



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.

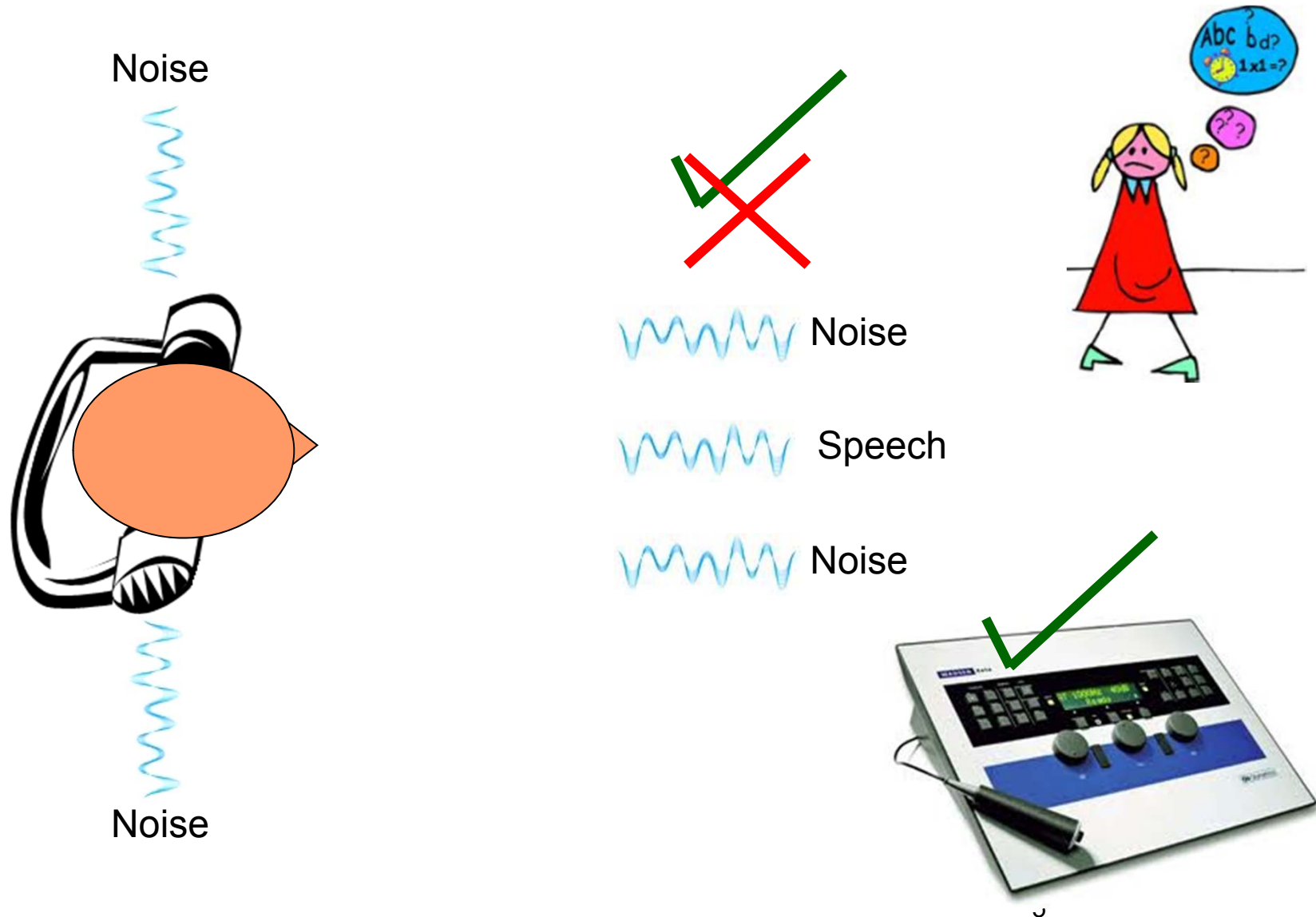
- NAL licences the LiSN-S test to Phonak, and is paid a royalty on sales.
- NAL directly sells the LiSN & Learn training package through its web site.



