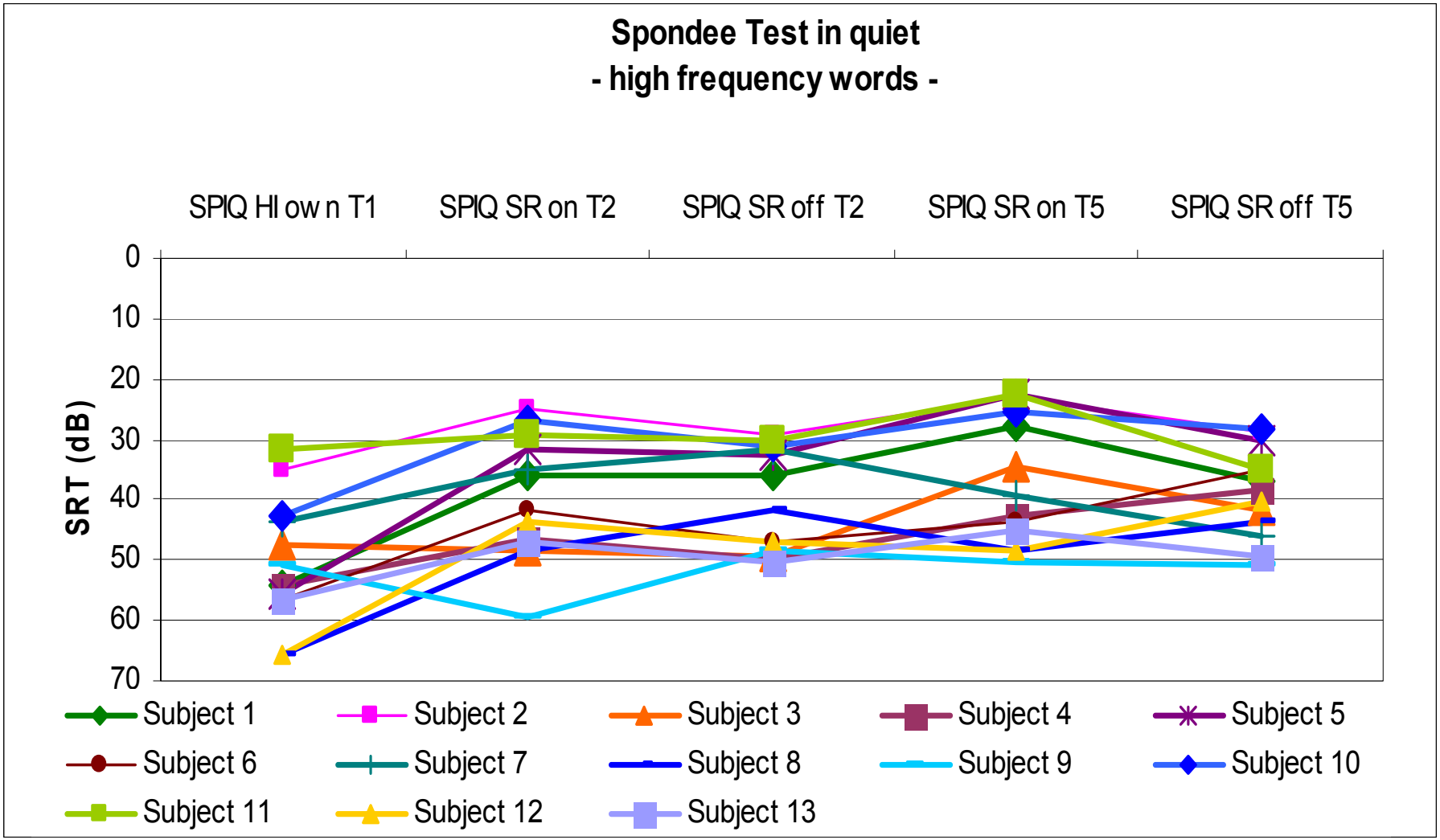


Study – Group results – AAST Spondee in quiet



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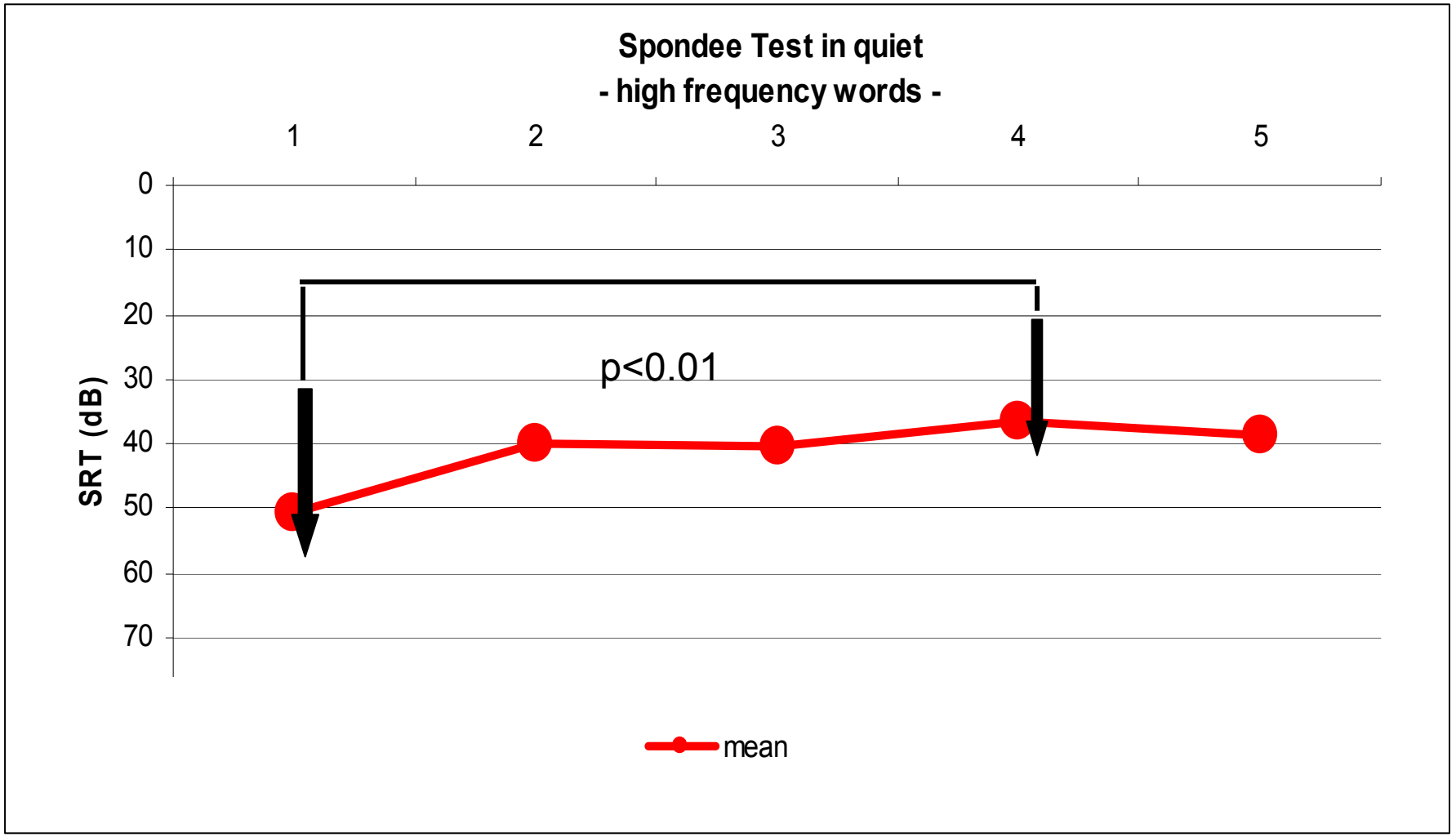
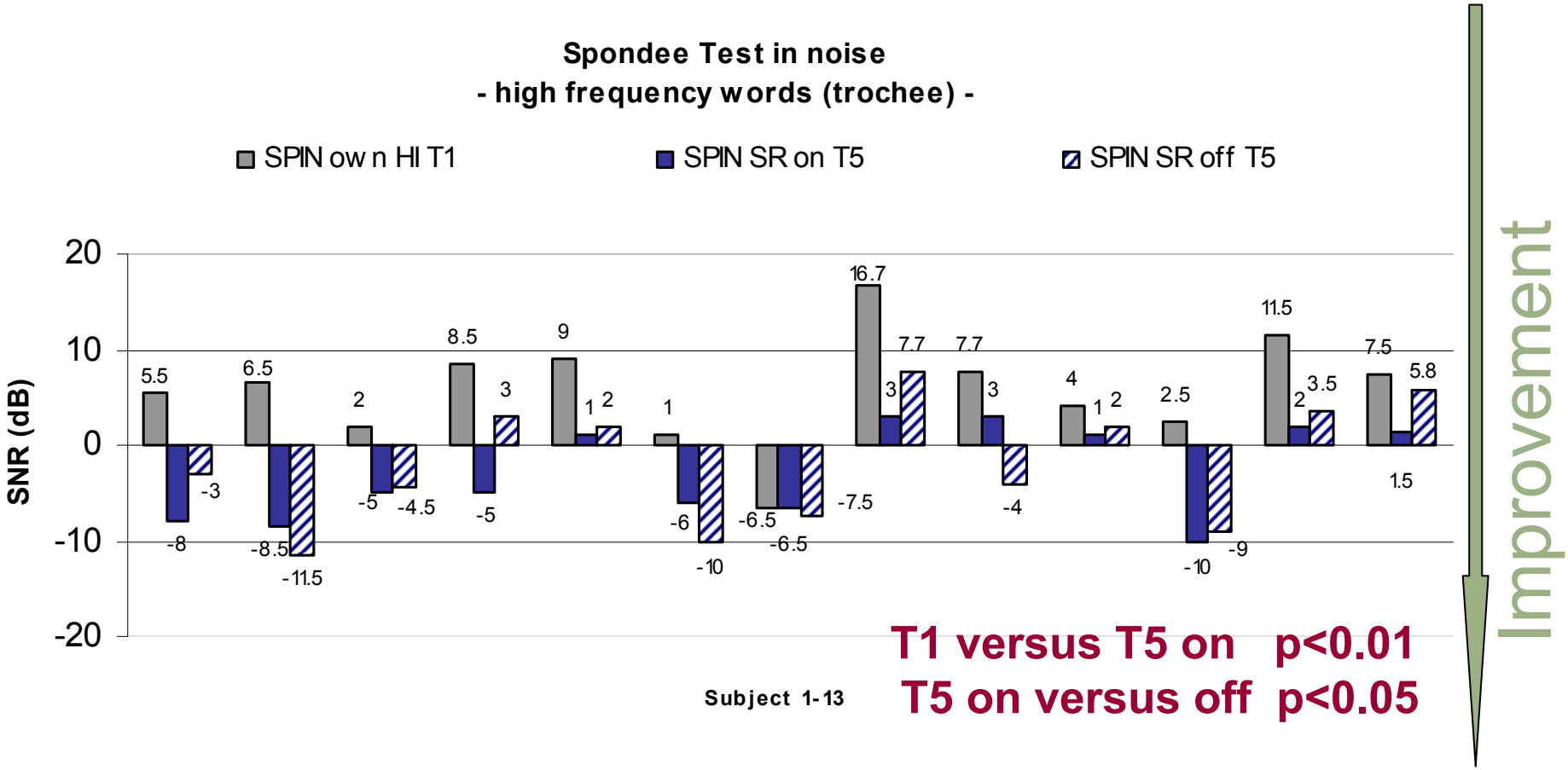
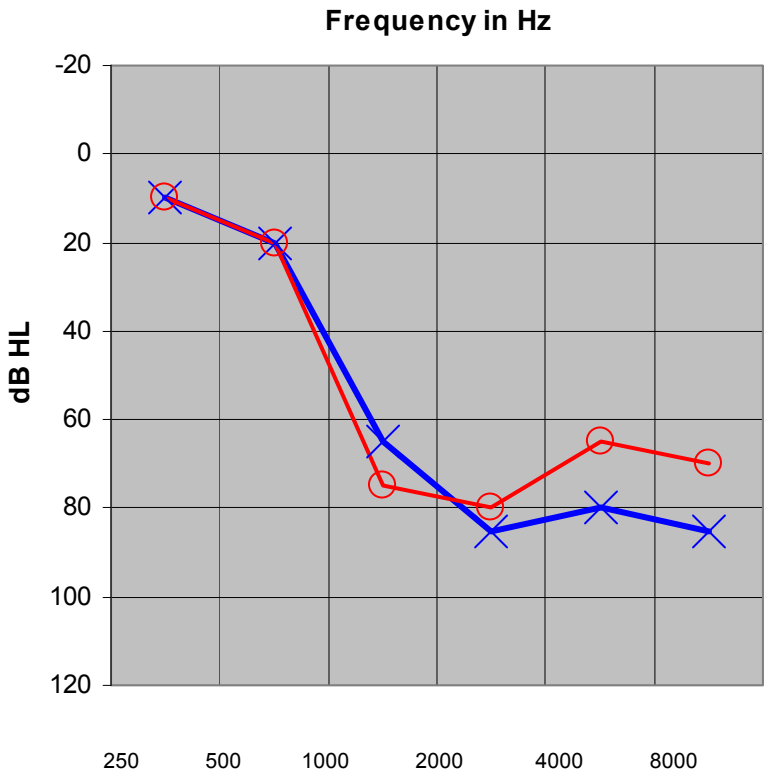


