Spatial Processing Disorder in Normal-Hearing Children

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Spatial processing disorder:

- In “normal hearing”
- Impact of task (cognitive load)
- Remediation
- [Non-speech sounds]
- [Electrophysiological correlates]

Disclosure

The National Acoustic Laboratories is a division of Australian Hearing, a Statutory Authority of the Australian Government.

- **NAL licences the LiSN-S test to Phonak, and is paid a royalty on sales.**
- **NAL directly sells the LiSN & Learn training package through its web site.**

LISN & Learn

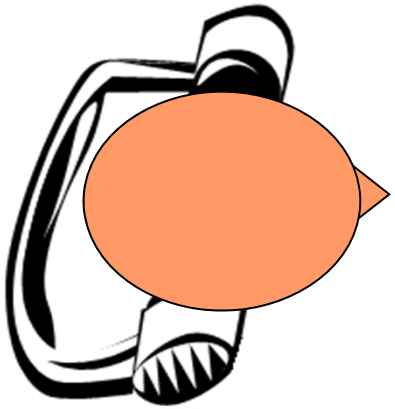
start game

SPATIAL PROCESSING DISORDER IN "NORMAL" HEARING

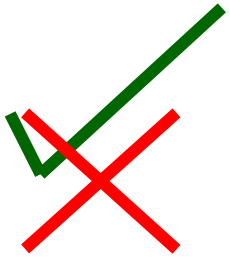
Spatial Processing Disorder

Lack of spatial release from masking

Noise



Noise



Noise

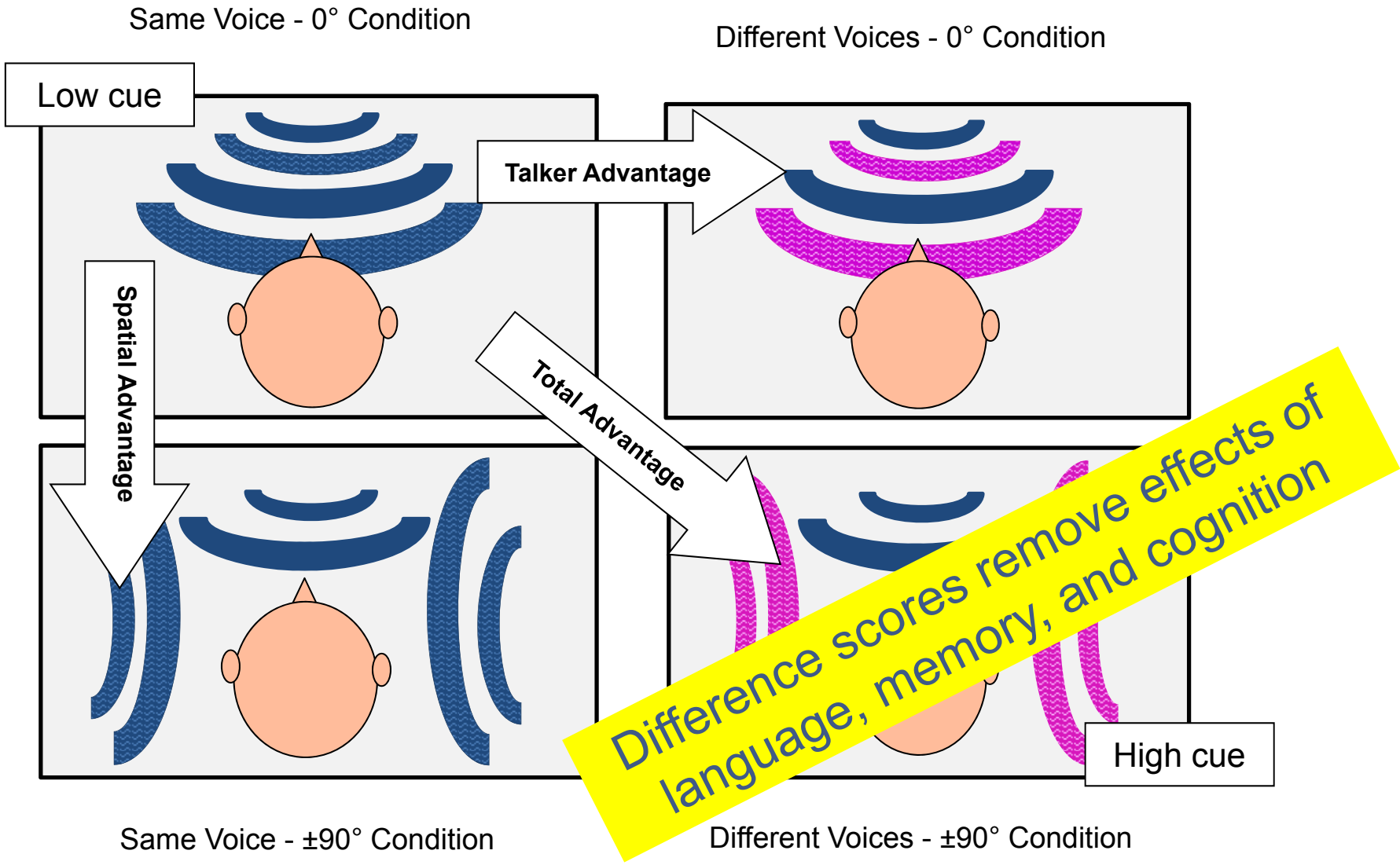
Speech

Noise

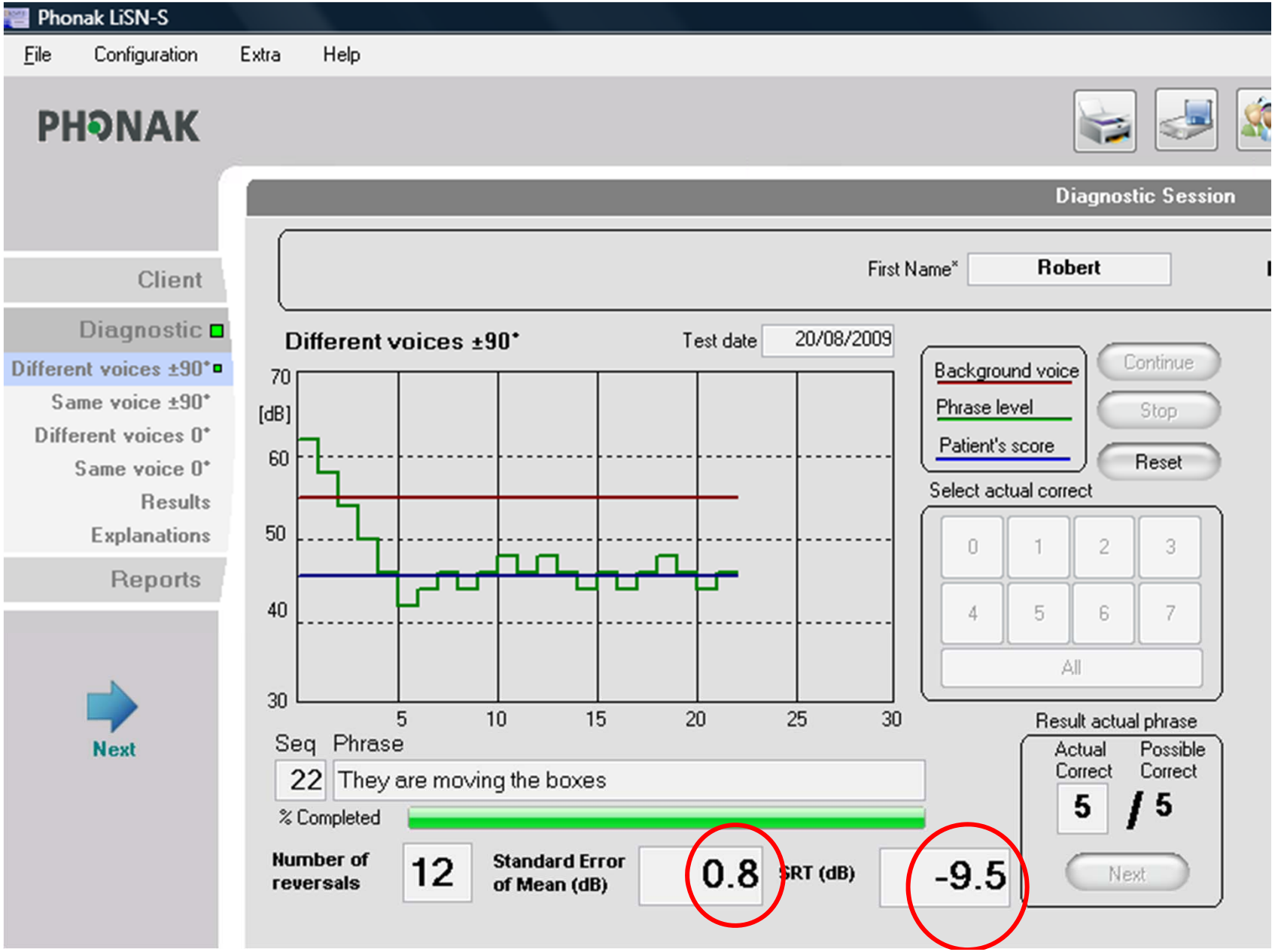
Listening in Spatialized Noise - Sentences test (LiSN-S)

1. Adaptive speech-in-noise-test
2. Virtual auditory environment under headphones
3. Target sentences - 0º azimuth
4. Competing speech - 0º or ±90º azimuth at 55 dB SPL
5. Runs on a PC with specified headphones
6. Four LiSN-S conditions

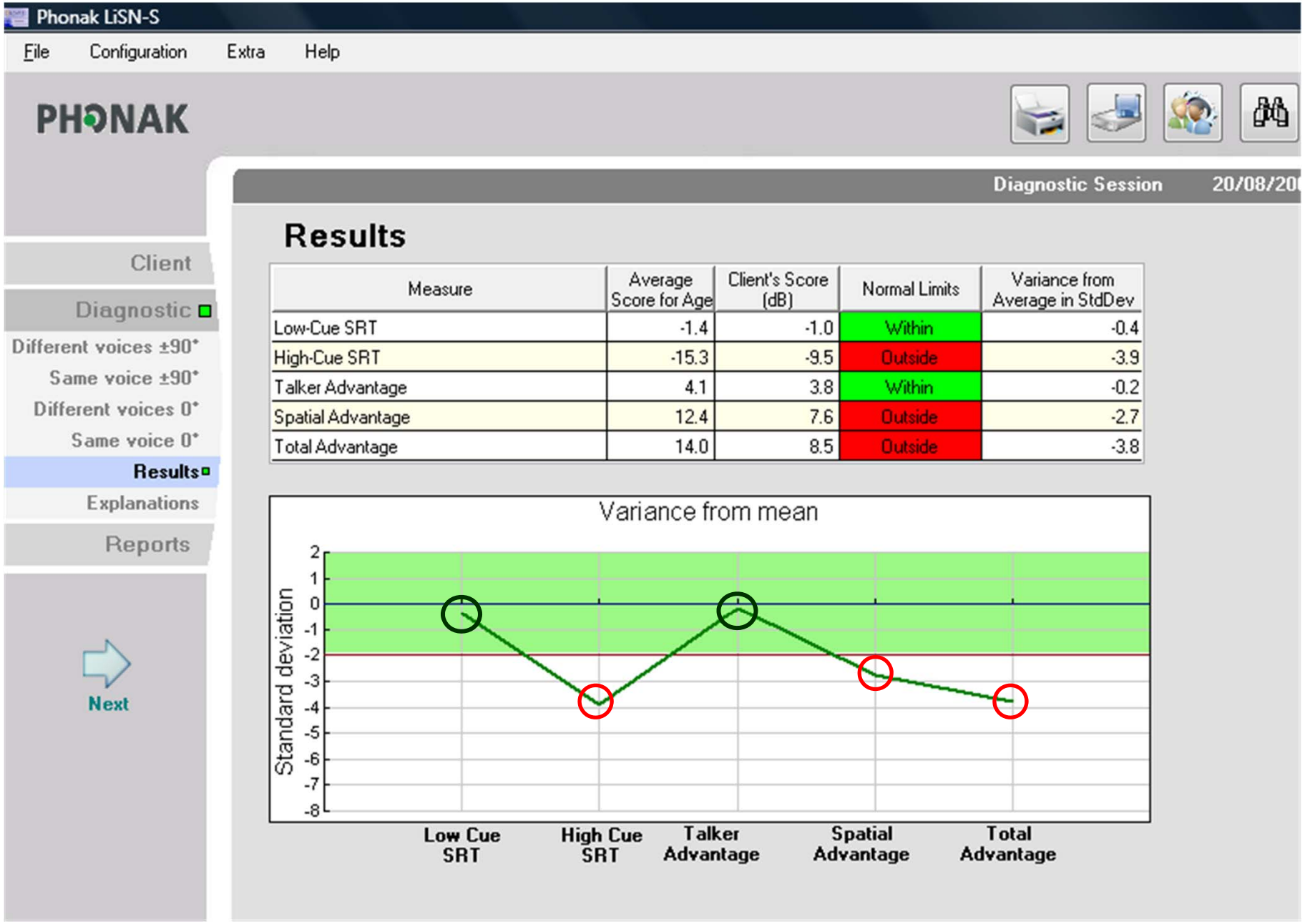
(LiSN-S) Conditions



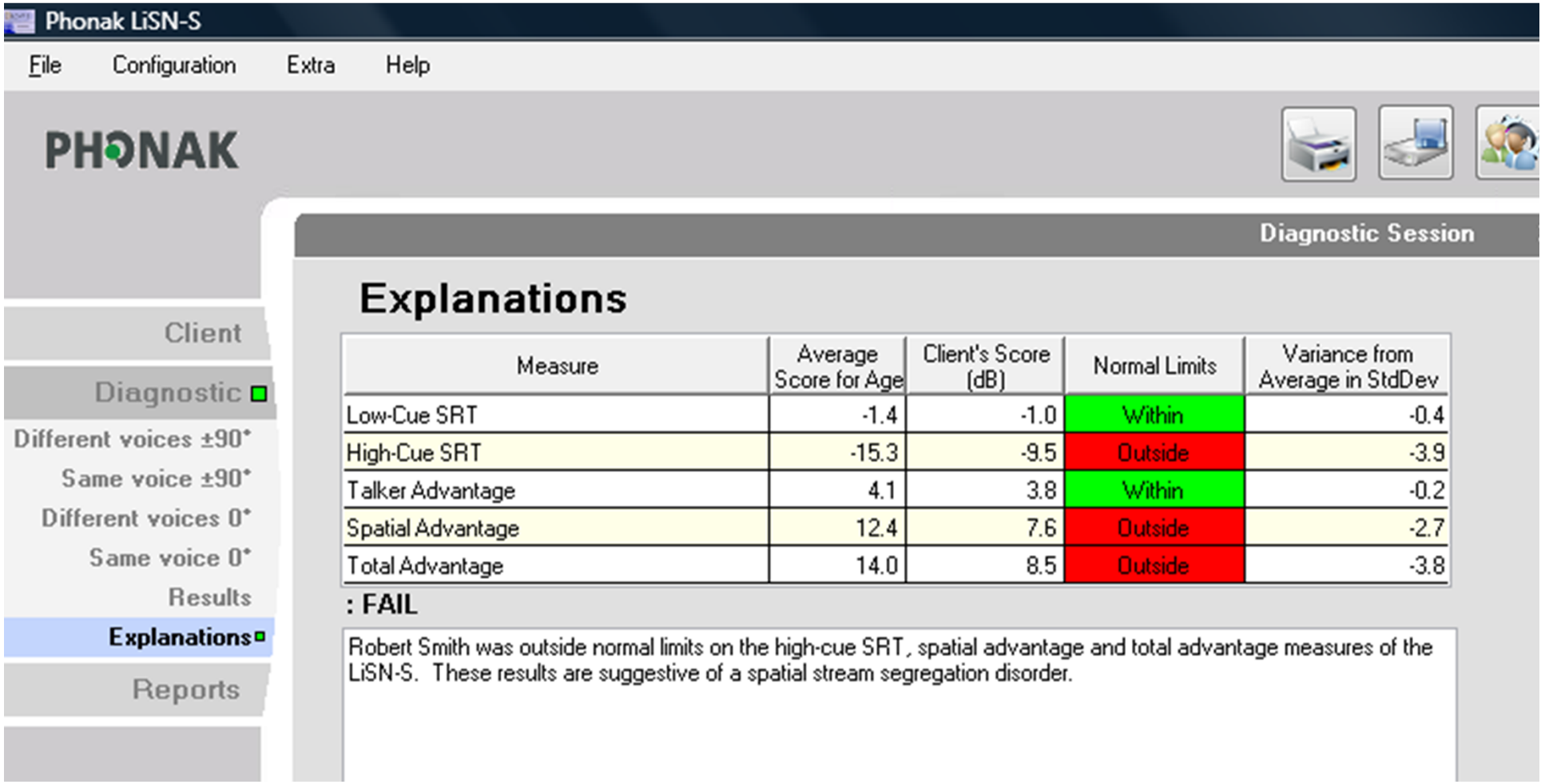
LiSN-S Diagnostic Screen



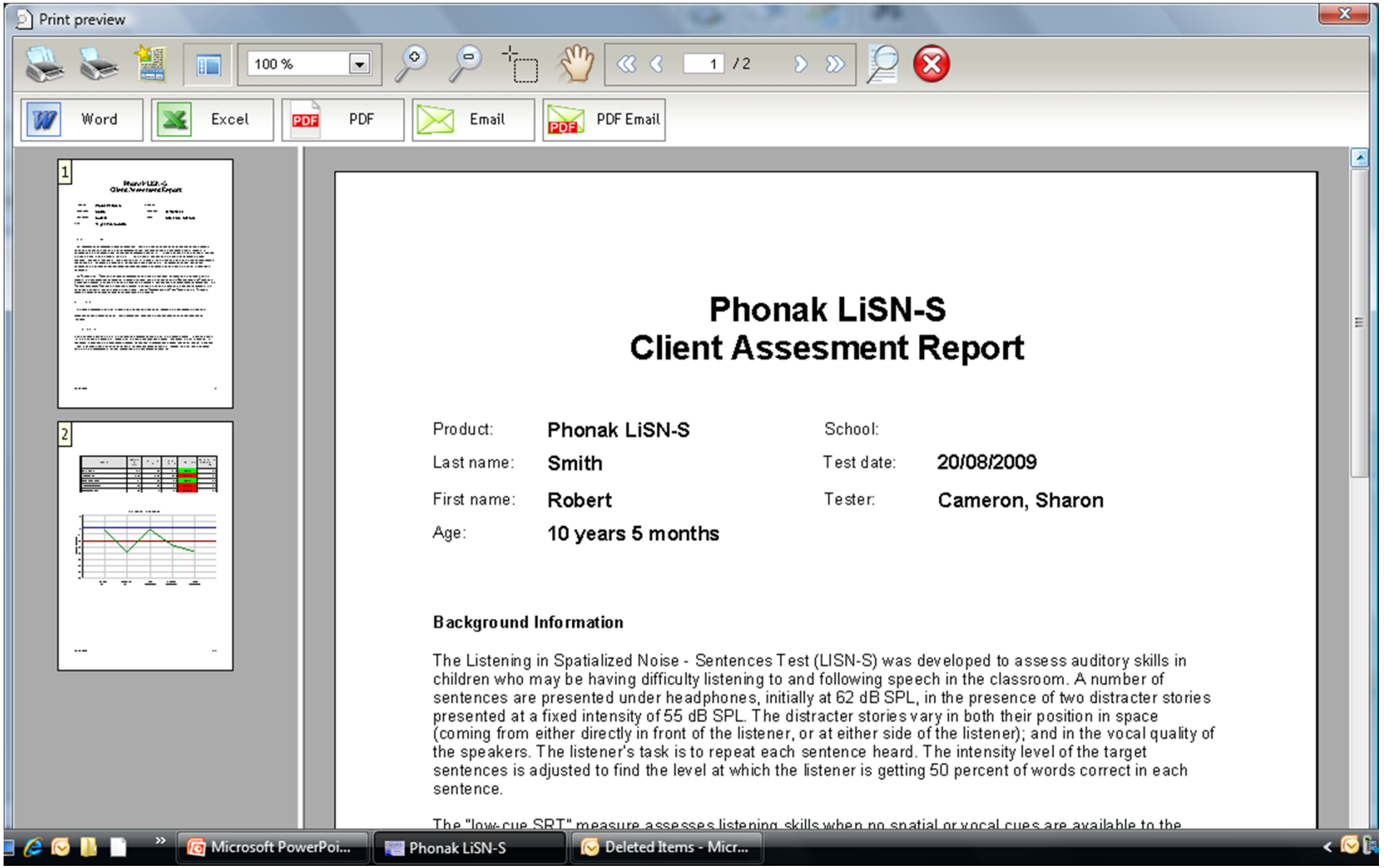
Results profile: spatial processing disorder