**SPATIAL PROCESSING
DISORDER IN “NORMAL”
HEARING**

Spatial Processing Disorder

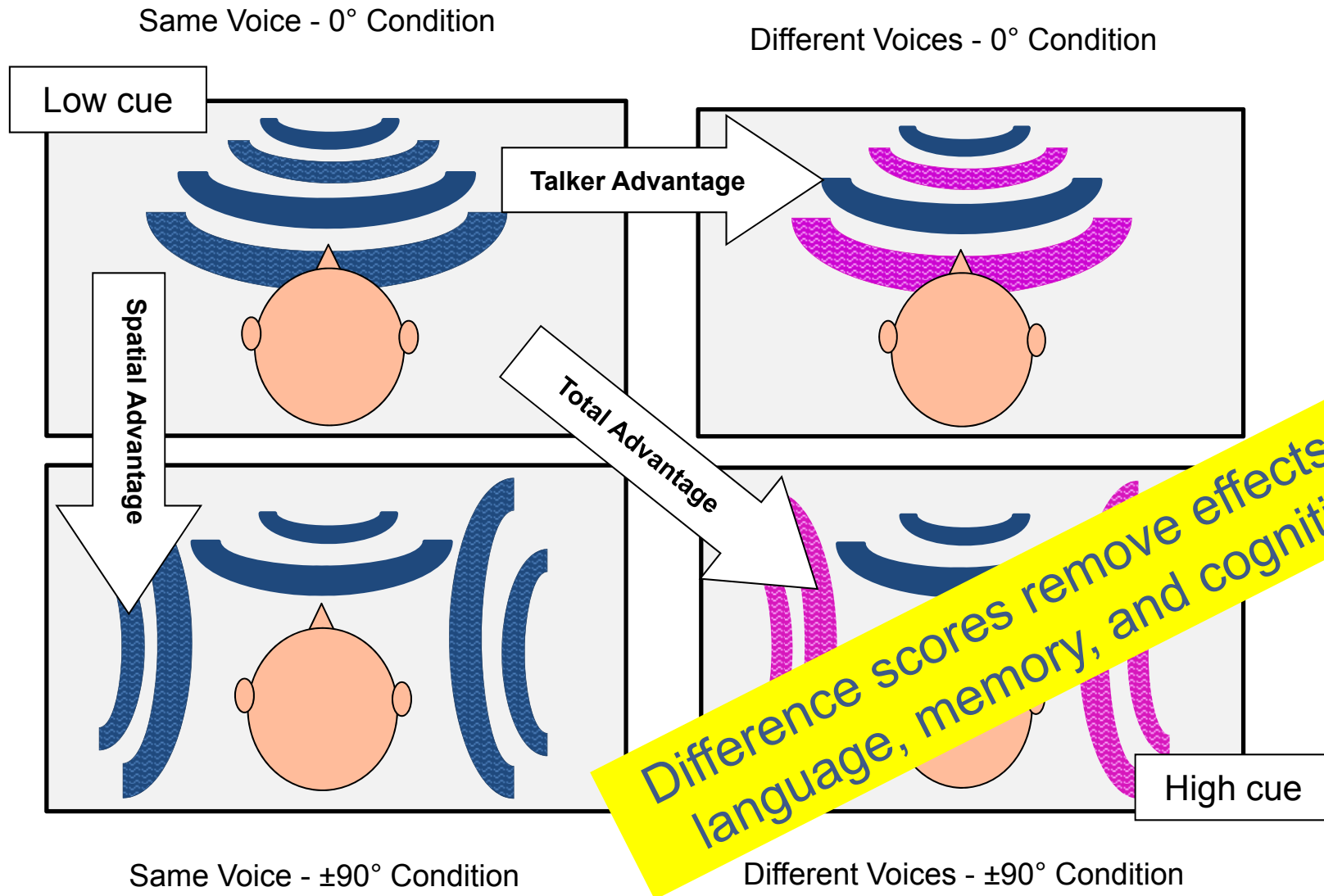
Lack of spatial release from masking



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

1. Adaptive speech-in-noise-test
2. Virtual auditory environment under headphones
3. Target sentences - 0° azimuth
4. Competing speech - 0° or $\pm 90^\circ$ 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