Study – Group results – AAST Spondee in noise



Two examples…

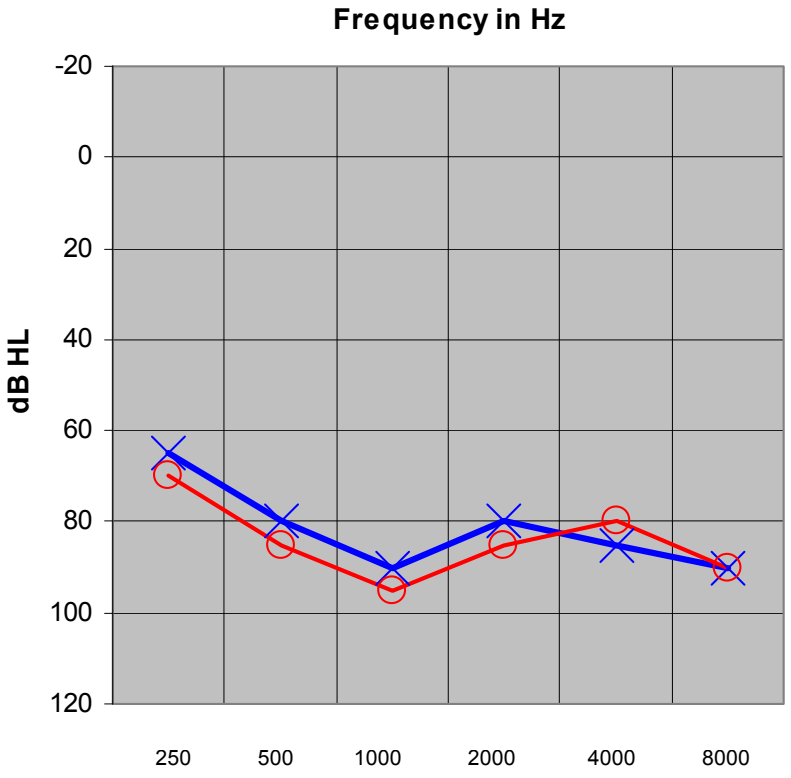
Sub A steep loss



10 y, good speech development

Own HI = Eleva 411

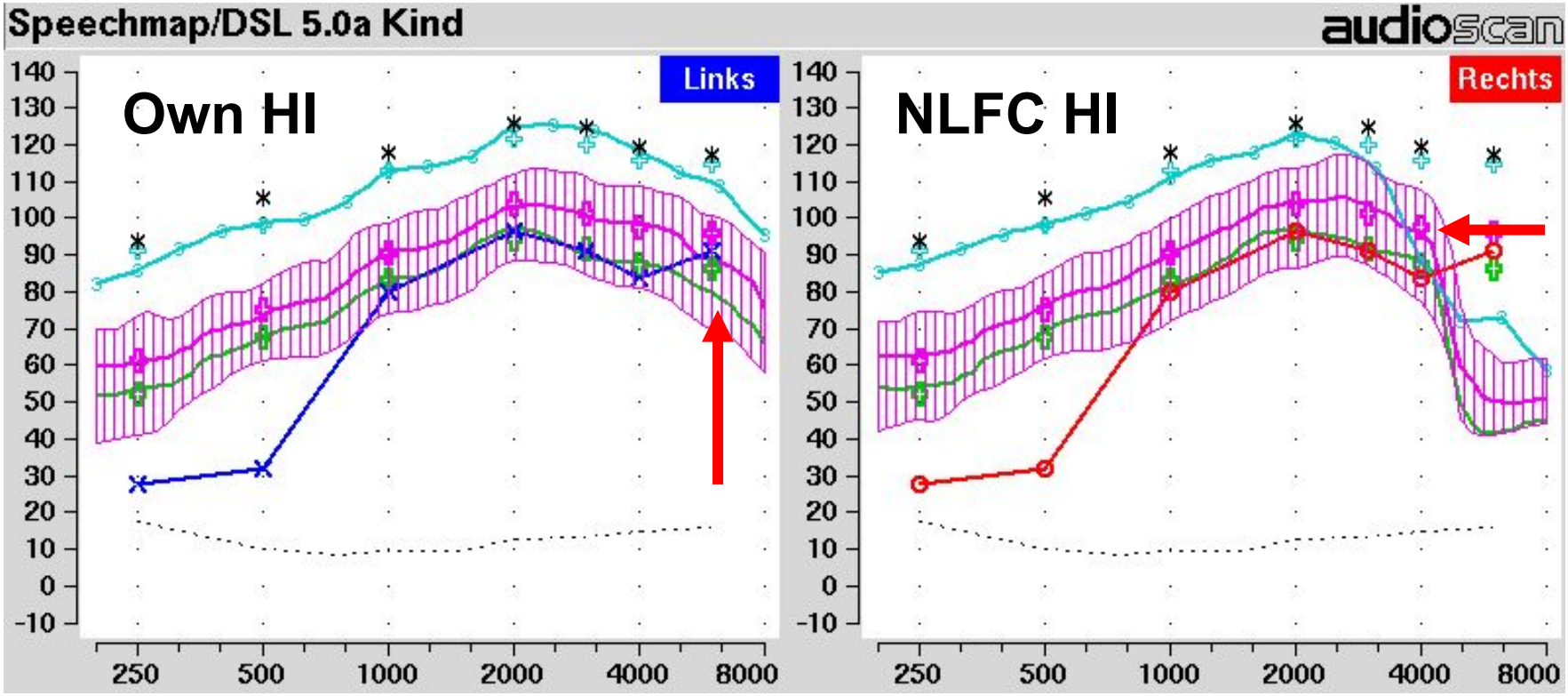
Sub B flat loss



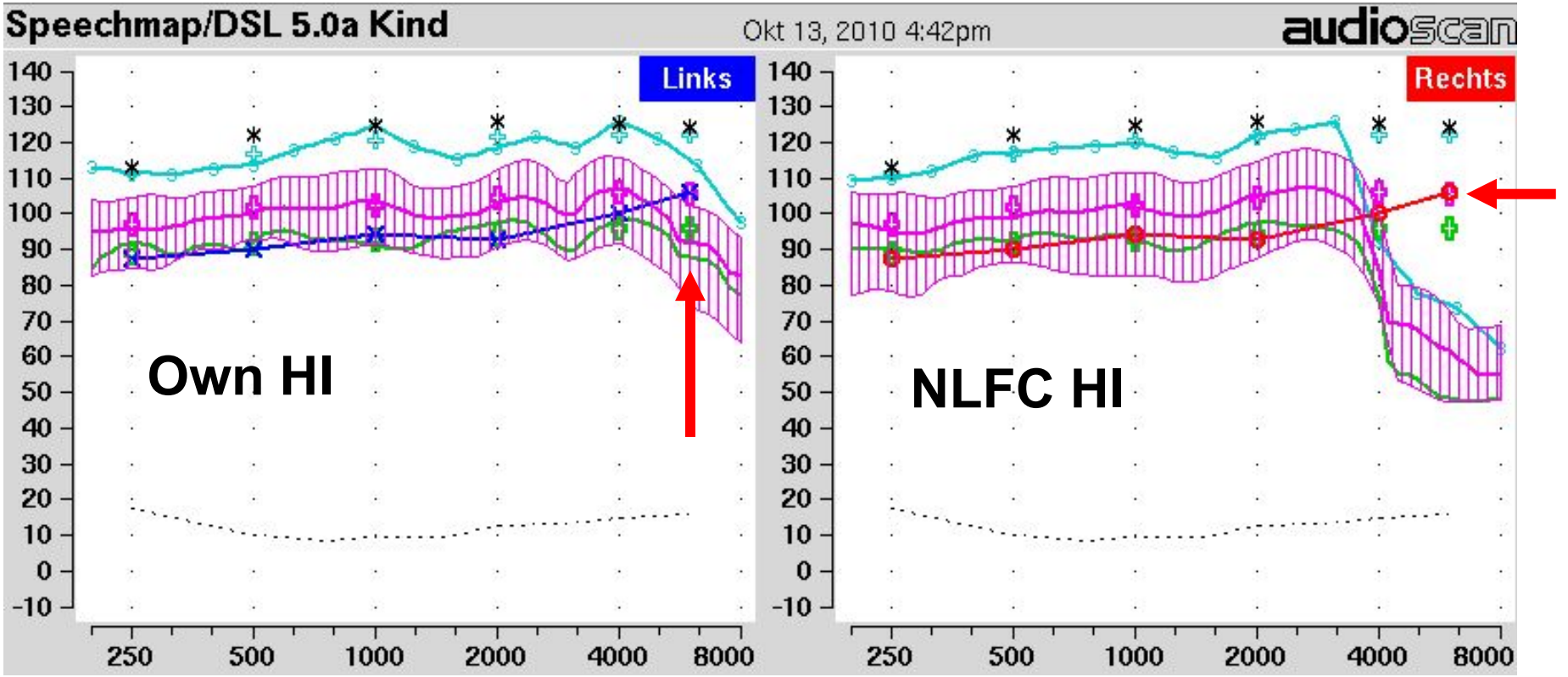
8 y, good speech development

Own HI = Siemens Artis P

Two examples… Sub A steep loss



Two examples… Sub B flat loss



Case Studies

- Speech Scores open and closed sets

Subj A

Open set words	Trad HA	Freq Comp T2	Freq Comp T5
55 dB	30 %	50 %	60%
65 dB	60%	70 %	90%
Closed set quiet 65 dB SRT	36 dB	32 dB	27 dB
Closed set noise 65 dB SNR	2 dB	-5 dB	-3,5 dB

Subj B

Open set words	Trad HA	Freq Comp T2	Freq Comp T5
55 dB	0 %	0 %	40%
65 dB	10 %	40%	70%
Closed set quiet 65 dB SRT	56 dB	42 dB	42 dB
Closed set noise 65 dB SNR	9 dB	7,7 dB	3 dB

Case studies:

Subject A

Hears new sounds, birds etc.

More relaxed after school

Rather relaxed facial expression

Trivial sounds are recognized earlier

TV set to normal volume

Speaks with clearer voice – more self confident

Subject B

Teacher can be heard with less effort

More relaxed after school

Audio books can be heard with normal volume

More open-minded – takes part in holiday camps with 50 children

Does not accept everything in conversation, but argues

Summary

- Good spontaneous acceptance for all kids
- Kids can hear many new sounds (birds, bells etc.)
- Improved communication
- More activities after school
- Families judge children‘s speech as clearer and more precise

Clinical implications - future questions….?

- ✓ Viable and robust technology for profound hearing losses
- ✓ It does need to be individually fitted

We still need to learn more……..for example:

- Cochlear implant candidacy
- Asymmetrical hearing loss
- Auditory neuropathy disorders
- Bimodal fittings

Clinical implications – future questions?

- ✓ Test results maybe not always consistent
- ✓ Do we have the right tests to show all effects of modern technology?

We should always listen to our children…..

Acknowledgements…

Clinic-Team University, Mainz

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Bianka Schramm, Prof. Annerose Keilmann

Audiology-Team Phonak, Stäfa

Dr. Myriel Nyffeler, Kai Hessefort, Steffi Kalis

and to all children!

Do children need an acclimatization period?

Danielle Glista, Ph.D.

Child Amplification Laboratory
National Centre for Audiology,
University of Western Ontario

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- Special thanks to:

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What is auditory acclimatization?

New acoustic information

Example: new audibility of speech cues post hearing aid fitting

Time to acclimatize

Systematic change in auditory performance

From the Eriksholm workshop on Auditory Deprivation and Acclimatization (Arlinger et al., 1996)

Why study auditory acclimatization?

- Work by Stuart Gatehouse and the Eriksholm Workshop on Auditory Deprivation and Acclimatization (1995):
  - Auditory acclimatization is a real phenomenon with important research/clinical implications
  - Evidence suggests the mean reported improvement in benefit over times ranges from 0 to 10% (across speech materials and presentation conditions)

    (Arlinger et al., 1996)

Why study auditory acclimatization?

