From Good to Great: Non-Linear Frequency Compression for Children

Jace Wolfe, Ph.D.

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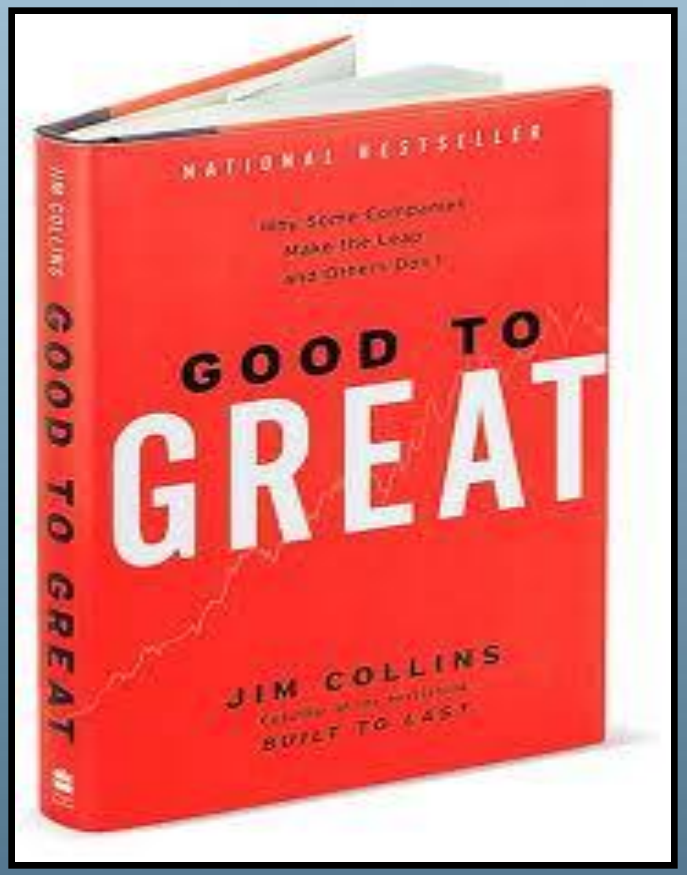
From Good to Great!

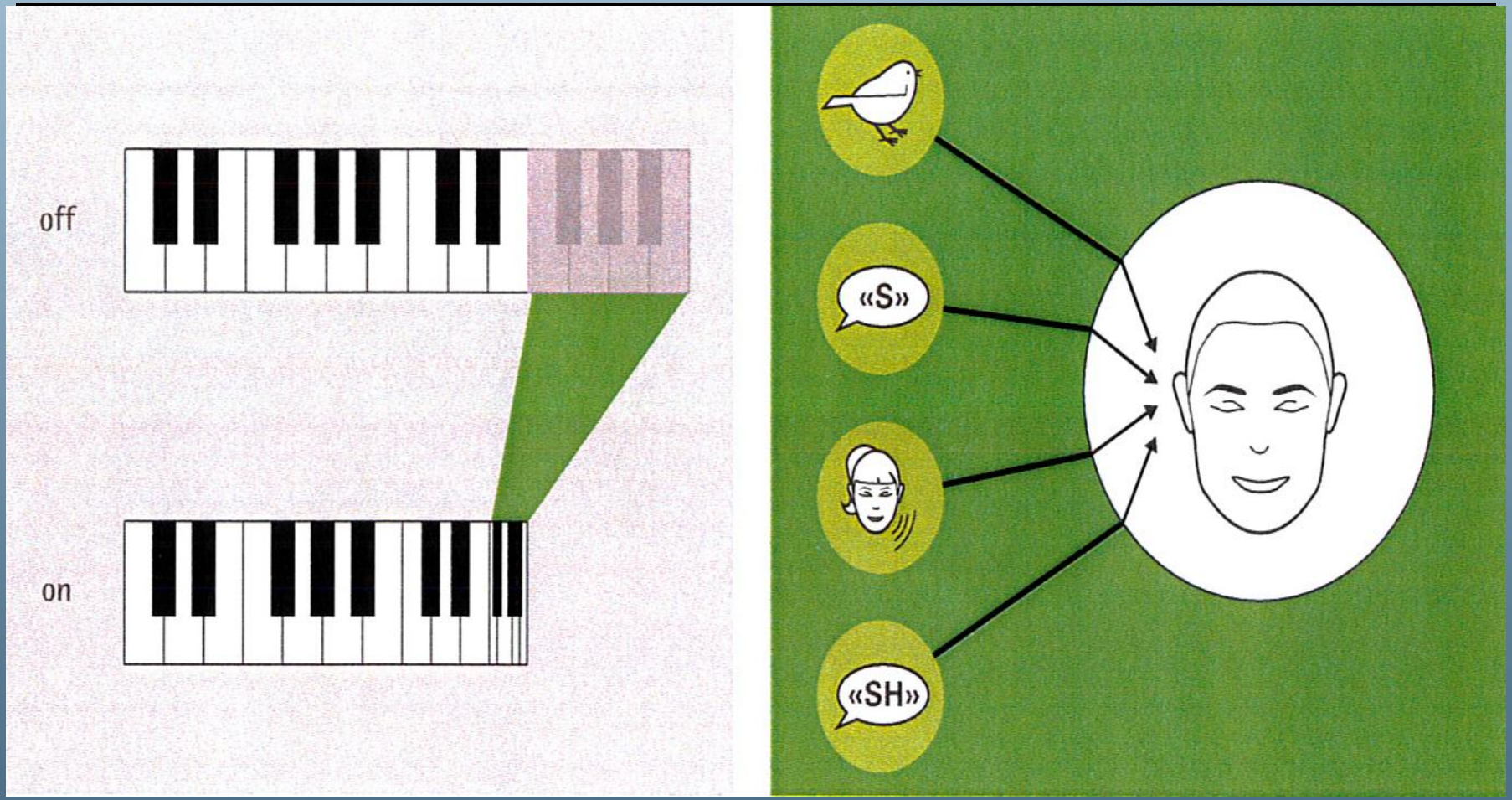


All too often, good is the enemy of great. – Jim Collins

Road Map

- Non-linear Frequency Principles and Previous Research
- Hearts for Hearing Experiences:
  - Research
  - Clinical
- Fitting and Verification
- Clinical Pearls

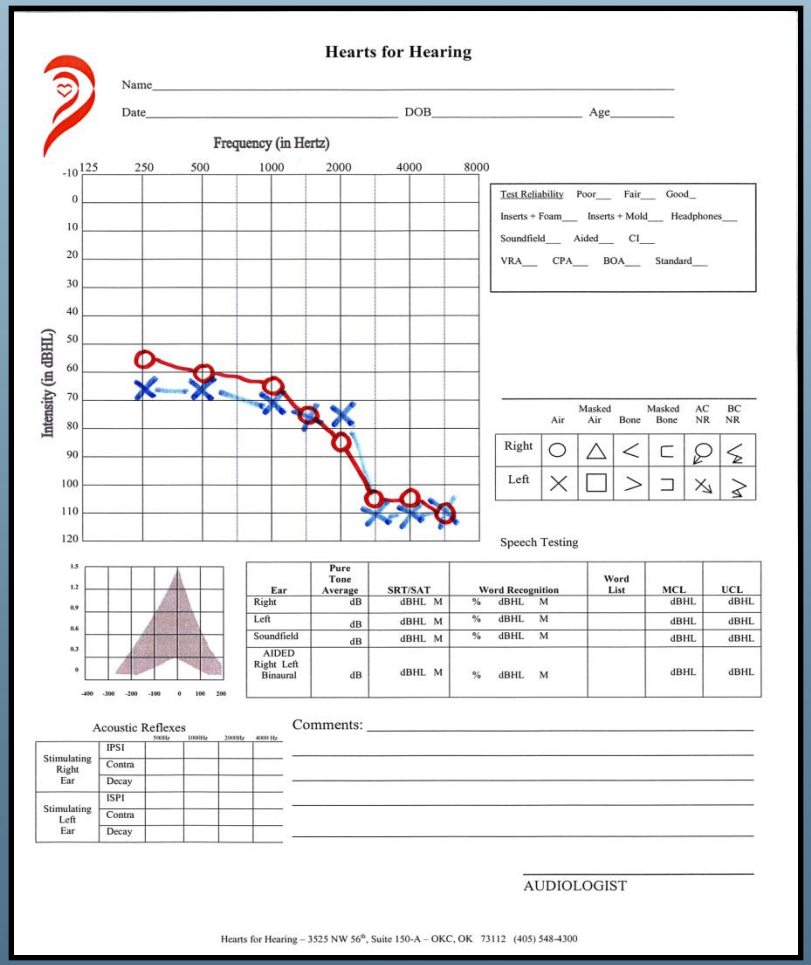
Non-linear Frequency Compression



Non-linear Frequency Compression

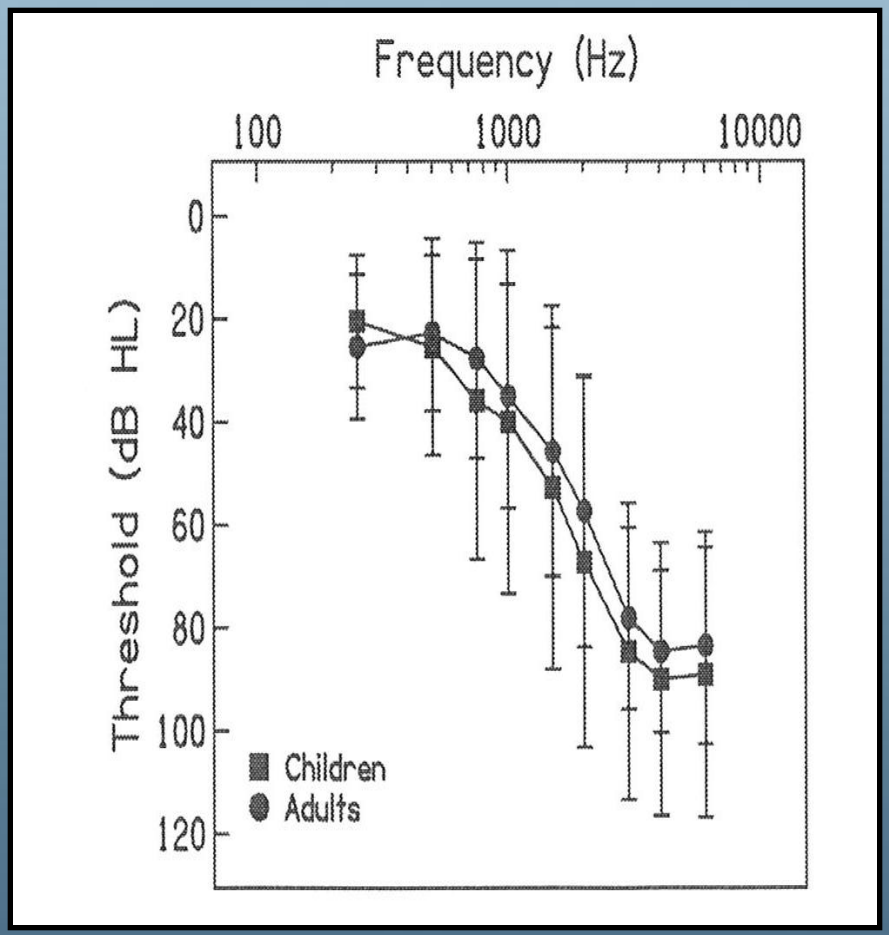
- Recent studies have shown that frequency lowering aids improves speech recognition for children and adults with severe to profound HF SNHL.
  - Simpson et al., (2005)
  - Glista et al., (2009)
  - Nyffeler, (2008)
  - Kuk, (2010)

- Richard Seewald: “Frequency compression is the most significant advance in pediatric amplification in over a decade.”



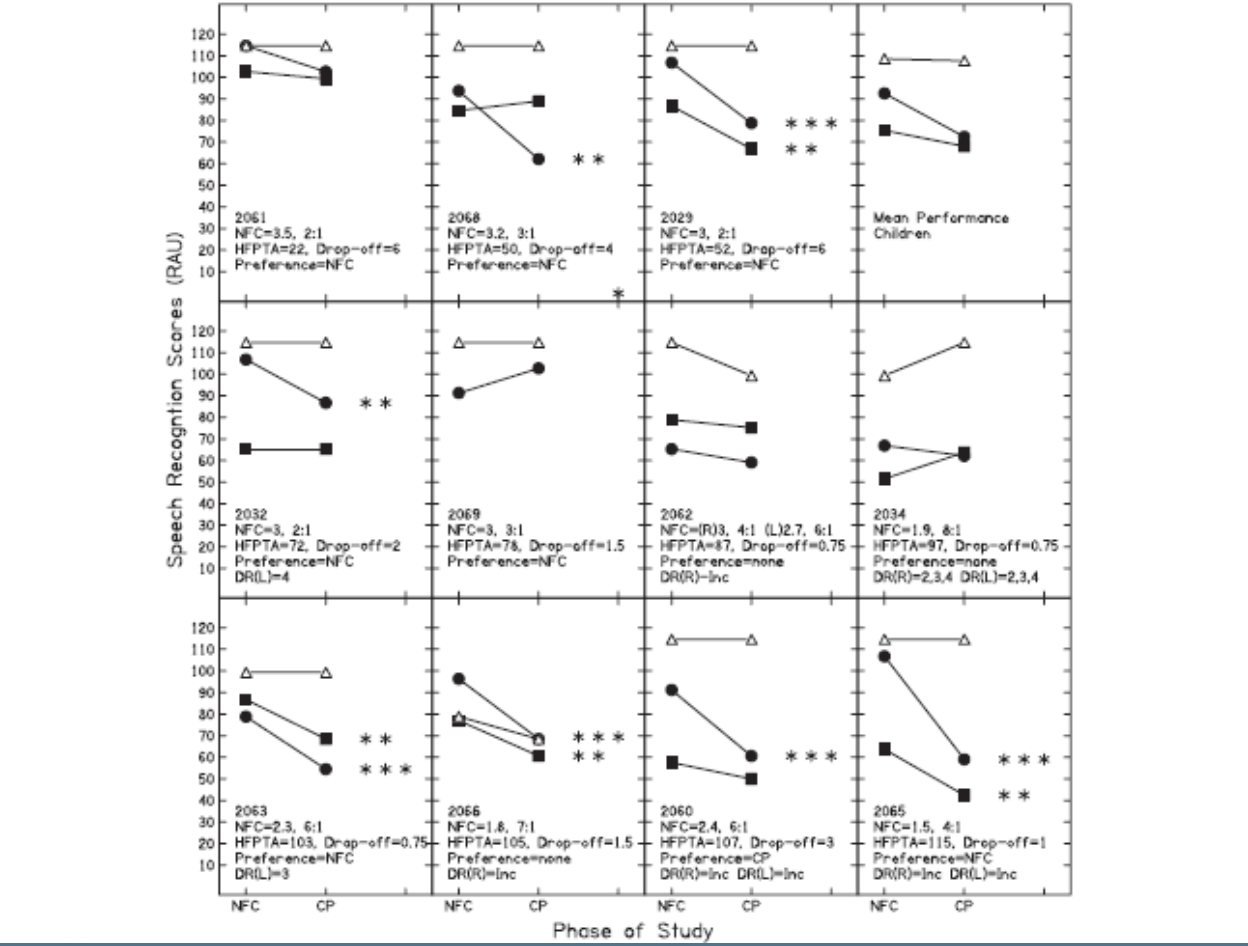
Glista, Scollie, Bagatto, et al., (2009)

- Evaluated NLFC in prototype Phonak aid for 13 adults & 11 children with sloping, HF SNHL.
- Protocol for selecting NLFC settings
- Measured aided speech sound detection thresholds, speech recognition, and perceptual benefit
- NLFC on vs. NLFC off



Glista et al (2009) Intl J Audiolo

Glista, Scollie, Bagatto, et al., (2009)



Glista et al (2009) Intl J Audiolo

What about children with moderate hearing loss?