Phonak LiSN-S

File Configuration Extra Help

PHONAK

Diagnostic Session

Client

Diagnostic

Different voices $\pm 90^\circ$

Same voice $\pm 90^\circ$

Different voices 0°

Same voice 0°

Results

Explanations

Reports

Next

First Name* **Robert**

Test date 20/08/2009

Different voices $\pm 90^\circ$

Background voice Continue

Phrase level Stop

Patient's score Reset

Select actual correct

0	1	2	3
4	5	6	7
All			

Result actual phrase

Actual Correct	Possible Correct
5	5

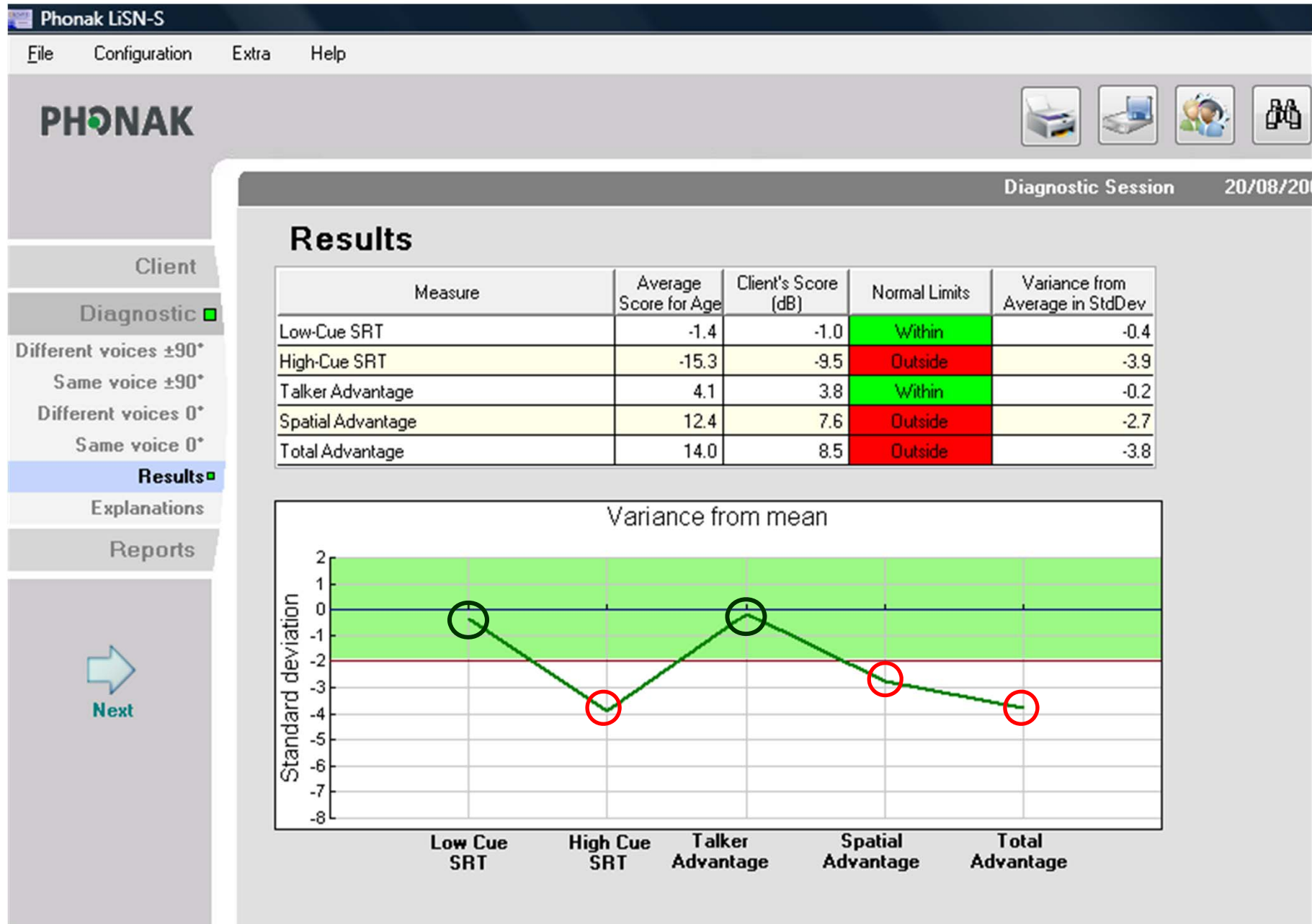
Next

Seq 22 Phrase They are moving the boxes

% Completed

Number of reversals **12** Standard Error of Mean (dB) **0.8** SRT (dB) **-9.5**

Results profile: spatial processing disorder



Explanation Screen

Phonak LiSN-S

File Configuration Extra Help

PHONAK

Diagnostic Session

Explanations

Measure	Average Score for Age	Client's Score (dB)	Normal Limits	Variance from Average in StdDev
Low-Cue SRT	-1.4	-1.0	Within	-0.4
High-Cue SRT	-15.3	-9.5	Outside	-3.9
Talker Advantage	4.1	3.8	Within	-0.2
Spatial Advantage	12.4	7.6	Outside	-2.7
Total Advantage	14.0	8.5	Outside	-3.8

: FAIL

Robert Smith was outside normal limits on the high-cue SRT, spatial advantage and total advantage measures of the LiSN-S. These results are suggestive of a spatial stream segregation disorder.

Client Assessment Report

Print preview

100 %

Word Excel PDF Email PDF Email

1

2

Phonak LiSN-S Client Assessment Report

Product: **Phonak LiSN-S** School:

Last name: **Smith** Test date: **20/08/2009**

First name: **Robert** Tester: **Cameron, Sharon**

Age: **10 years 5 months**

Background Information

The Listening in Spatialized Noise - Sentences Test (LiSN-S) was developed to assess auditory skills in children who may be having difficulty listening to and following speech in the classroom. A number of sentences are presented under headphones, initially at 62 dB SPL, in the presence of two distracter stories presented at a fixed intensity of 55 dB SPL. The distracter stories vary in both their position in space (coming from either directly in front of the listener, or at either side of the listener); and in the vocal quality of the speakers. The listener's task is to repeat each sentence heard. The intensity level of the target sentences is adjusted to find the level at which the listener is getting 50 percent of words correct in each sentence.

The "low-cue SRT" measure assesses listening skills when no spatial or vocal cues are available to the

Microsoft PowerPoi... Phonak LiSN-S Deleted Items - Micr...

Language: USA English or Australian English

Phonak LISN-S

File Configuration Extra Help

PHONAK

Client

List of Clients

Client Session

Detailed results

Diagnostic

Reports

Next

List of Clients

Last Name

Address

Zip

City

State

Country

Other 1

Look for Last clients All

Phone

Date of Birth*

Mother lang.