- Previous research on nonlinear frequency compression (FC) and speech perception benefit suggests:
  - Considerable performance variability at the level of the individual - adult and child data (Simpson, 2009)
  - Pediatric pilot data provides informal evidence of an acclimatization effect for some listeners (Glista et al, 2009)
- As with all fittings involving new, complex signal processing, adaptation time becomes important

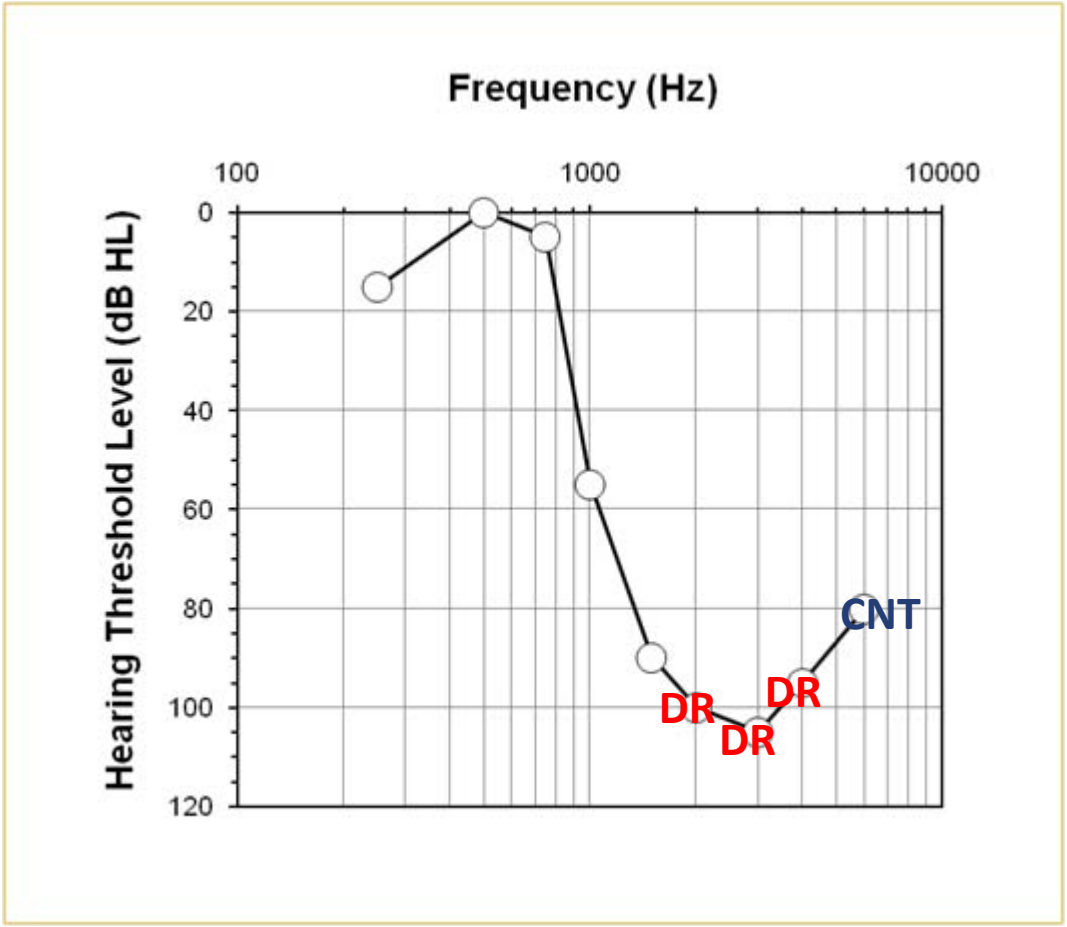
Study design

Study Phase	Structure/Objective
Baseline Phase (No FC)	Real-world usage DSL v5.0 with adjustments to preference 2 - 3 testing sessions Stopping criterion: Asymptotic performance Goal: Minimize practice effects and/or acclimatization effects from previous fitting
Treatment Phase (with FC)	4 testing sessions, spaced 2 weeks apart + 2 monthly testing sessions Goal: Track time course/magnitude of an acclimatization effect
Withdrawal Phase (No FC)	1 testing session FC disabled in lab only Goal: Establish FC effect post-acclimatization

Case Study

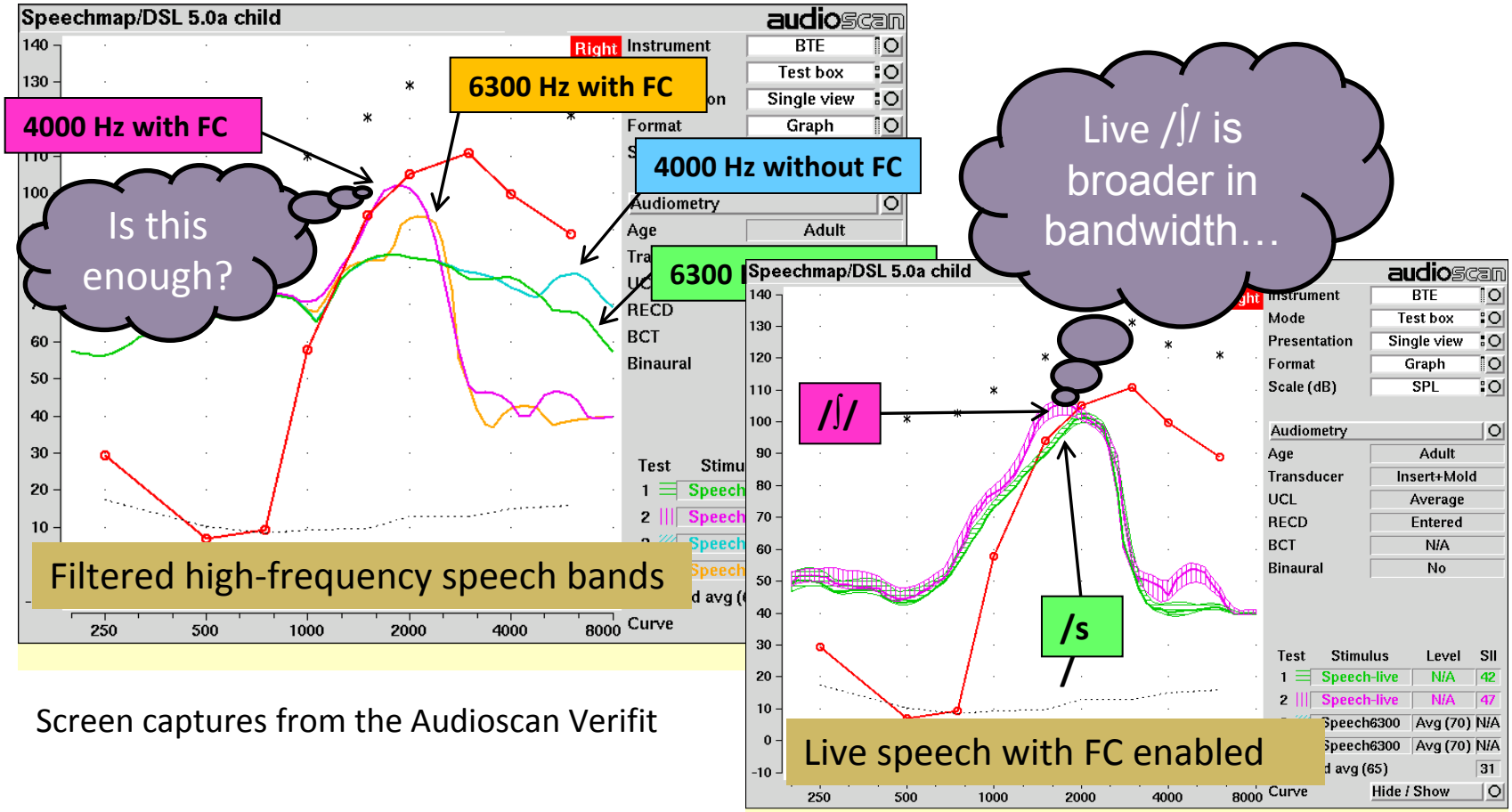
- 11 years of age
- Exposure to ototoxic medication
- Long-term, full-time HA user
- Suspected dead regions

  (TEN test: Moore, Glasberg & Stone, 2004)



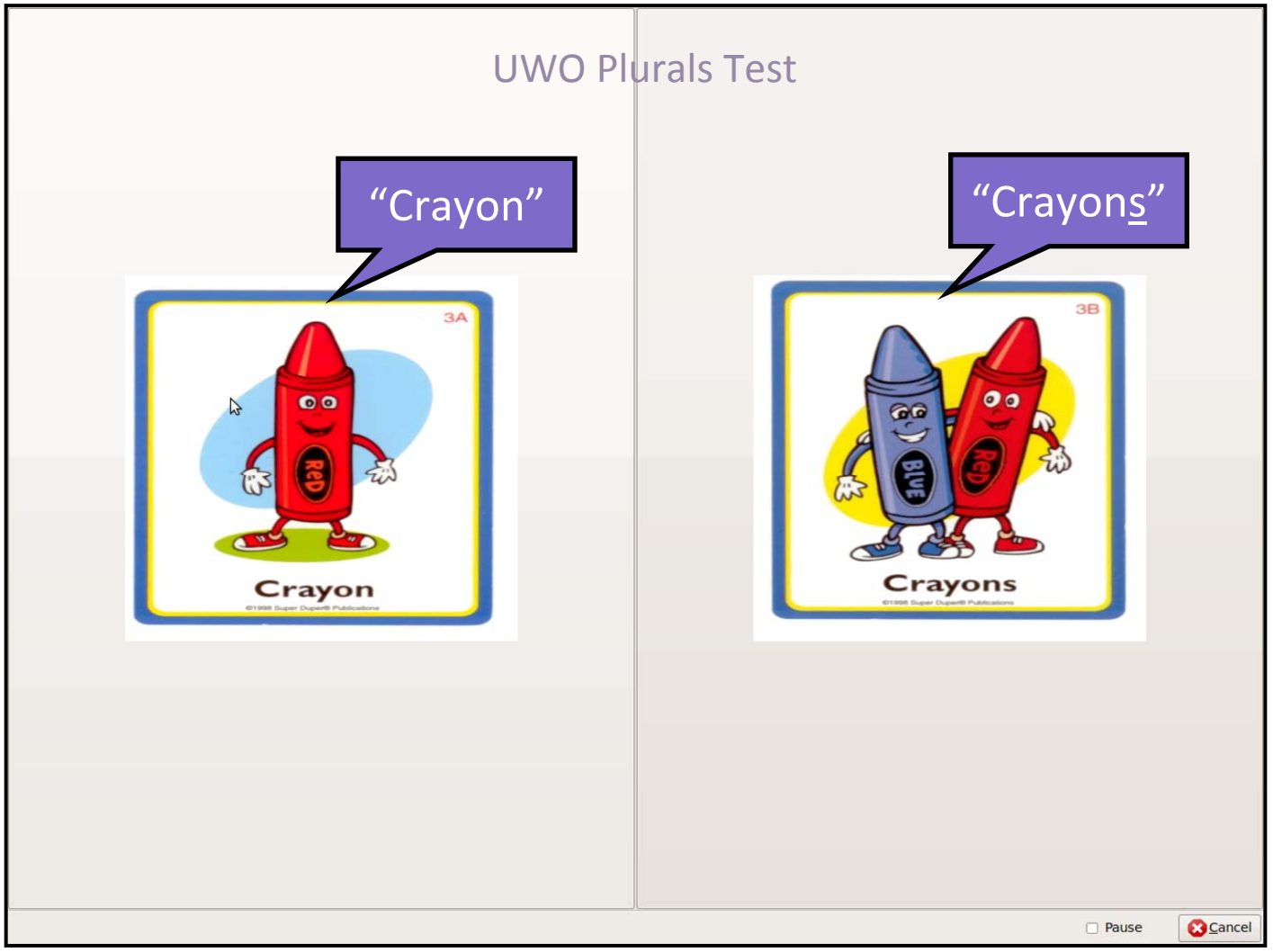
Fitting details

- Study worn aids = Naida IX SP, SoundRecover setting = 1600 Hz cut-off, 4:1 ratio
- DSL v5.0, FC setting individualized (refer to AudiologyOnline: Glista & Scollie, 2009)