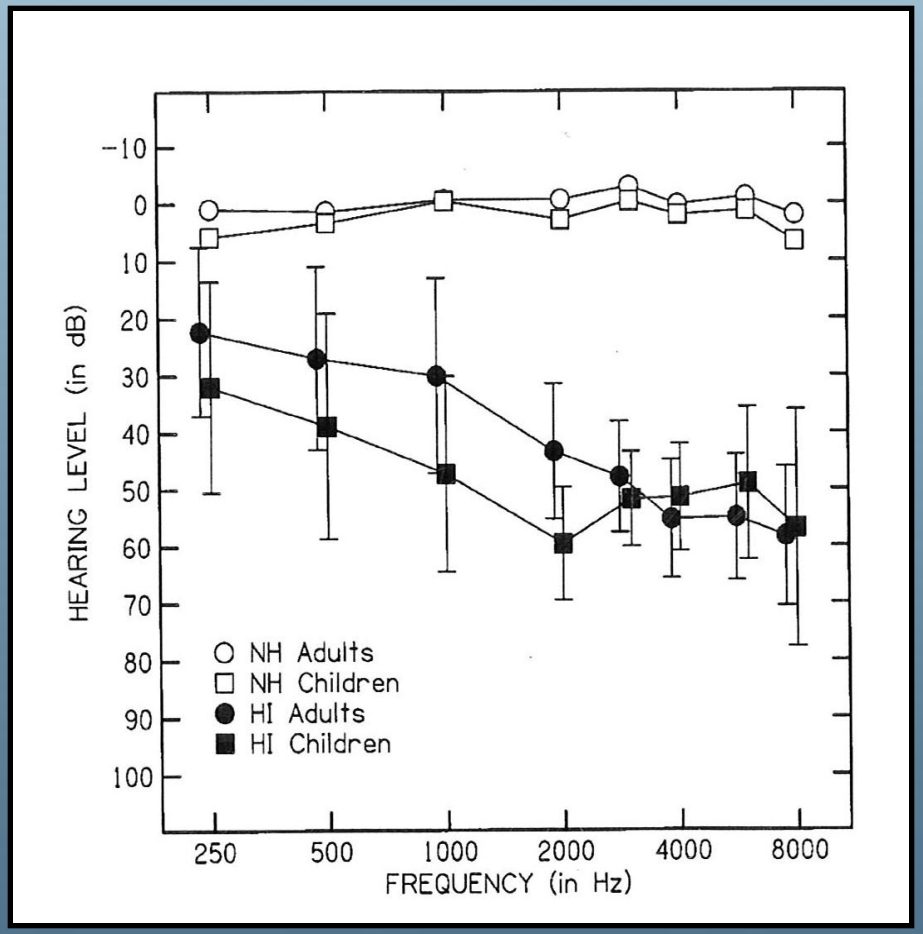
- Stelmachowicz and colleagues (2000, 2001, 2002, 2004) have shown that children with moderate to moderately severe SNHL need a wider bandwidth for optimal speech recognition.

- 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).

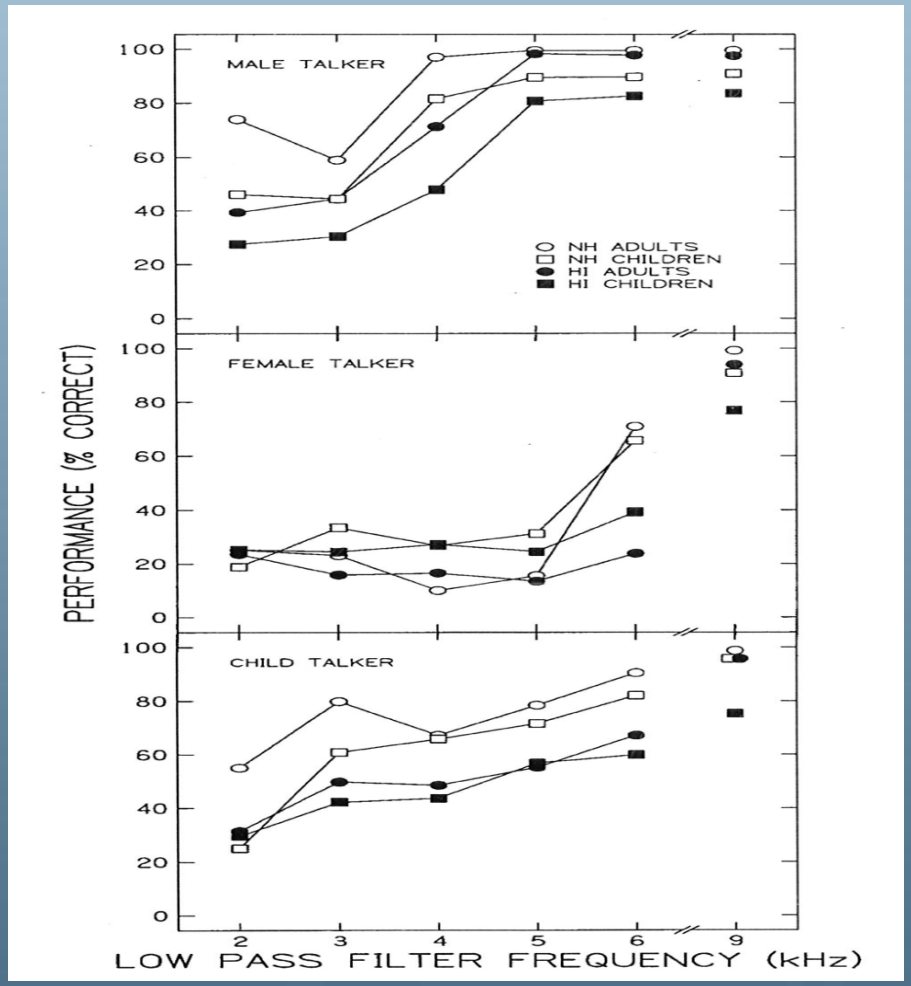
Stelmachowicz et al., 2001

- 20 adults & 20 children with moderate to severe HF SNHL
- Nonsense syllables with /s/, /f/, and /th/.
- Evaluated recognition as a function of BW (2,3,4,5,6, & 9K Hz.
- Stimuli presented through headphones



Stelmachowicz et al., (2001), JASA

Stelmachowicz et al, 2001



- BW to 6000 Hz required for optimal recognition of male /s/.
- BW to 9000 Hz required for optimal recognition of /s/ when spoken by a female and child talker.

Stelmachowicz et al., (2001), JASA

What about children with moderate hearing loss?

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- Children with access to high-frequency information (i.e., >4K Hz) demonstrate better short-term word learning (Pittman, 2008).

- Hearts for Hearing Research

- Evaluation of NLFC for Children with Moderate Hearing Loss

Study Objectives

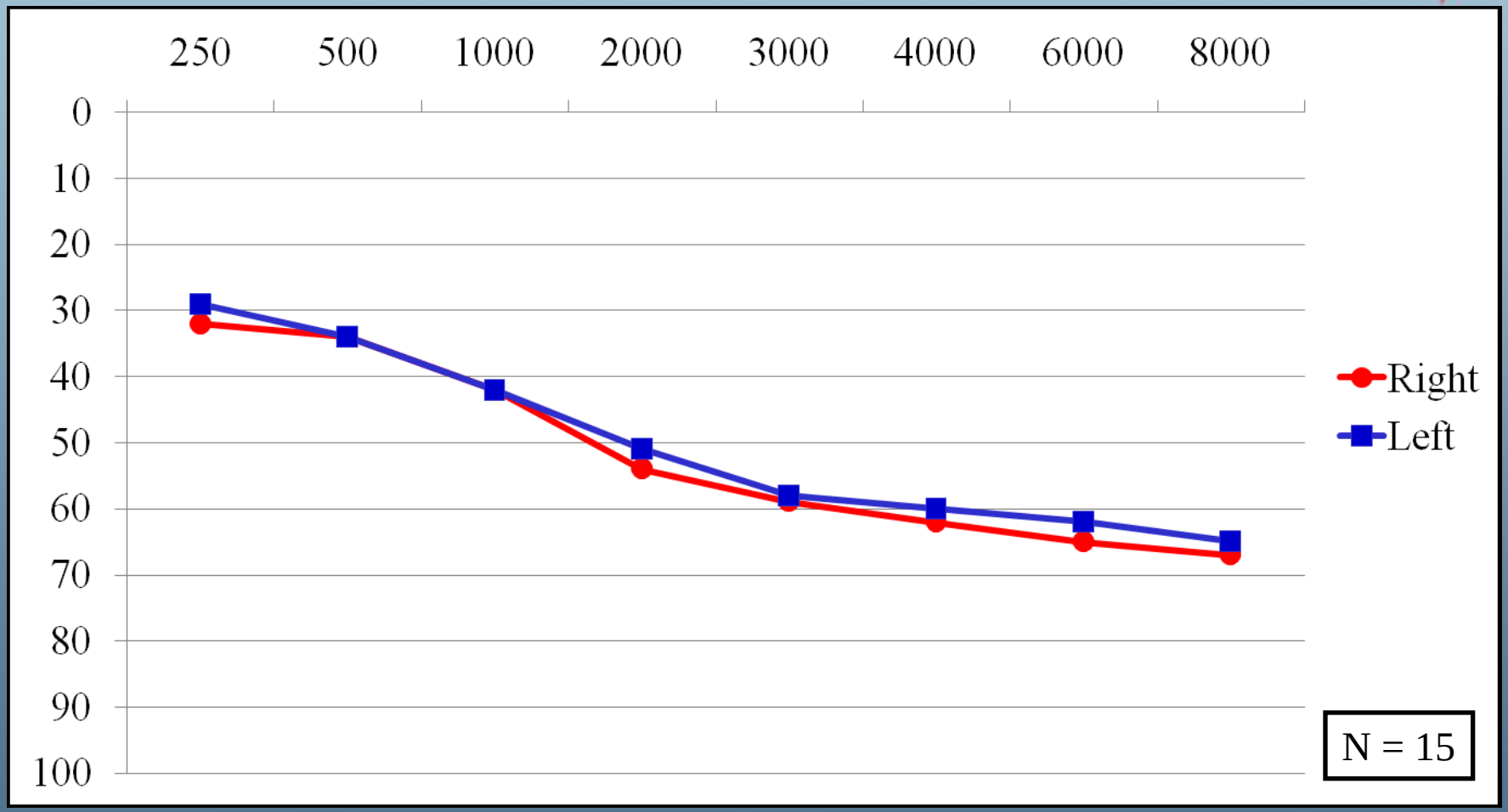
- Does non-linear frequency compression (SoundRecover in the Nios hearing aid) improve speech recognition for children with moderate SNHL?

- 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)

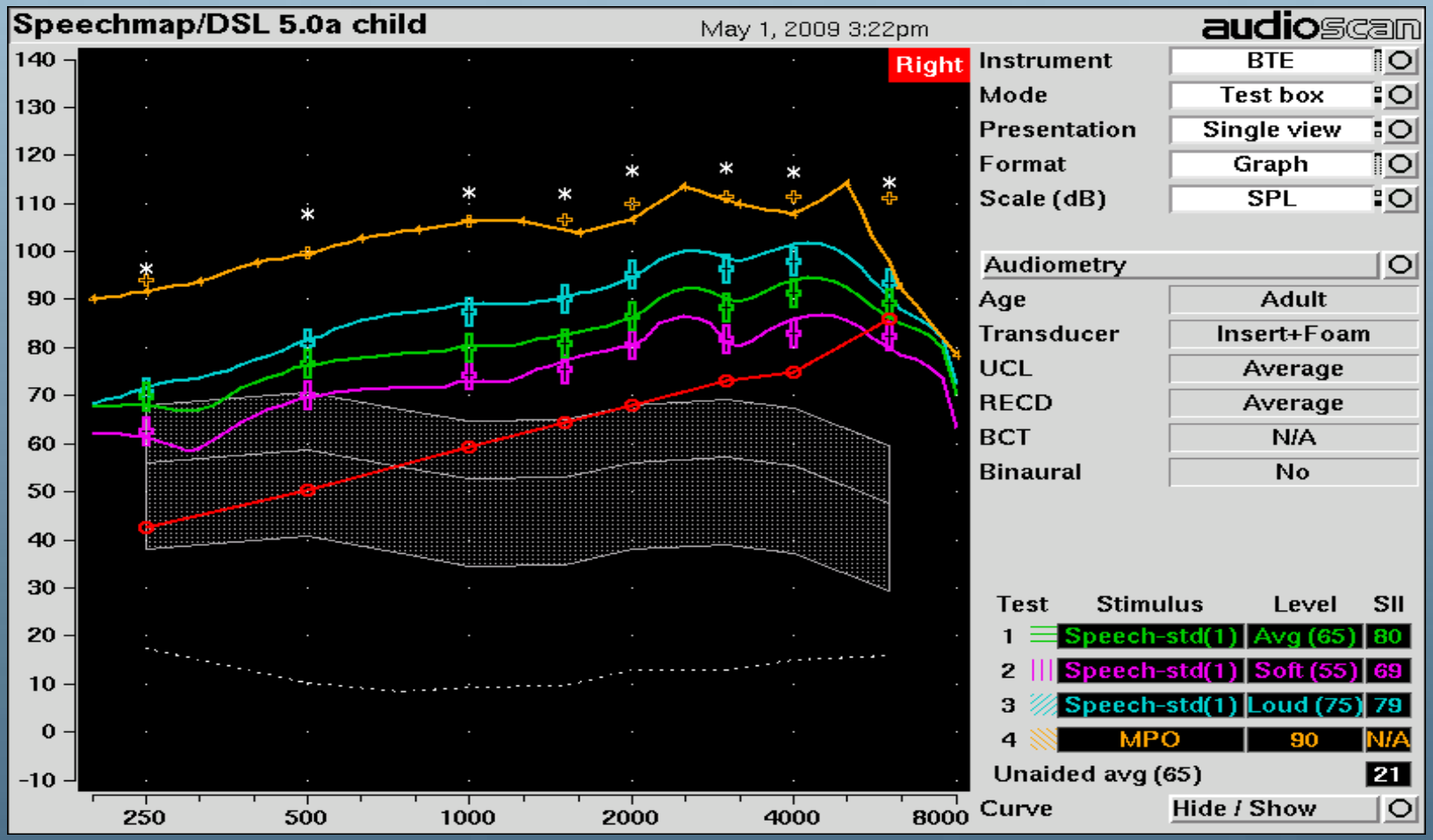
Procedures

- 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.

Procedures

- Conducted acoustic feedback test in iPFG to set maximum gain limits and optimize feedback cancellation system
- Disabled SoundRecover (Non-linear Frequency Compression)
- Conducted real ear probe microphone measures to match (+/- 5 dB) hearing aid output to DSL v5.0 targets at:
  - Std. Speech – 55 dB SPL
  - Std. Speech – 65 dB SPL
  - Std. Speech – 75 dB SPL
  - Swept Pure Tone at 90 dB SPL

Step 1: Fit to target without frequency compression



Audioscan Verifit Frequency Lowering Verification Stimulus

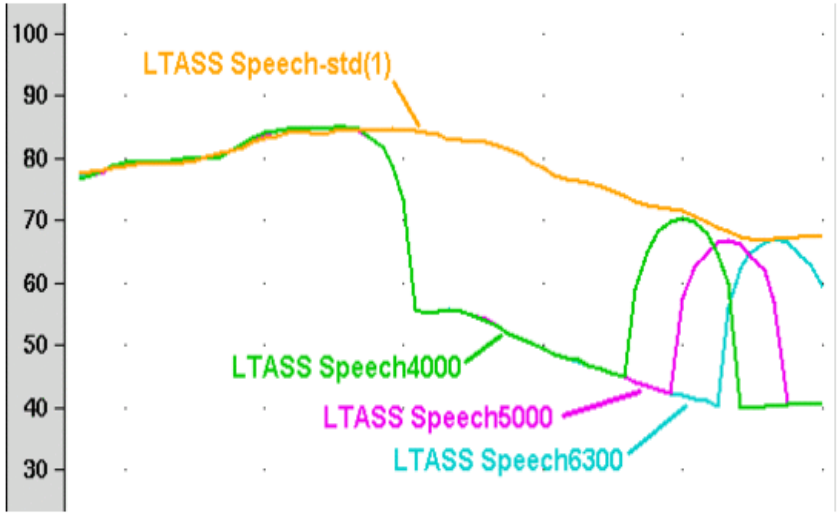
- Intended to verify the function of hearing aids with frequency lowering technology
- The "Standard Speech Passage" (Carrot Passage), is filtered past 1000 Hz except for a 1/3-octave band centered at one of 4 frequencies
  - 3150
  - 4000
  - 5000
  - 6300
- Std Speech 4000 and 6300 are most likely representative of the phonemes /sh/ and /s/, respectively.