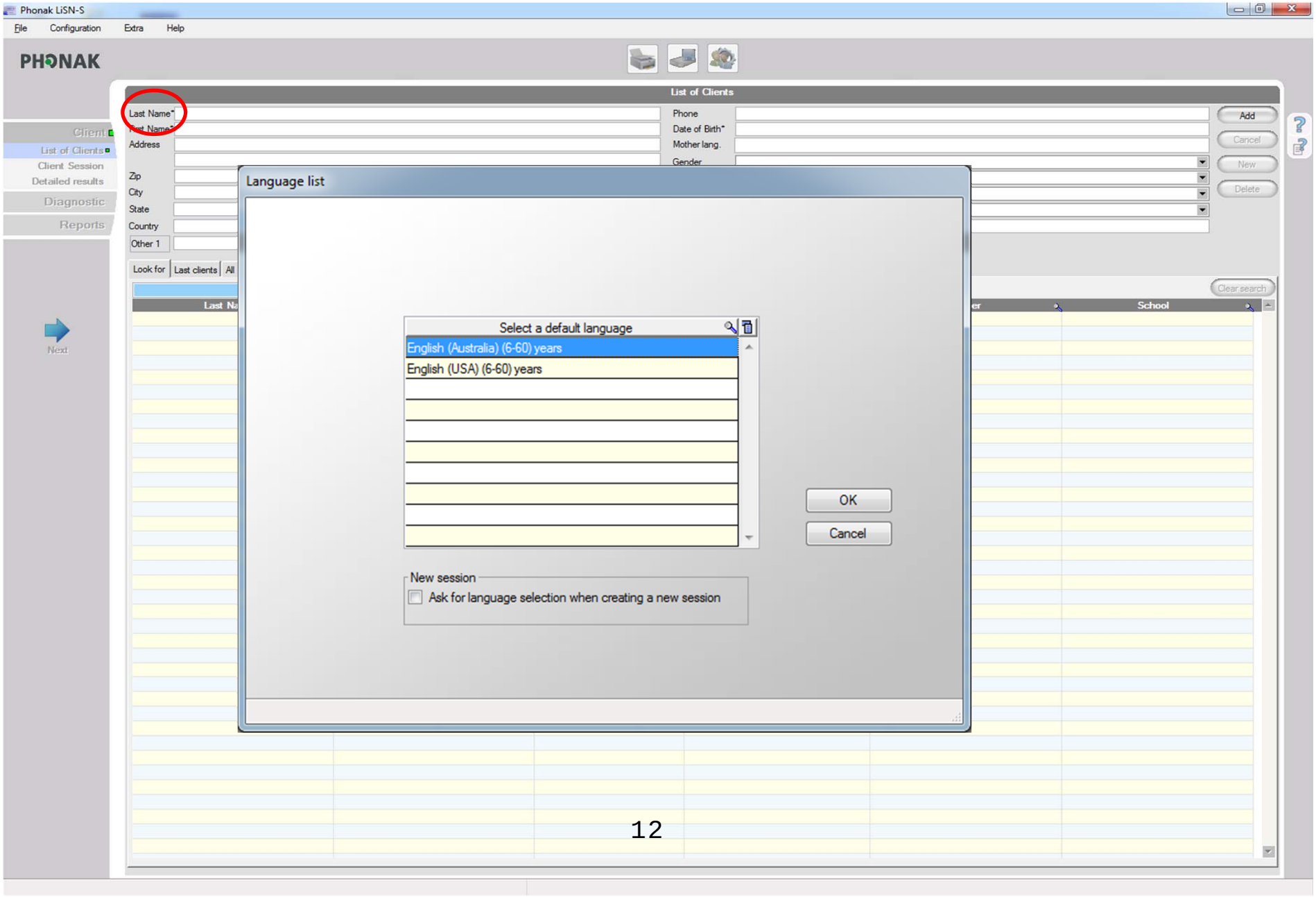
Explanation Screen



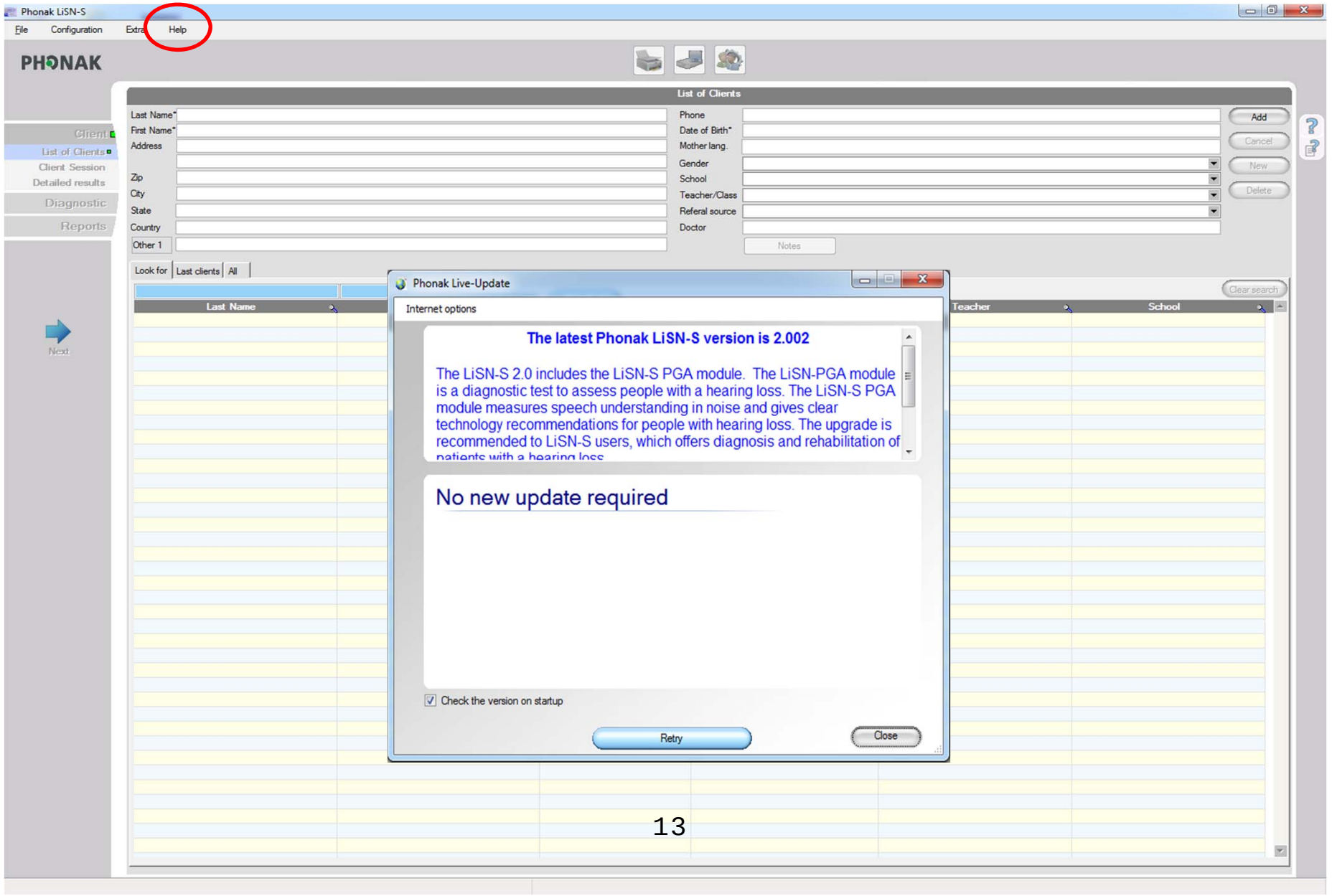
Client Assessment Report



Language: USA English or Australian English



Latest version of LiSN-S



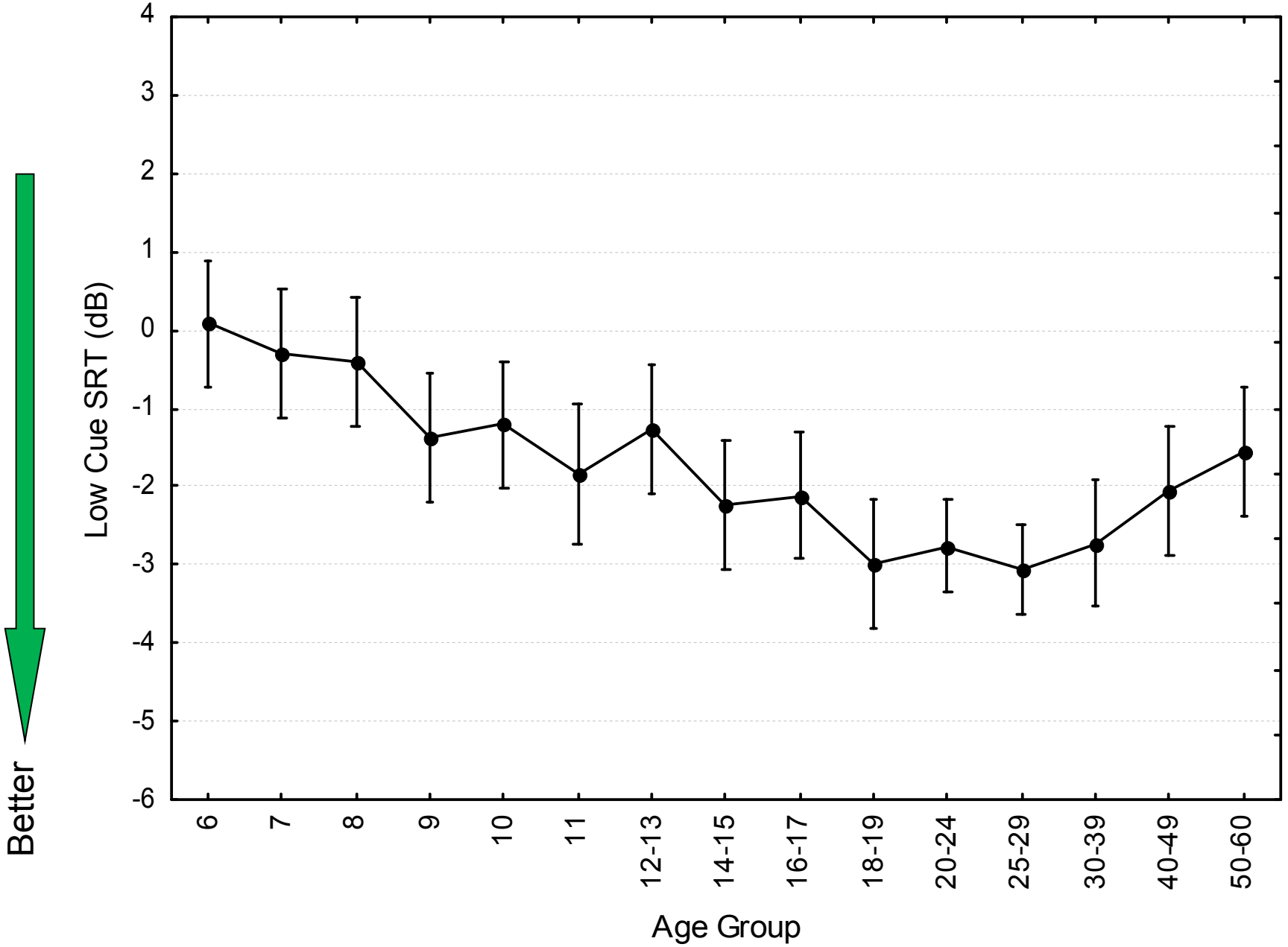
LiSN-S Normative Data (Australian version)

202 participants:

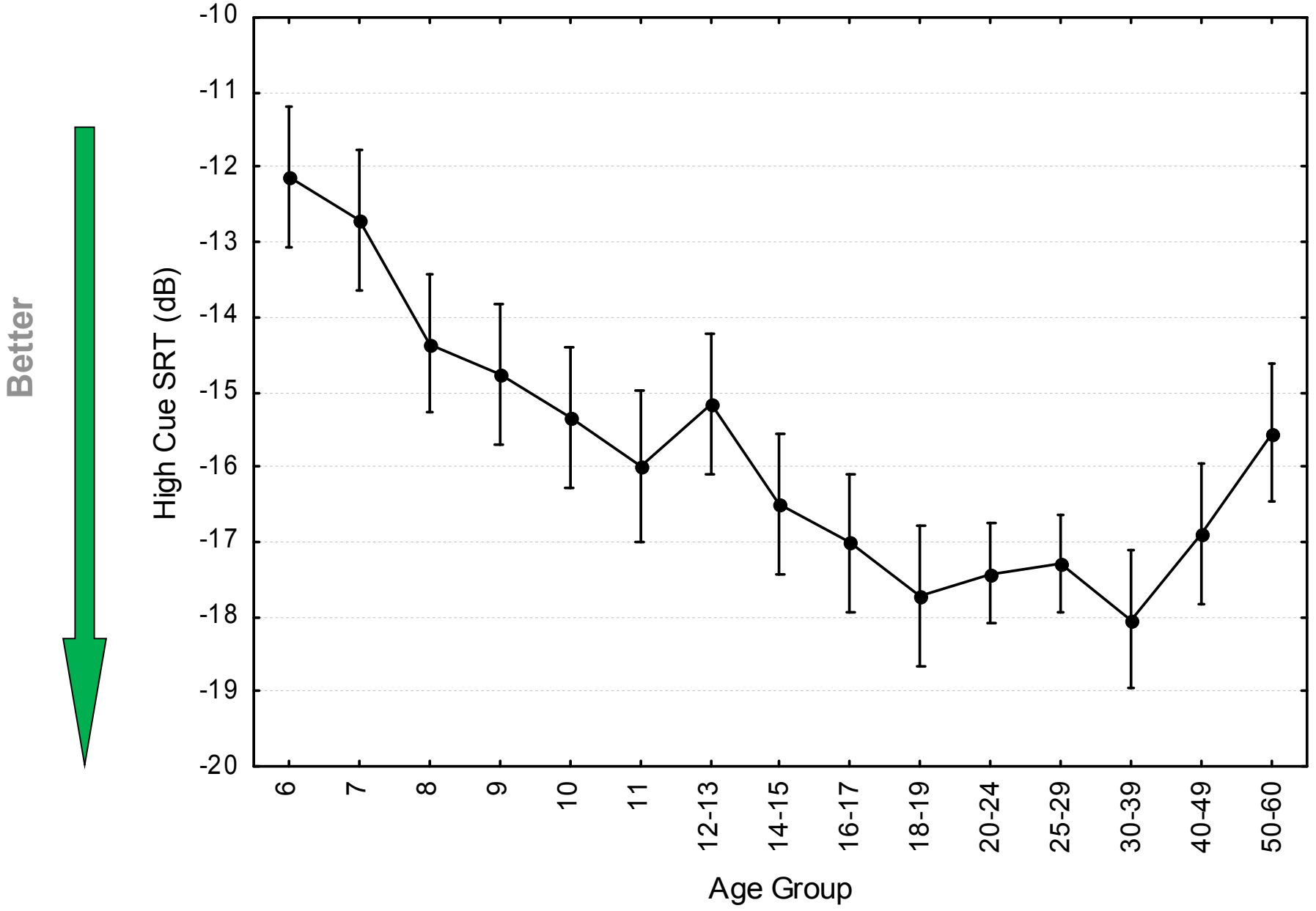
- 106 children - 6 yrs, 2 mths to 17 yrs, 7 mths
- 60 young adults - 18 yrs, 1 mth to 29 yrs, 10 mths
- 36 older adults – 31 yrs, 8 mths to 60 yrs, 7 mths

- English as a first language;
- no history of hearing disorders;
- no learning or attention disorders;
- normal pure tone audiogram and middle ear function.