Gender

Add

Cancel

New

Delete

Clear search

School

Language list

Select a default language

- English (Australia) (6-60) years
- English (USA) (6-60) years

OK

Cancel

New session

Ask for language selection when creating a new session

Latest version of LiSN-S

The screenshot shows the Phonak LiSN-S software interface. The main window has a menu bar with 'File', 'Configuration', 'Extra', and 'Help' (the 'Help' menu is circled in red). Below the menu bar is the 'PHONAK' logo and three icons. The main area is divided into a left sidebar with 'Client', 'List of Clients', 'Client Session', 'Detailed results', 'Diagnostic', and 'Reports'. The 'List of Clients' section is active, showing a form for adding a new client with fields for Last Name, First Name, Address, Zip, City, State, Country, Other 1, Phone, Date of Birth, Mother lang., Gender, School, Teacher/Class, Referral source, and Doctor. There are 'Add', 'Cancel', 'New', and 'Delete' buttons. A 'Notes' field is also present. Below the form is a table with columns for 'Last Name', 'Teacher', and 'School'. A 'Phonak Live-Update' dialog box is open in the foreground, displaying the following text:

The latest Phonak LiSN-S version is 2.002

The LiSN-S 2.0 includes the LiSN-S PGA module. The LiSN-PGA module is a diagnostic test to assess people with a hearing loss. The LiSN-S PGA module measures speech understanding in noise and gives clear technology recommendations for people with hearing loss. The upgrade is recommended to LiSN-S users, which offers diagnosis and rehabilitation of patients with a hearing loss.

No new update required

Check the version on startup

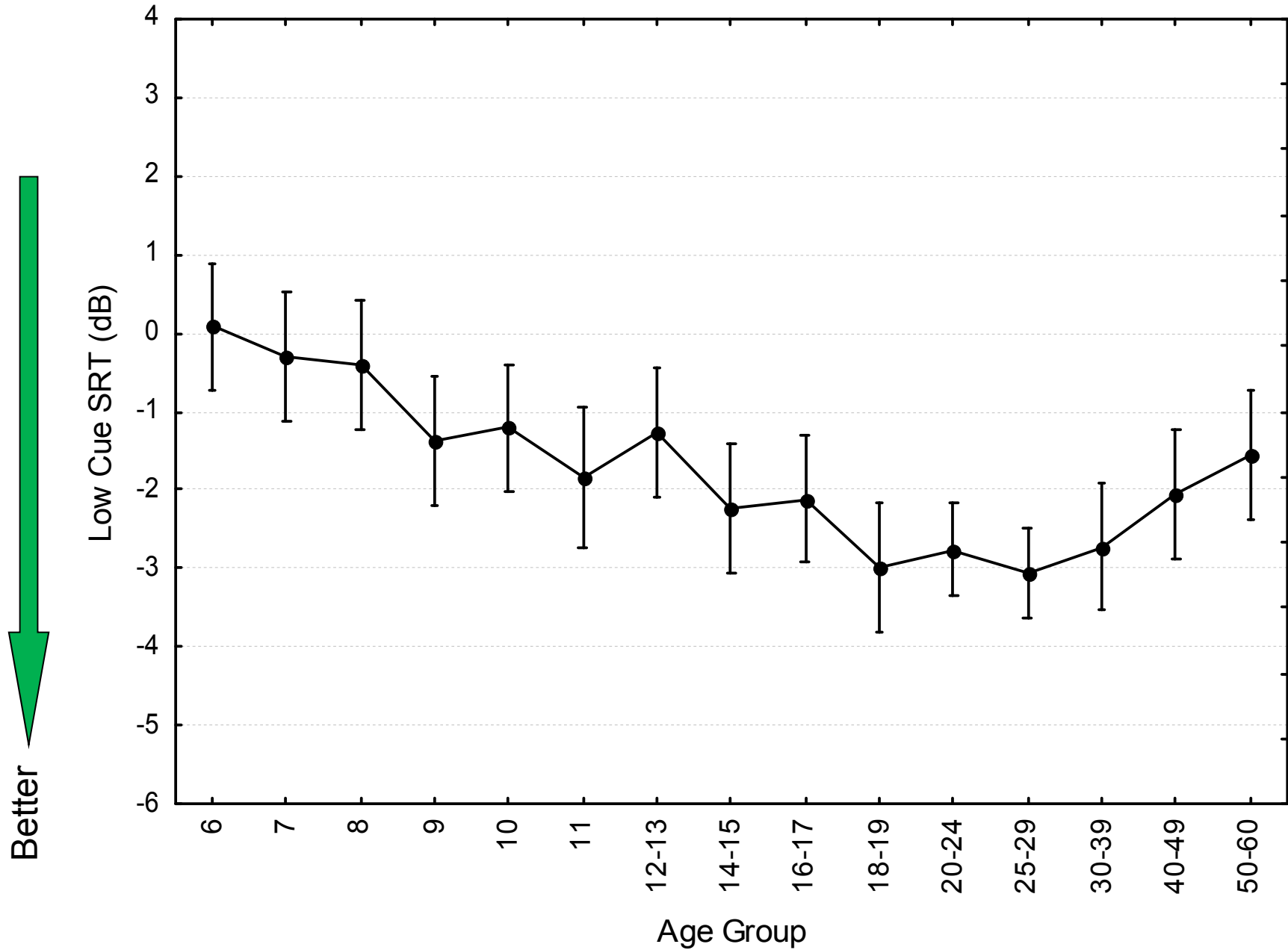
Buttons: Retry, Close

LiSN-S Normative Data (Australian version)