18 Speechmap Fitting Procedures

Verifying Frequency-Lowering (Frequency Transposition) Hearing Instruments in Speechmap

Frequency lowering is used when it is not possible to amplify the high frequency components of speech sufficiently to raise them above threshold. In this case, the high frequency components may be shifted to a lower frequency with a better hearing threshold where the available gain will render them audible.

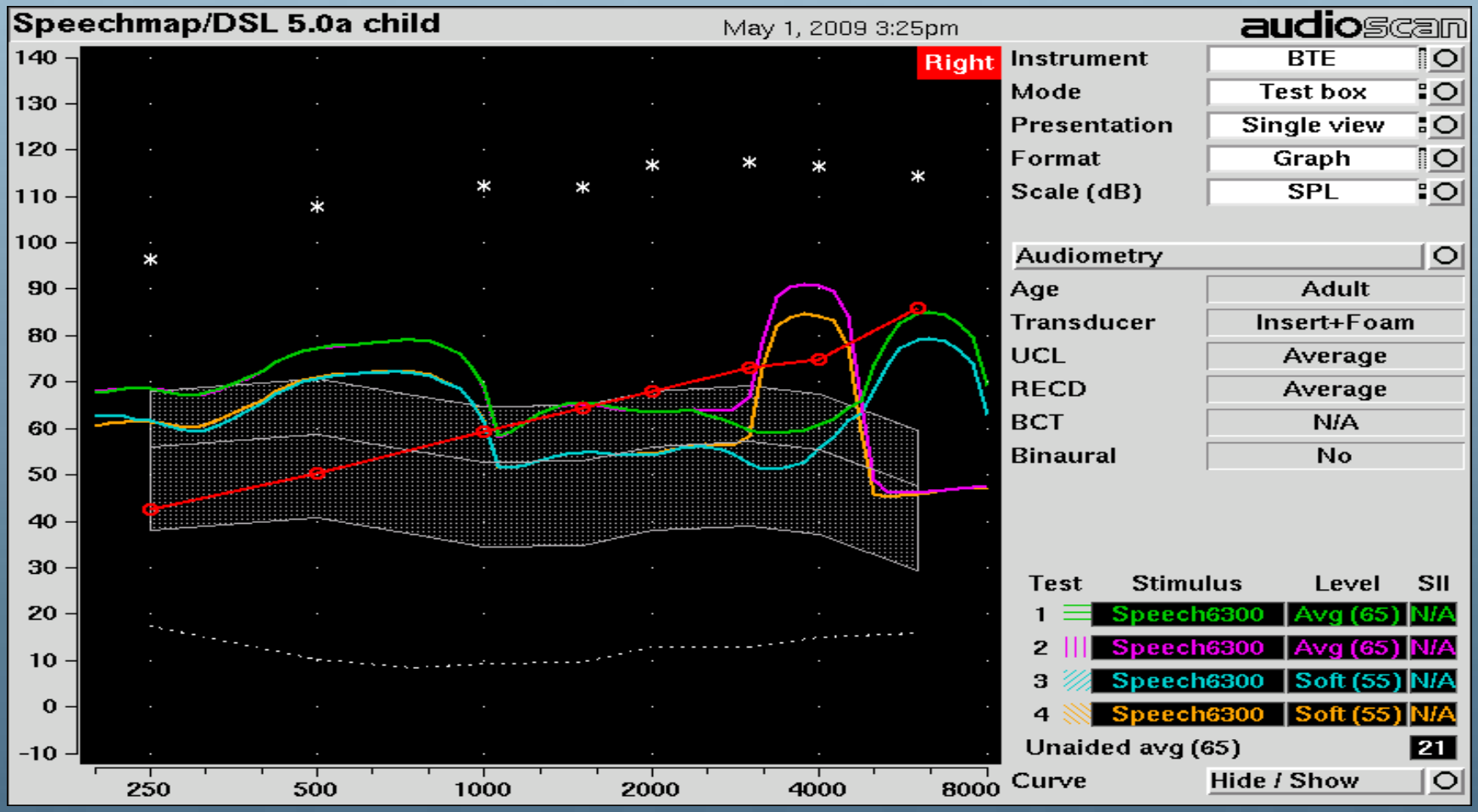
Three modified versions of the Speech-std (1) test stimulus (Speech4000, Speech 5000 and Speech6300) are provided in Speechmap to assist in verifying and adjusting frequency lowering devices. In each of these modified test stimuli, the 1/3 octave band levels above 1000Hz are reduced by 30dB, except for an isolated 1/3 octave band centered at the frequency indicated in the selected test stimulus' name. With these reduced band levels, the resulting LTASS produces a distinct "cavity" between 1000Hz and the selected high frequency band, as seen below for the FM Boom test signal.



Procedures

- With NLFC disabled, measured output to AudioScan Verifit for Frequency Lowering Verification Stimuli:
  - Std. Speech 6300 – 65 dB SPL
  - Std. Speech 6300 – 55 dB SPL
- Enabled NLFC at default settings and measured hearing aid output to AudioScan Verifit for Frequency Lowering Verification Stimuli:
  - Std. Speech 6300 – 65 dB SPL
  - Std. Speech 6300 – 55 dB SPL

Step 2: Ensure that high-frequency sounds are audible



Procedures

- Ensure adequate audibility for Speech Std 6300 Hz stimulus at 65 dB SPL.
- Ensure that child and clinician feel sound quality is adequate.
- Ensure child can detect and discriminate /sh/ from /s/ through audition alone.
- Never had to reduce “strength” of frequency compression.
- For 5 subjects, strength of frequency compression was increased to improve audibility.

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
  - Phoneme Perception Test
  - BKB-SIN

UWO Plurals Test

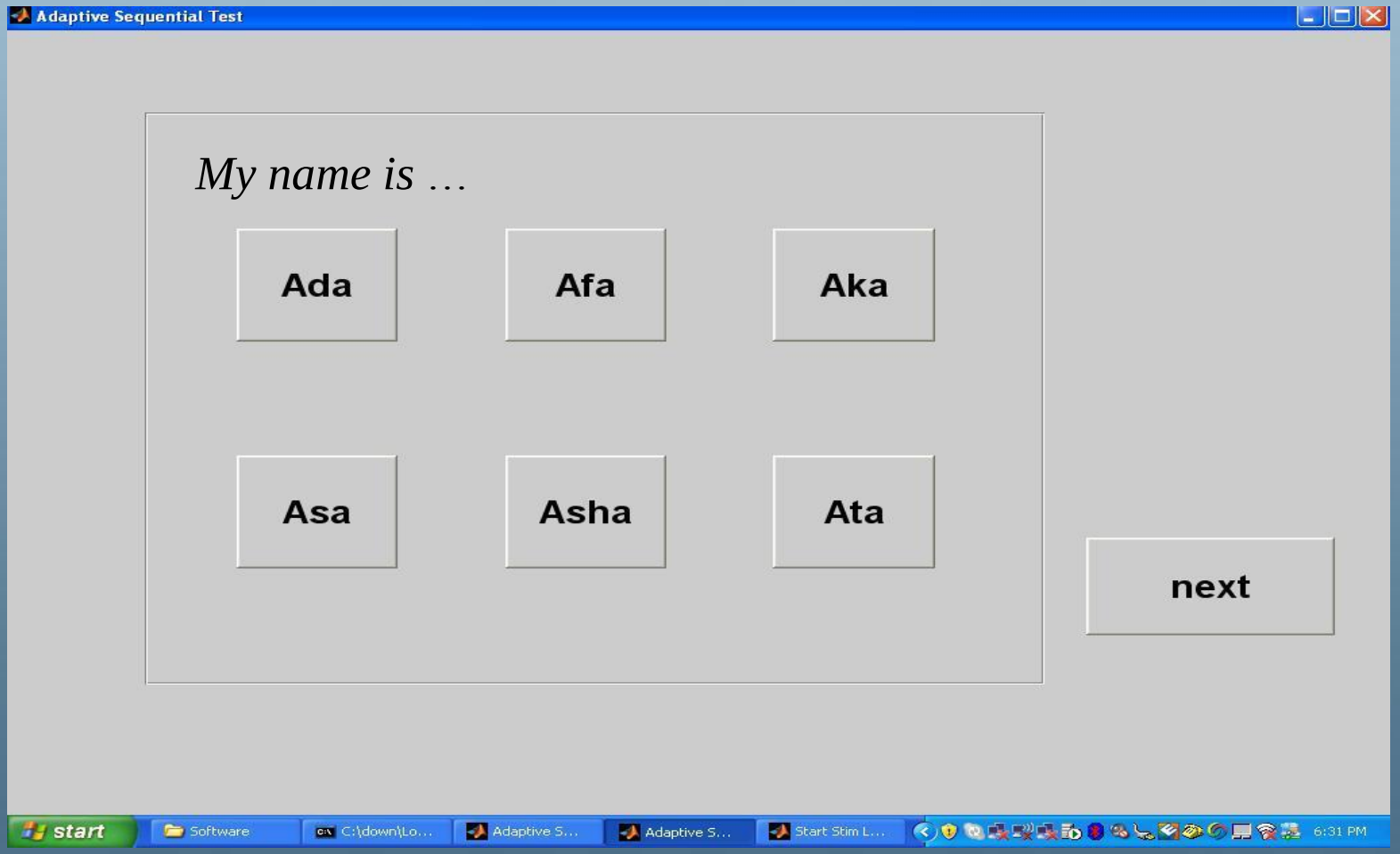
- Female Speaker
- 15 words familiar to school-aged children in both singular and plural form (/s/ or /z/ in final position) → CF = 9000 Hz
  - Book/Books
  - Cup/Cups
  - Dog/Dogs
  - Sock/Socks

  } Designed to be presented in closed-set
- Presented at 50 dB A from loudspeaker directly in front of the child. → Presentation level may vary dependent upon HL.

Phoneme Perception Test

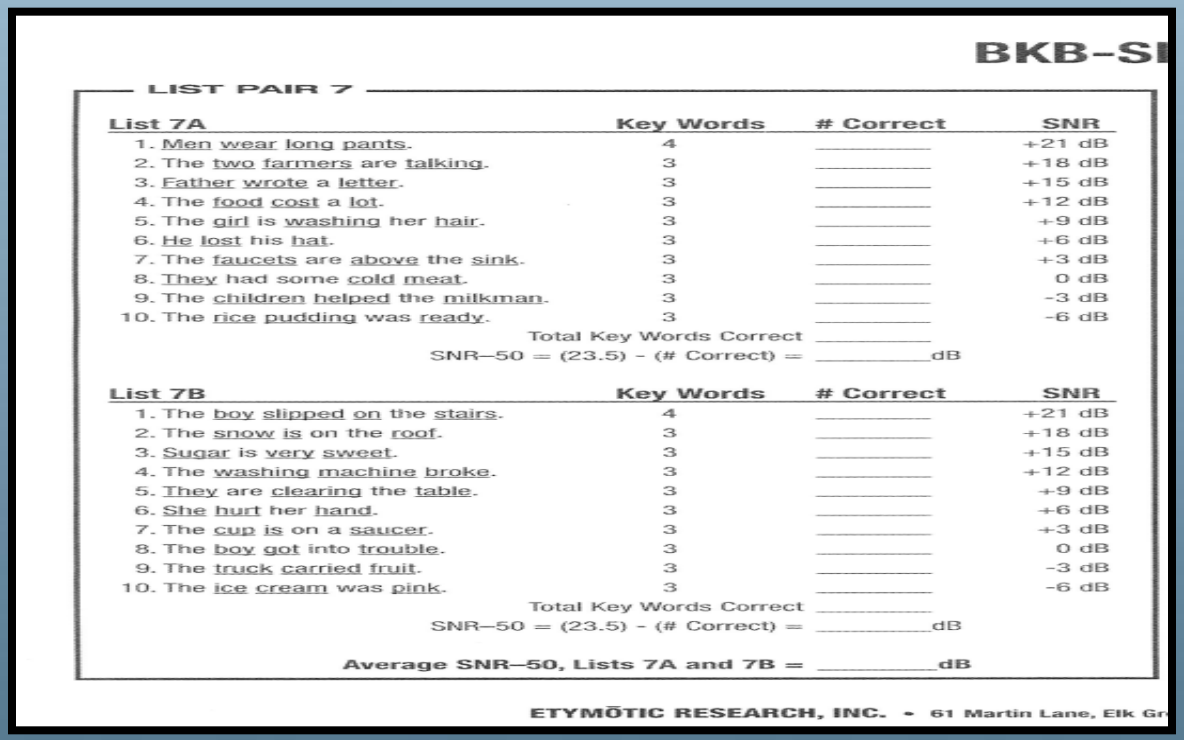
- Adaptive, computer-controlled test
- Female speaker saying, “My name is ..”
  - ASA
  - ASA6K
  - ADA
  - AKA
  - AFA
  - ASHA
  - ATA
- Software tracks level in dB SPL that corresponds to 50% correct performance.

Phoneme Perception Test



BKB-SIN

- Two 10-sentence lists
- Sentence level at 50 dB HL
- Determines dB SNR for 50% Correct



BKB–SI

LIST PAIR 7

List 7A	Key Words	# Correct	SNR
1. Men wear long pants.	4	_____	+21 dB
2. The two farmers are talking.	3	_____	+18 dB
3. Father wrote a letter.	3	_____	+15 dB
4. The food cost a lot.	3	_____	+12 dB
5. The girl is washing her hair.	3	_____	+9 dB
6. He lost his hat.	3	_____	+6 dB
7. The faucets are above the sink.	3	_____	+3 dB
8. They had some cold meat.	3	_____	0 dB
9. The children helped the milkman.	3	_____	-3 dB
10. The rice pudding was ready.	3	_____	-6 dB
	Total Key Words Correct	_____	
	SNR–50 = (23.5) - (# Correct) =	_____dB	

List 7B	Key Words	# Correct	SNR
1. The boy slipped on the stairs.	4	_____	+21 dB
2. The snow is on the roof.	3	_____	+18 dB
3. Sugar is very sweet.	3	_____	+15 dB
4. The washing machine broke.	3	_____	+12 dB
5. They are clearing the table.	3	_____	+9 dB
6. She hurt her hand.	3	_____	+6 dB
7. The cup is on a saucer.	3	_____	+3 dB
8. The boy got into trouble.	3	_____	0 dB
9. The truck carried fruit.	3	_____	-3 dB
10. The ice cream was pink.	3	_____	-6 dB
	Total Key Words Correct	_____	
	SNR–50 = (23.5) - (# Correct) =	_____dB	