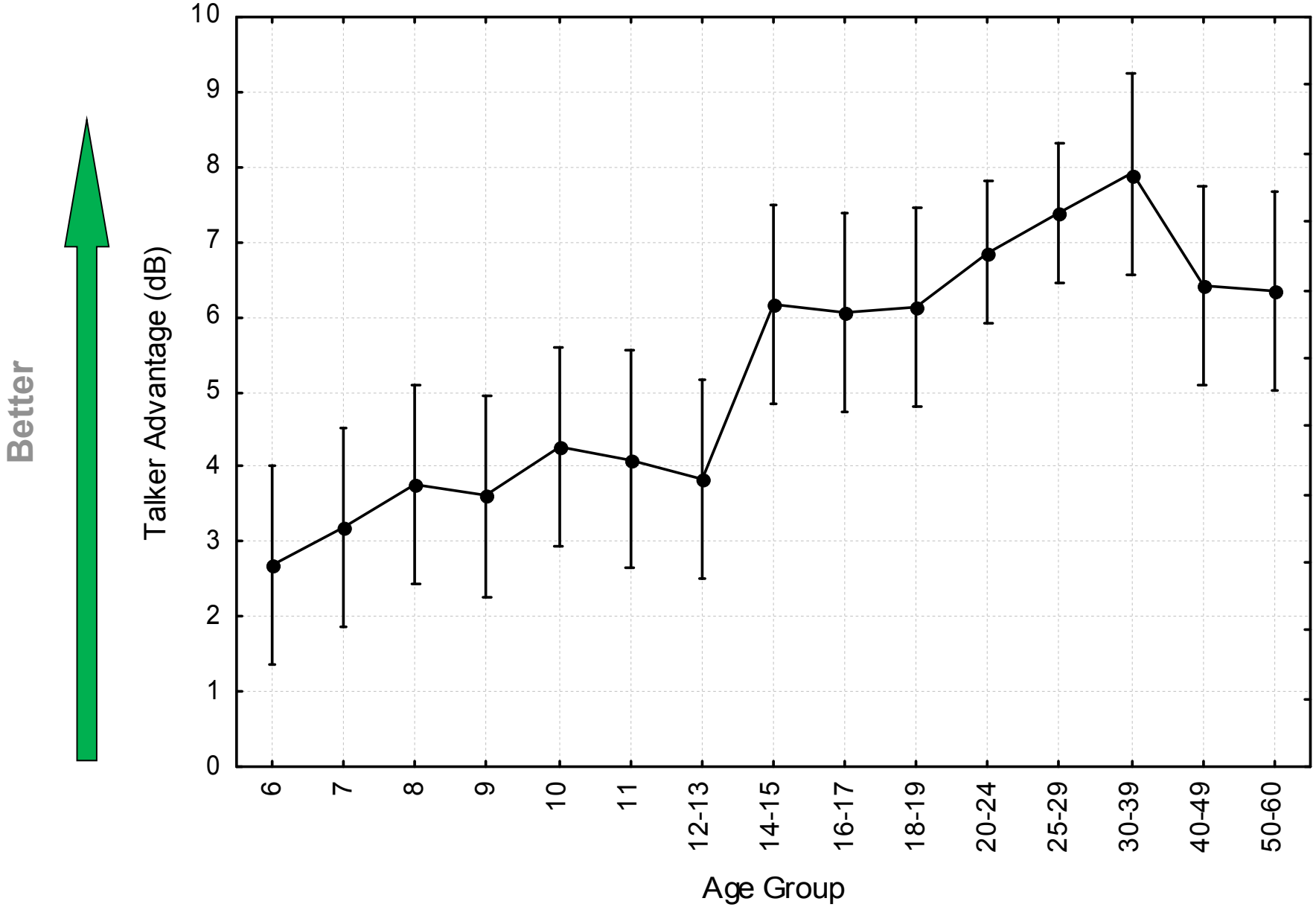
Low Cue SRT


Better
Low Cue SRT (dB)
4
3
2
1
0
-1
-2
-3
-4
-5
-6
6
7
8
9
10
11
12-13
14-15
16-17
18-19
20-24
25-29
30-39
40-49
50-60
Age Group

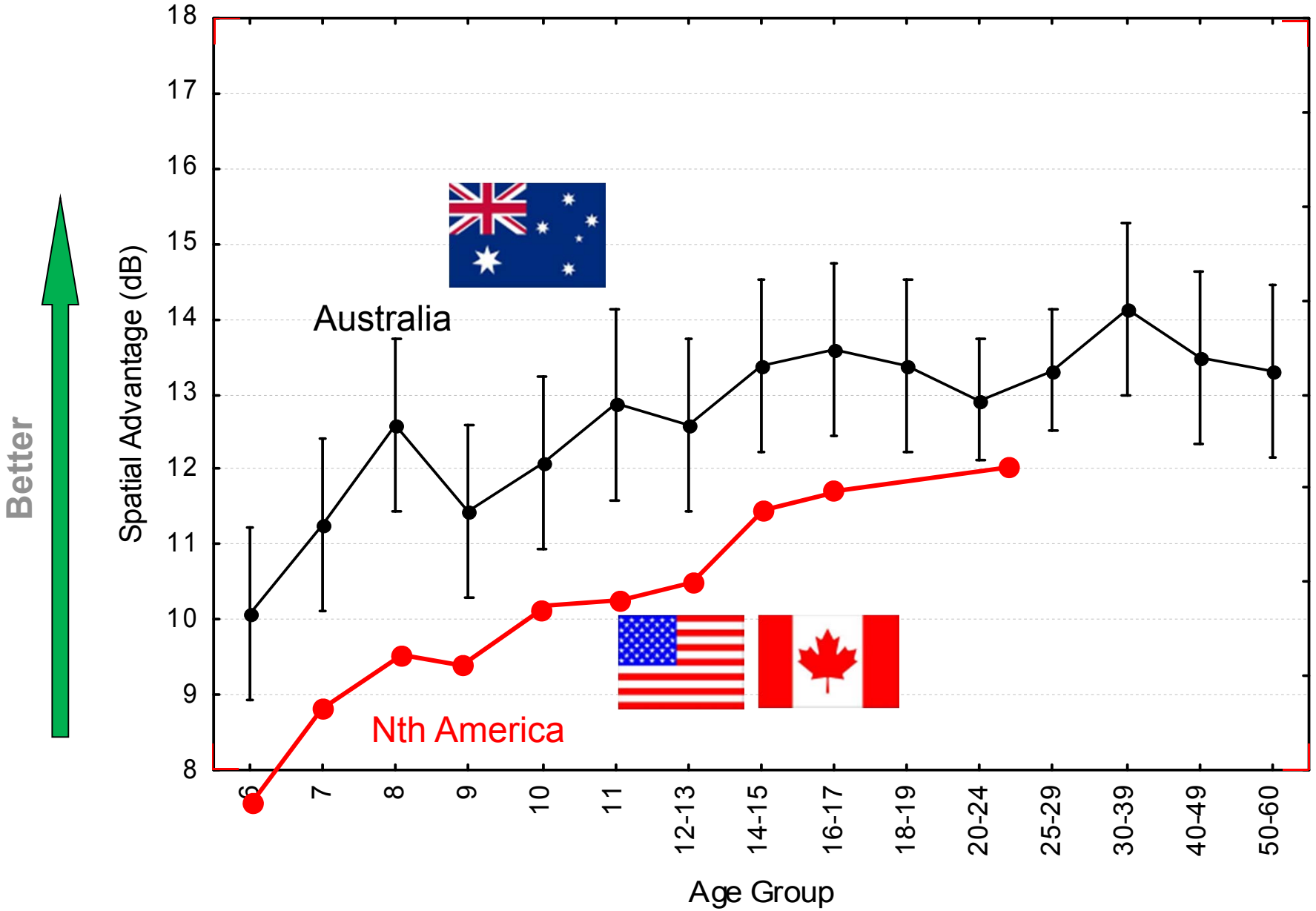
High Cue SRT


Better
High Cue SRT (dB)
-10
-11
-12
-13
-14
-15
-16
-17
-18
-19
-20
6
7
8
9
10
11
12-13
14-15
16-17
18-19
20-24
25-29
30-39
40-49
50-60
Age Group

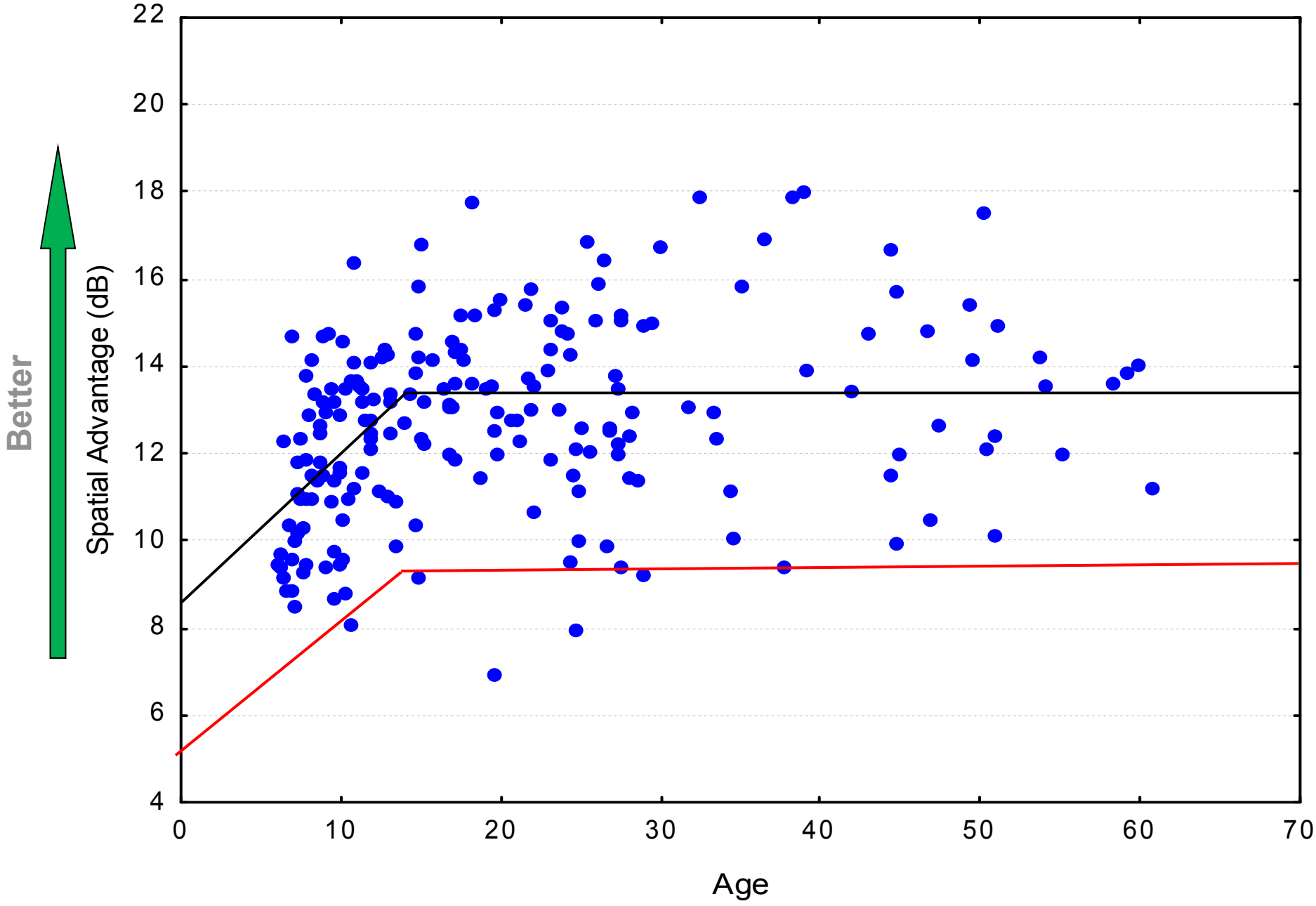
Talker Advantage



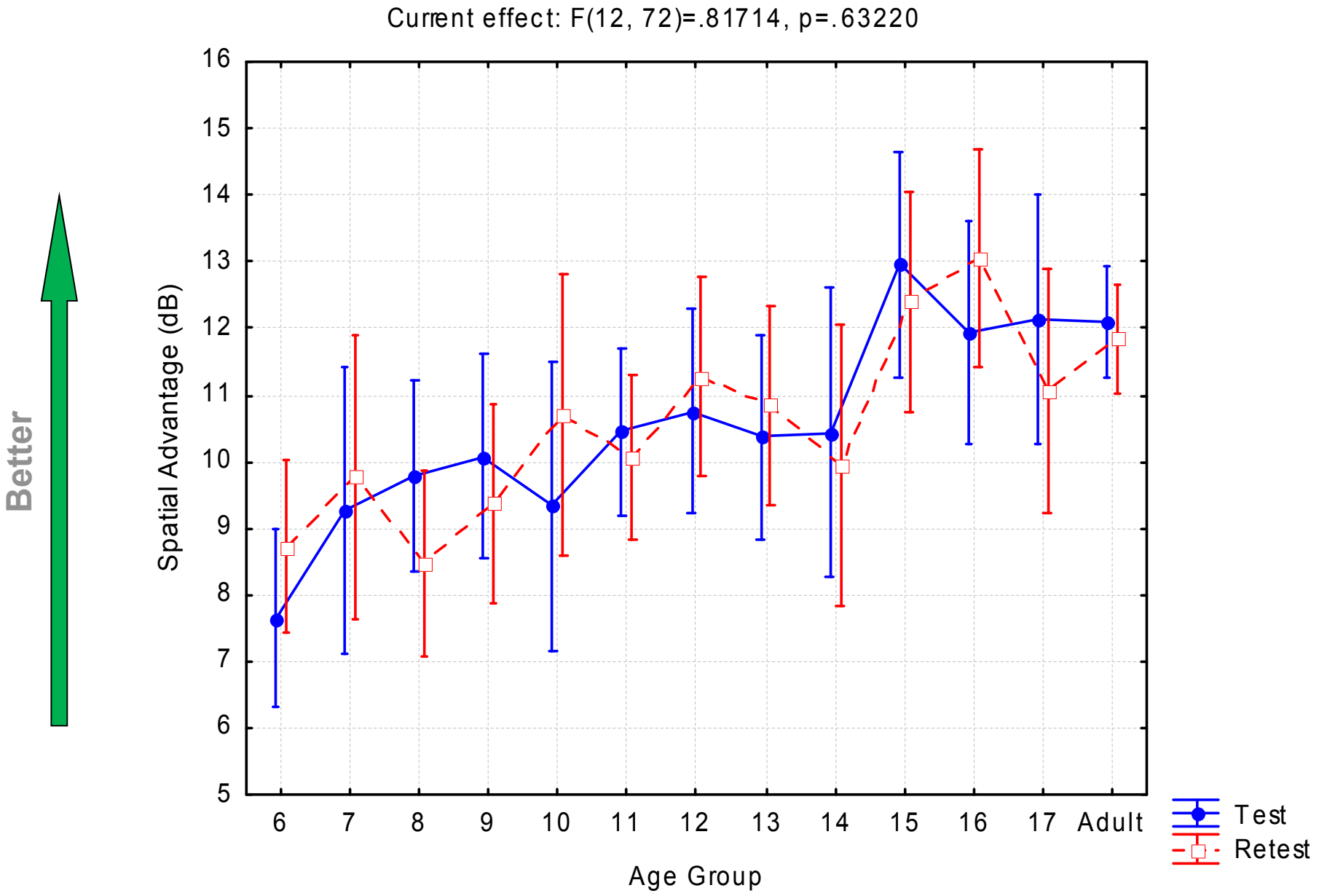
Spatial Advantage (≡ Spatial Release from Masking)



Cut-off Scores – Spatial Advantage



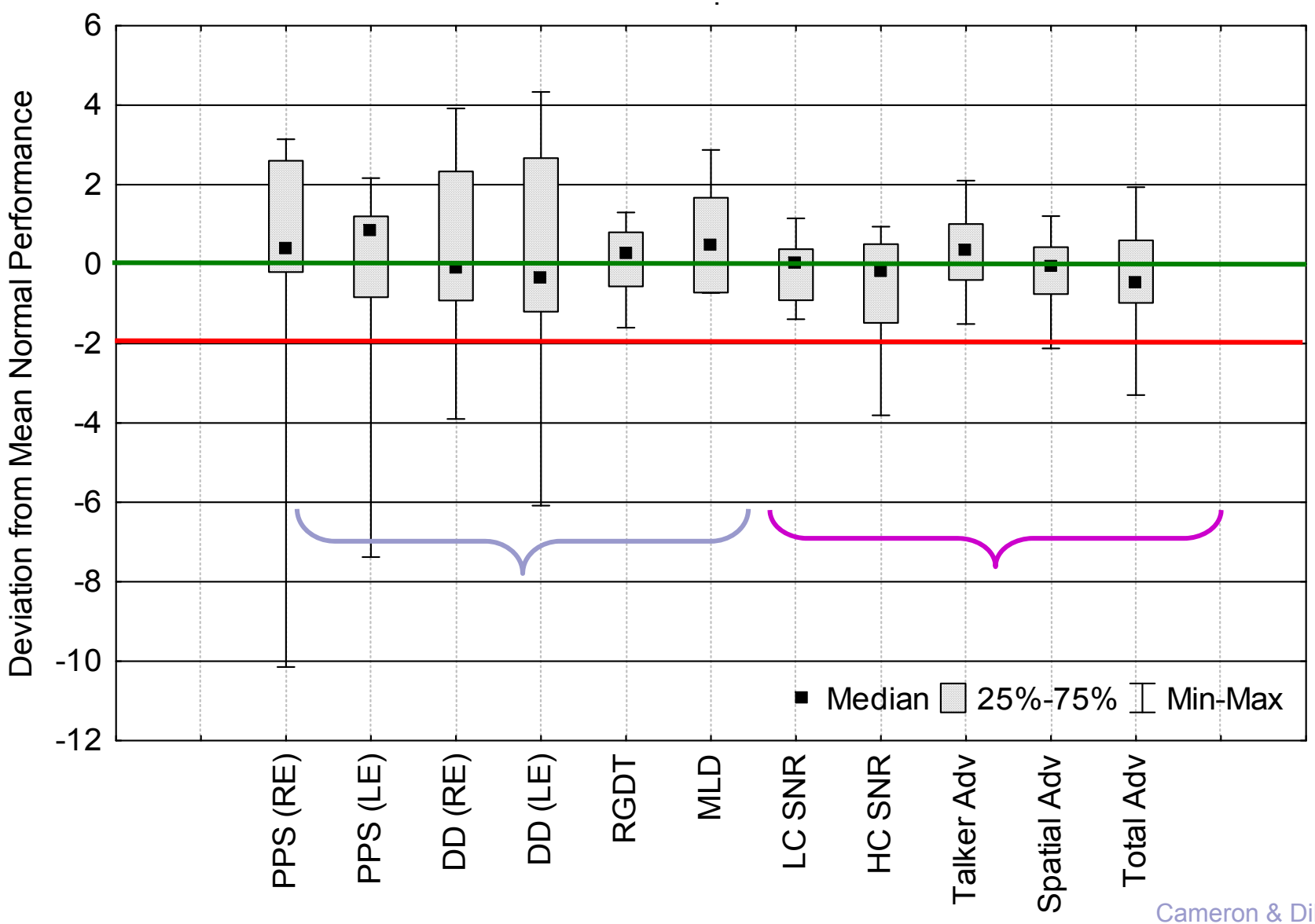
Test-retest reliability - Spatial Advantage