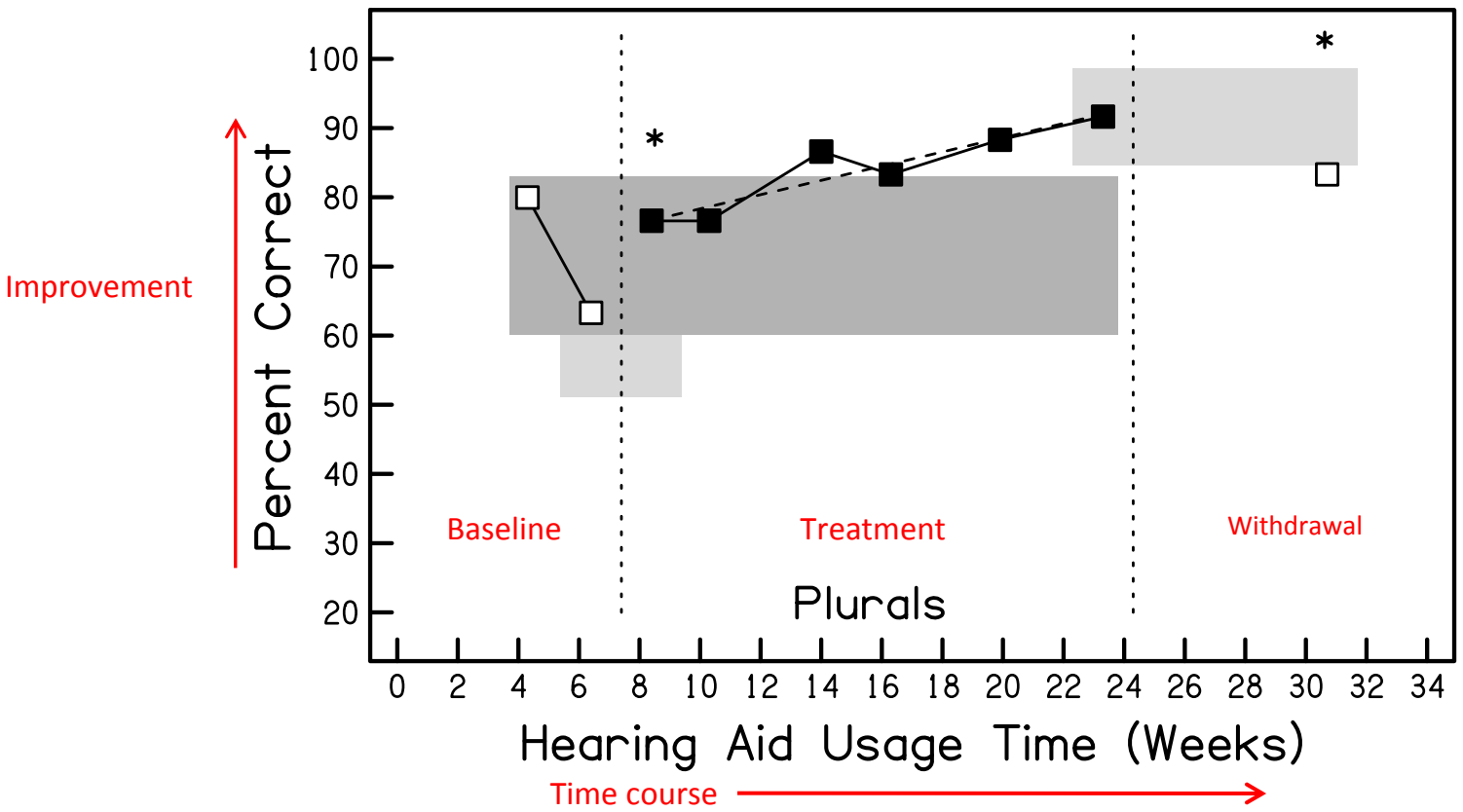


Screen captures from the Audioscan Verifit

Results – Speech recognition: Plurality

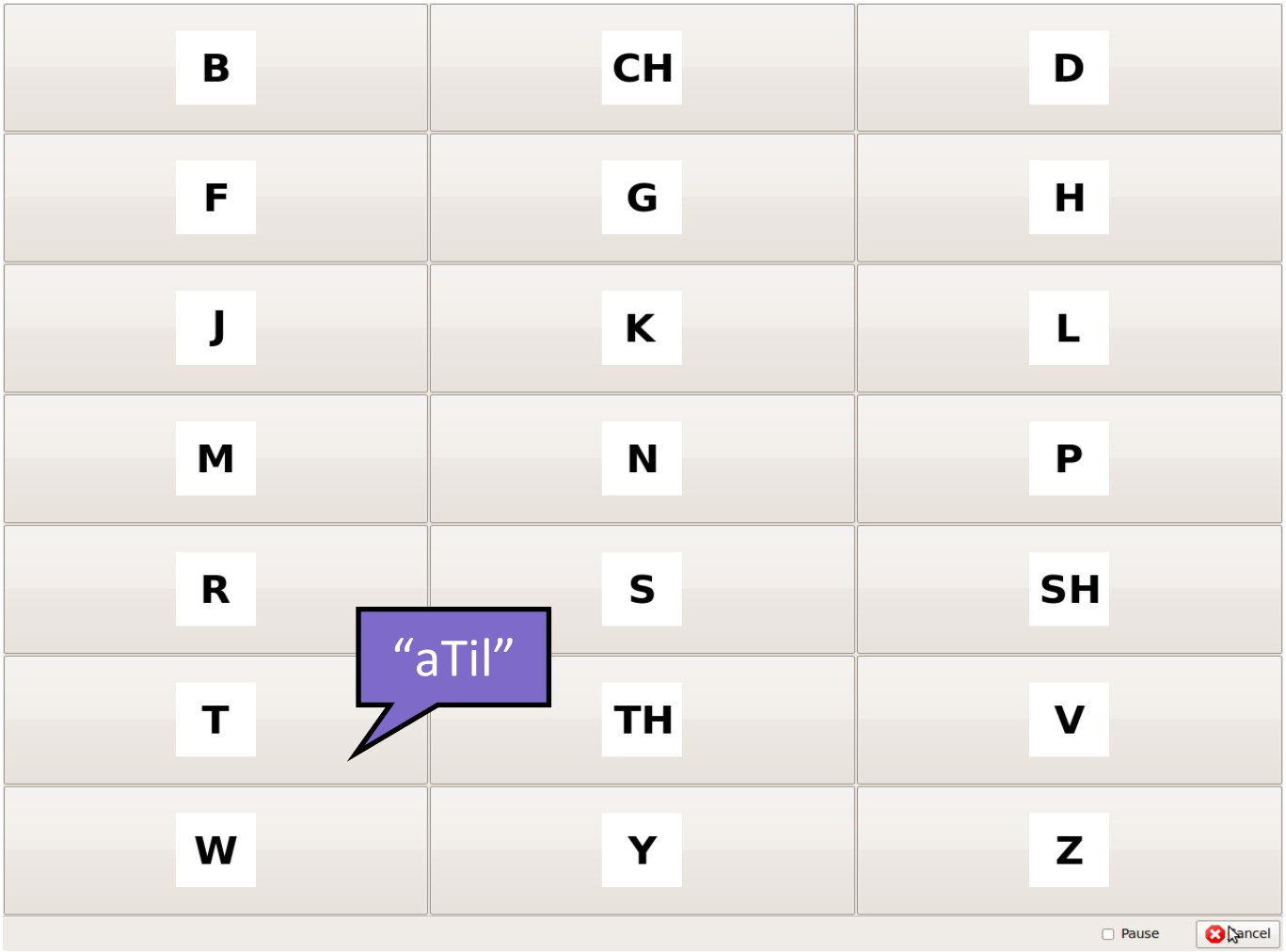


Results – Speech recognition: Plurality

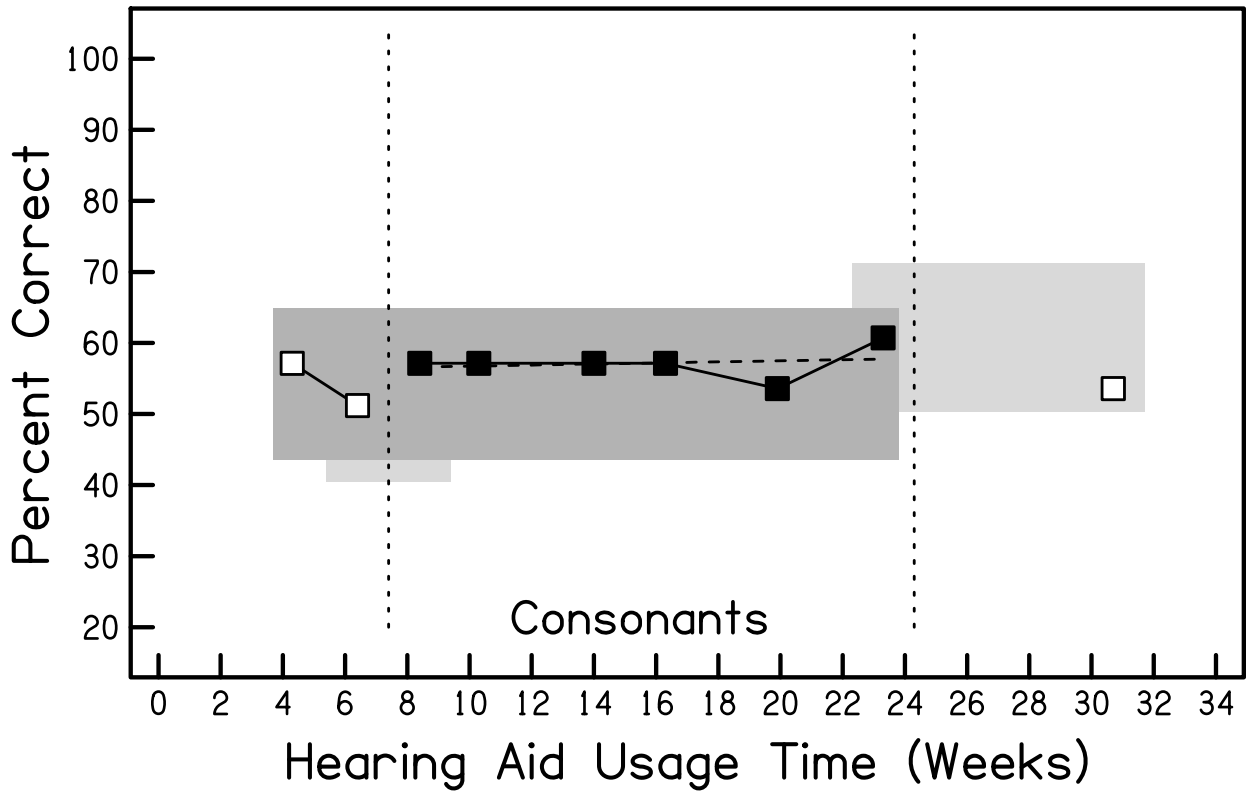


Results – Speech recognition: Consonants

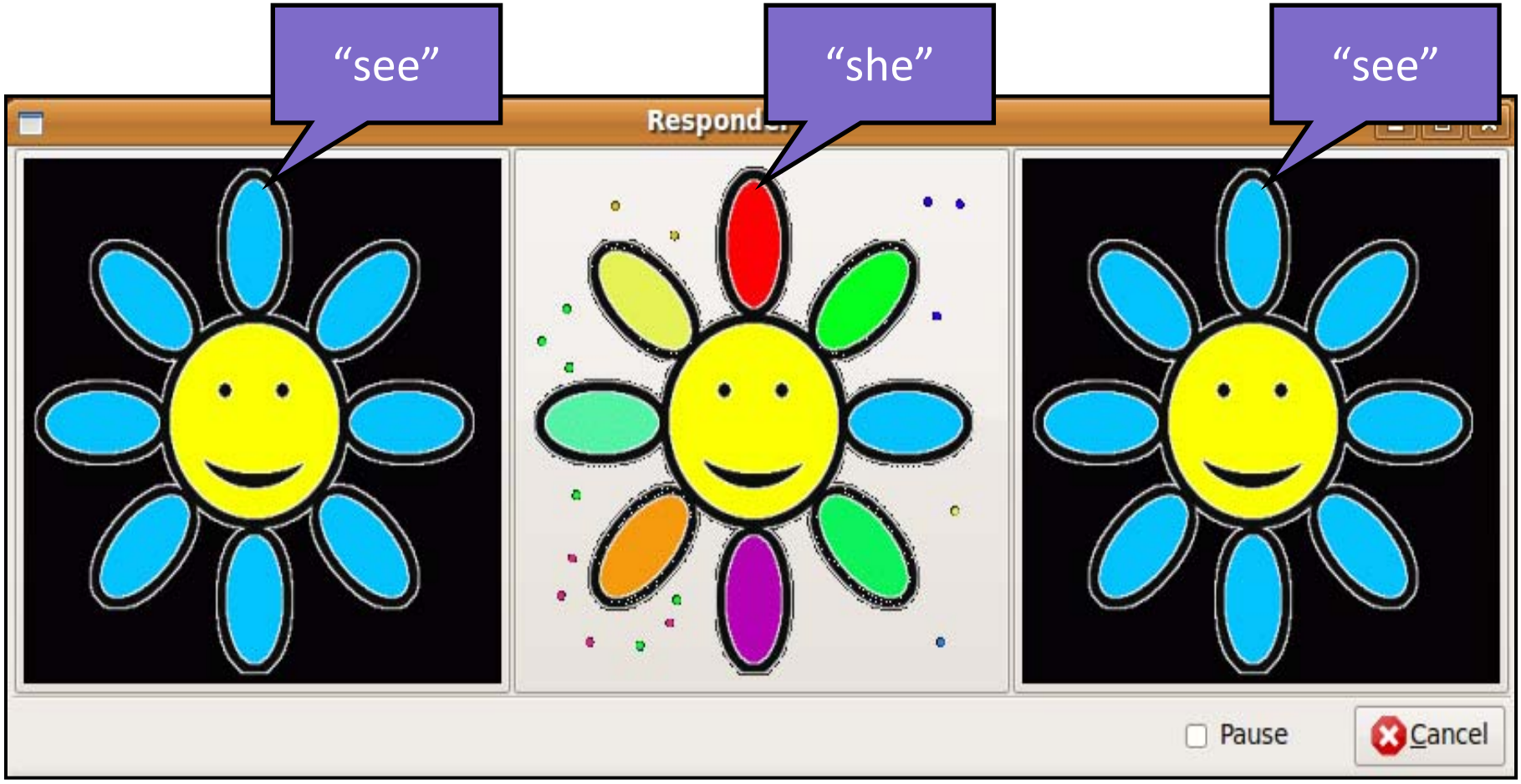
DFD Test (Cheesman & Jamieson, 1996)