Average SNR–50, Lists 7A and 7B = _____dB

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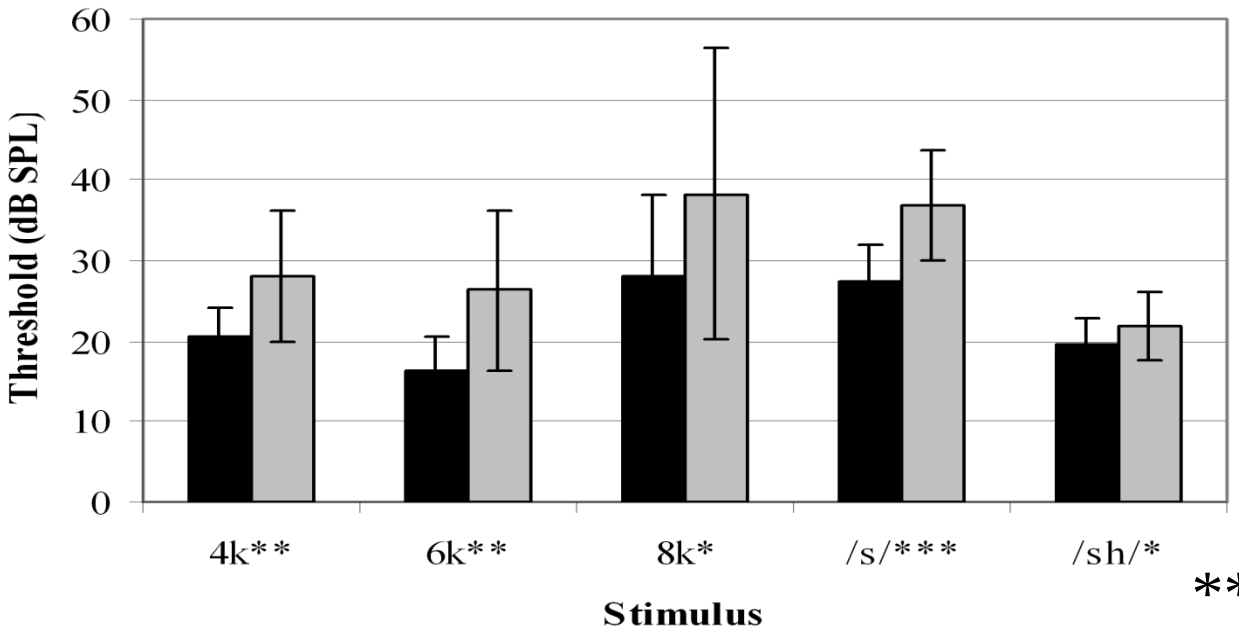
Hearts for Hearing FOUNDATION

- Results

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



*: p < .05

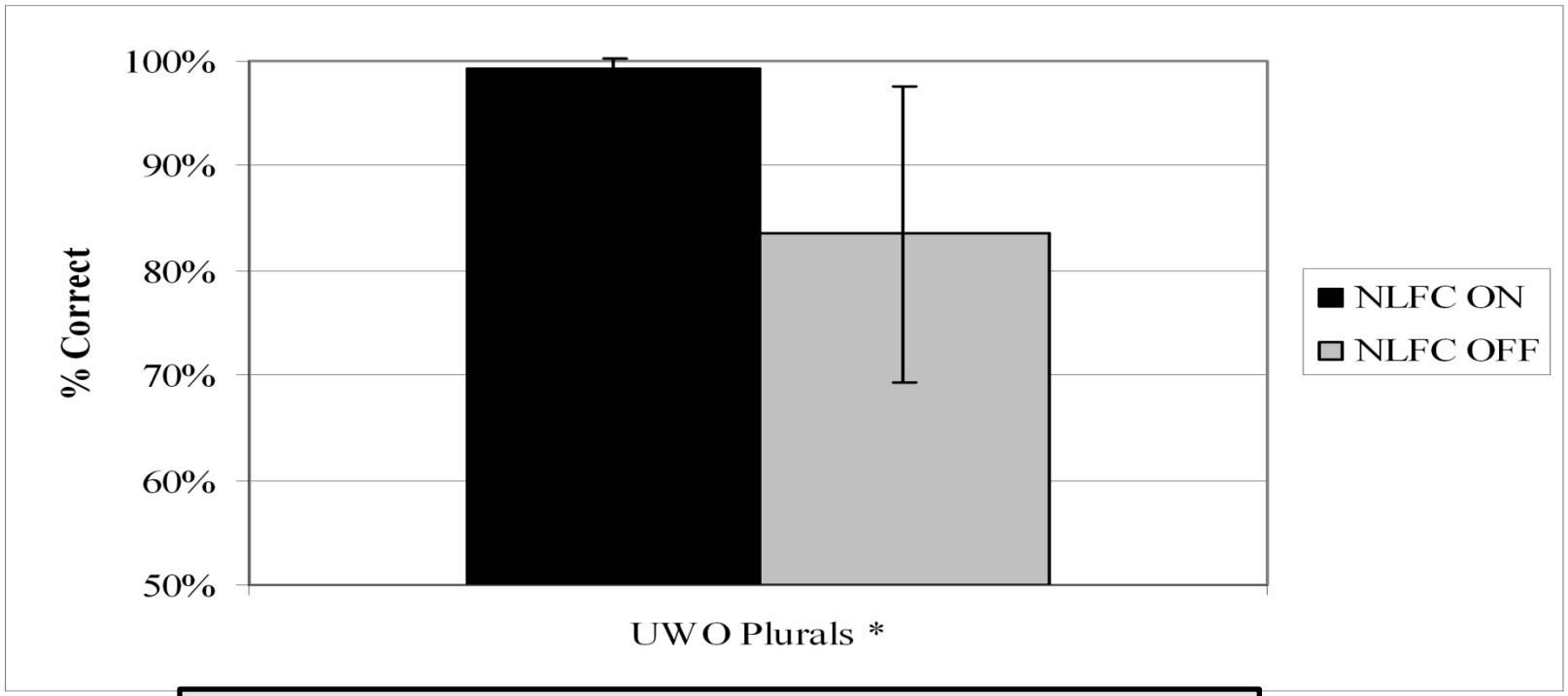
**: p < .01

***: p < .001

NLFC provides a statistically significant improvement in aided thresholds.

Wolfe et al. (2010), J Am Acad of Audiol

UWO Plural Test
NLFC Off vs. NLFC On

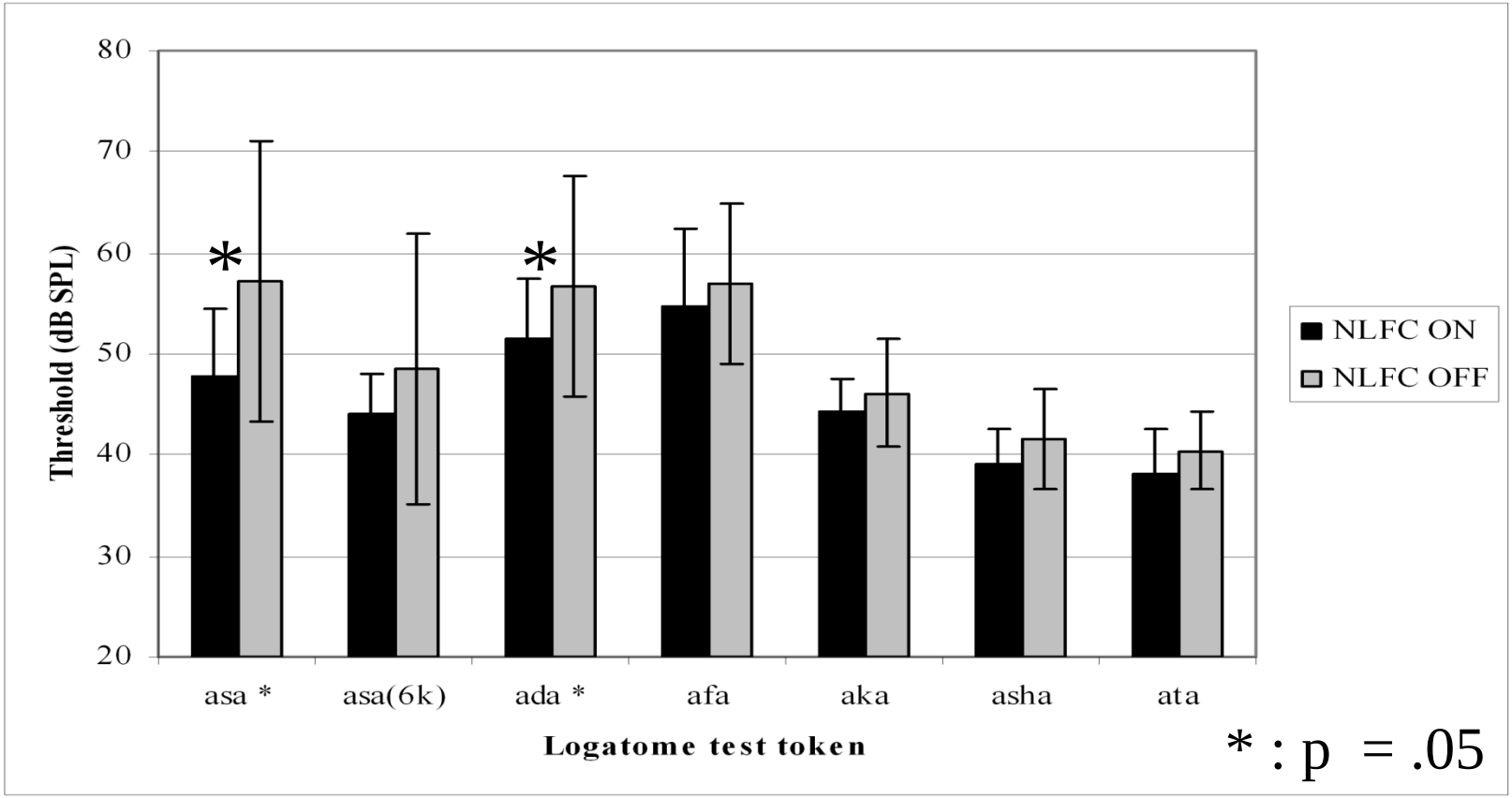


NLFC improves speech recognition on UWO Plural Test by 16% points.

* P < .001

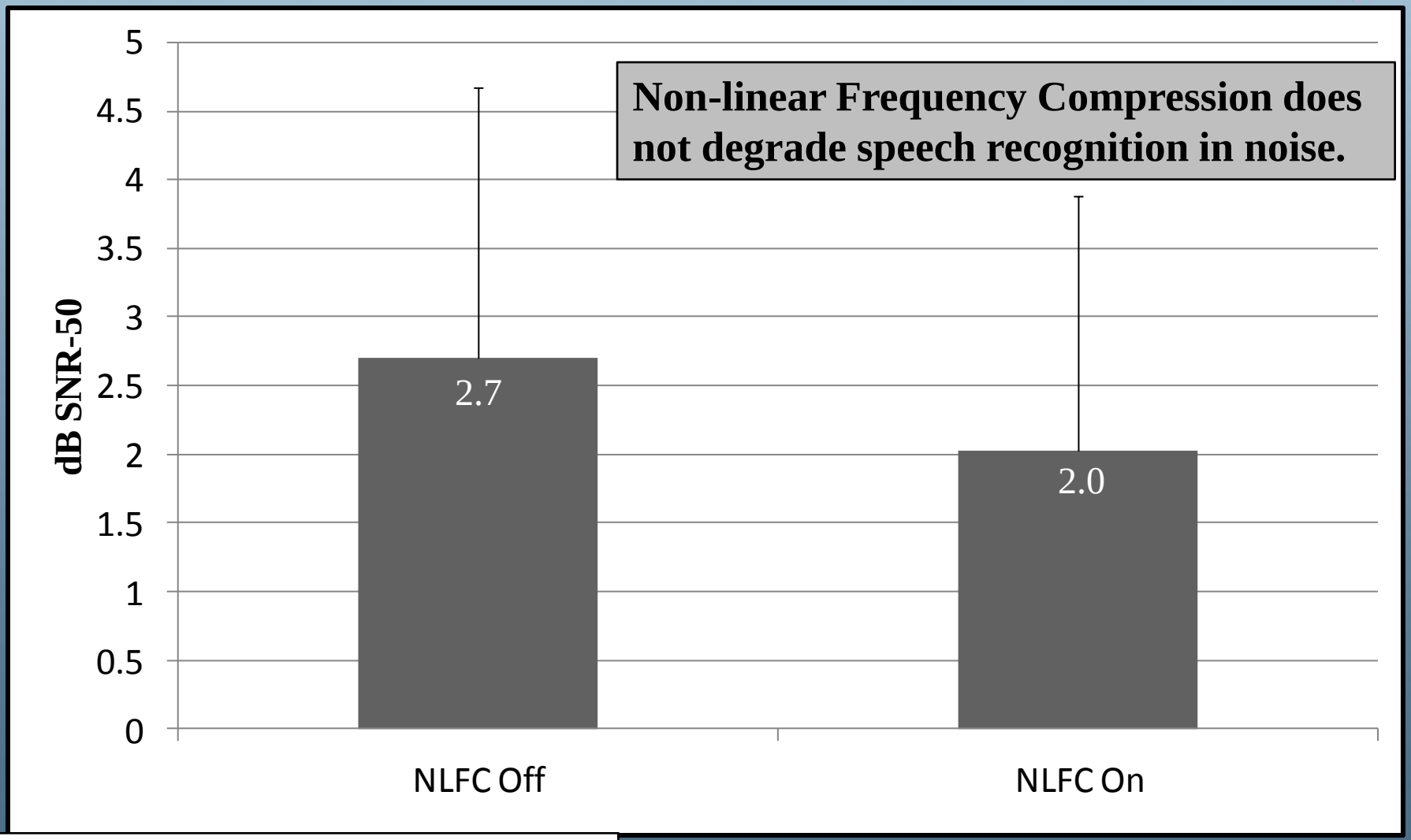
Wolfe et al. (2010), J Am Acad of Audiol

Speech Recognition Threshold (dB SPL) for 7 VCV Tokens



Wolfe et al. (2010), J Am Acad of Audiol

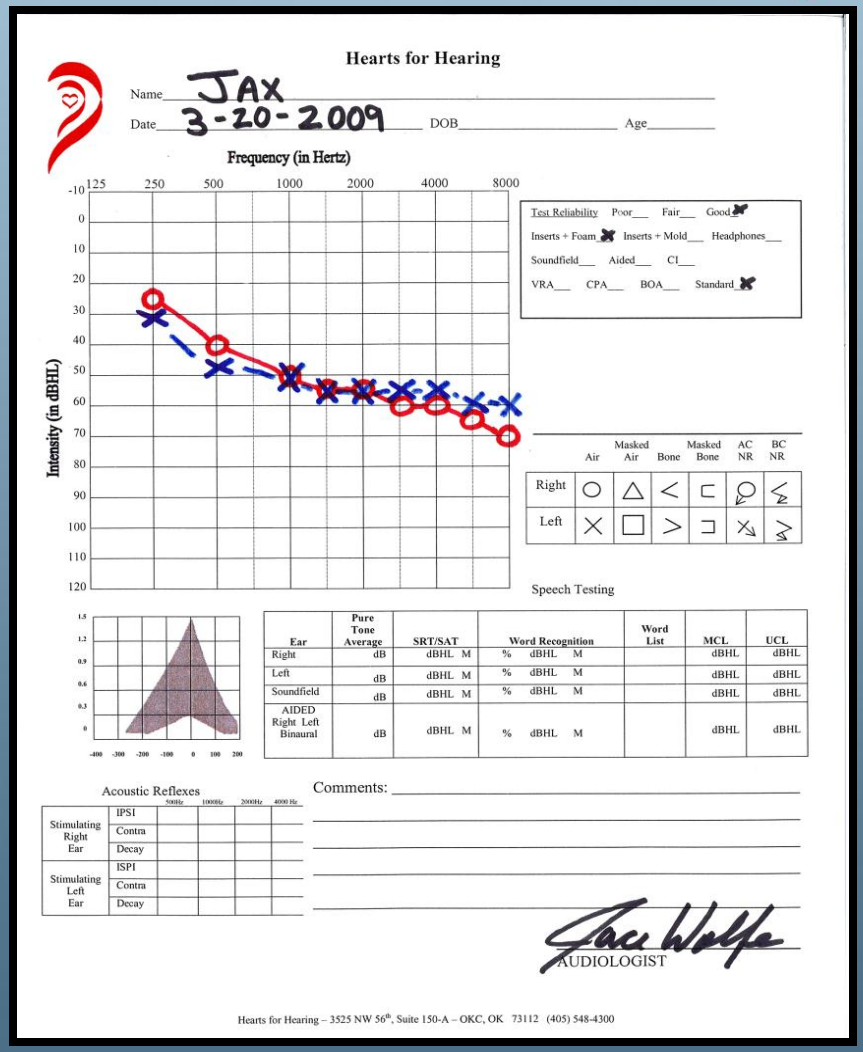
Speech Recognition in Noise
NLFC Off vs NLFC On