Children with Spatial Processing Disorder

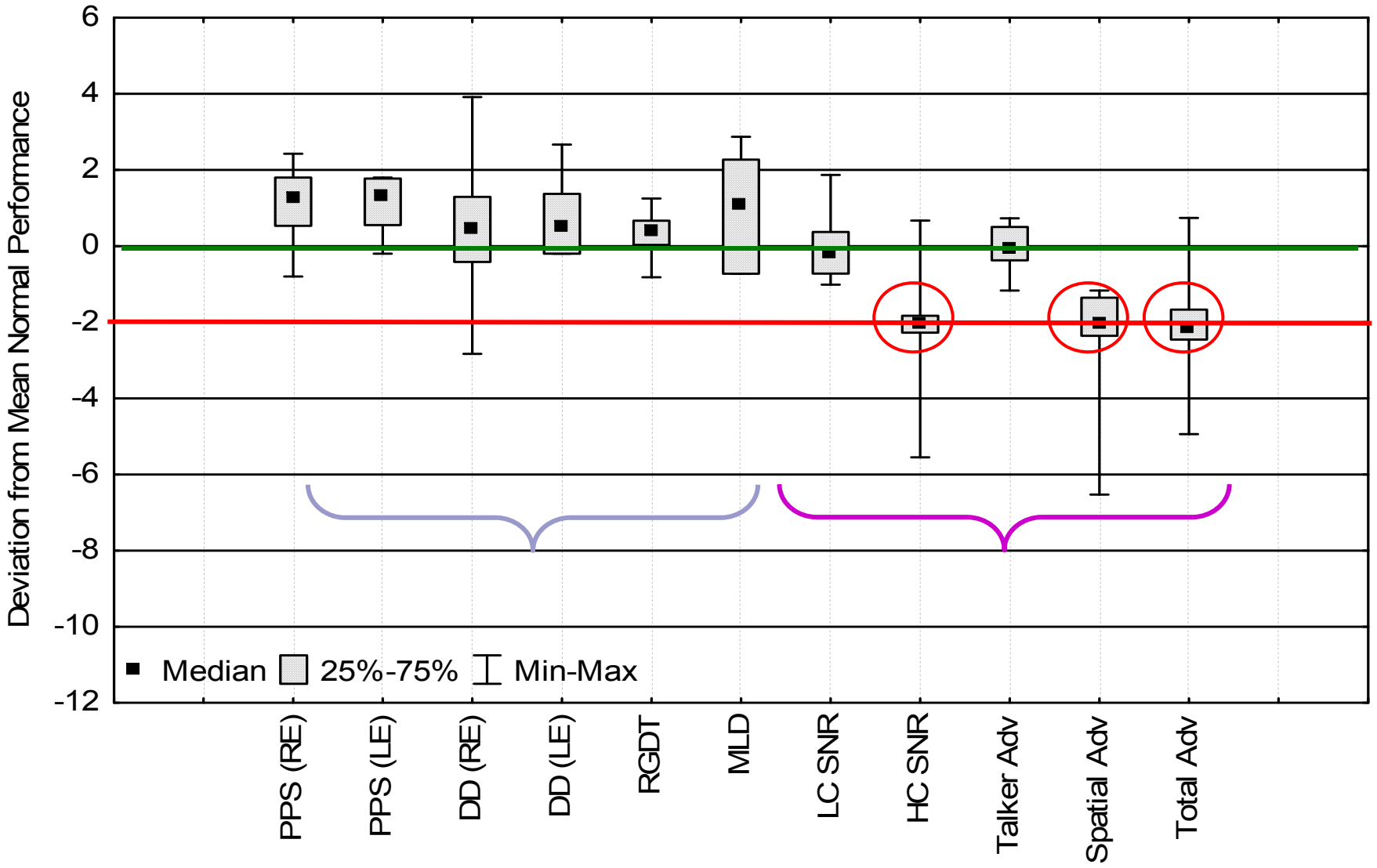
- Nine children aged 6 to 11 years experiencing listening difficulties in class relative to peers who had no learning or attention disorder and WISC IQ >90 on all subscales (SusAPD group).
- Eleven children with confirmed language, memory or attention disorders, and WISC IQ overall score >90 (LD group).
- Assessed on LISN-S and results compared to 70 age-matched controls.
- Assessed with a traditional (C)APD test battery

LiSN-S vs. Traditional Battery (LD Group)



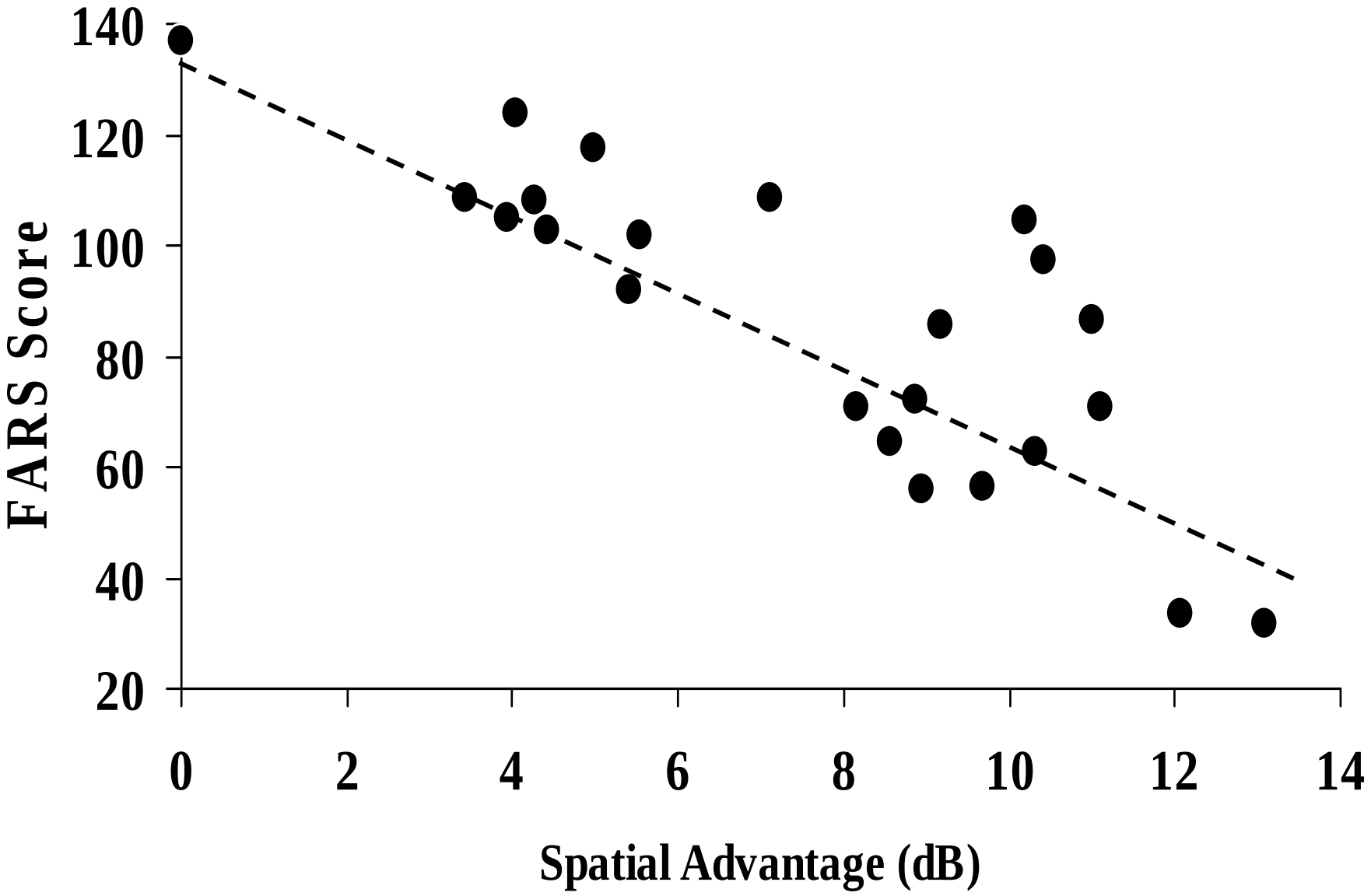
Cameron & Dillon (2008)

LiSN-S vs.Traditional Battery (sus CAPD Group)



Cameron & Dillon (2008)

Friedreich Ataxia Rating Scale vs LiSN-S spatial advantage



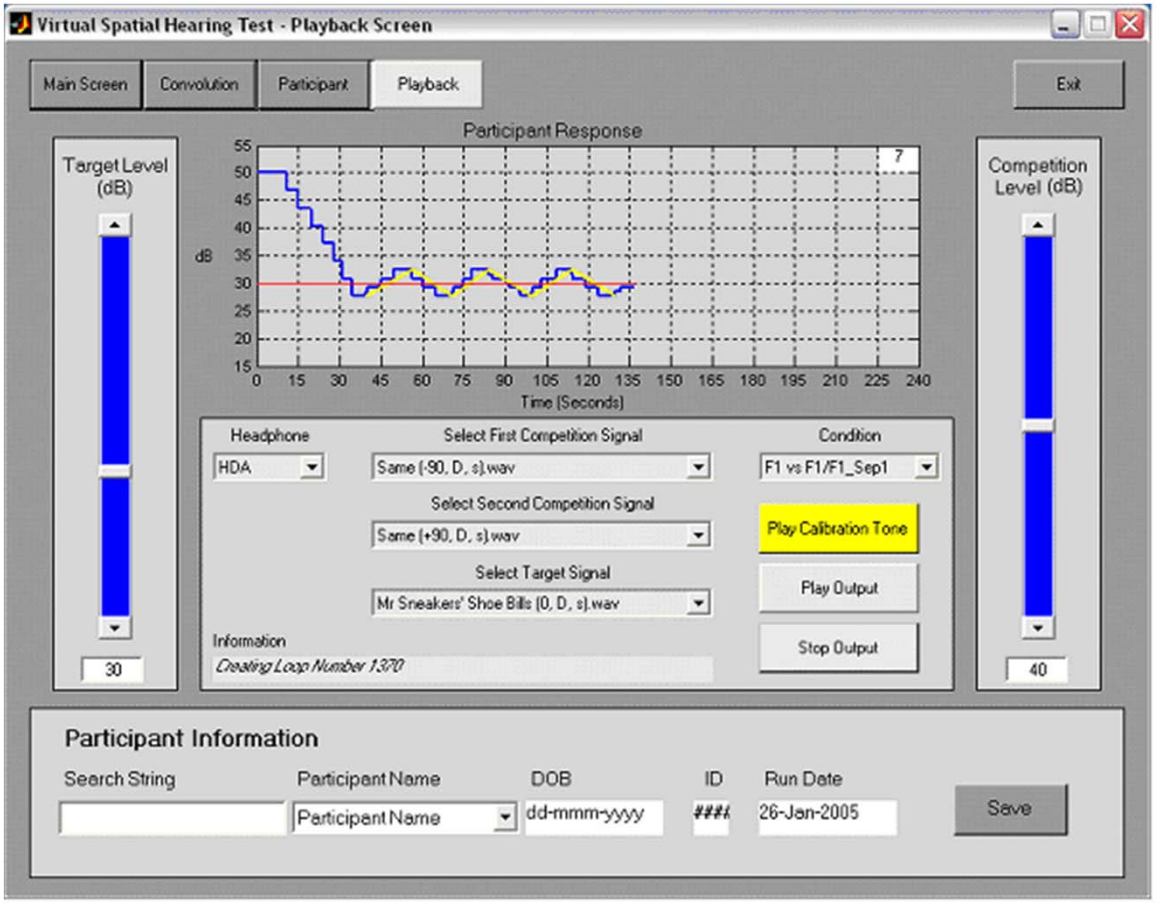
Source: Rance (Neuroscience, 2012)

IMPACT OF TASK (COGNITIVE LOAD)

ON

SPATIAL PROCESSING DISORDER

LiSN – continuous discourse test



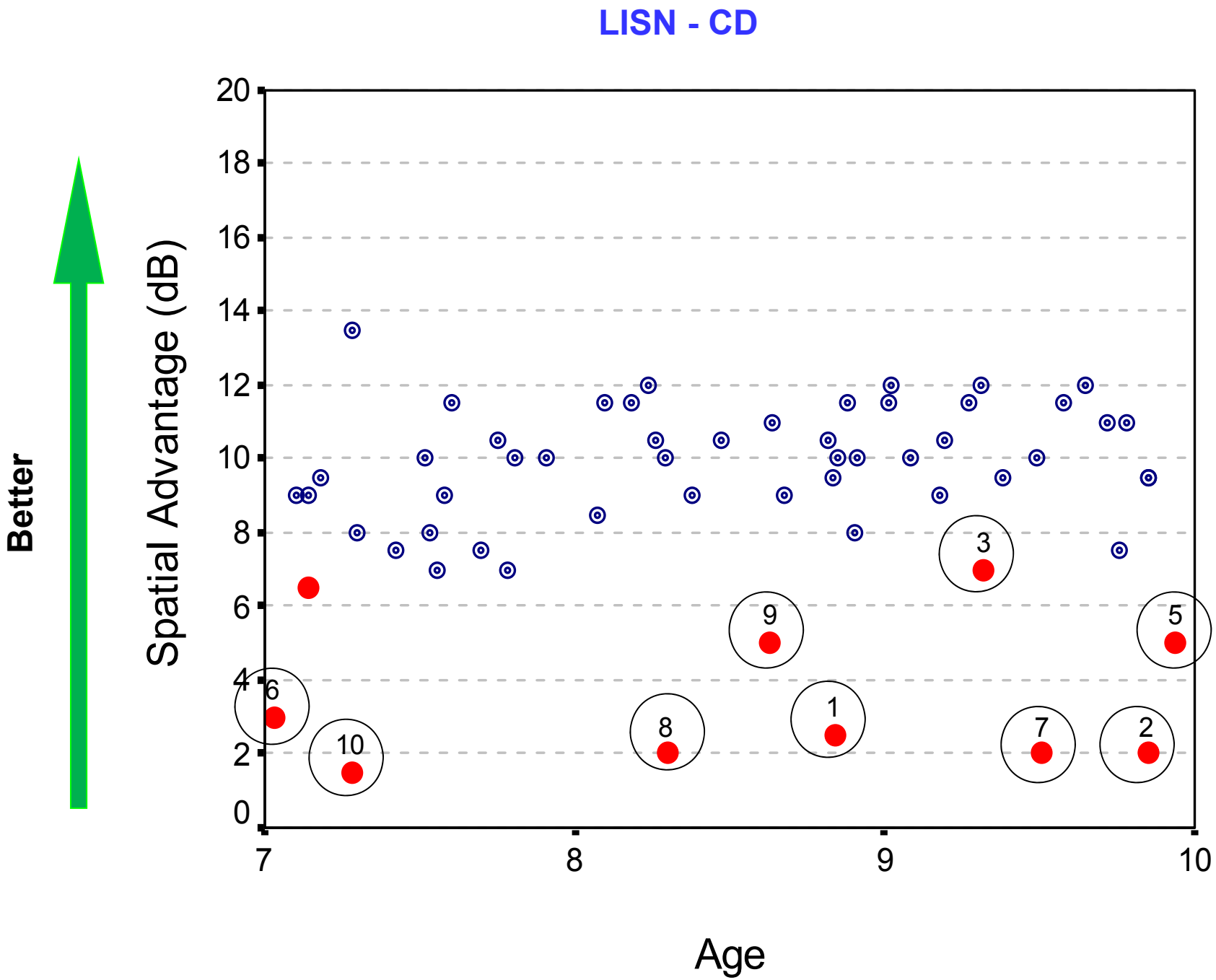
1. Listen and seek to understand
2. Make judgement about difficulty
3. Recount story after 3 minutes