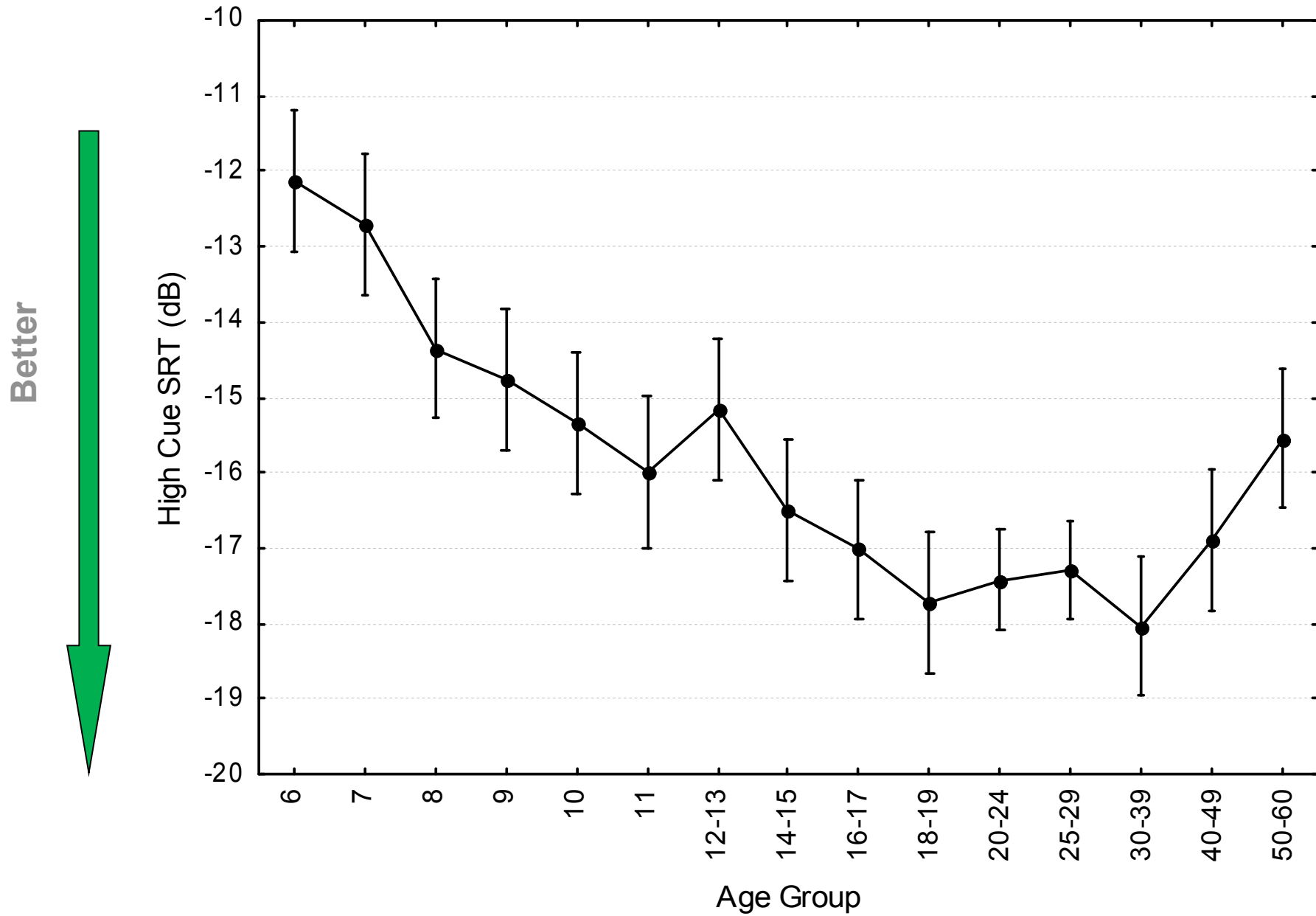
202 participants:

- 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.