Wolfe et al. (2010), J Am Acad of Audiol

Jax

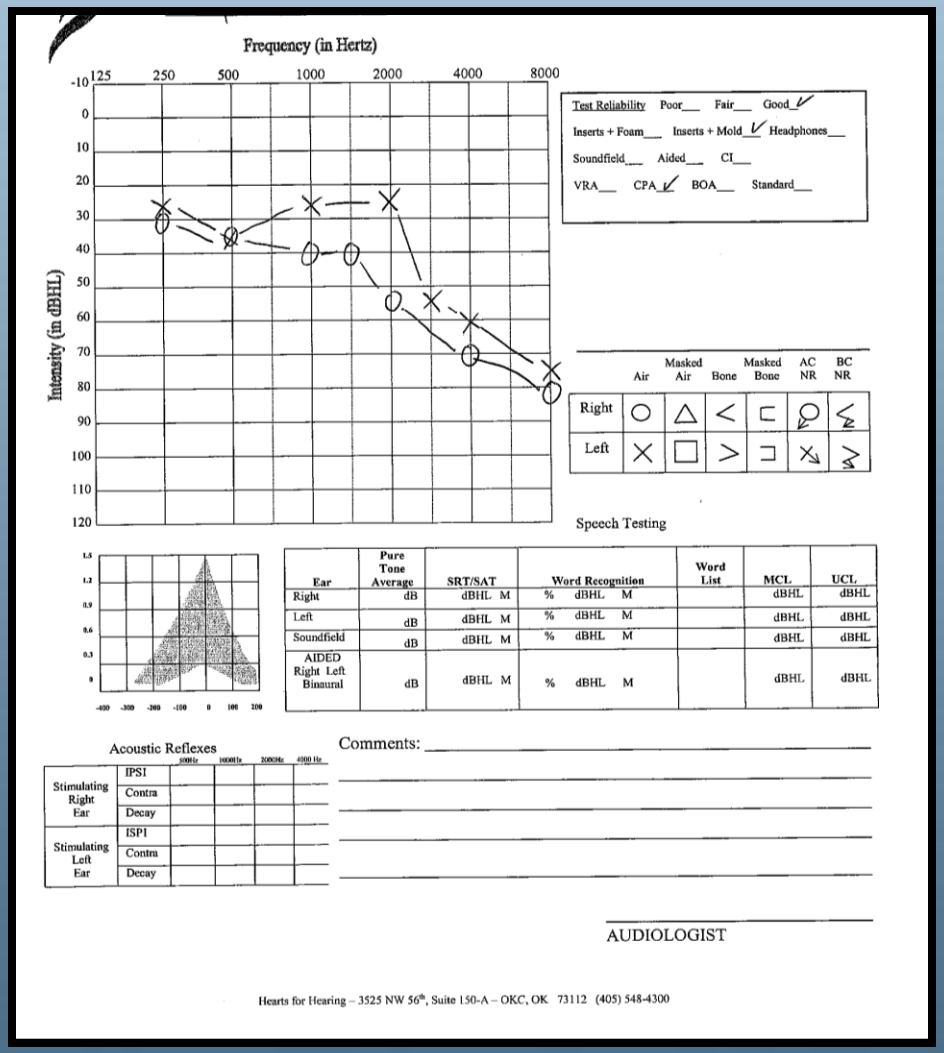
- 13-year old boy
- Congenital hearing loss of unknown etiology
- Previously wore Perseo 211 Behind-the-Ear hearing aids
- Excels in typical classroom placement



Jax -- NLFC Off

Jax – NLFC On

Speech Production -- Riley



Frequency (in Hertz)

125 250 500 1000 2000 4000 8000

Intensity (in dBHL)

-10 0 10 20 30 40 50 60 70 80 90 100 110 120

Test Reliability Poor___ Fair___ Good ✓

Inserts + Foam___ Inserts + Mold ✓ Headphones___

Soundfield___ Aided___ CI___

VRA___ CPA ✓ BOA___ Standard___

	Air	Masked Air	Bone	Masked Bone	AC NR	BC NR
Right	○	△	<	⊏	○	<
Left	×	□	>	⊐	×	>

Speech Testing

Ear	Pure Tone Average	SRT/SAT	Word Recognition	Word List	MCL	UCL
Right	dB	dBHL M	% dBHL M		dBHL	dBHL
Left	dB	dBHL M	% dBHL M		dBHL	dBHL
Soundfield	dB	dBHL M	% dBHL M		dBHL	dBHL
AIDED Right Left Binaural	dB	dBHL M	% dBHL M		dBHL	dBHL

Acoustic Reflexes

		500Hz	1000Hz	2000Hz	4000 Hz
Stimulating Right Ear	IPSI				
	Contra				
	Decay				
Stimulating Left Ear	ISPI				
	Contra				
	Decay				

Comments: _____

AUDIOLOGIST

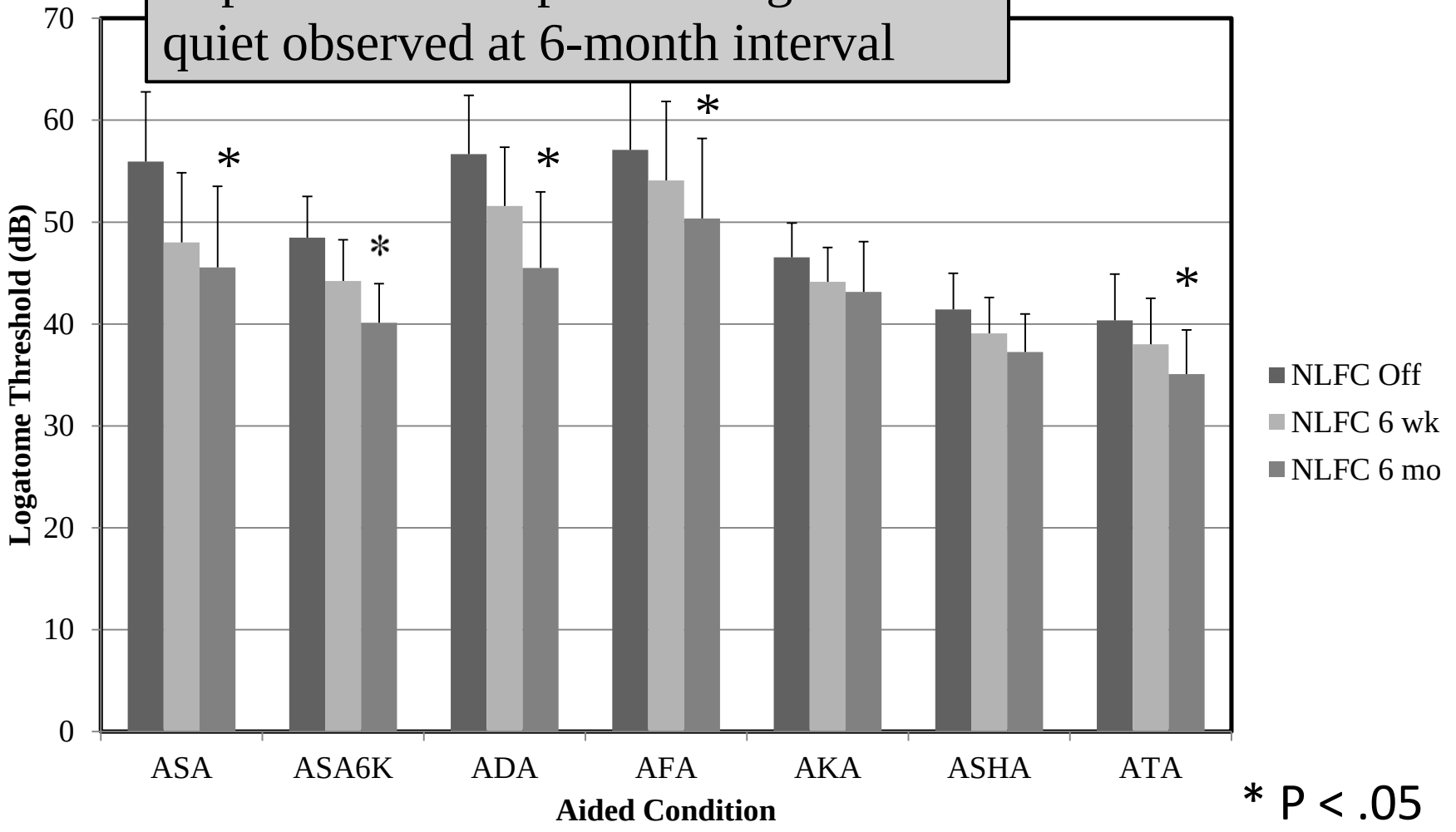
Hearts for Hearing – 3525 NW 56th, Suite 150-A – OKC, OK 73112 (405) 548-4300

Baseline

SoundRecover On

Logatome Thresholds

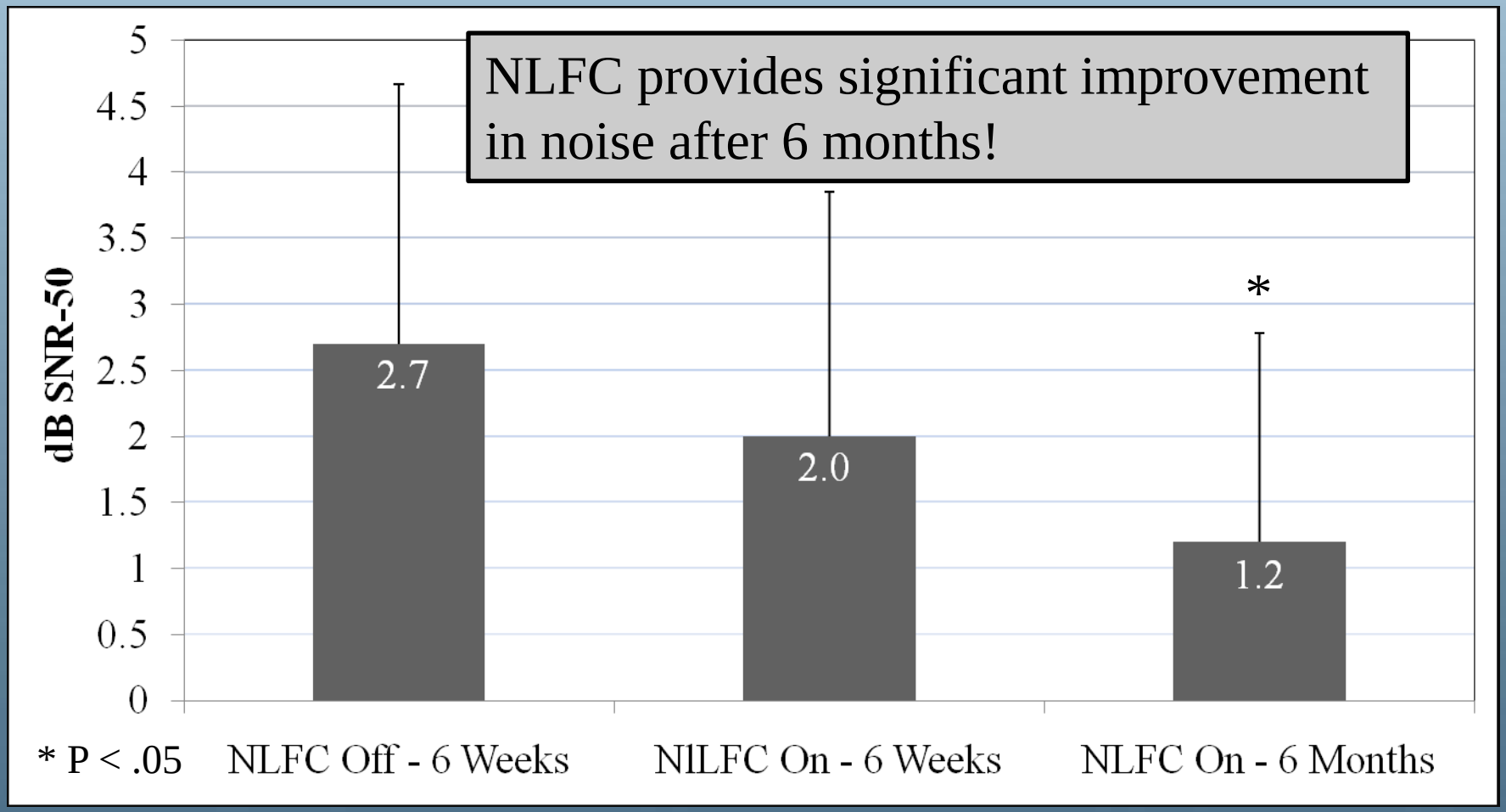
Improvement in speech recognition in quiet observed at 6-month interval



* P < .05

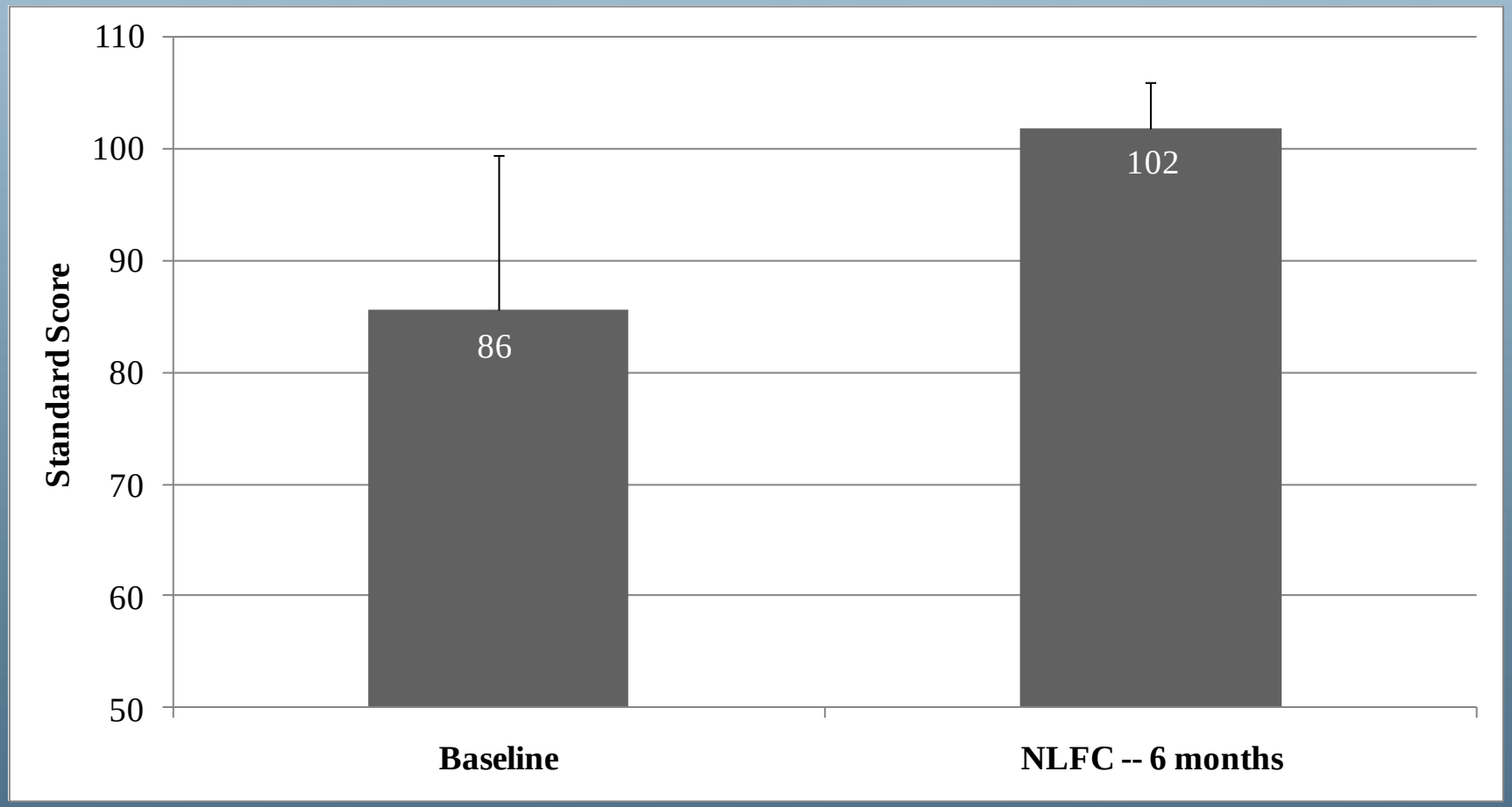
Wolfe et al. (2011), Intl J Audiol

Speech Recognition in Noise on BKB-SIN



Wolfe et al. (2011), Intl J Audiol

Speech Production
Goldman-Fristoe Test of Articulation - 2



Wolfe et al. (submitted),

Subjective

- No child objected to NLFC.
- 8/15 preferred the 6-week period using NLFC over the 6-week period without NLFC (7/15 had no preference).
  - Subjects were blinded to settings over 6-week period