Extract meaning, memorise and recall

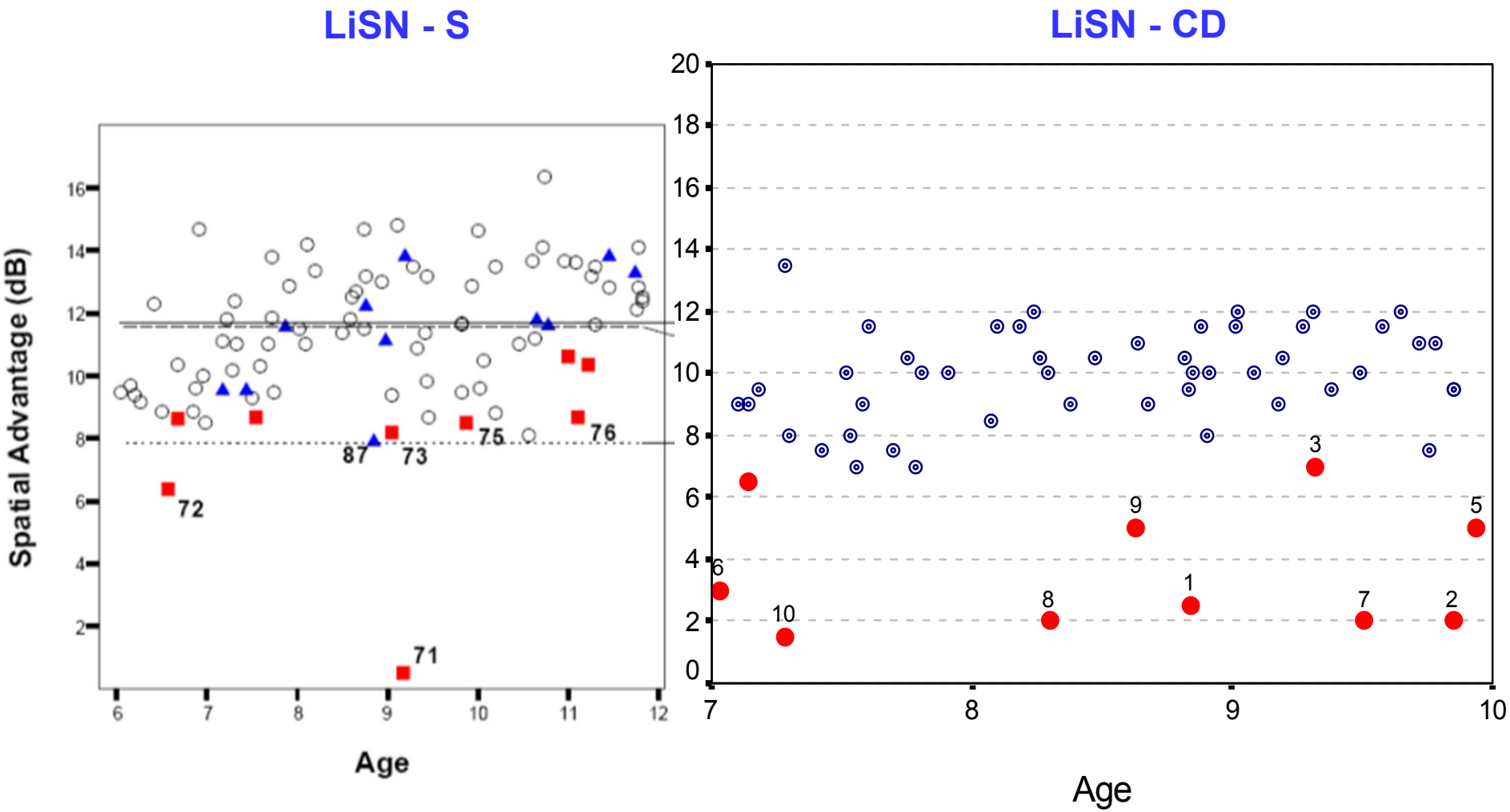
Easy to understand

Just understand

Too hard to understand


LISN - CD
Better
Spatial Advantage (dB)
20
18
16
14
12
10
8
6
4
2
0
7
8
9
10
Age
6
10
8
9
1
3
7
2
5

Impact of task on spatial processing deficit

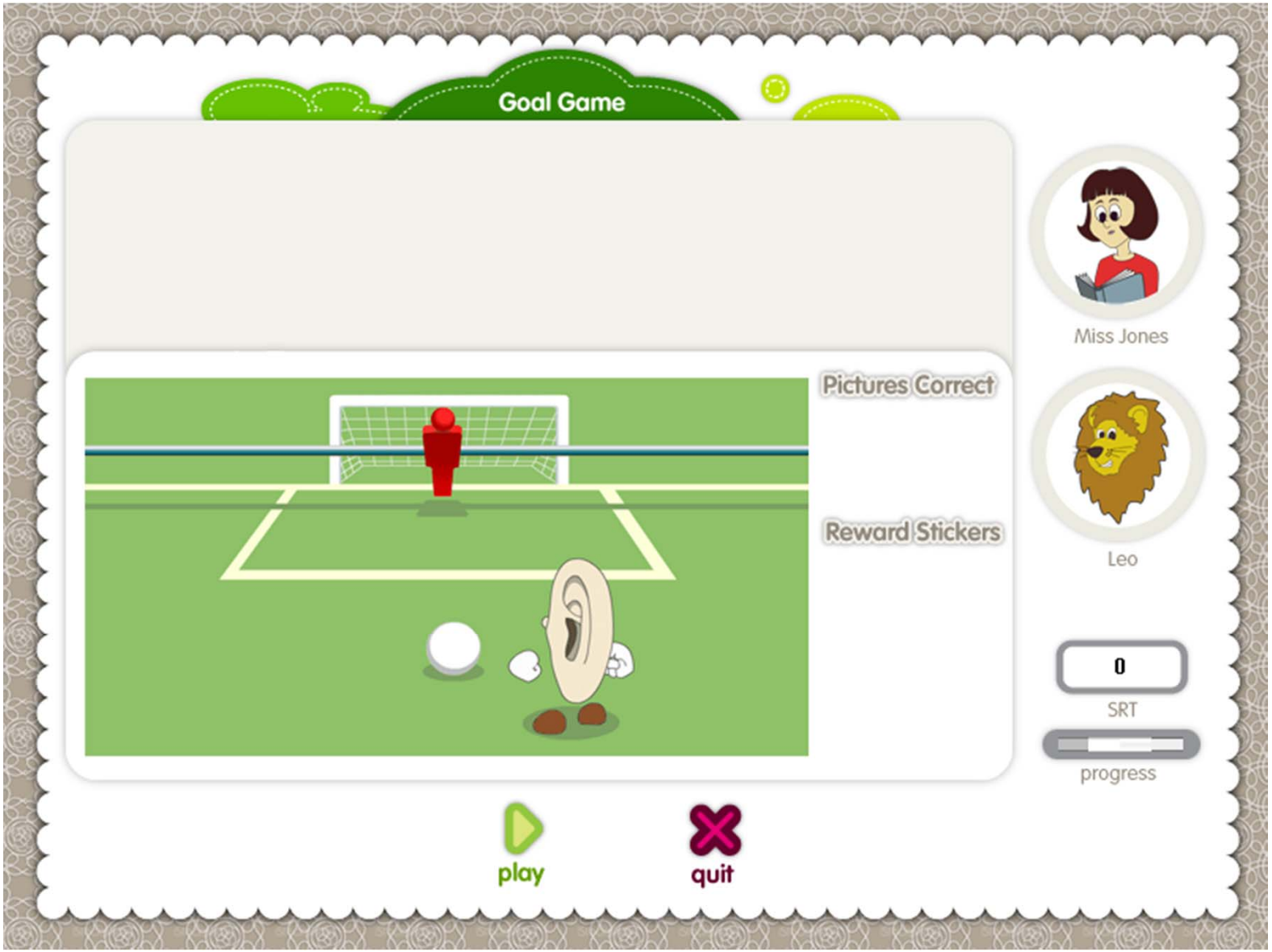


REMEDIATION OF SPATIAL PROCESSING DISORDER

LISN & Learn game

- Five games presented on PC over headphones
- Target sentences at 0º azimuth (initially 62 dB SPL)
- Competing stories at ±90º azimuth (55 dB SPL)
- Weighted up-down adaptive procedure used to adjust the signal level of the target to keep performance at 75% correct
- SRT calculated over 40 sentences
- 131,220 unique sentences can be generated

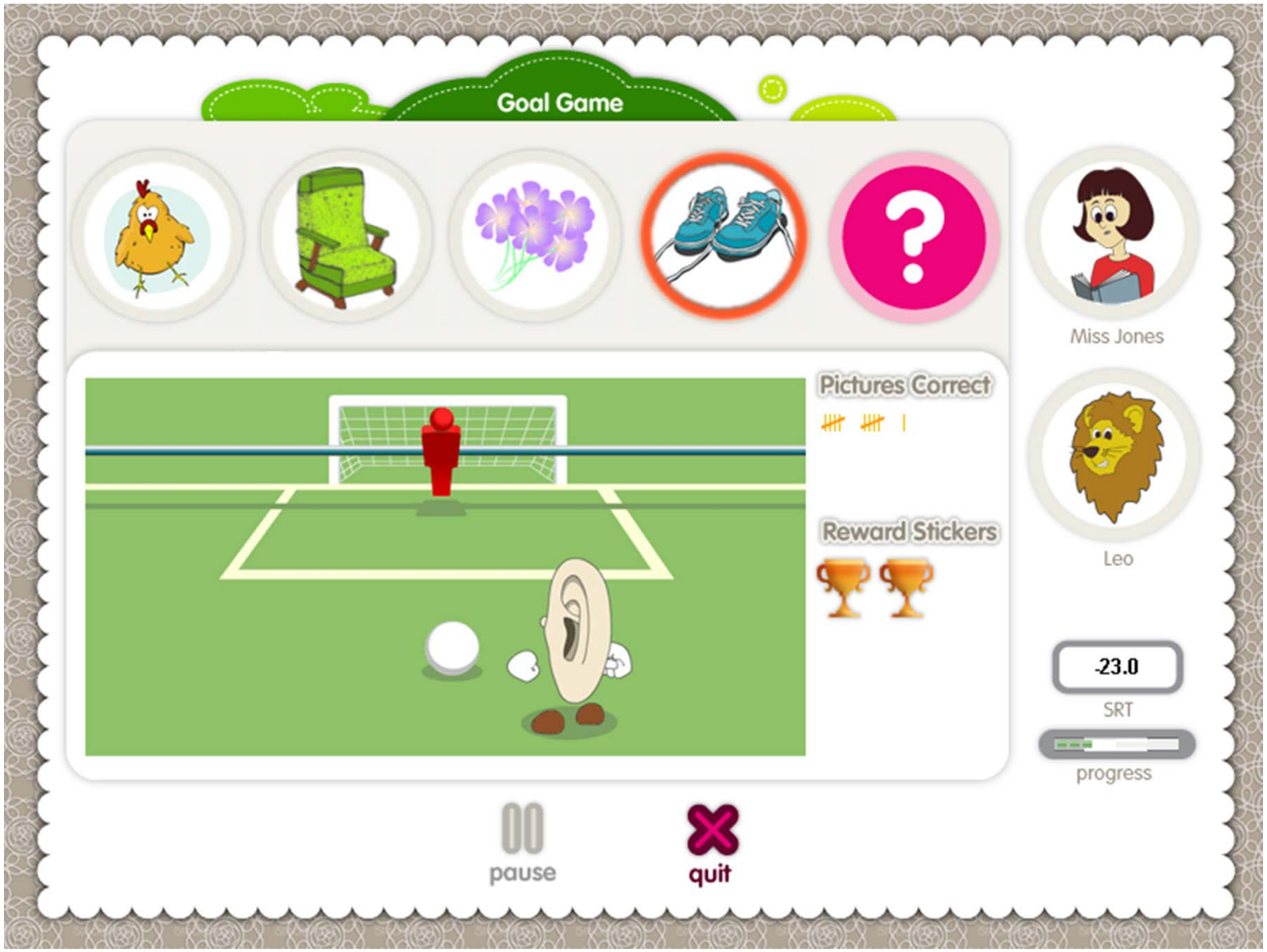
LISN & Learn Game

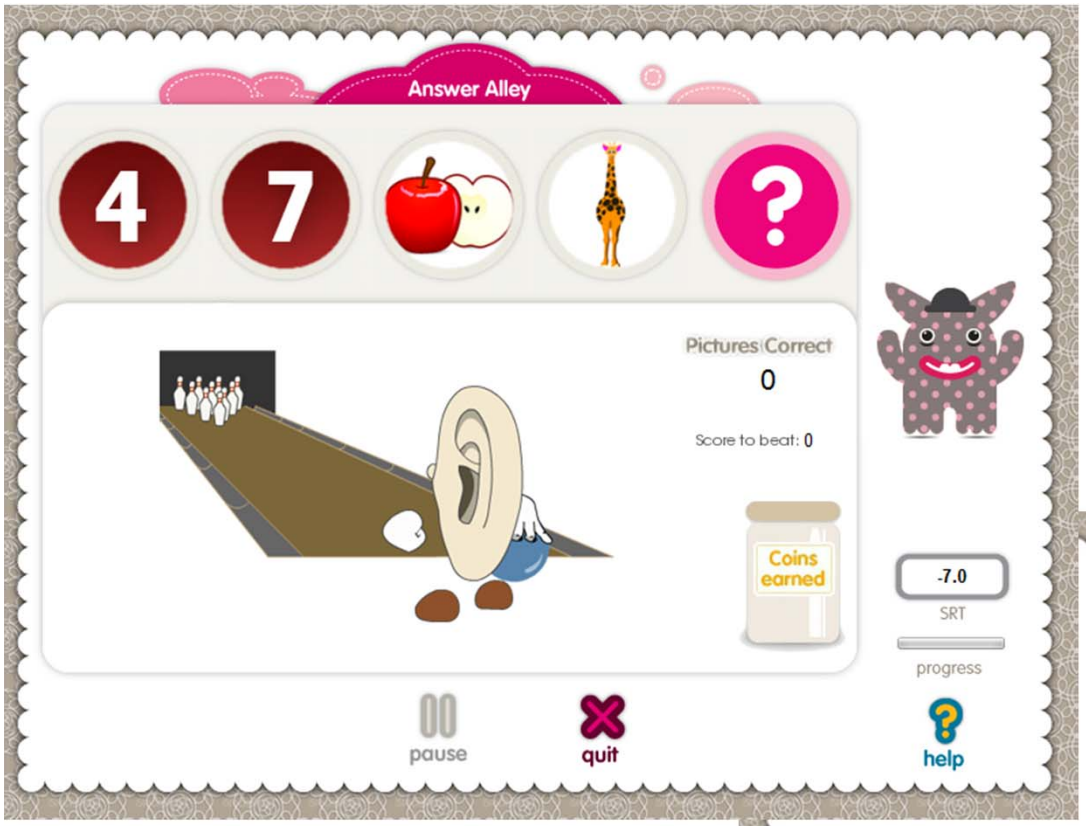


Target at 0˚:

Distracters at + and -90˚:

Target: The horse kicked six wet <u>shoes</u>



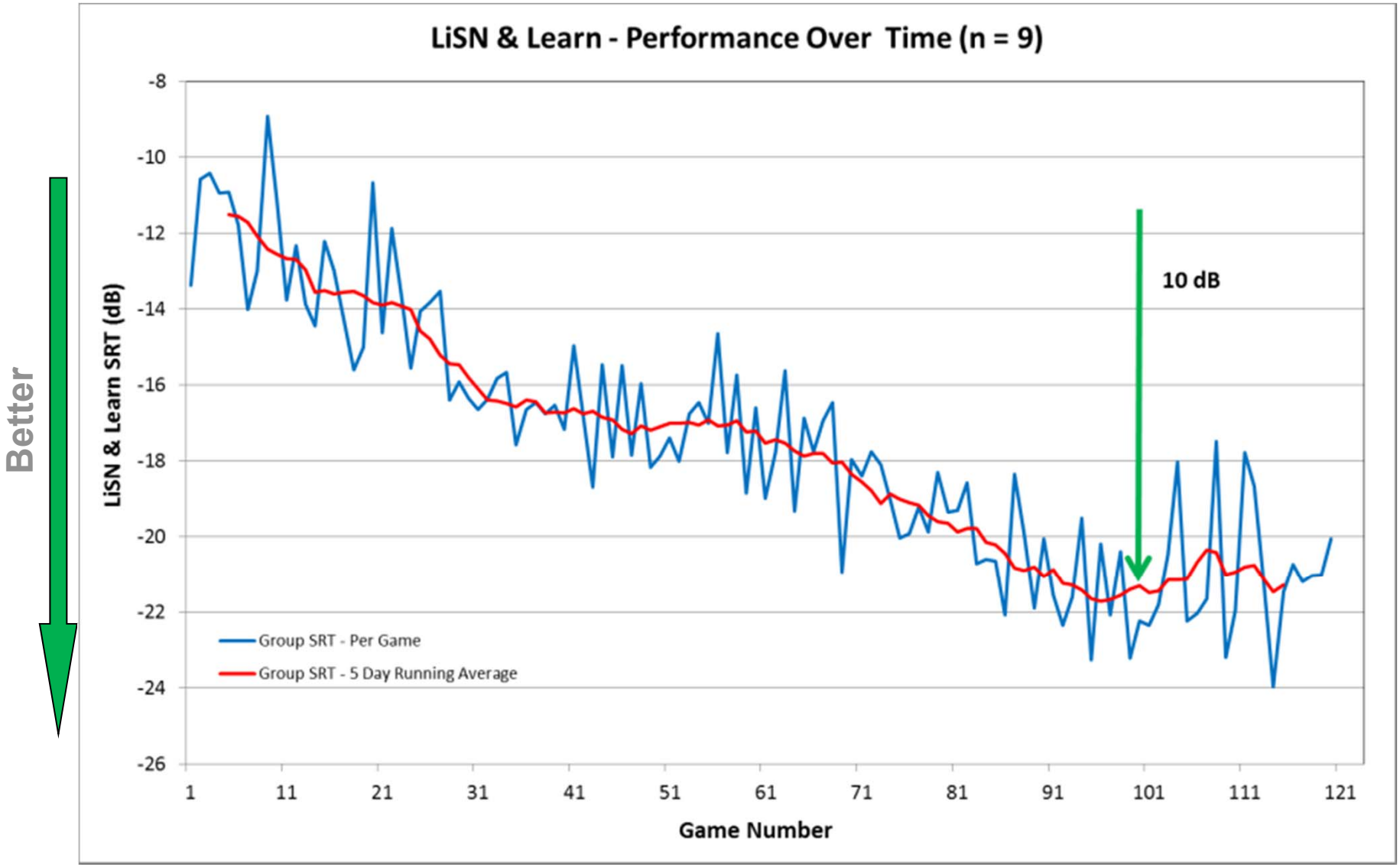

Answer Alley
4
7
?
Pictures Correct
0
Score to beat: 0
Coins earned
-7.0
SRT
progress
pause
quit
help


LISN & Learn
National Acoustic Laboratories
start game
Sound calibration
start demo game
reward shop
change my details
progress report
help
quit