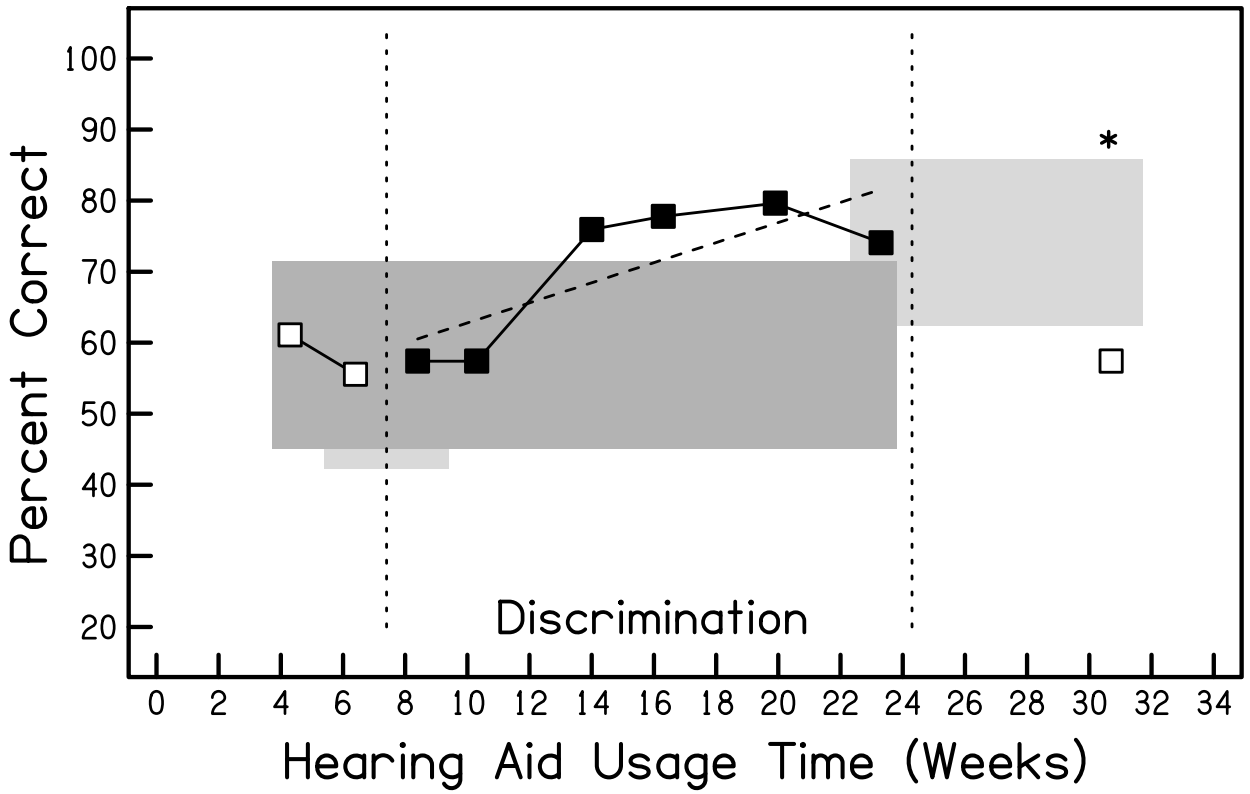
Results – Speech recognition: Consonants



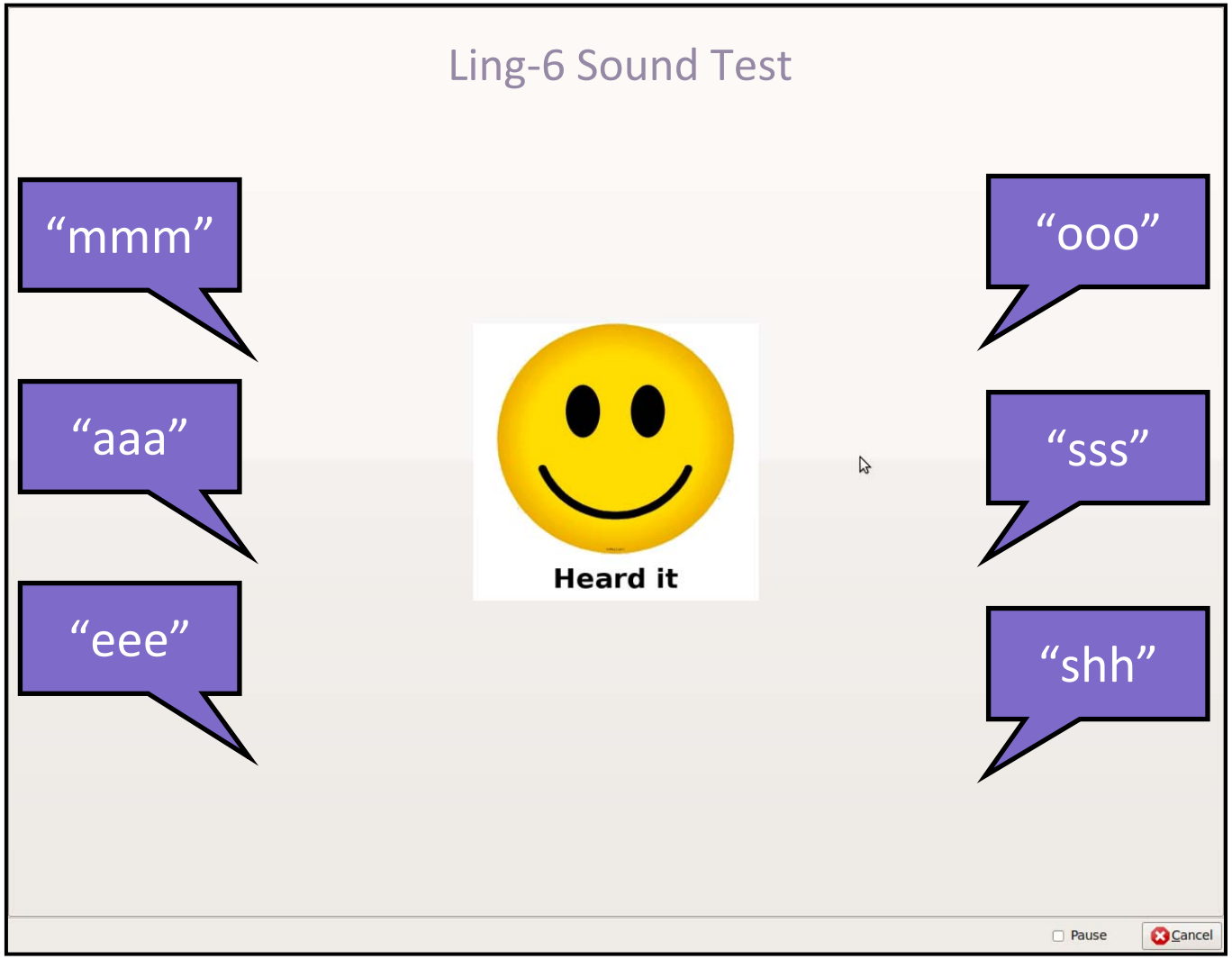
Results – Discrimination of /s/ vs. /ʃ/



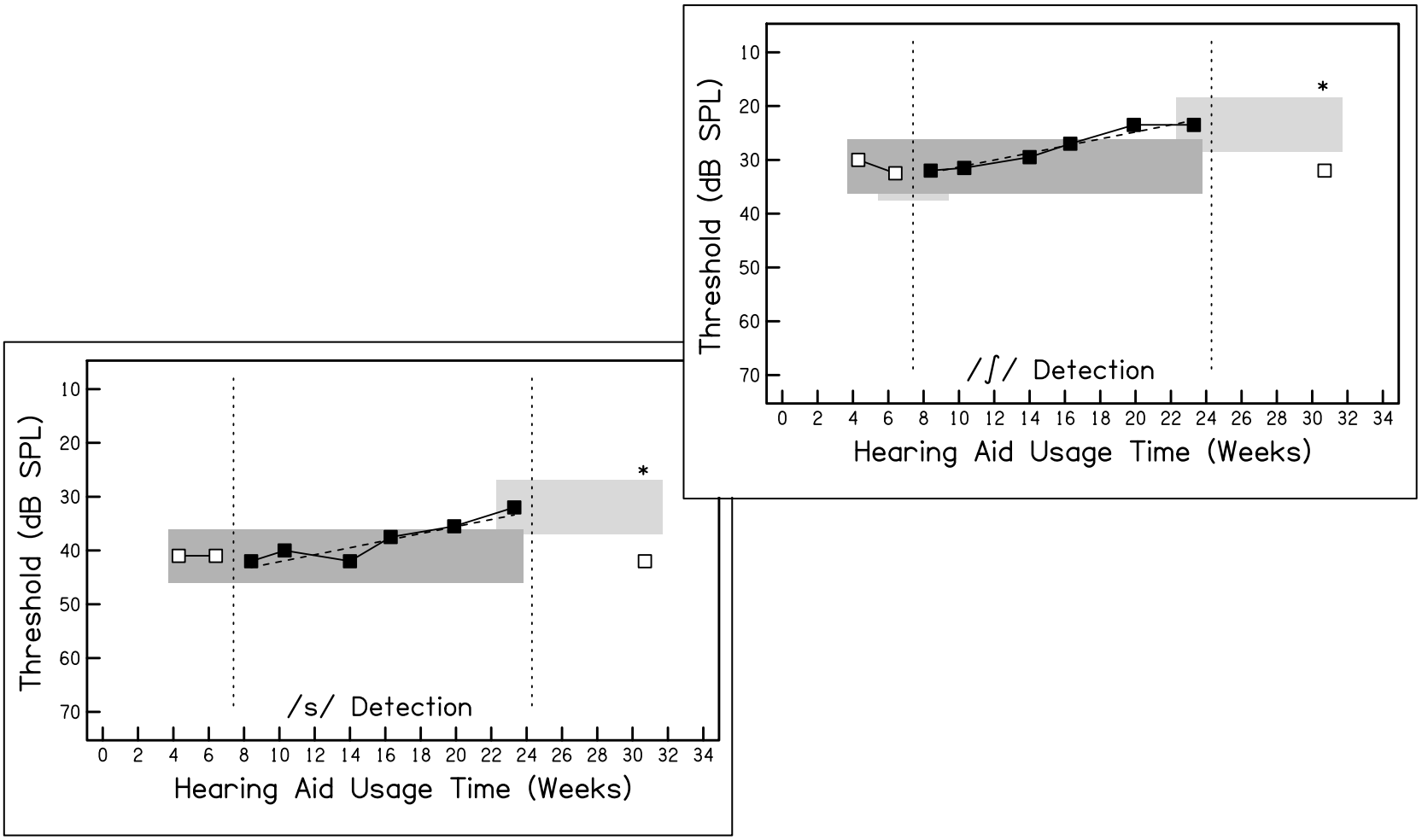
Results – Discrimination of /s/ vs. /ʃ/



Results – Detection of /s/ and /ʃ/



Results – Detection of /s/ and /ʃ/



Clinical implications

- Overall, significant speech perception benefit was reported with FC compared to without FC
- Acclimatization trends with FC:
  - Benefit change ranged from 0 to 17%, across measures
  - Significant acclimatization trends were observed after approximately 6 weeks or longer
  - Two unique acclimatization patterns where exemplified:
    - Gradual improvement over time
    - Improvement after a specific period of acclimatization (S-shaped curve)
- Further cases are currently under analysis

Clinical implications

- Speech perception testing administered on more than one appointment, and after allowing a period of acclimatization can assist in validating FC benefit

Thank you for listening

Future directions in evaluating SoundRecover

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Katrin Meisenbacher
Juliane Raether

Overview

1. Background and goals
2. Design and development
3. Prototype evaluation
4. Test revision
5. Future directions

Goals in Development of the Logatome test

Development Goals:

1)We wanted a computer-based test with high sensitivity and specificity to high frequency phoneme intelligibility!