High-Frequency Amplification for Children with Mild Hearing Loss & Cookie-Bite Audiograms

Jace Wolfe and Andrew John

Evaluation of Hearing Aid Technology for Children with Mild SNHL

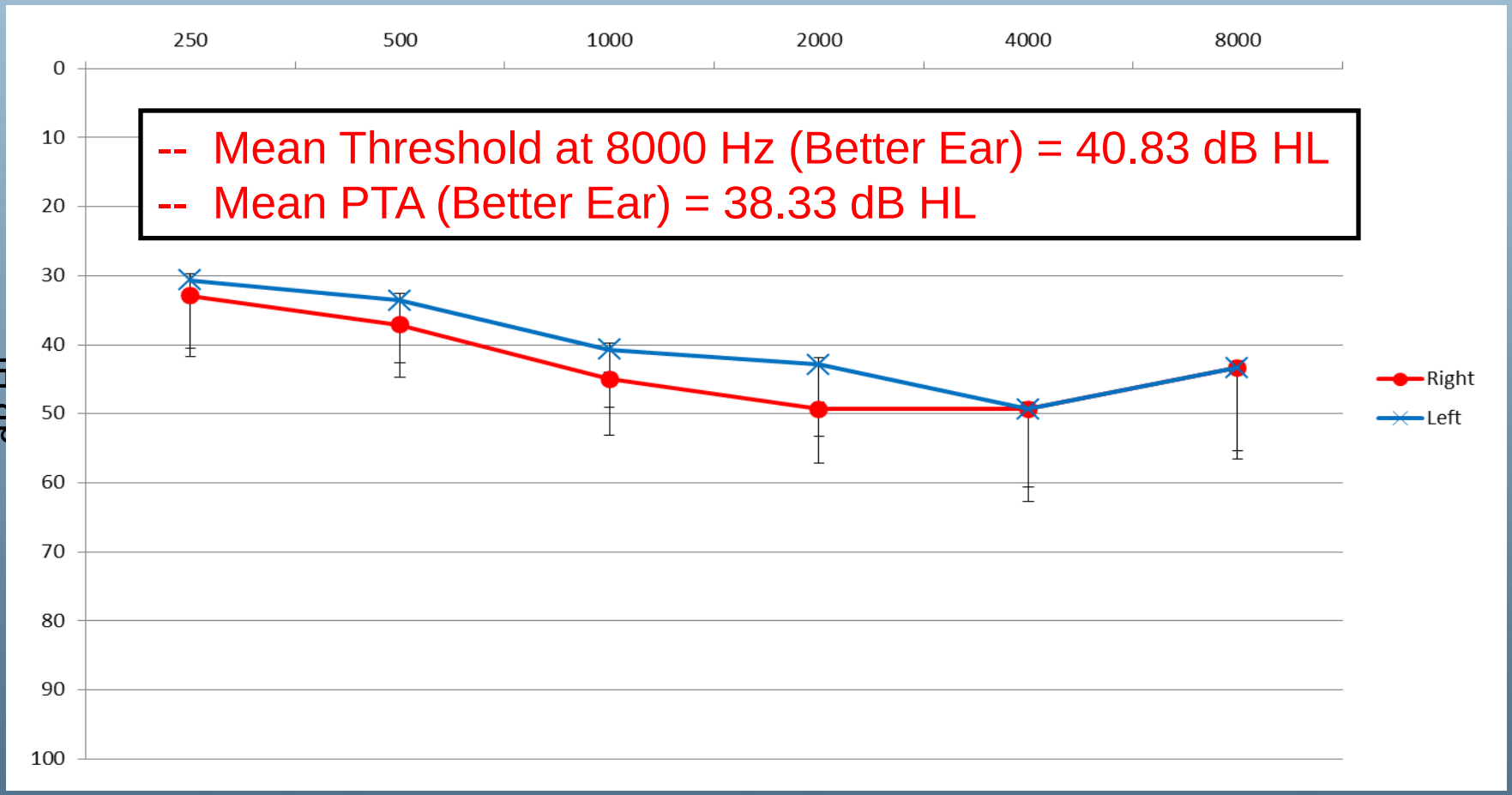
- 11 children with symmetrical, mild SNHL hearing loss
  - PTA (better ear) < 50 dB HL
  - Threshold 8K (better ear) < 50 dB HL
  - 7 yrs, 4 mths to 13 yrs, 3 mths (Mean = 10 yrs, 1 month)

- Phonak Nios S H_2O and Oticon Safari 300 BTEs fitted to DSL v 5.0 target for children (simulated real ear).
  - Phonak Nios H2O with NLFC On
  - Phonak Nios H2O with NLFC Off
  - Oticon Safari 300 Wideband Hearing Aid

- Tested after 4-6 weeks of use with each setting.

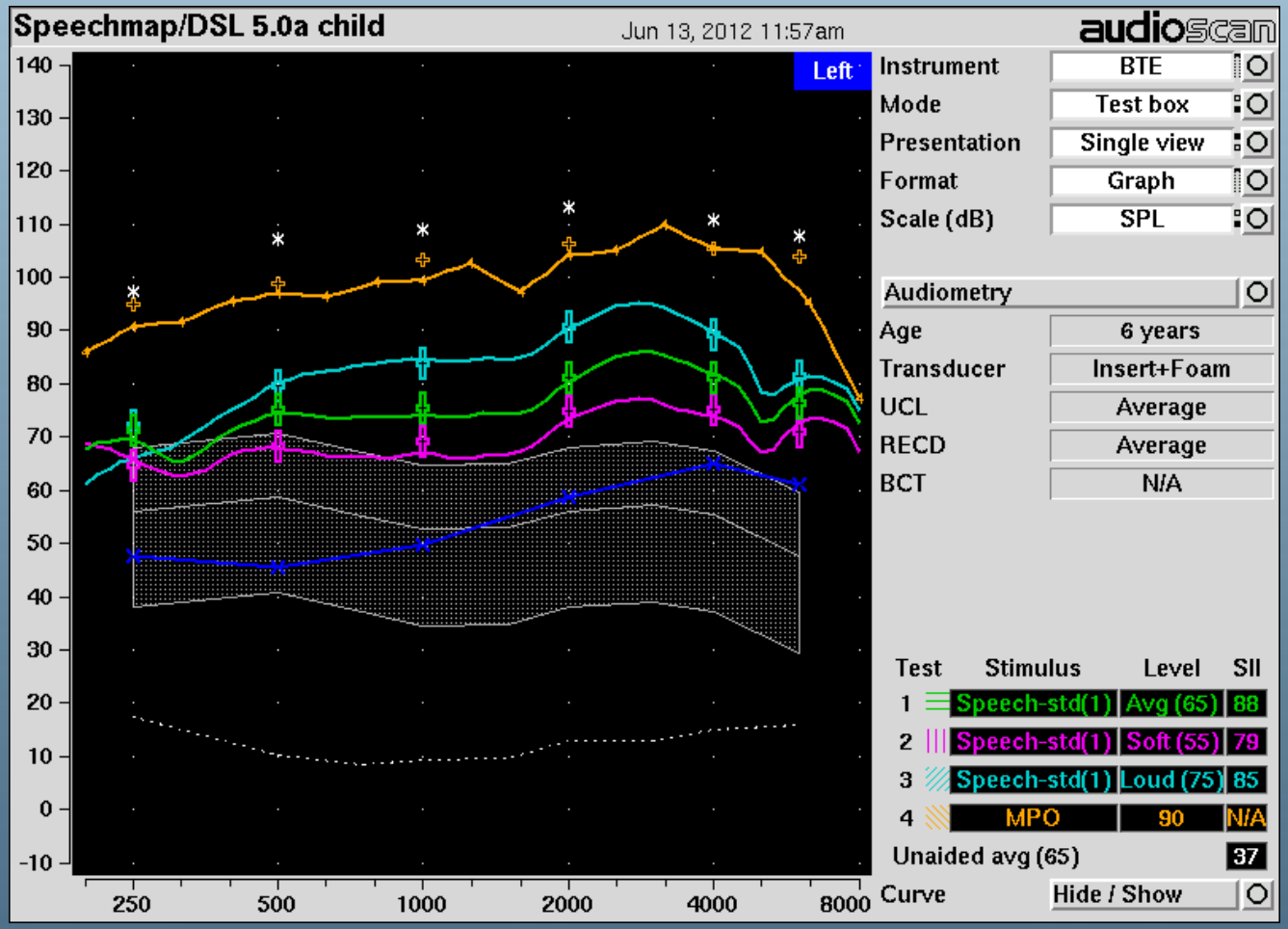
- Patient was partially-blinded.

Audiogram

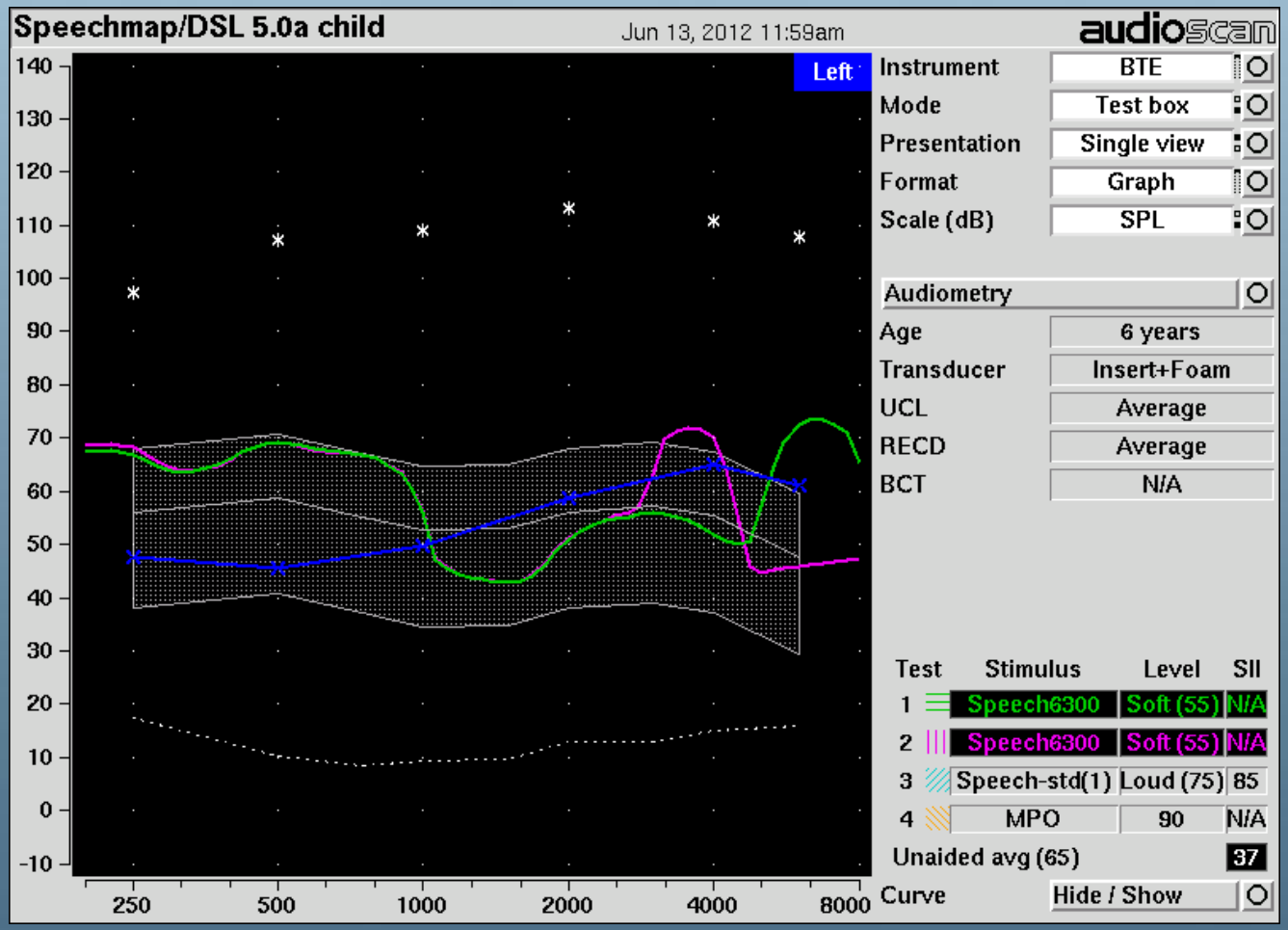


n = 11

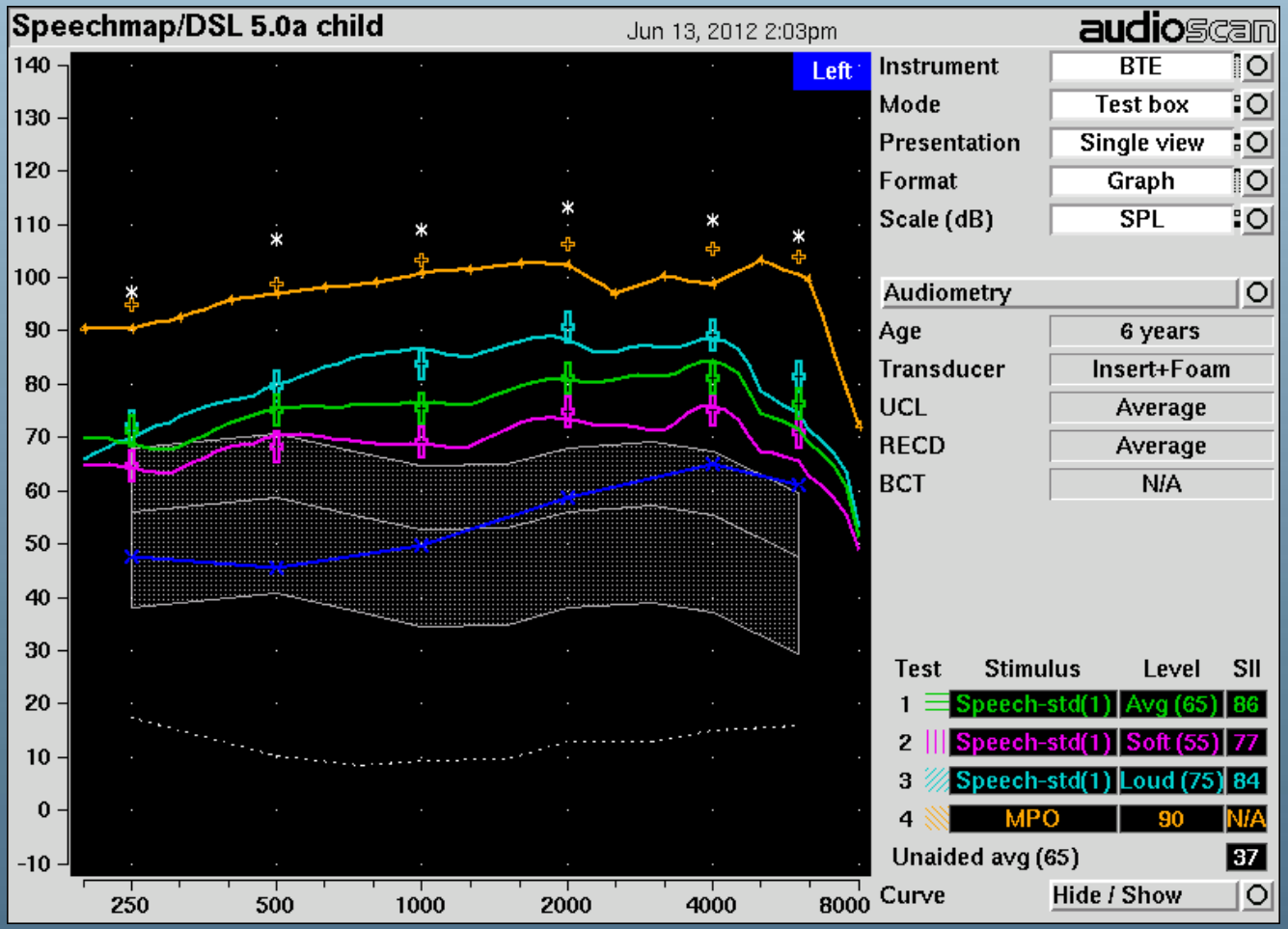
Simulated Real Ear Measures
Phonak Nios H20 NLFC Off