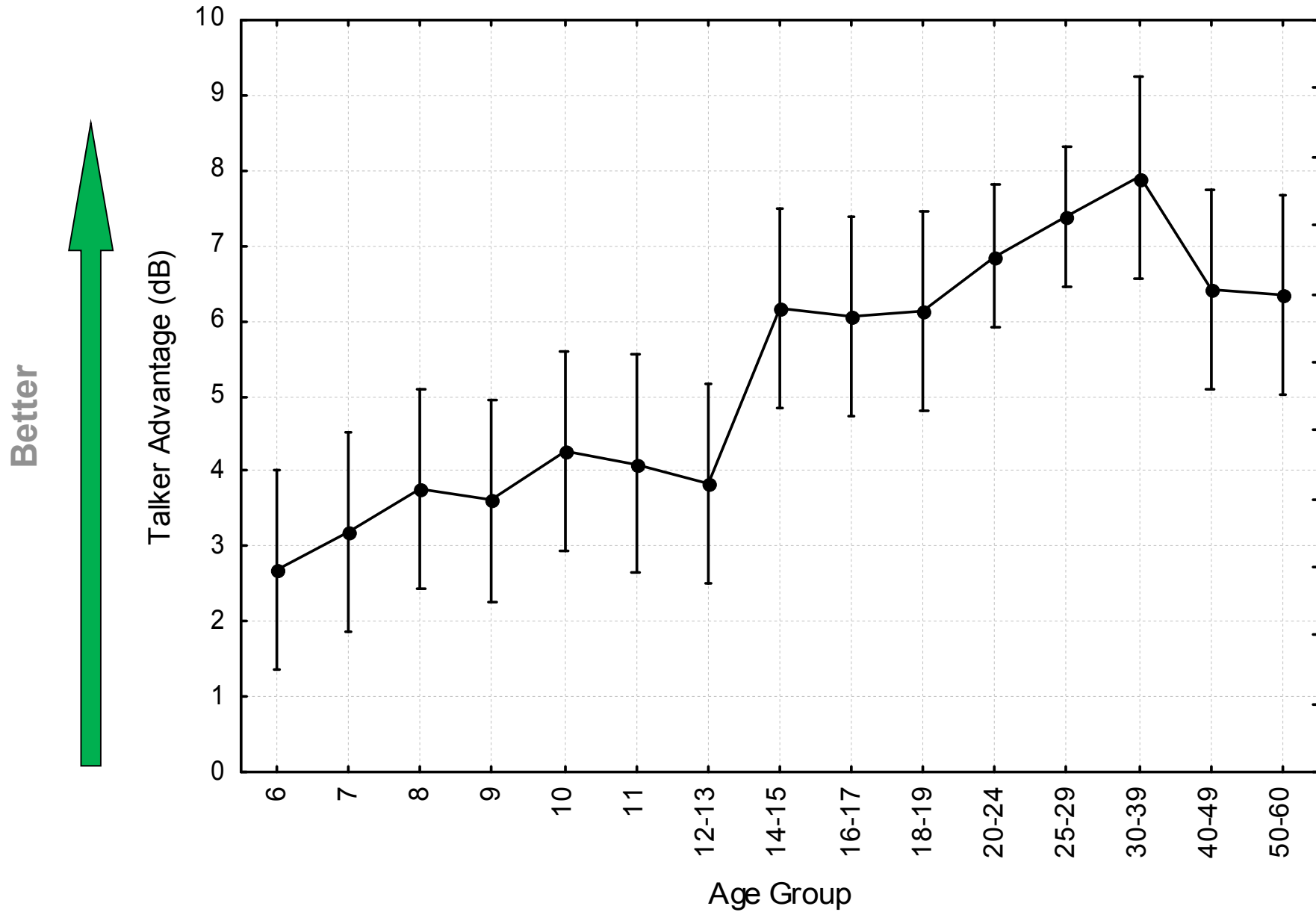
Low Cue SRT



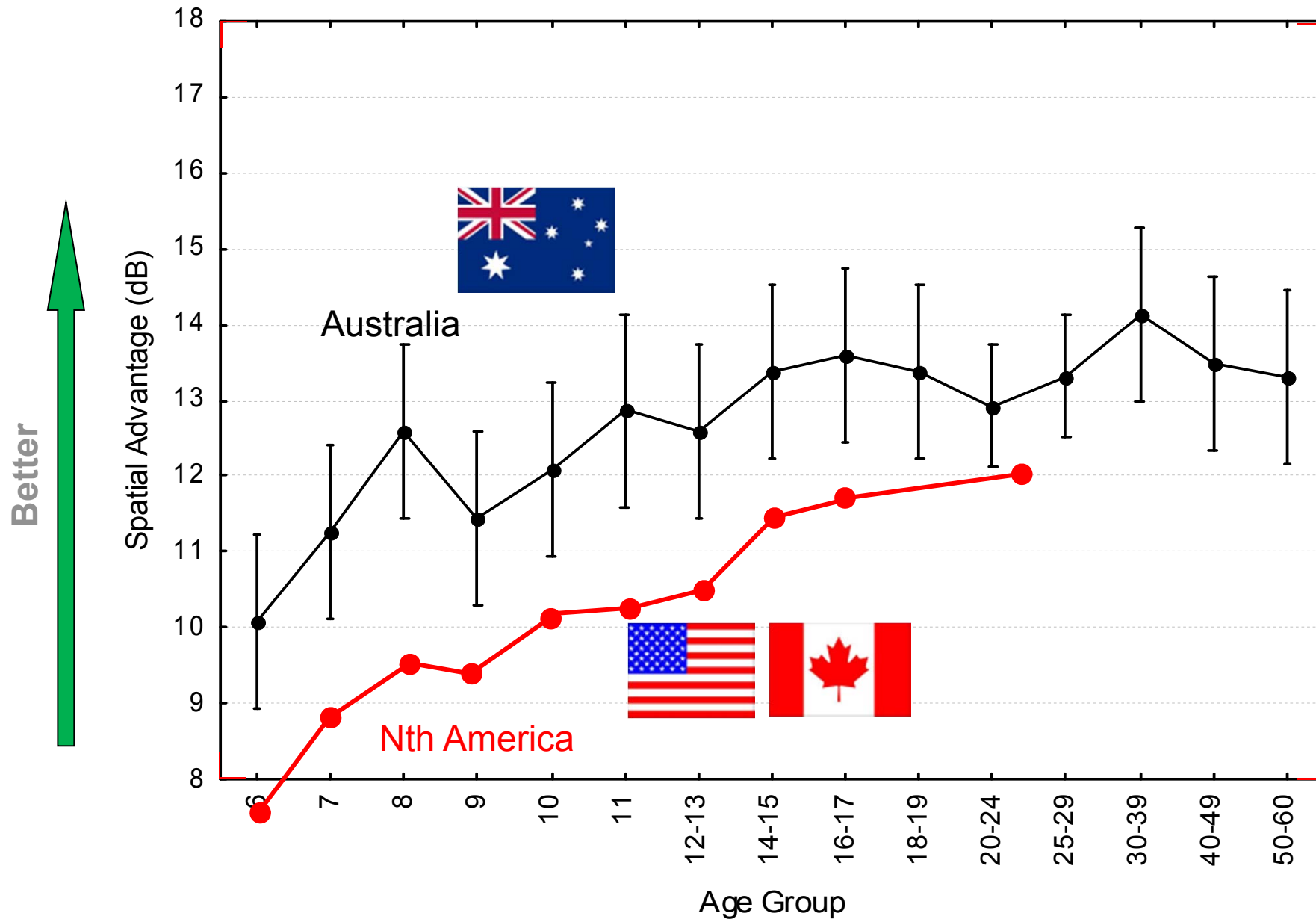
High Cue SRT