2)We wanted a language-neutral test!

3)We wanted a test that would be applicable with mild-to-moderate hearing losses!

Application Goals:

1)Suitable for comparison of different hearing aids,

2)Suitable for evaluation of different settings of a hearing aid

- For example, frequency compression on versus off

What does *Logatome* mean?

„A **logatome** is an artificial word of one or more syllables which obeys all the phonotactic rules of a language but has no meaning. Examples of English logatomes would be the nonsense words *snarp* or *bluck*.“ from: Wikipedia

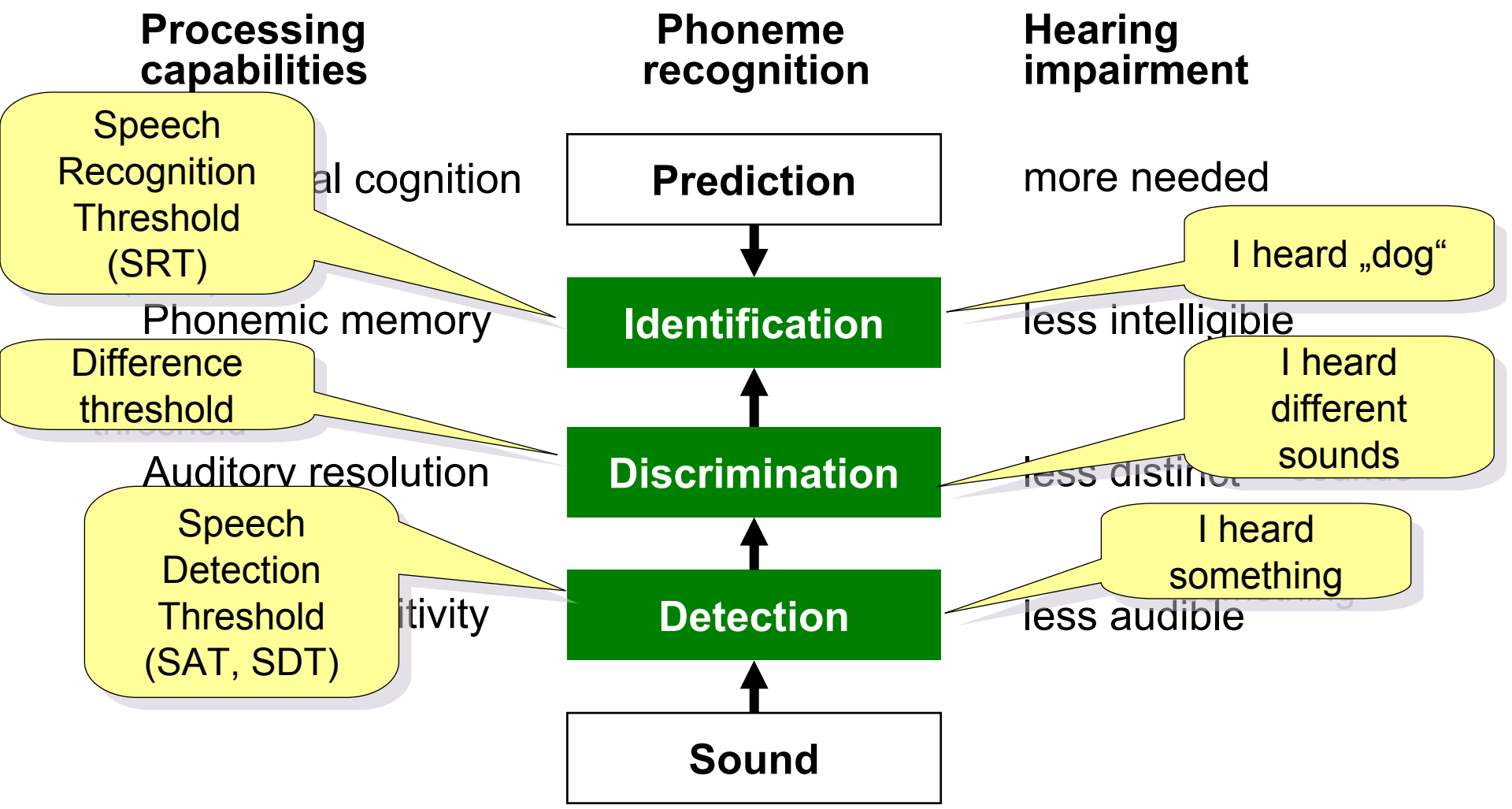
In our test, all of the Logatomes are /aCa/:

For example: Asa, ata, asha

Test construction: What are we measuring?

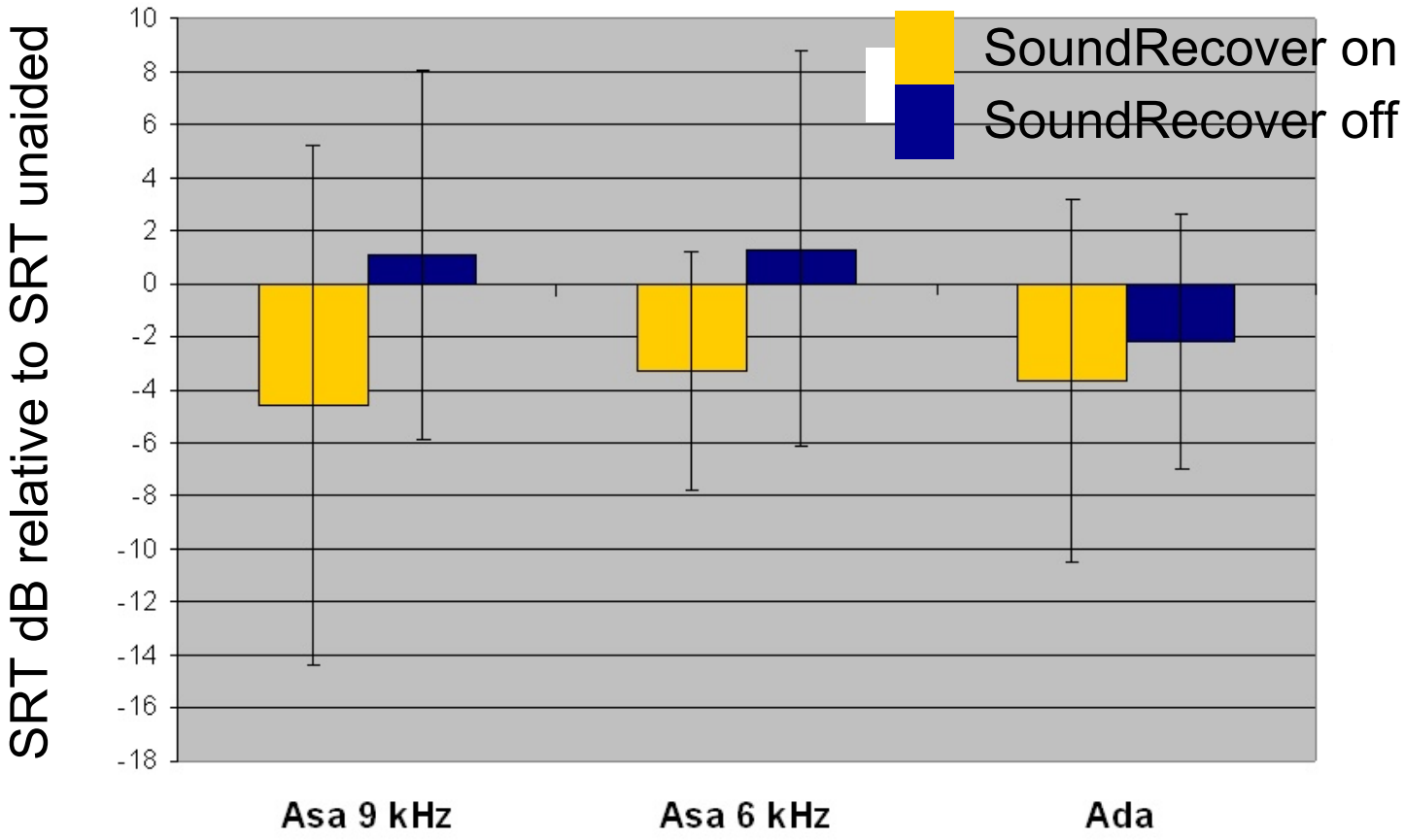
Processing capabilities	Phoneme recognition	Hearing impairment
Contextual cognition	**Prediction**	more needed
Phonemic memory	**Identification**	less intelligible
Auditory resolution	**Discrimination**	less distinct
Auditory sensitivity	**Detection**	less audible
	Sound	

Test construction: What are we measuring?



Is the Logatome test sensitive to Frequency compression?

n=12 adult subjects with mild hearing loss



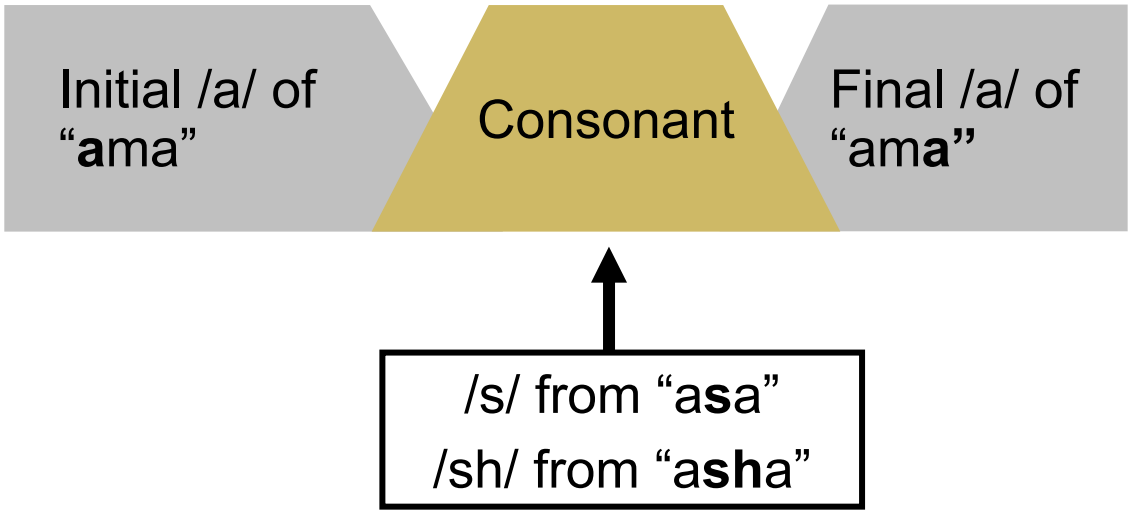
Boretzki, M.; Kegel, A. (2009). The benefits of nonlinear frequency compression for people with mild hearing loss. Audiology Online, November 2009

Logatome Test Design: Factors Evaluated

1) Minimize phoneme predictability!
2) Minimize non-consonant cues!
3) Challenge high frequency hearing loss!
4) Minimize floor and ceiling effects!
5) Maximize valid responses!
6) Improve consistency! (revised test)