Set NLFC so that 6300 Hz verification stimulus was within roll-off



Simulated Real Ear Measures for Oticon Safari 300

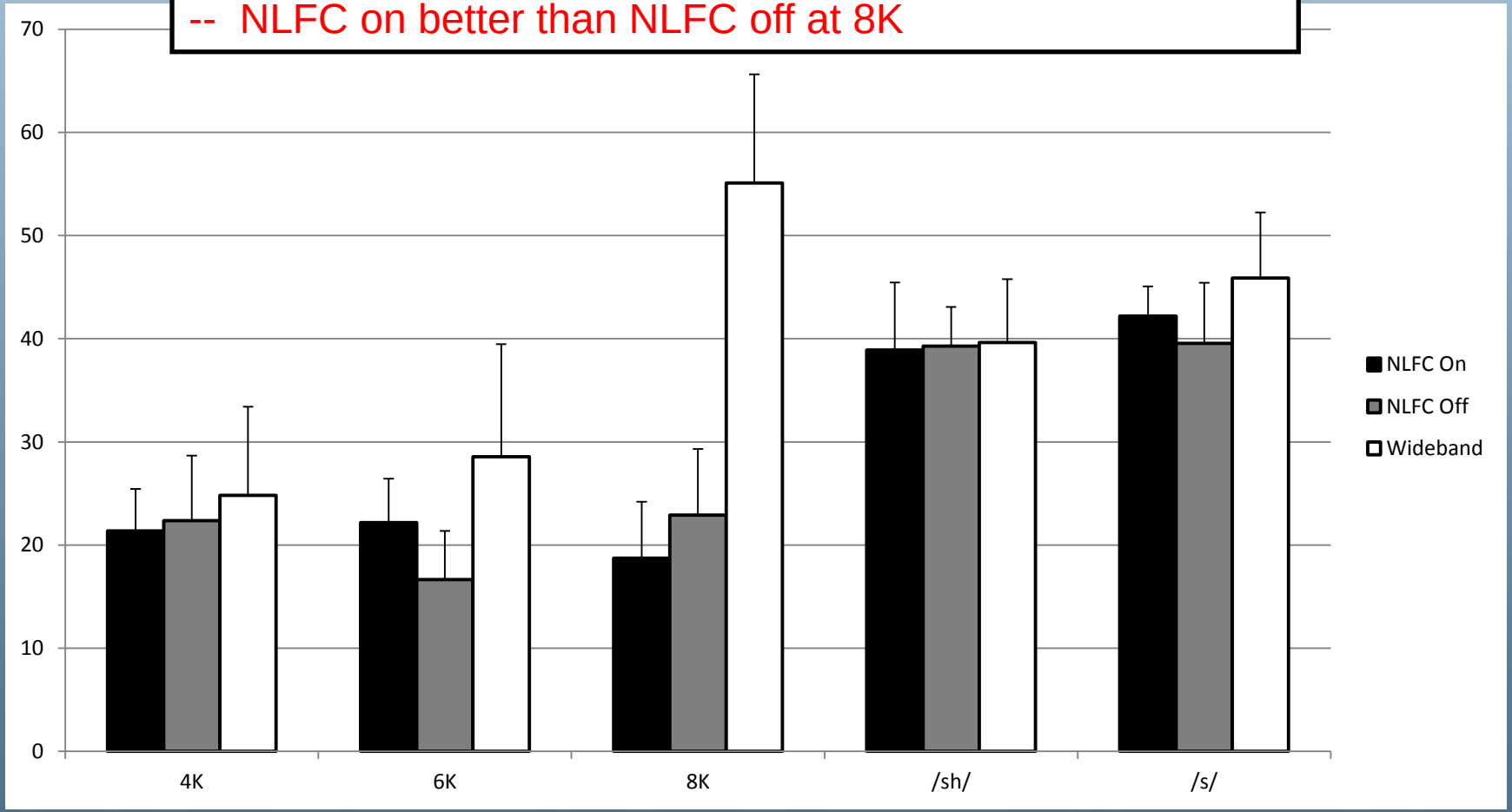


Measures

- Aided Thresholds
- UWO Plural Test
- UWO DFD Test
- Phoneme Perception Test
- BKB-SIN

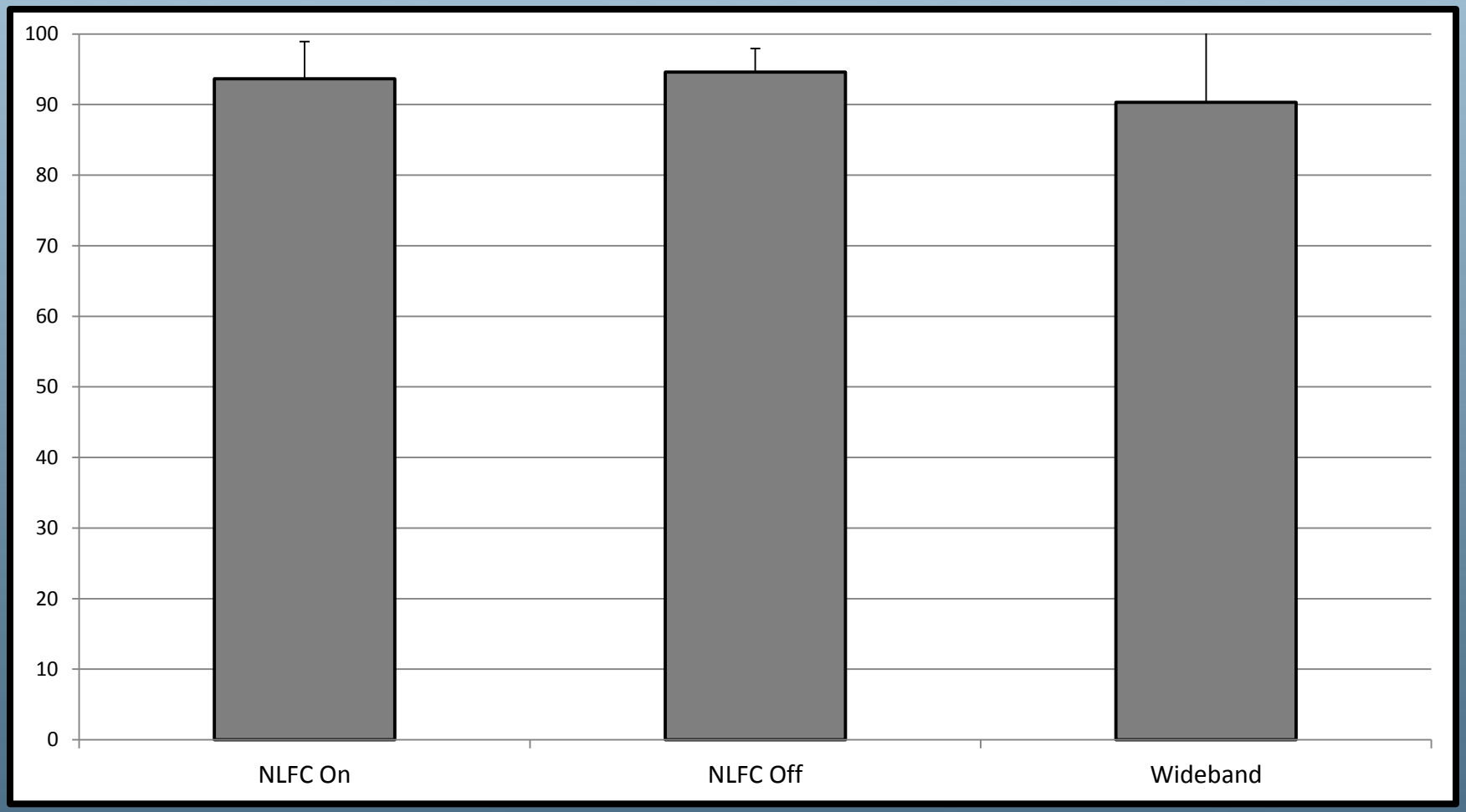
Aided Thresholds

-- Wideband poorer for /s/ and for 6K and 8K warble tones
-- NLFC on better than NLFC off at 8K