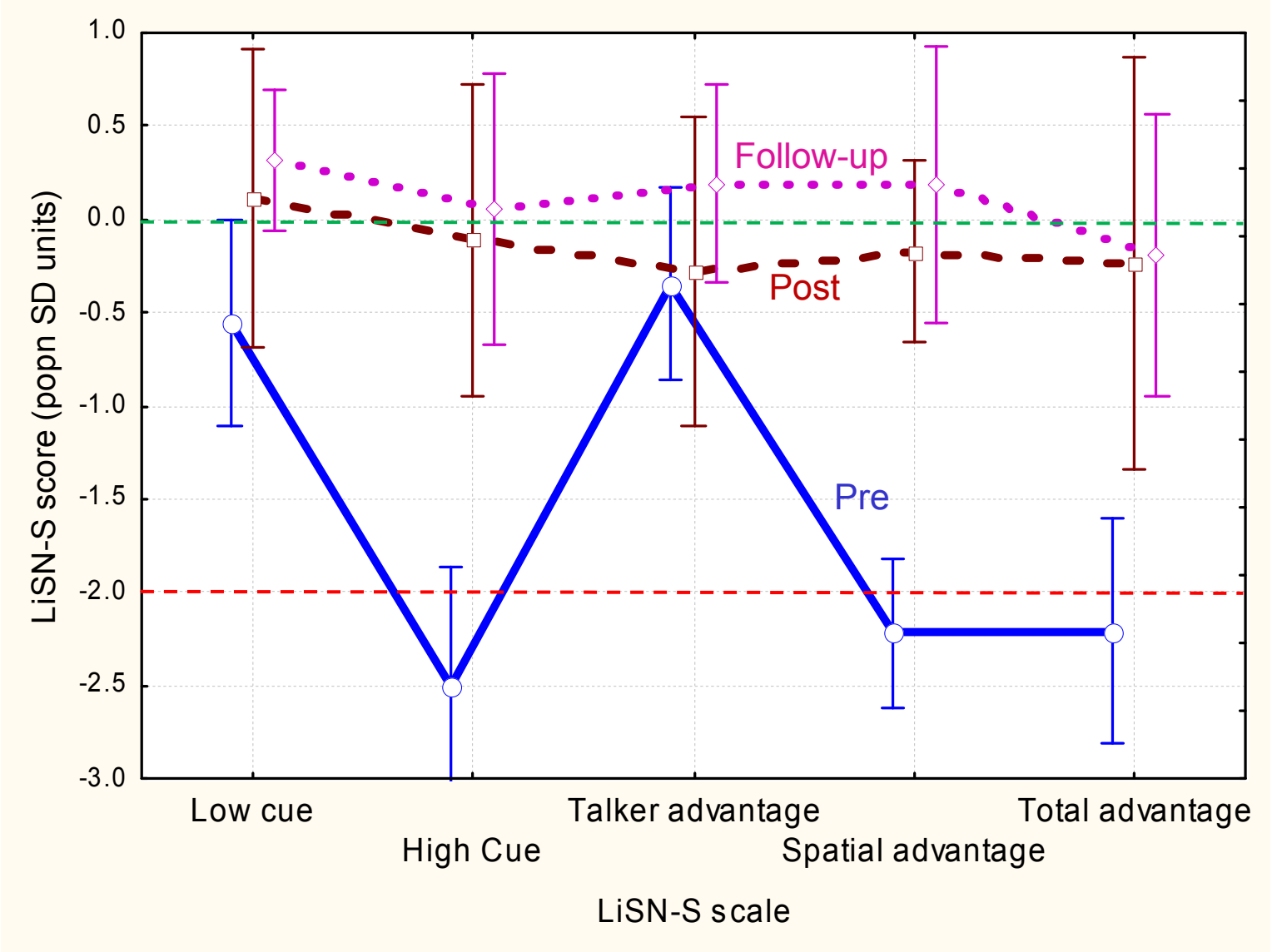
Method

- 9 children (6 to 11 years) - LISN-S SA >2SD
- CAPD Pediatric SSQ
- *LISN & Learn* - 15 minutes per day; 5 days per week; over 12 weeks (120 games)
- Re-evaluate post-training; 3 months post-training

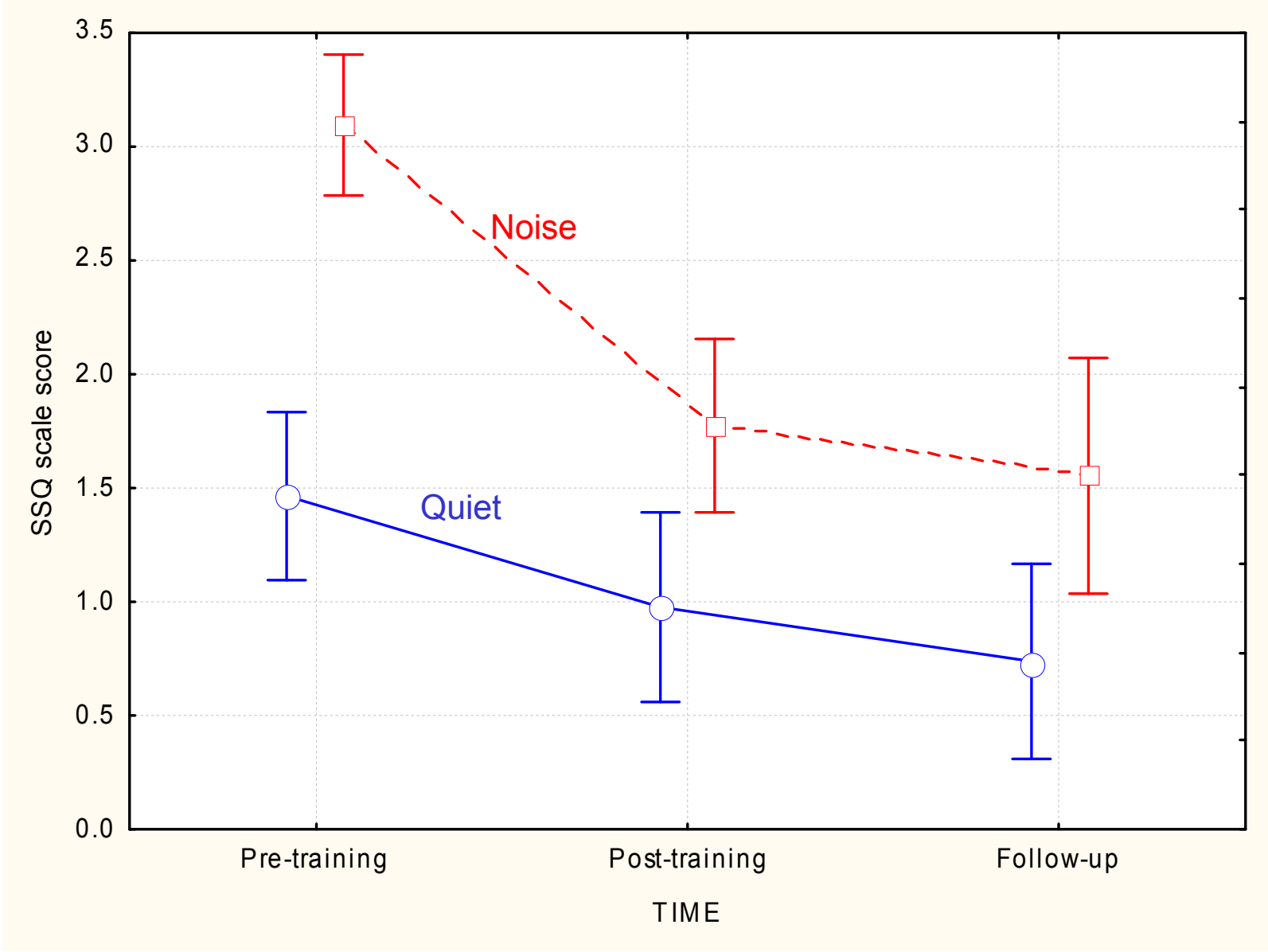
LiSN & Learn - Performance Over Time (n=9)



Effect of training on LiSN-S scores



Effect of training on Speech Spatial Quality Scores



Additional Results – Pre- vs. Post Training

- CAPD SSQ:
  - Listening in Quiet – p = 0.103
  - Listening in Noise – p = 0.0002
- TOVA-A
  - Omissions – p = 0.168
  - Commissions – p = 0.0004
- TAPS-3
  - Memory Index – p = 0.003

Phase II Clinical Study

1. 16 children - LISN-S spatial advantage >2SD from mean
   a) 8 x *LiSN & Learn* (experimental group) → 5
   b) 8 x *Earobics* (control group) → 5

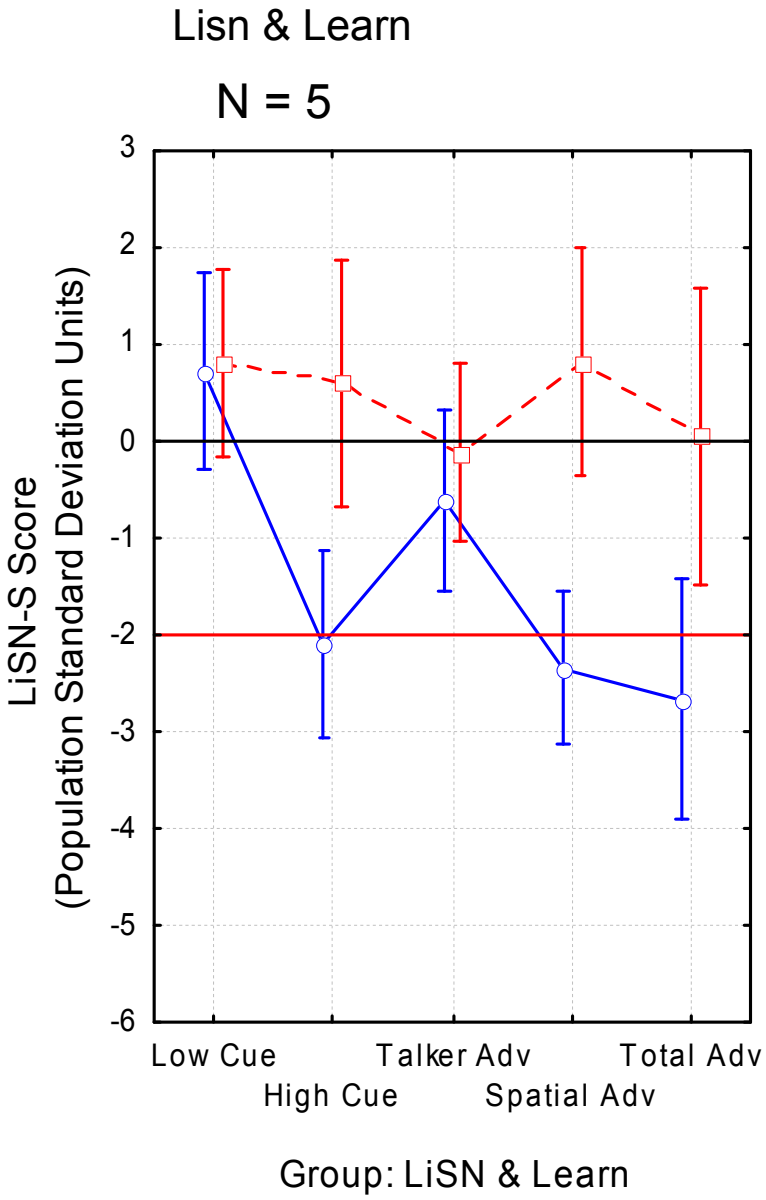
2. Questionnaire
   a) Participant (LIFE)
   b) Parent (Fishers)
   c) Teacher (LIFE)

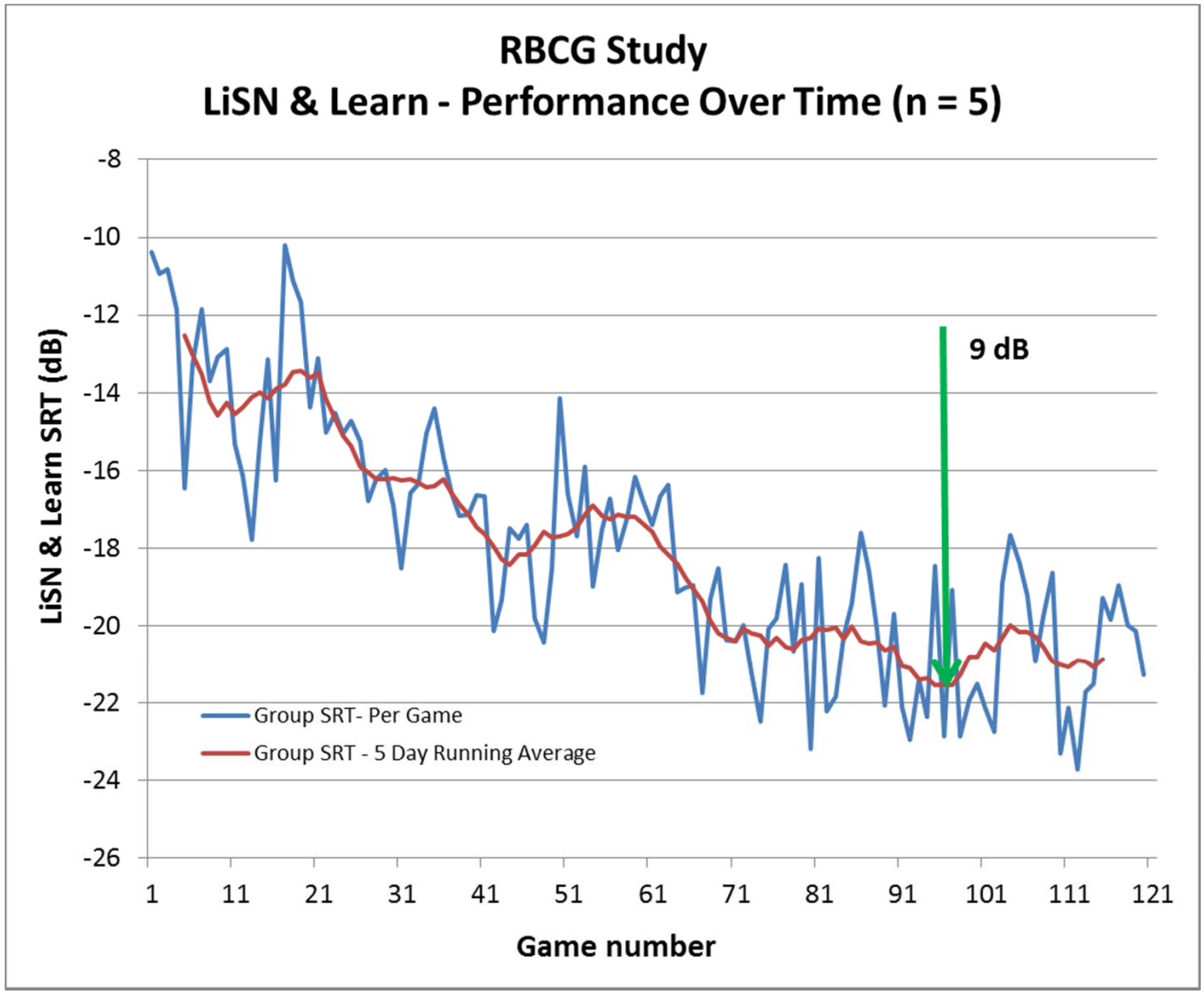
3. *LiSN & Learn* or *Earobics* training – 15 minutes per day

4. Re-evaluate LiSN-S and questionnaires post-training

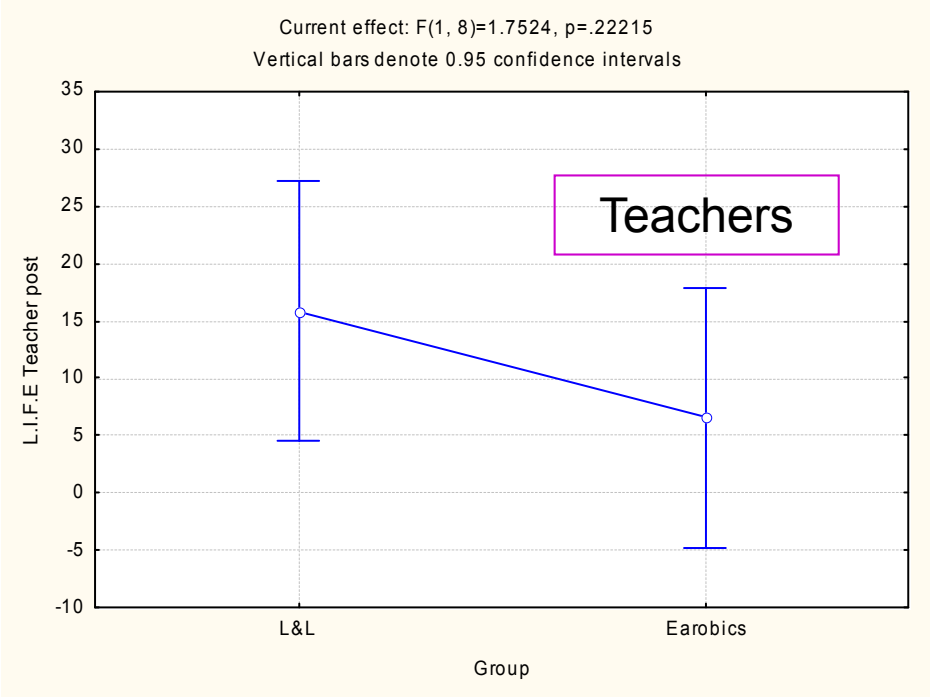
5. Offer *LiSN & Learn* to control group.