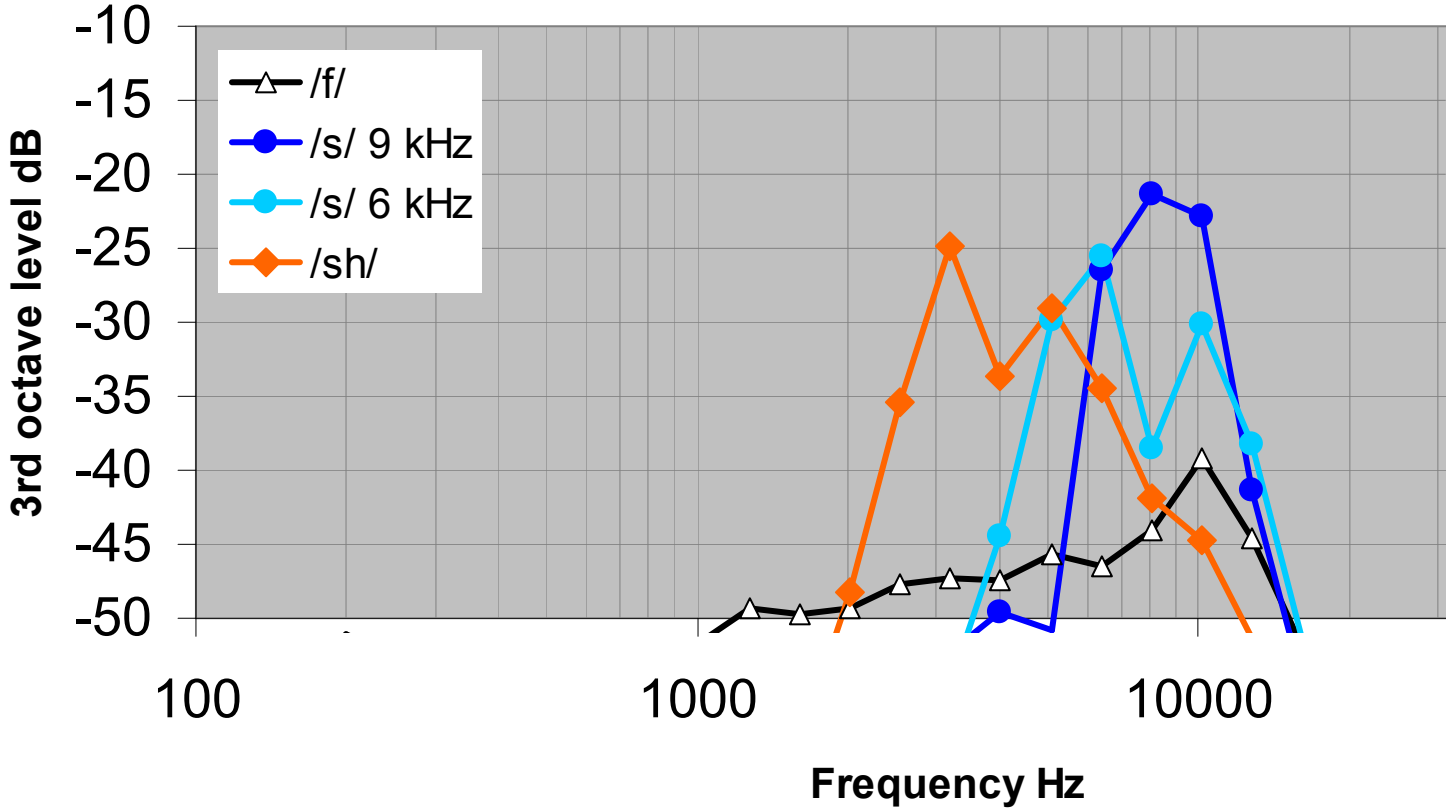
Goals 1 and 2: Reduce confounds

- Goal 1: Minimize phoneme predictability!
  - By using logatomes (asa, asha, afa) we can reduce guessing from context.
- Goal 2: Minimize non-consonant cues!
  - Embed „asa“, „asha“ etc. in identical vowels, we can prevent guessing from vowel cues.



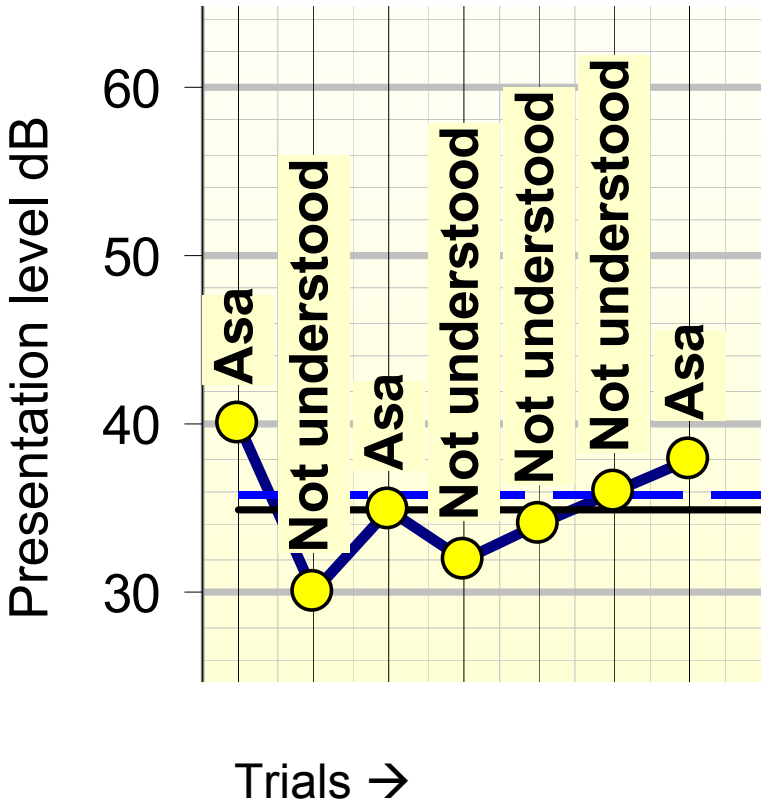
Goal 3: Challenge high frequency hearing loss!

- Unvoiced fricatives from a female talker
- Created /s/ at both 6 and 9 kHz



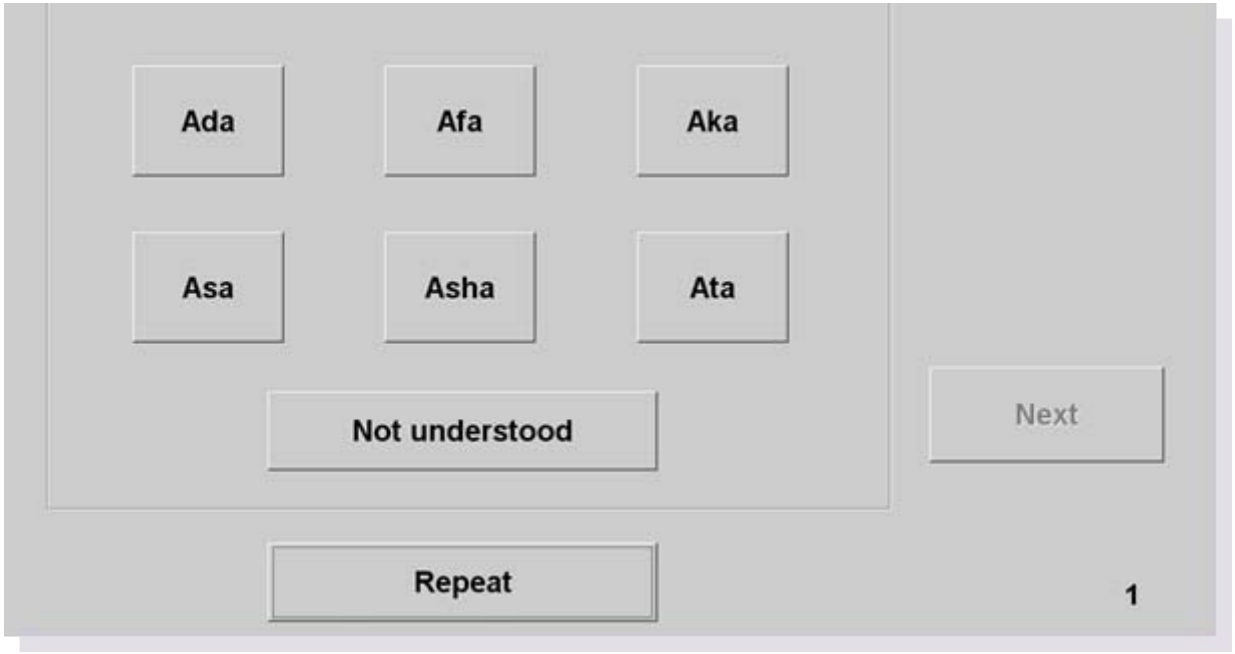
Goal 4: Minimize floor and ceiling effects!

- We use an adaptive tracking procedure to measure the levels needed for understanding
- The score:
  - Is not a speech detection threshold
  - Is a speech recognition threshold, in dB(A) per consonant.



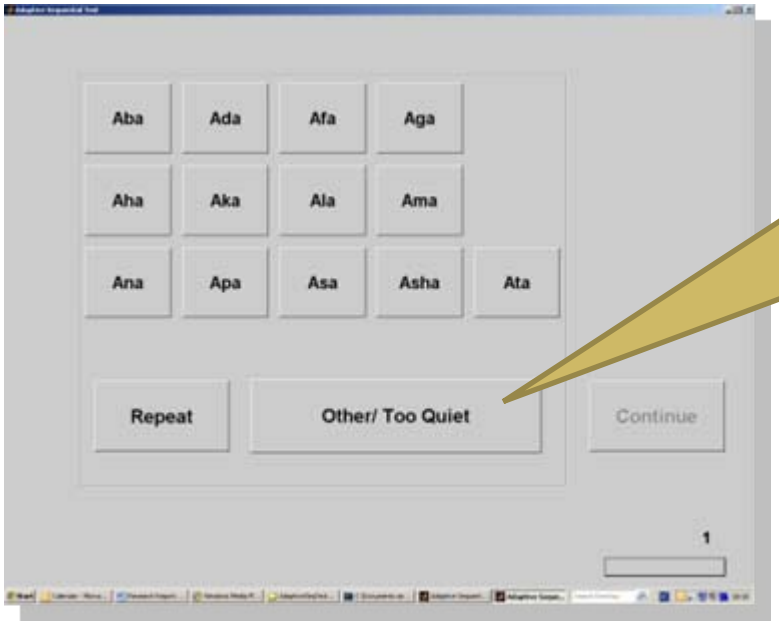
Goal 5: Maximize valid responses!

- Un-forced choice procedure reduces guessed answers
- Listeners can indicate that they don‘t know
- Listeners can repeat a trial



Goal 5: Improve consistency

- Providing repetitions of each sound improved consistency by 0 to 4 dB per Logatome:
  - „asa, asa, asa“ rather than just „asa“.
  - Near threshold, repeated stimuli may sound different

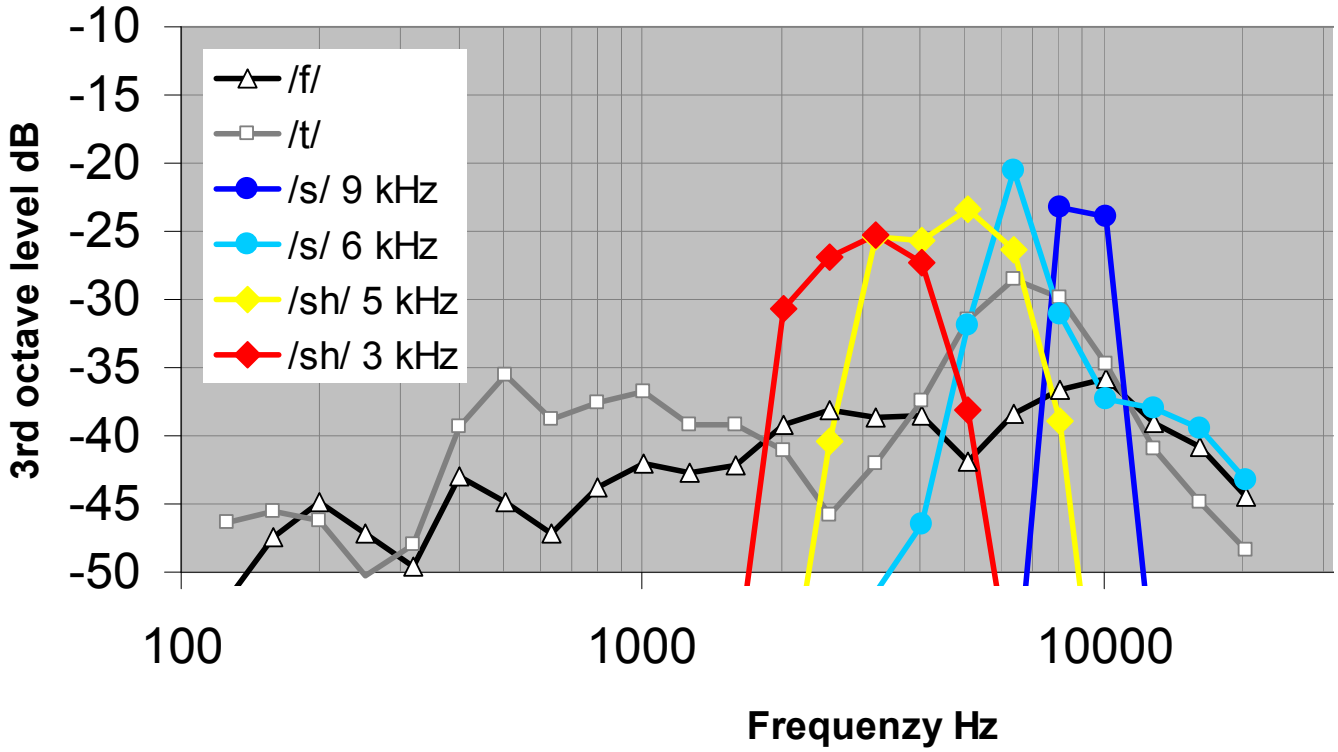


Click here if the 3 sounds are not all the same, or if the sounds are too soft to be heard.