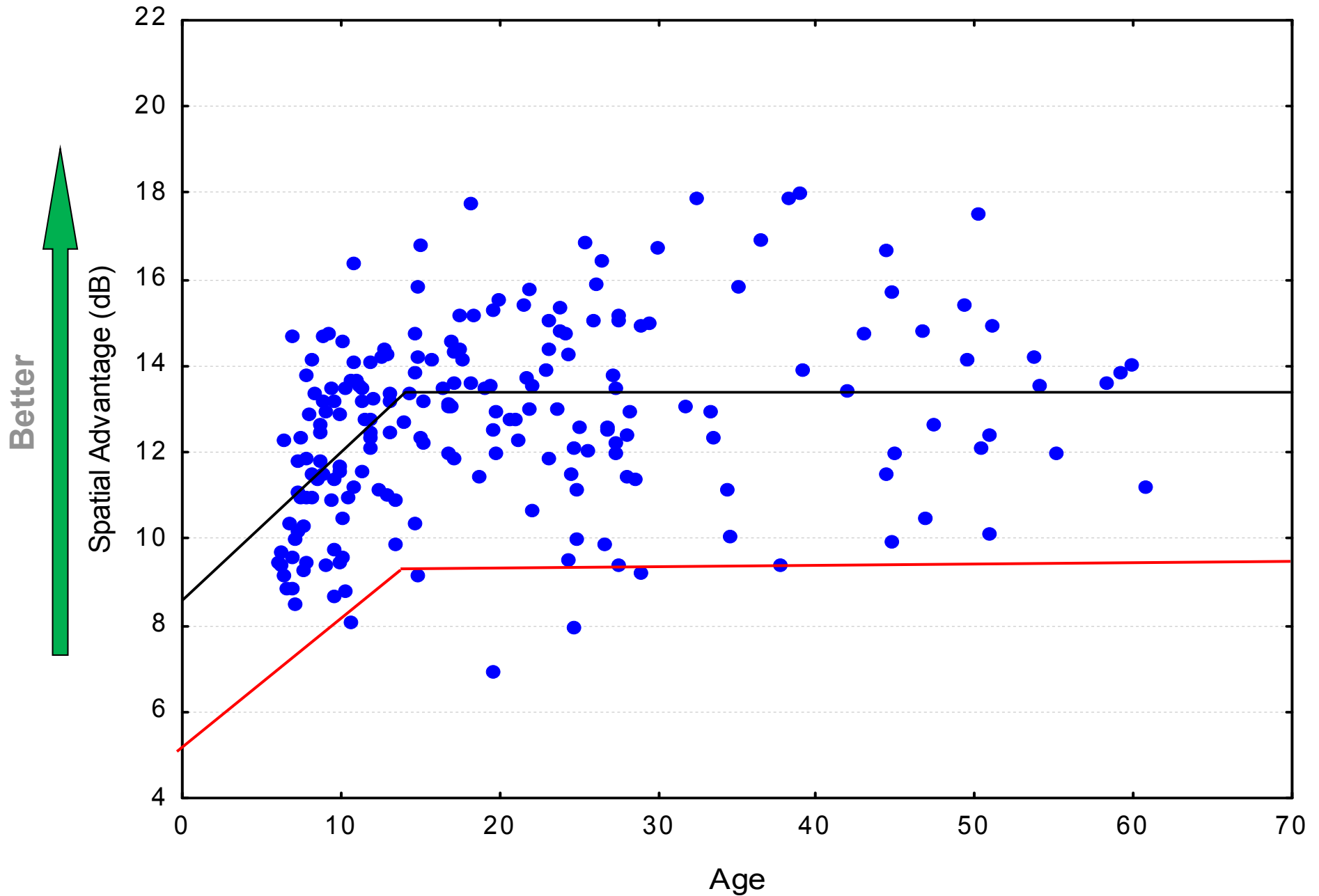
Talker Advantage



Spatial Advantage (\equiv Spatial Release from Masking)