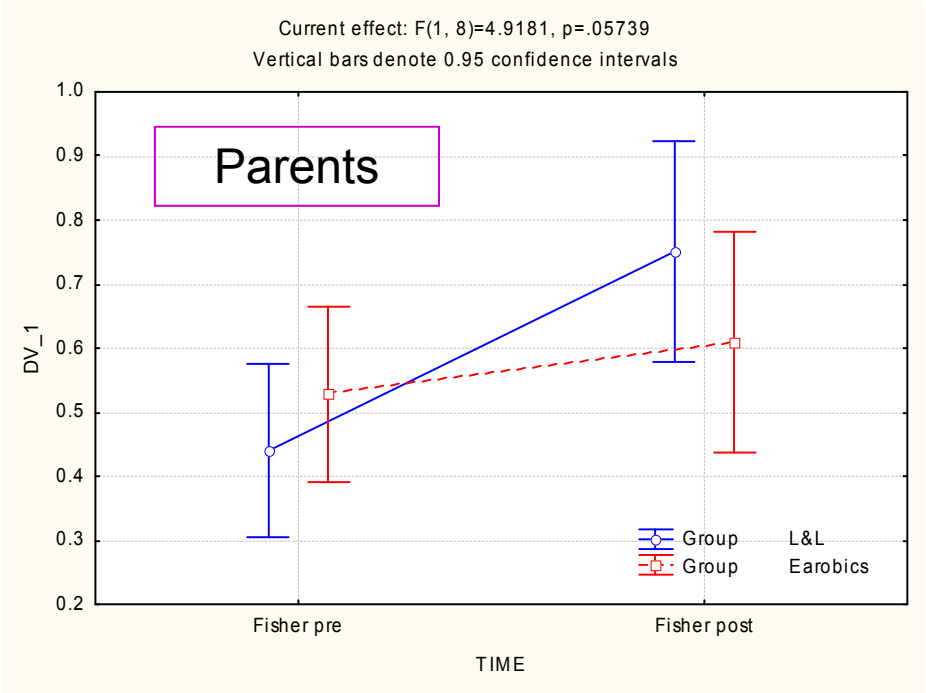
Randomized Control Trial

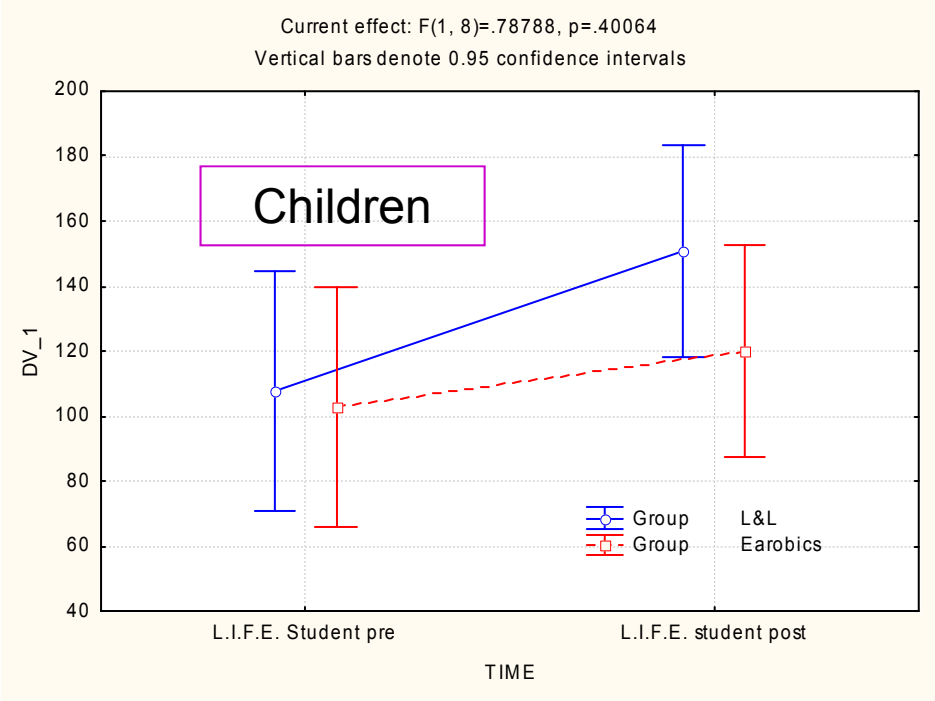



RBCG Study
LiSN & Learn - Performance Over Time (n = 5)
LiSN & Learn SRT (dB)
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
1
11
21
31
41
51
61
71
81
91
101
111
121
Game number
9 dB
Group SRT- Per Game
Group SRT - 5 Day Running Average

Questionnaire results







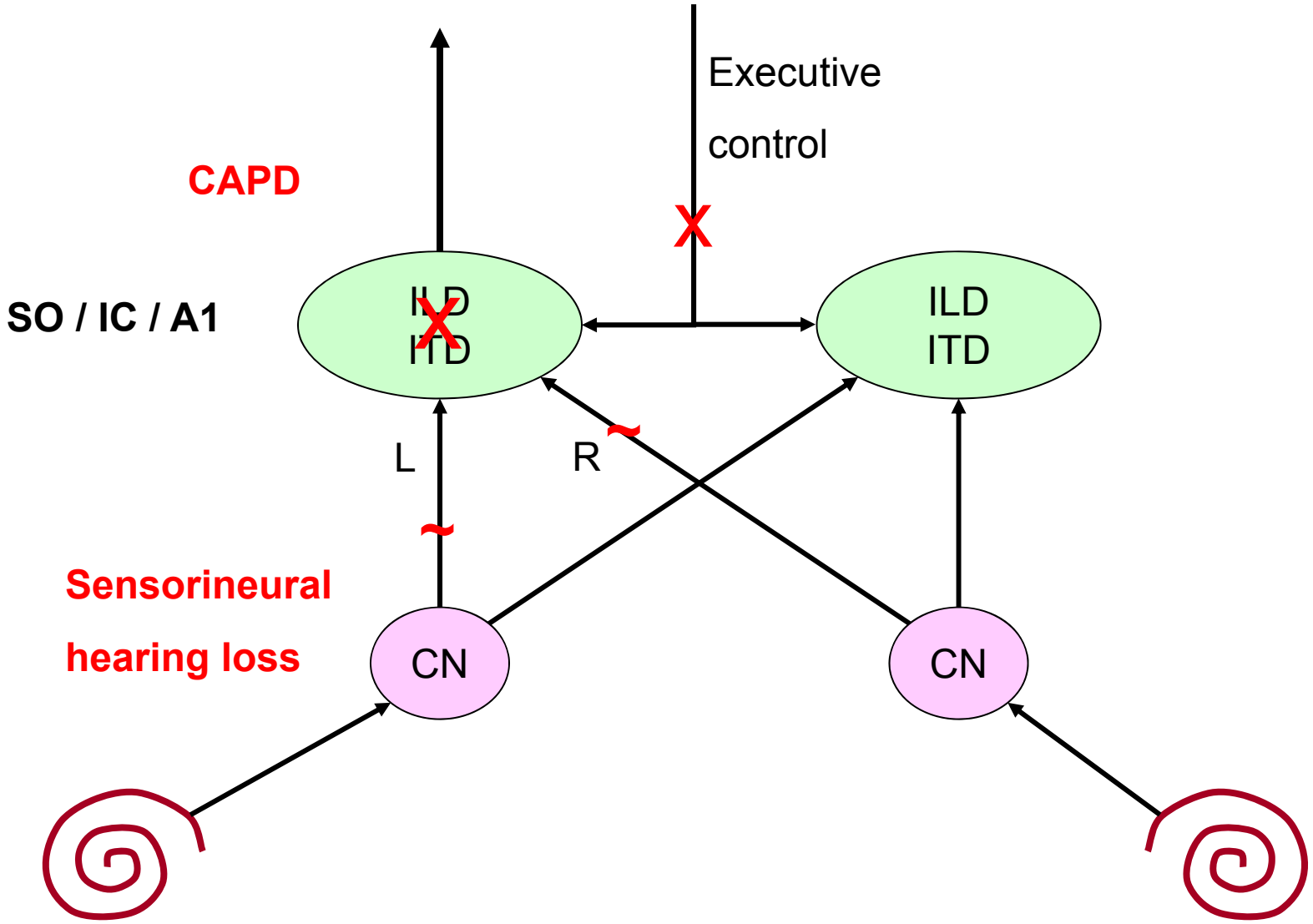
Conclusion

- *LiSN & Learn* training has the potential to strengthen or reorganize connections dedicated to binaural processing of frontal sounds.

- Training results in enhanced ability to process frontal speech in background noise.

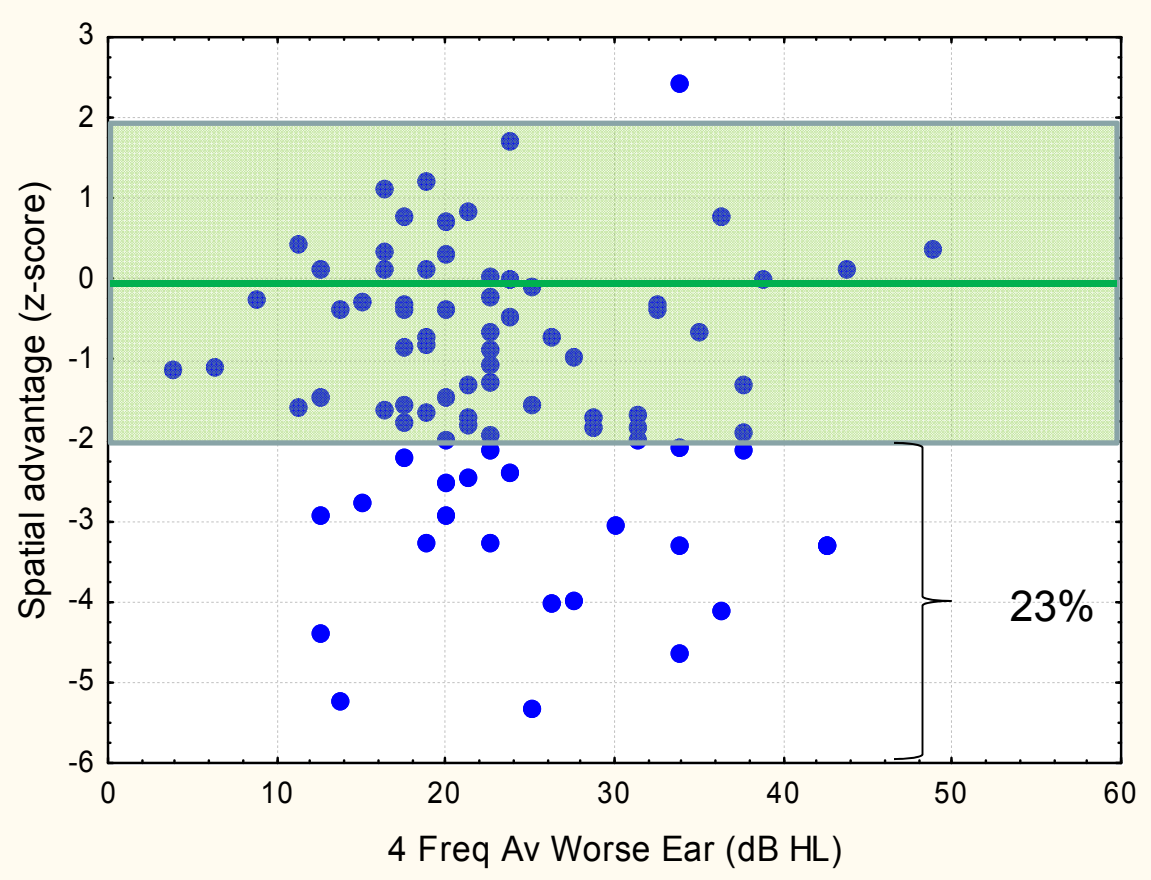
MECHANISMS IN SPATIAL PROCESSING AND ITS DISORDERS

Binaural processing mechanisms



Origins

Of 49 children with spatial processing disorder seen in research studies at NAL, 25 had three or more episodes of ear infections when younger.



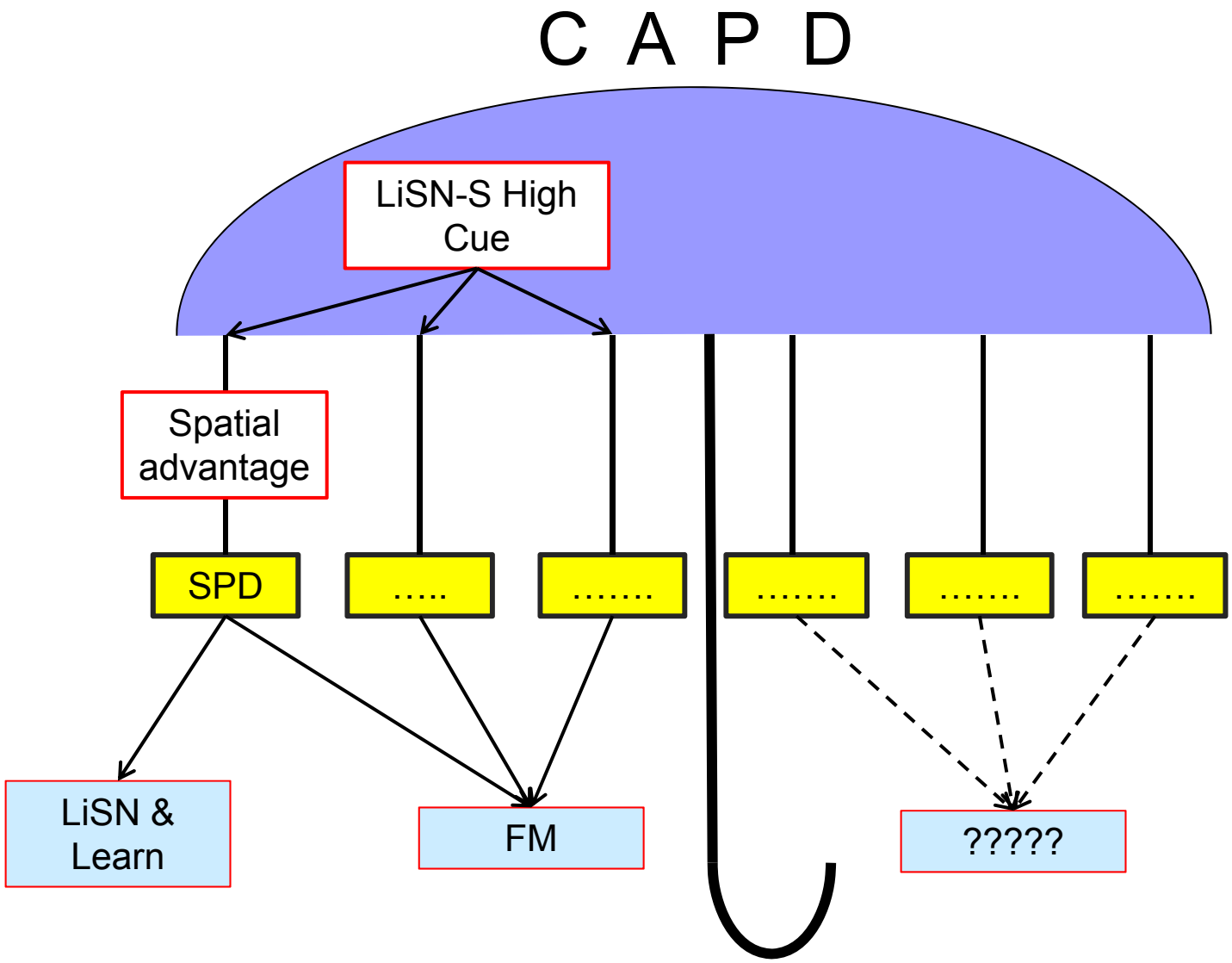
Indigenous children in a remote community:
87 children aged 8-9 yrs

→ 10% had SPD profile

Indigenous children in a regional town:
144 children aged 6-12 yrs

→ 7% had SPD profile

SPD ≠ CAPD



SPATIAL PROCESSING FOR NON-SPEECH SOUNDS

Jorg Buchholz

→ Spatial processing (disorder) is not specific to speech

OBJECTIVE MEASUREMENT OF SPATIAL PROCESSING

→ Cortical response larger in separated condition
→ cABR (aka FFR) larger in separated condition

References

1. Dillon, H., Cameron, S., Glyde, H., Wilson, W., & Tomlin, D. (2012). Opinion: Re-designing the process of assessing people suspected of having central auditory processing disorders. *Journal of the American Academy of Audiology* (Accepted 17 June 2011).

2. Cameron, S., Glyde, H. & Dillon, H. (in press). Listening in Spatialized Noise- Sentences Test (LiSN-S): Normative and retest reliability data for adolescents and adults up to 60 years of age. *Journal of the American Academy of Audiology* (Accepted 18 May 2011).

3. Cameron, S. & Dillon, H. (in press). Development and Evaluation of the LiSN & Learn Auditory Training Software for Deficit-Specific Remediation of Binaural Processing Deficits in Children: Preliminary Findings. *Journal of the American Academy of Audiology* (Accepted 29 April 2011).

4. Cameron, S., & Dillon, H. (2010). *LiSN & Learn* Auditory Training Software (Version 1.1.0) [Computer software]. Sydney, NSW: National Acoustic Laboratories.

5. Brown, D., Cameron, S. Martin, J., Watson, C., & Dillon, H. (2010). The North American Listening in Spatialized Noise – Sentences Test (NA LiSN-S): Normative data and test-retest reliability studies for adolescents and young adults. *Journal of the American Academy of Audiology*, *21*(10), 629-641.

6. Cameron ,S., Brown, D., Keith, R., Martin, J., Watson, C., & Dillon, H. (2009). Development of the North American Listening in Spatialized Noise - Sentences Test (NA LISN-S): Sentence equivalence, normative data and test-retest reliability studies. *Journal of the American Academy of Audiology*, *20*(2), 128-146.

7. Cameron, S. & Dillon H. (2009) *Listening in Spatialized Noise – Sentences test (LISN-S)* (Version 1.013) [Computer software]. Murten, Switzerland: Phonak Communications AG.

8. Cameron, S. & Dillon, H. (2008). The Listening in Spatialized Noise – Sentences Test: Comparison to prototype LISN test and results from children with either a suspected (central) auditory processing disorder of a confirmed language disorder. *Journal of the American Academy of Audiology*, *19*(5), 377-391.

9. Cameron, S. & Dillon, H. (2008). Spatial hearing deficits as a major cause of auditory processing disorders: Diagnosis with the LISN-S and management options. In R. Seewald & J. Bamford, eds. *A Sound Foundation Through Early Amplification 2007. Proceedings of the Fourth International Conference*: Phonak AG, Switzerland, 235-241.

10. Cameron, S. & Dillon, H. (2007). Development of the Listening in Spatialized Noise - Sentences Test (LISN-S). *Ear and Hearing, 28(2),* 196-211.

11. Cameron, S. & Dillon, H. (2007). The Listening in Spatialized Noise - Sentences Test (LISN-S): Test-retest reliability study. *International Journal of Audiology, 46*, 145-153.