The software will increase the test level automatically.

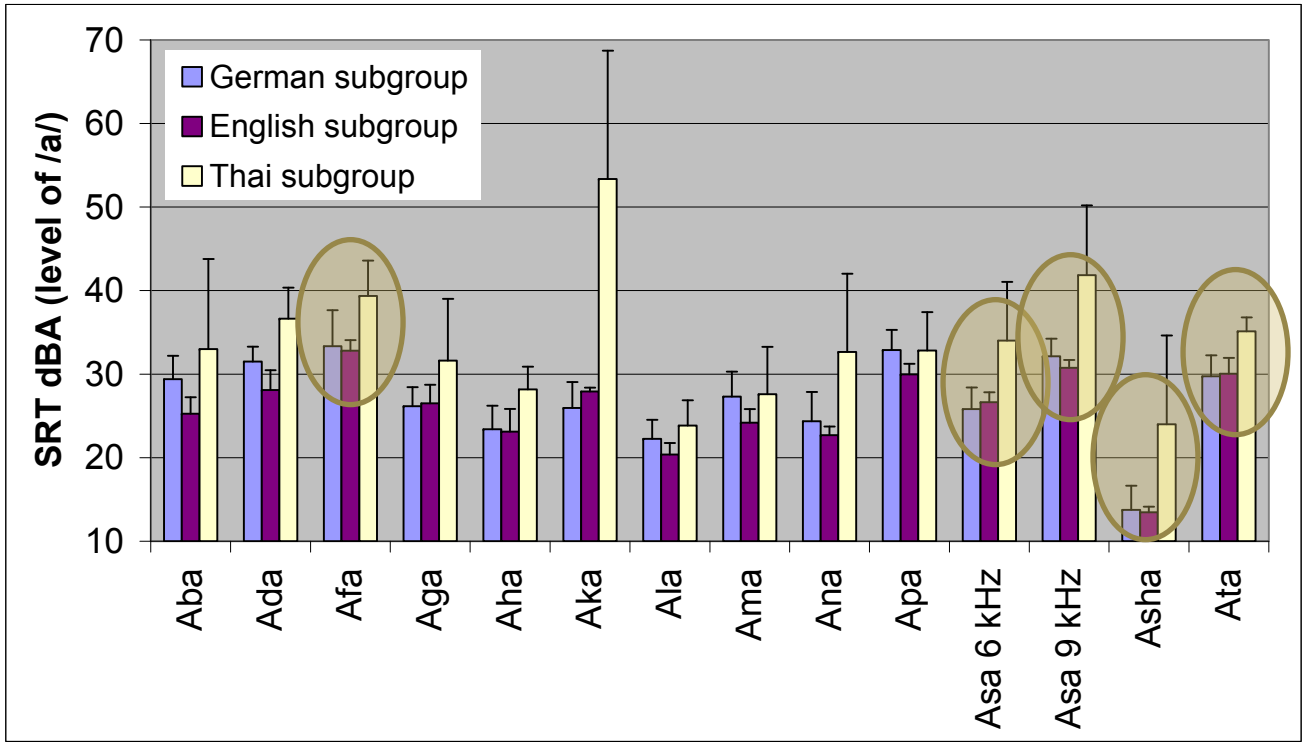
Goal 5: Improve consistency

- Carefully selecting the set of Logatomes:
  - Including a wide range of sounds improves consistency
  - Our final set for clinical use includes six Logatomes, 3 to 9 kHz region:

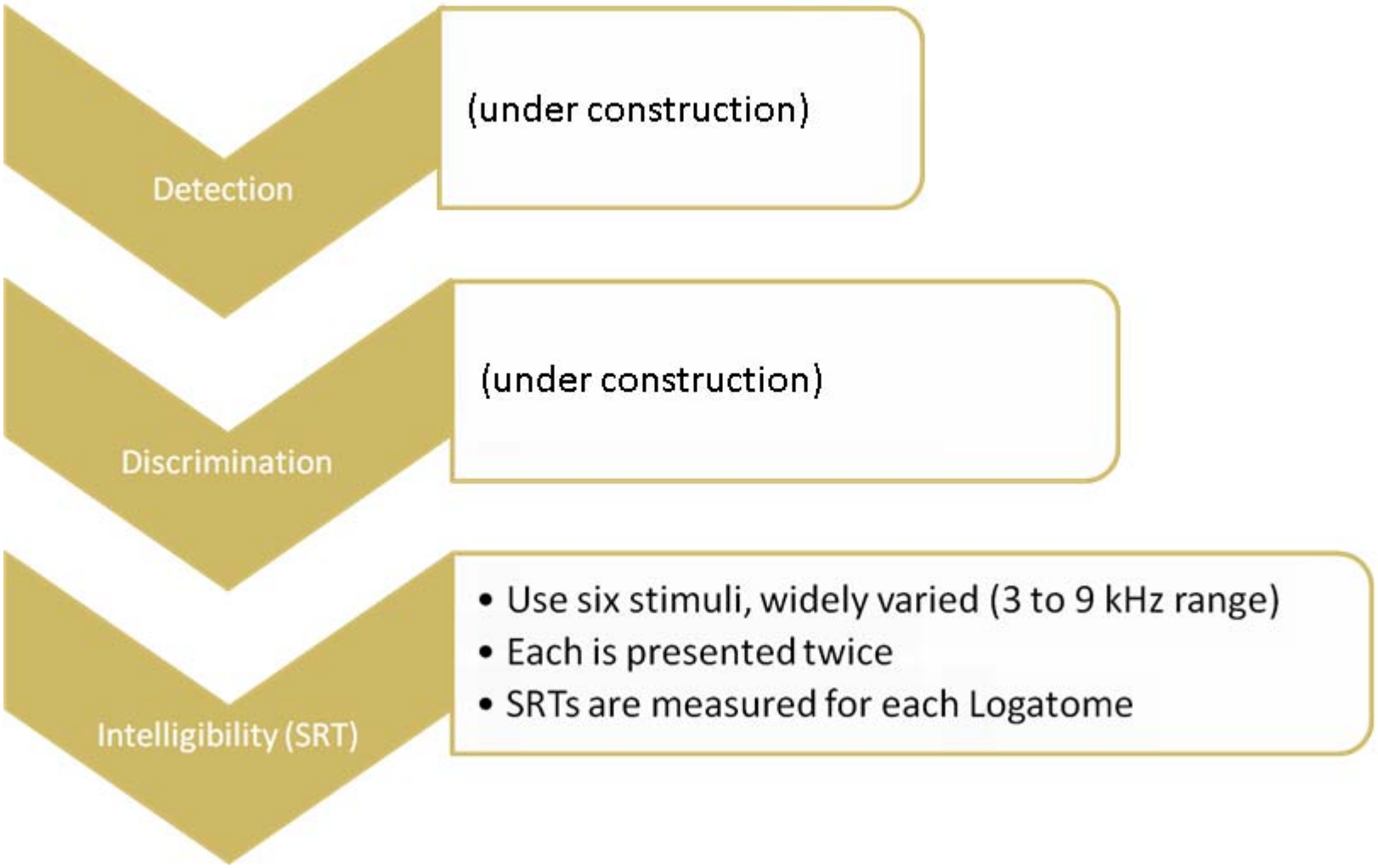


Goal 5: Improve consistency

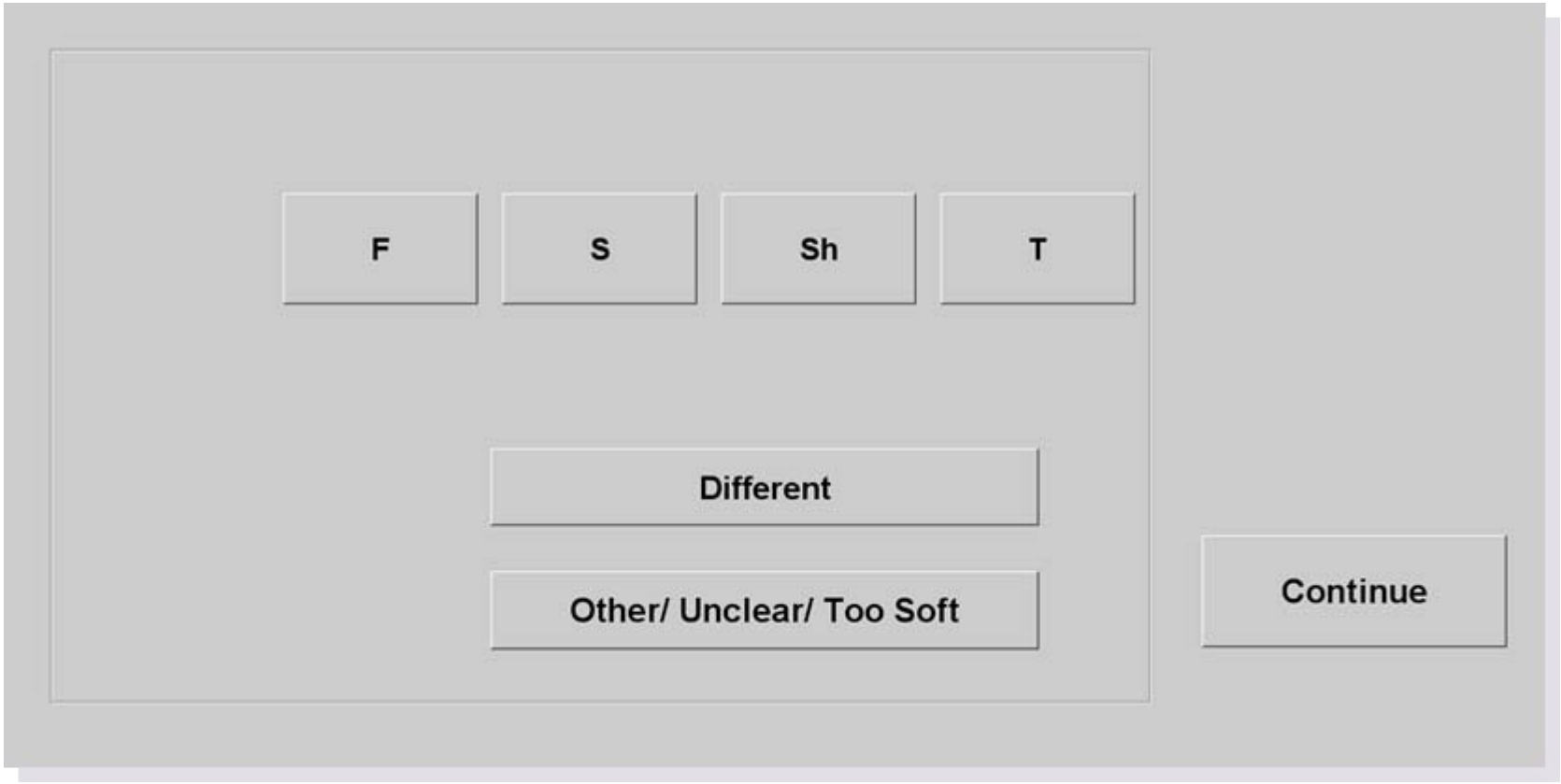
- Evaluate across languages:
  - This testing will continue, early results shown for 25 listeners with NH
  - 10 German, 6 English, 9 Thai native speakers
  - Logatomes that vary by language (e.g., aka) excluded (final set circled)



Development of a Clinical Logatome Test: Order of Tasks



Development of a Clinical Logatome Test:
RESPONSE SCREEN



Summary and Future Directions

1) **Goal:** To develop a language-neutral intelligibility test that is sensitive and specific to high frequency phoneme intelligibility
2) **Method:** Female talker, unforced choice, non-consonant cues mimimized, adaptive SRT measurement for each stimulus, multiple presentation
   - This method may be challenging for listeners with profound losses
3) **Validation studies:** Appears sensitive to the effects of frequency compression in mild and moderate hearing losses, other evaluations are in progress (normative data, data across losses & languages)
4) **Adaptation for use with children:** A next step .... Feedback?

Thanks for your attention!

Selected References for panel session:

Boretzki, M., Kegel, A. 2009. The benefits of nonlinear frequency compression for people with mild hearing loss. Audiology Online, November.

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Time for discussion (15 minutes)