n = 11

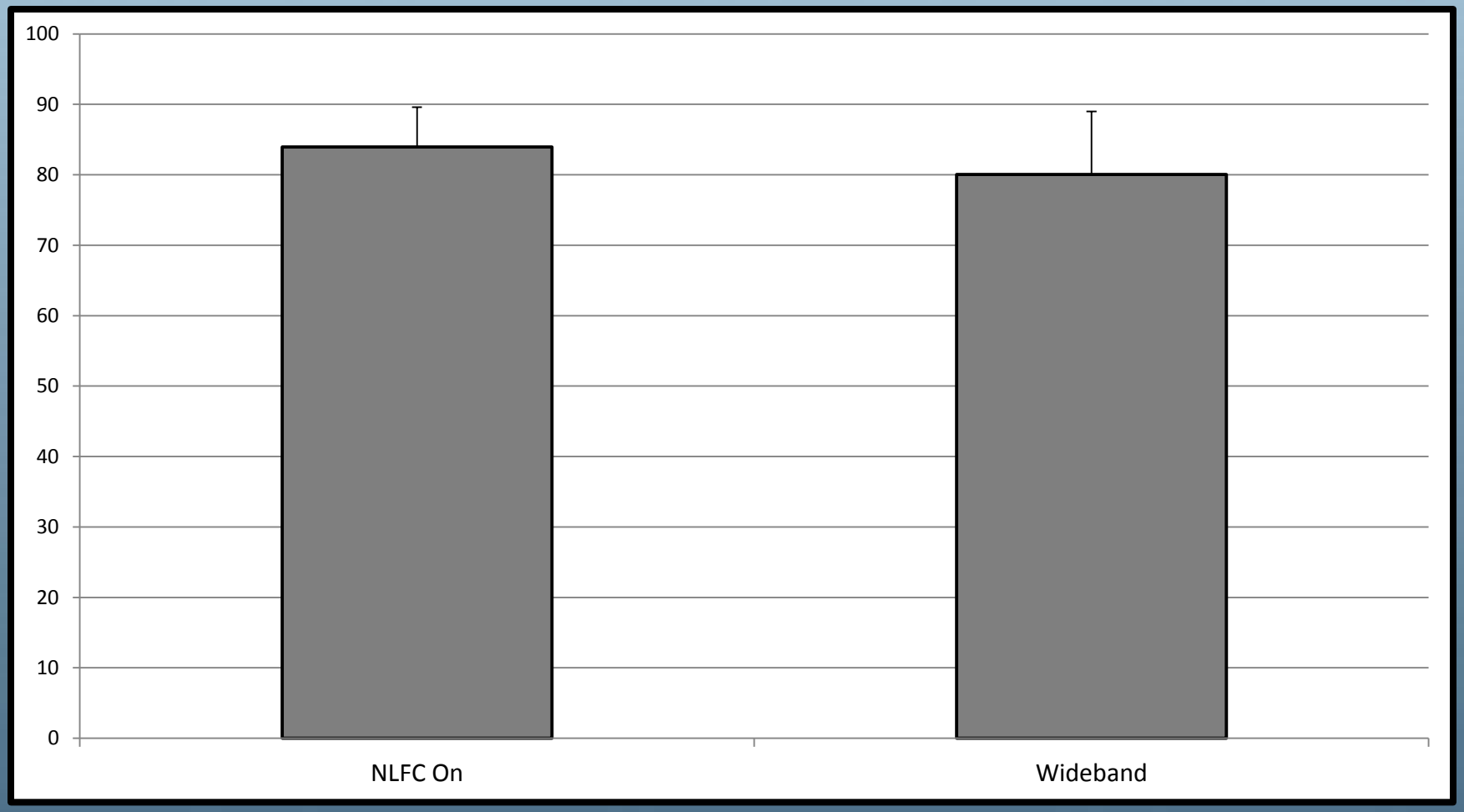
UWO Plural Test



No significant difference between conditions

n = 11

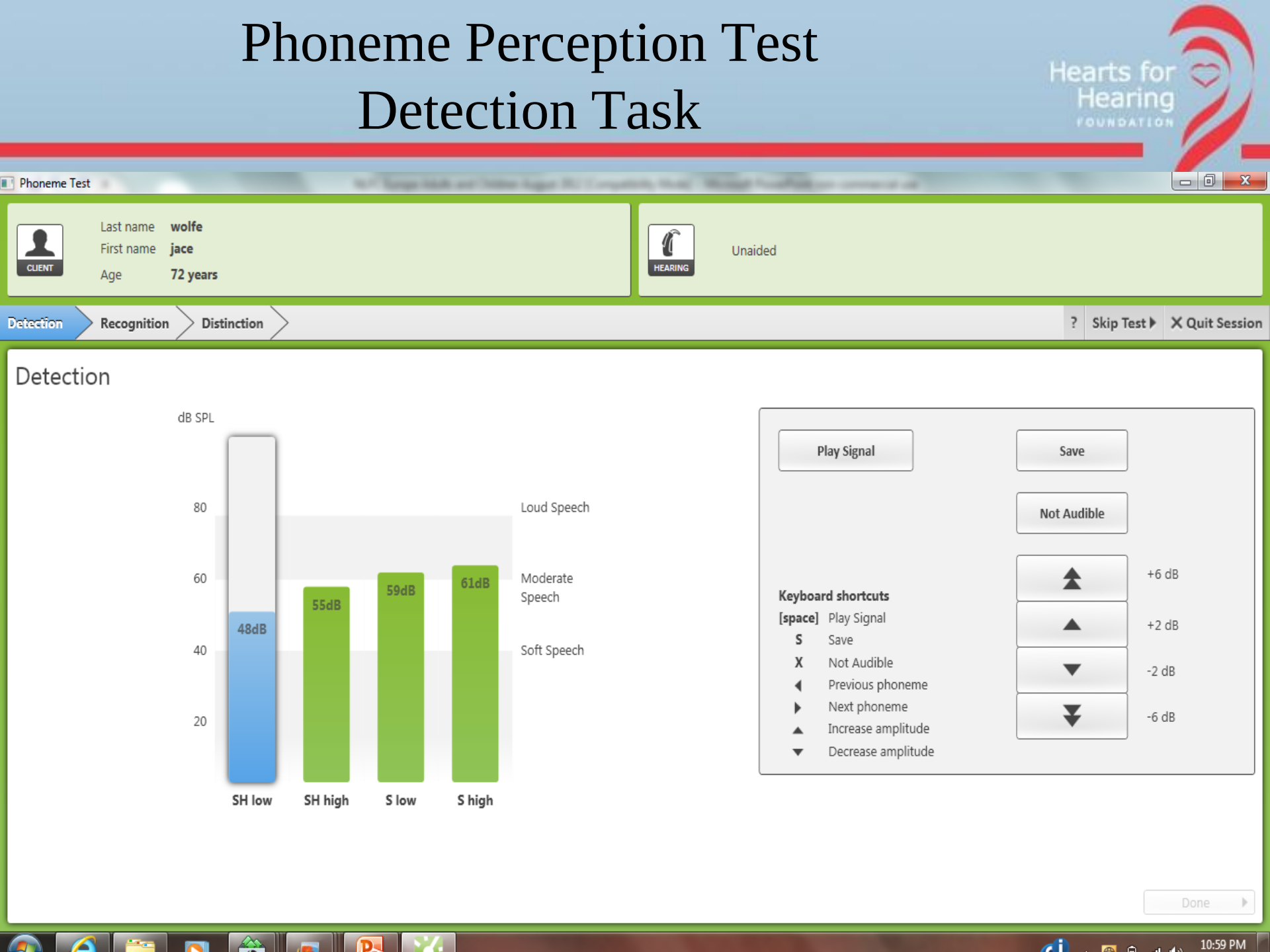
UWO DFD Test



No significant difference between conditions

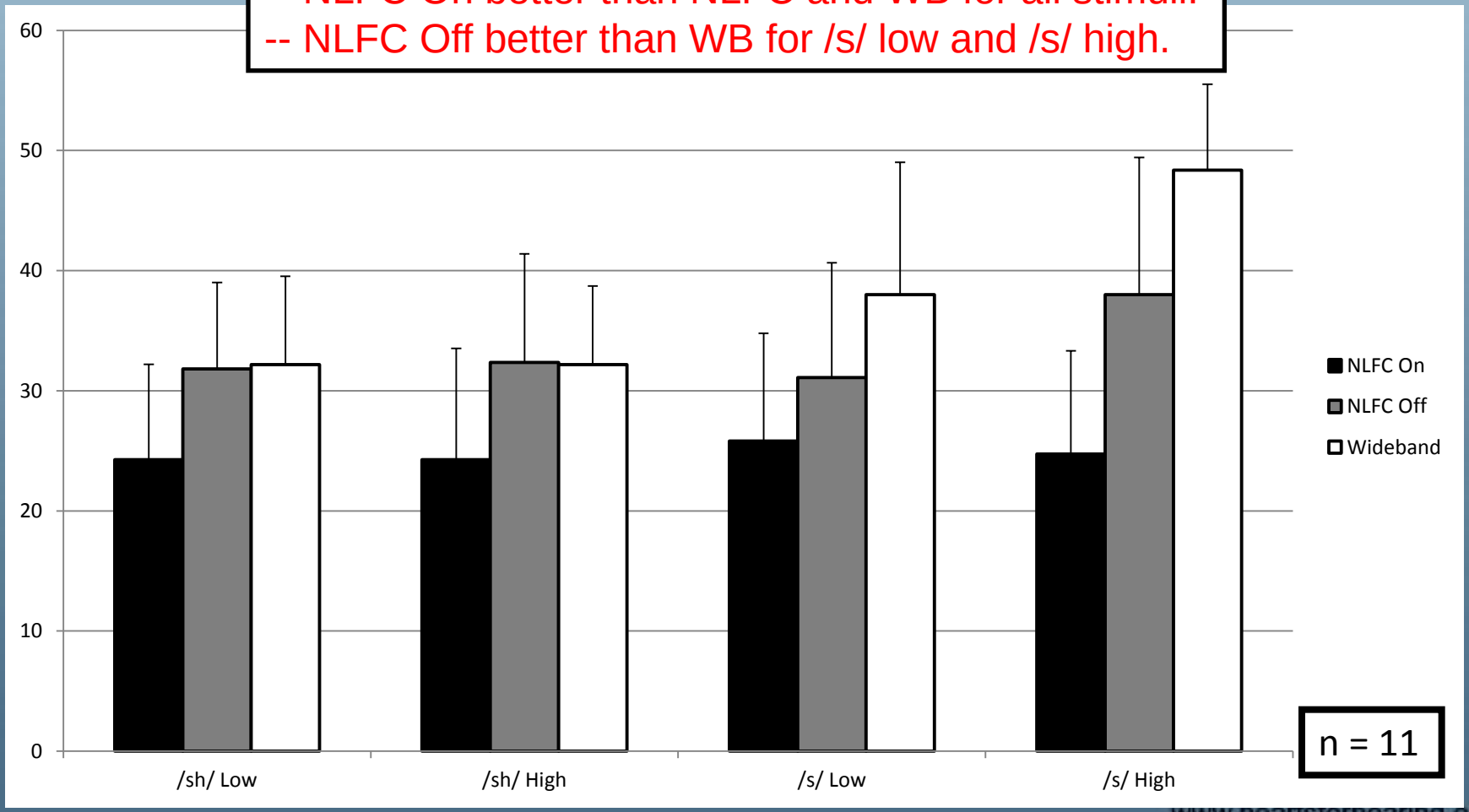
n = 11

Phoneme Perception Test
Detection Task

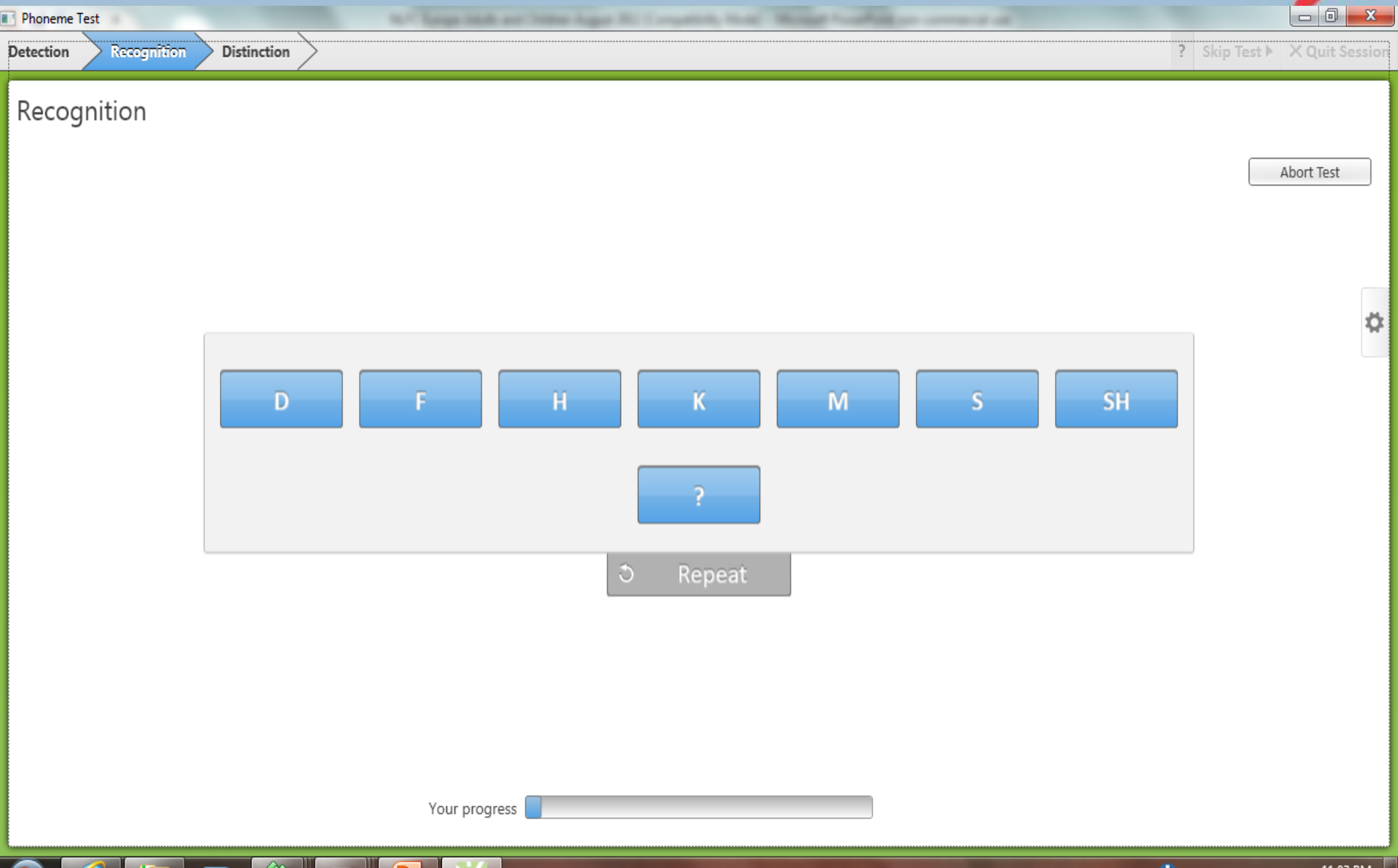


Phoneme Perception Test
Detection Task

-- NLFC On better than NLFC and WB for all stimuli.
-- NLFC Off better than WB for /s/ low and /s/ high.

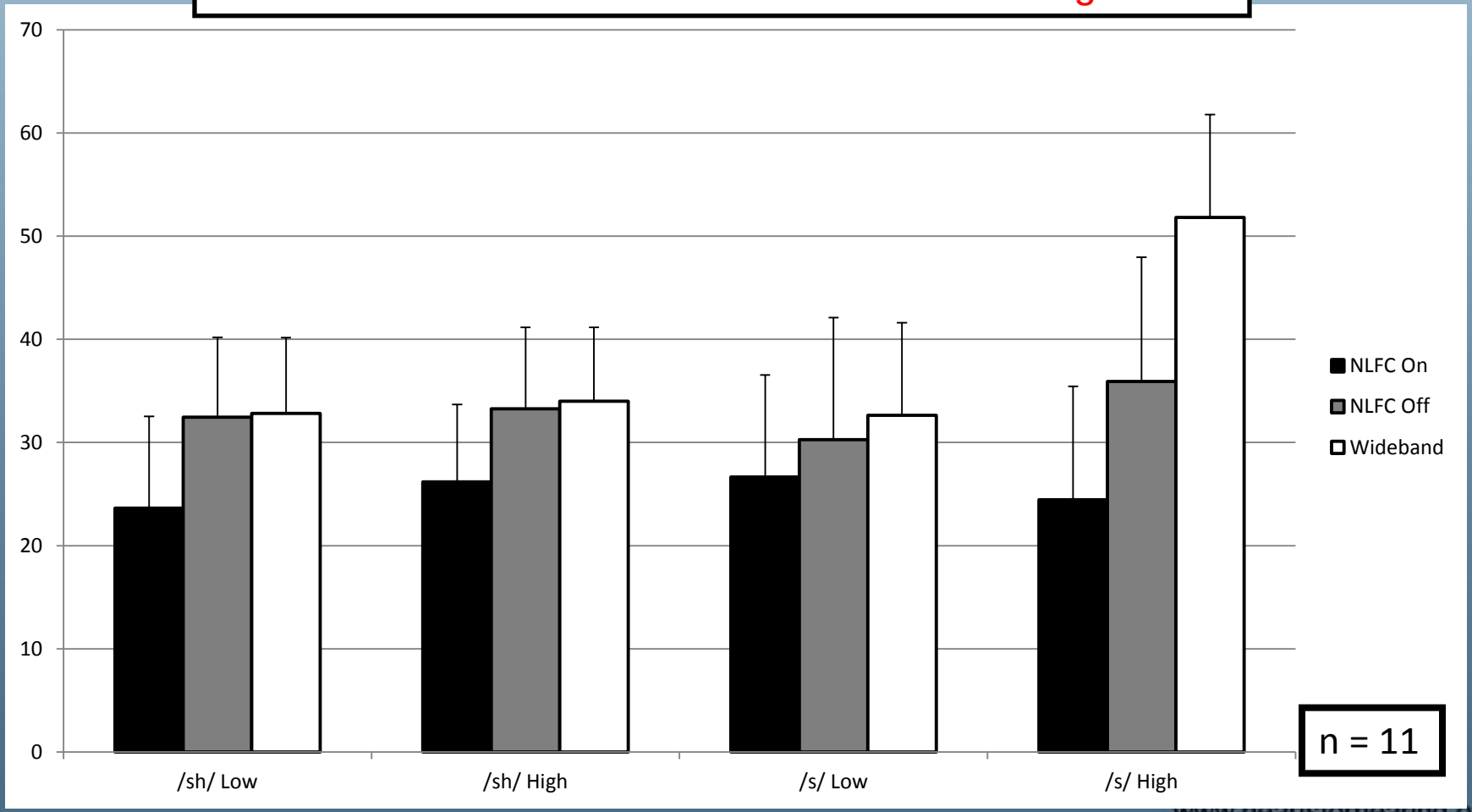


Phoneme Perception Test
Recognition Task

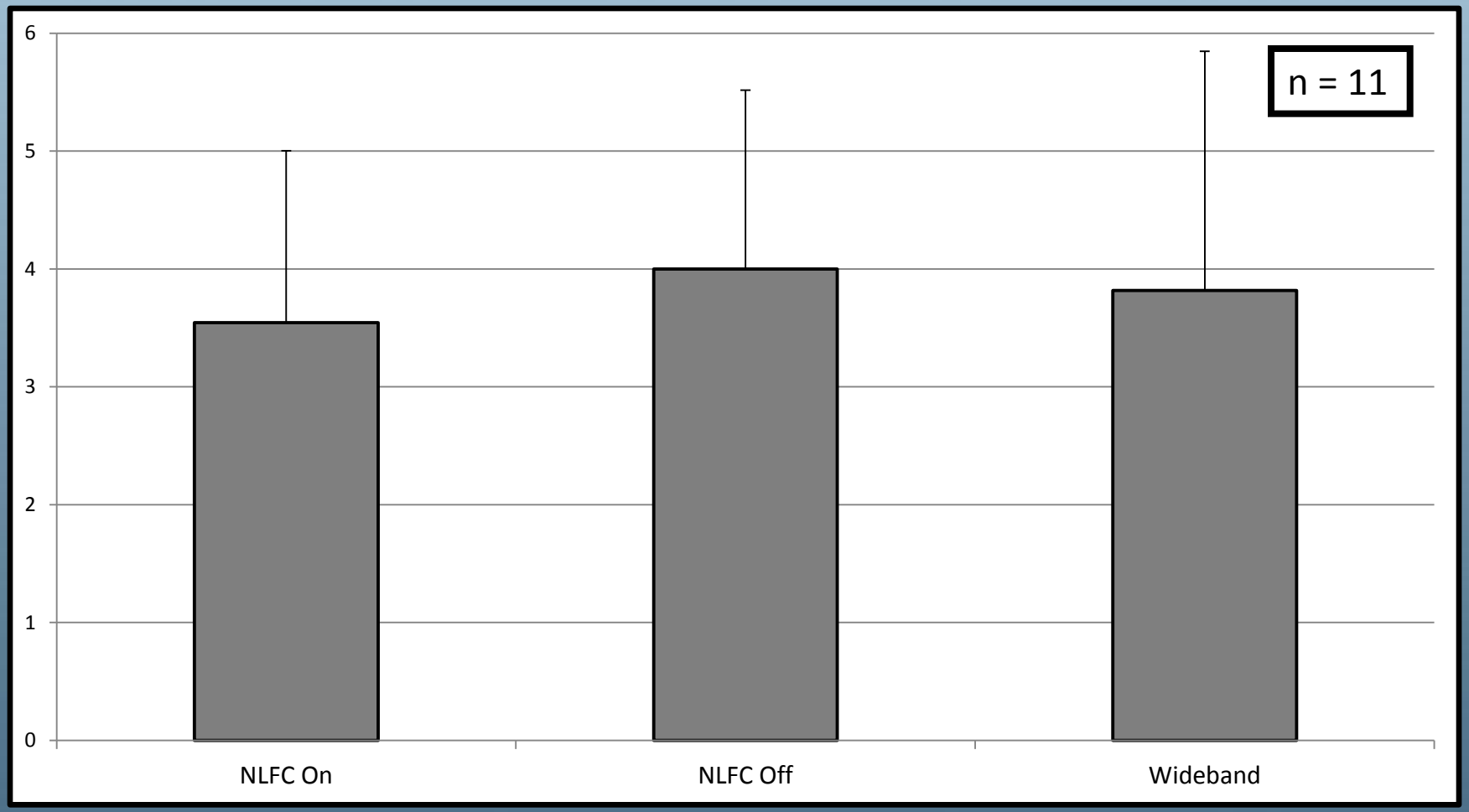


Phoneme Perception Test
Recognition Task

-- NLFC On better than NLFC Off and WB for all stimuli.
-- NLFC Off better than WB for /s/ low and /s/ high.



BKB-SIN



No significant difference between conditions

Additional UWO Plural Case Study

Summary

- NLFC improves speech recognition and speech production for children with mild to profound high-frequency hearing loss.
- NLFC should be considered for all children with mild to profound high-frequency hearing loss.
- 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.

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Shoot for the moon!

- **Thank you for your attention!**
- **Questions?**