Language, literacy and cognition in children with hearing impairment

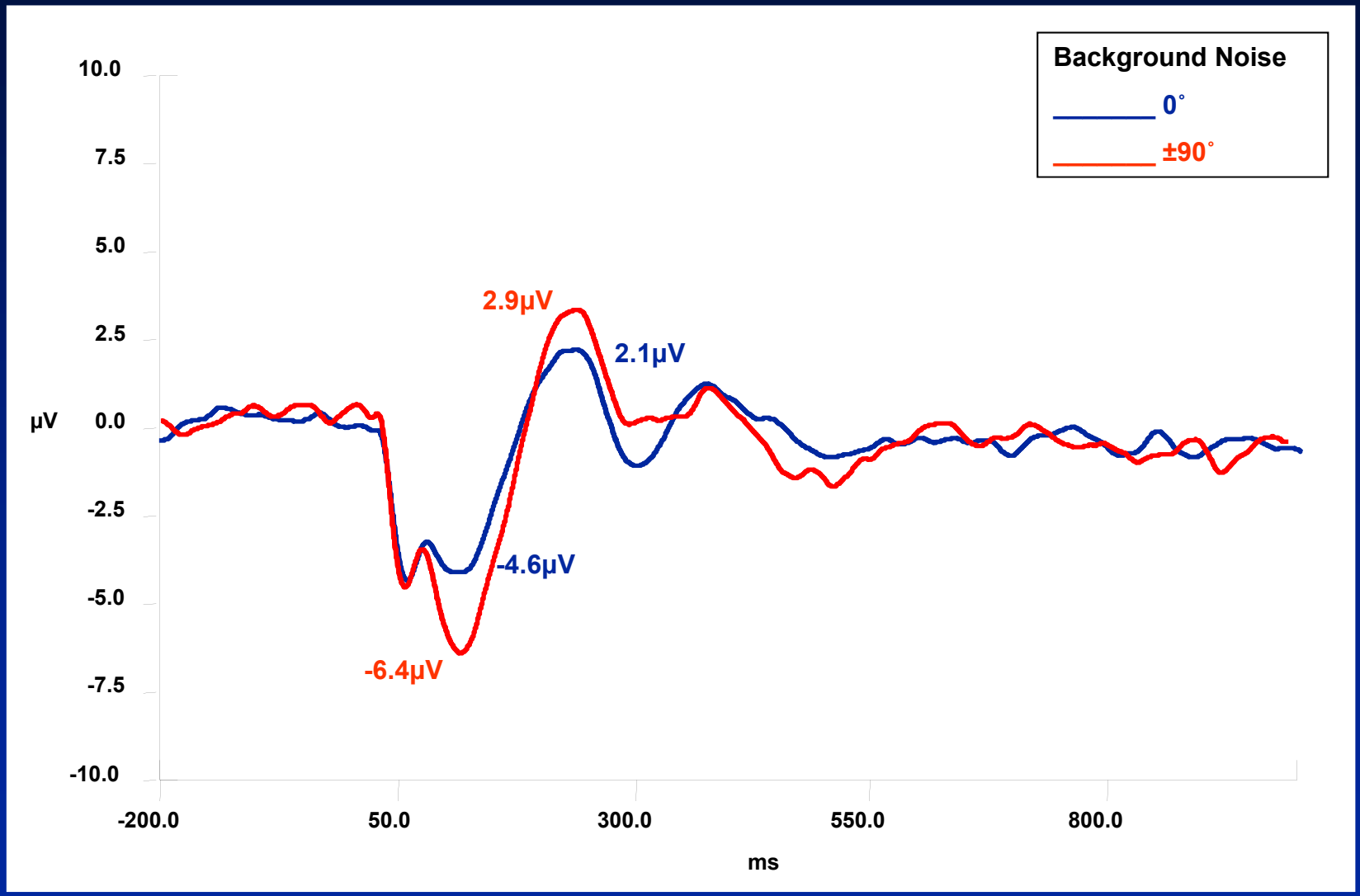
Thanks for listening

The support of the Commonwealth Department of Aging is greatly appreciated

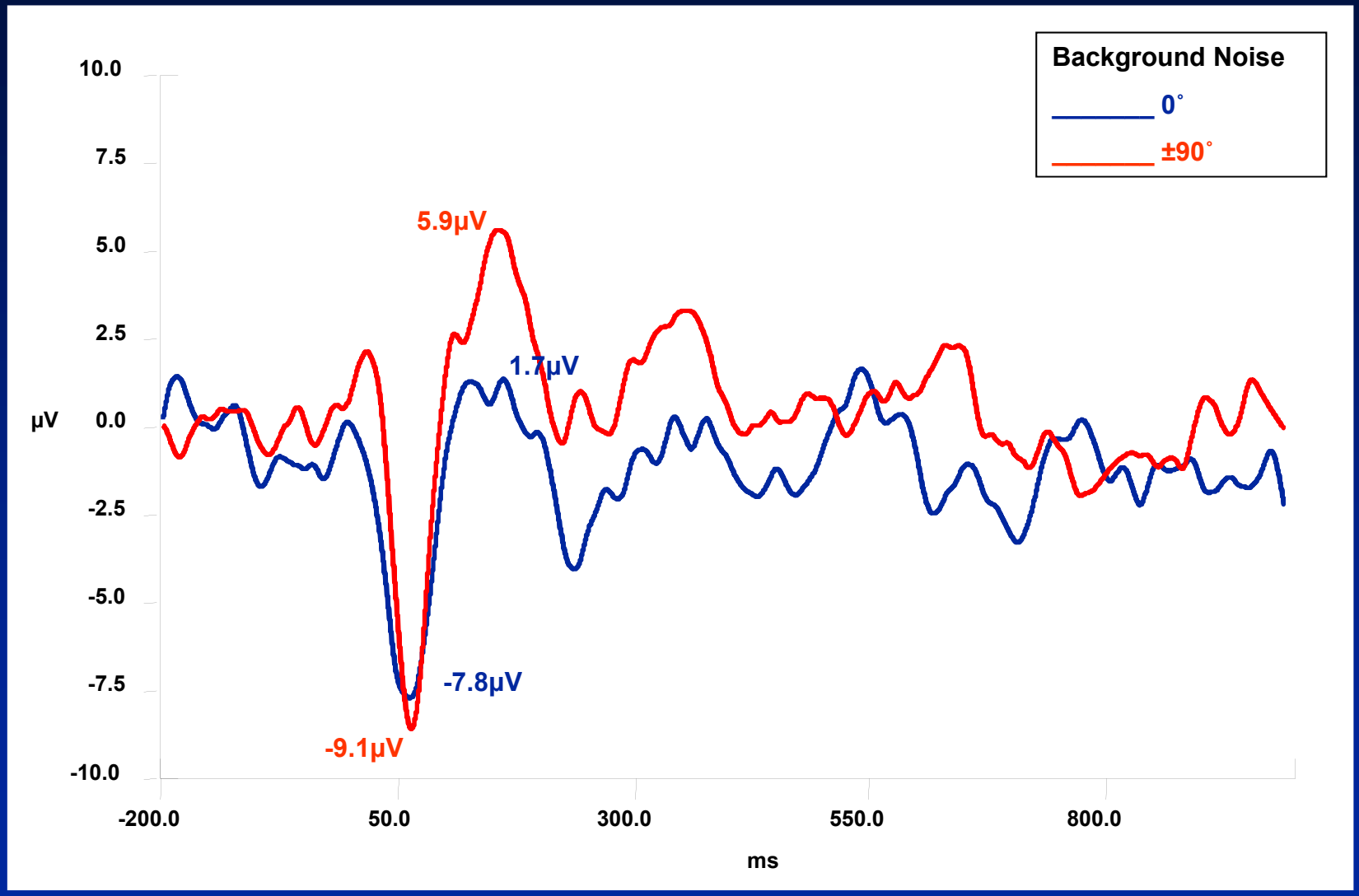
capd.NAL.gov.au - *TV news story*

- *science TV show*

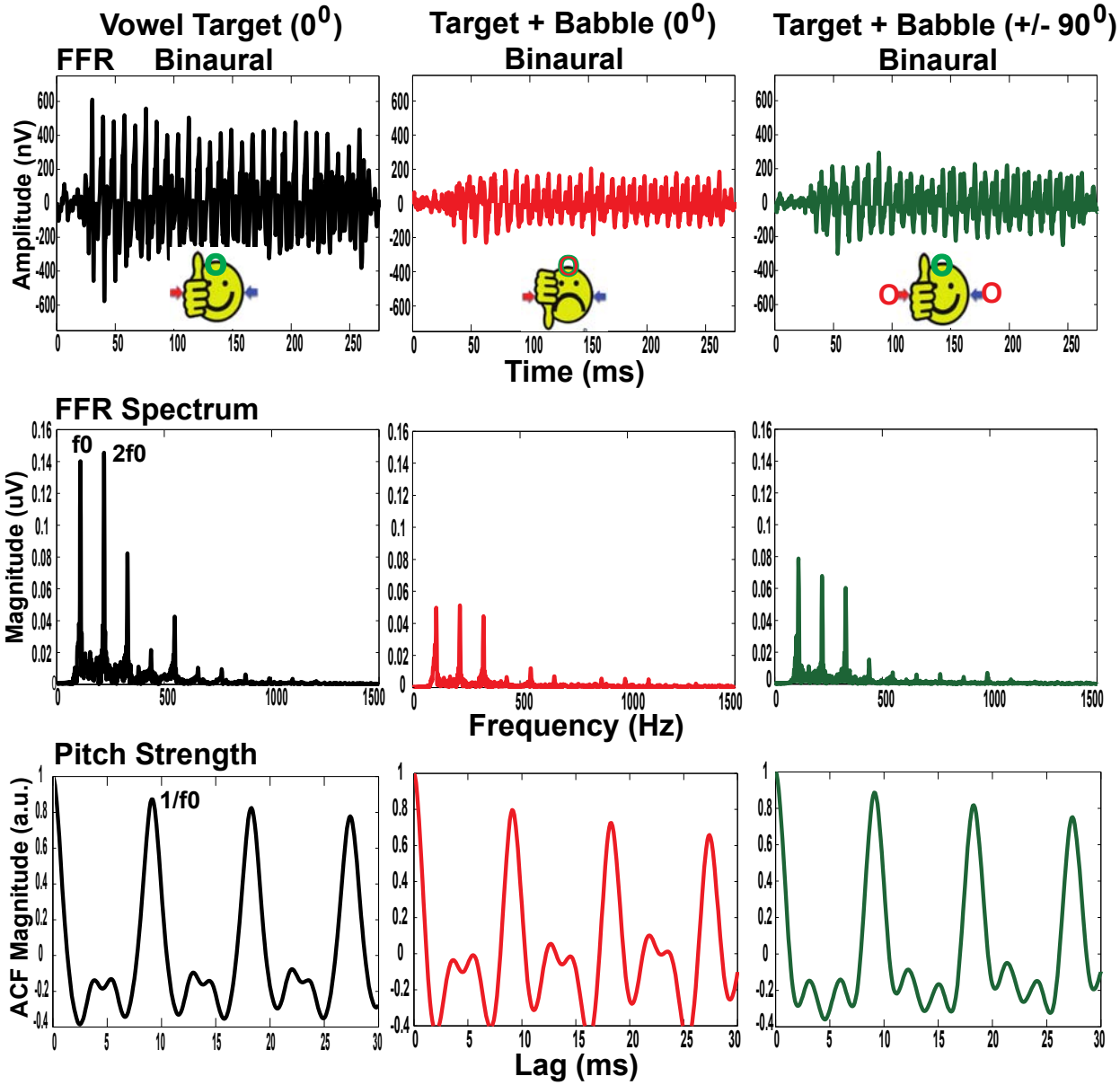
Adult Control Group – Active Task
N1 and P2 to Standard Stimulus at Cz



Age Matched Control - Passive Task
N1 and P2 to Standard Stimulus at Cz



Frequency following response



Krishnan et al 2012

Time for quick check: True or false?

1.
2.
3.
4.
5.
6.
7.
8.
9.

Time for quick check: True or false?

The LiSN-S test:

1. **Detects all forms of CAPD (T/F ?)**
2. **Is suitable for children down to the age of 4 years**
3. **Can detect spatial processing disorder in children and adults**
4. **Gives much better scores on retest than on initial test**
5. **Must be performed in an echo-free sound environment**
6. **Gives several sub-scores some of which should be affected by language disorders, attention, and cognition, and some of which shouldn't.**
7. **Detects spatial processing disorder, which causes most cases of CAPD**
8. **Reliably tests localization of speech sounds.**
9. **Is a validated intervention tool.**

Time for quick check: True or false?

The LiSN-S test:

1. **Detects all forms of CAPD - False**
2. **Is suitable for children down to the age of 4 years - False**
3. **Can detect spatial processing disorder in children and adults - True**
4. **Gives much better scores on retest than on initial test - False**
5. **Must be performed in an echo-free sound environment - False**
6. **Gives several sub-scores some of which should be affected by language disorders, attention, and cognition, and some of which shouldn't - True**
7. **Detects spatial processing disorder, which causes most cases of CAPD - False**
8. **Reliably tests localization of speech sounds - False**
9. **Is a validated intervention tool - False**

Some more review questions

1

2

3

4

Some more review questions

LiSN & Learn:

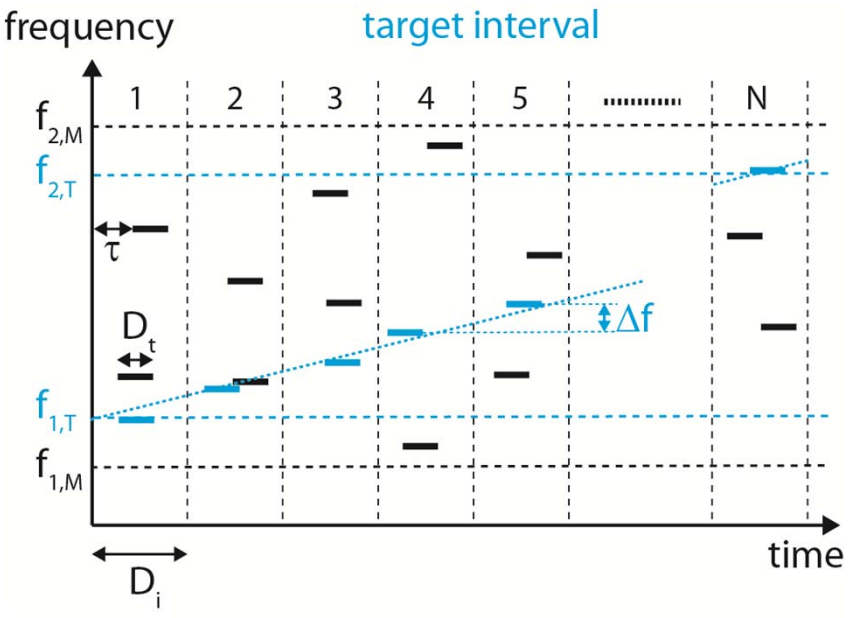
1. Is a proven treatment for children with CAPD
2. Reliably enables a child to perform better on the LiSN-S diagnostic test
3. Provides a near-instantaneous cure
4. Enables improved listening in noise in real life for children with SPD

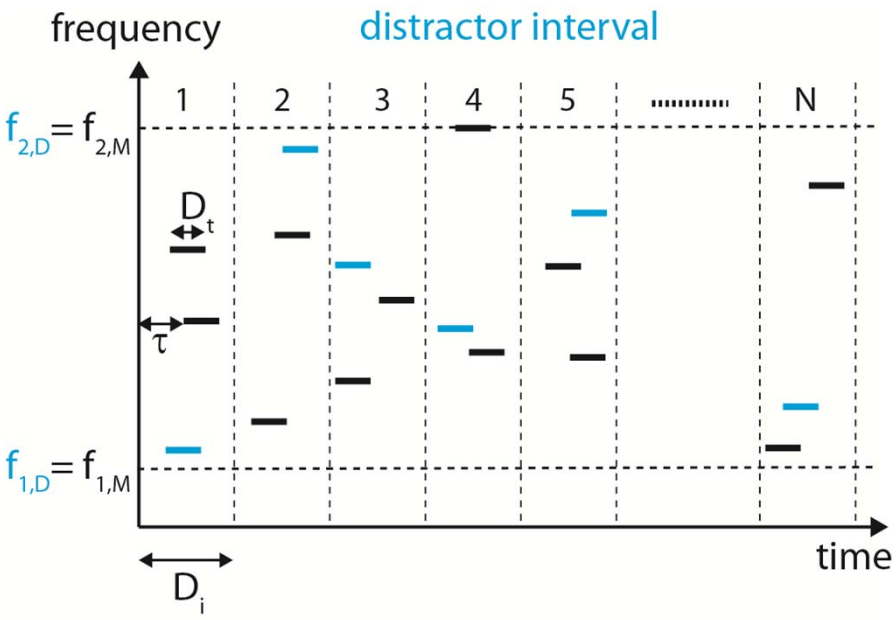
Some more review questions

LiSN & Learn:

1. Is a proven treatment for children with CAPD - F
2. Reliably enables a child to perform better on the LiSN-S diagnostic test - T
3. Provides a near-instantaneous cure - F
4. Enables improved listening in noise in real life for children with SPD - T

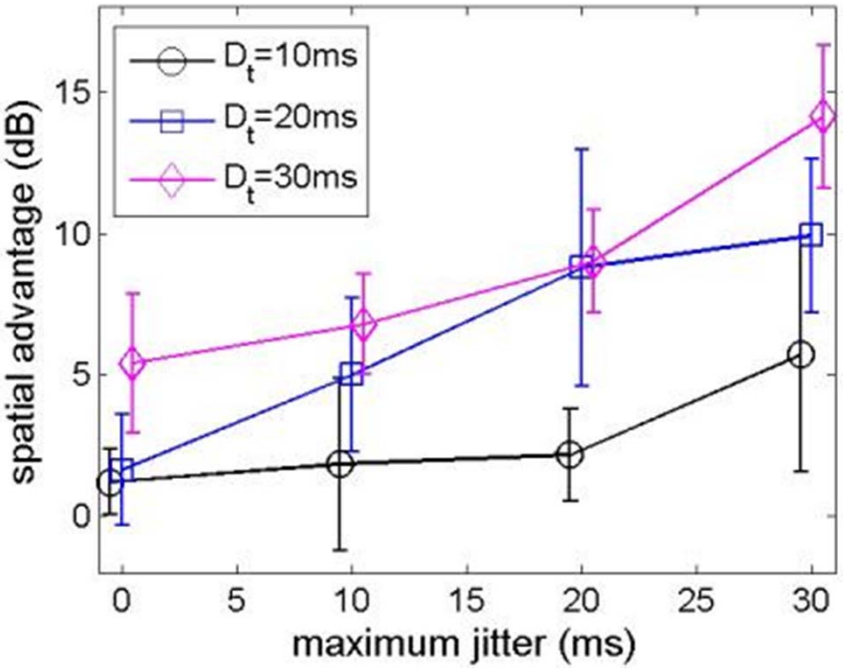
Spectro-temporal properties





		Tone duration	
		10ms	30ms
Max jitter	0ms		
	30ms		

Results – spatial advantage



Threshold difference between spatially co-located and separated conditions

- Spatial advantage increases with increasing amount of jitter
  → dip-listening improves spatial advantage…?
- Spatial advantage increases with increasing tone-burst duration
  → pitch strength influences spatial advantage...?
- Temporal integration and jitter benefit are ~additive

Preliminary data from 3 listeners

To end