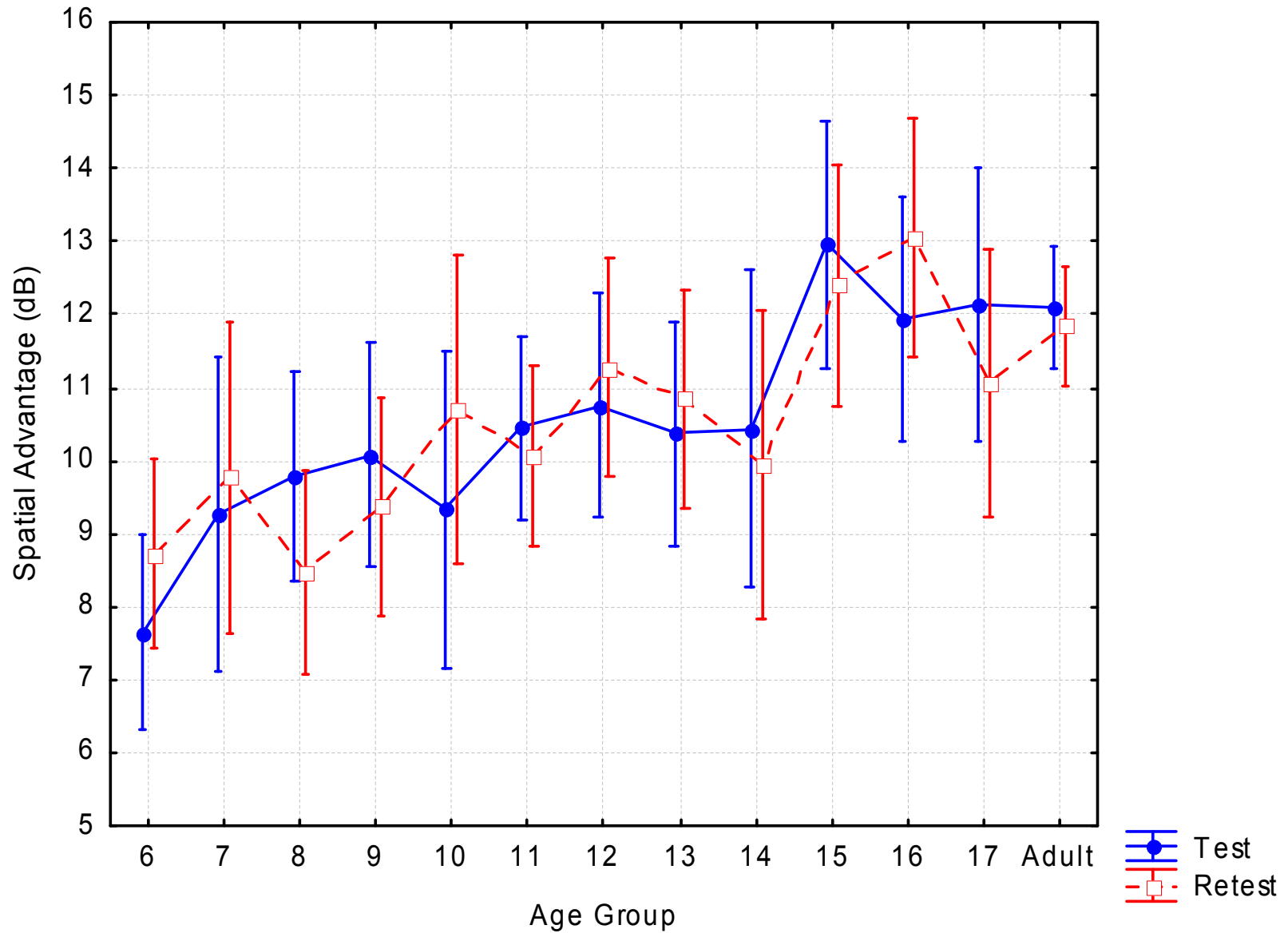


Cut-off Scores – Spatial Advantage



Test-retest reliability - Spatial Advantage

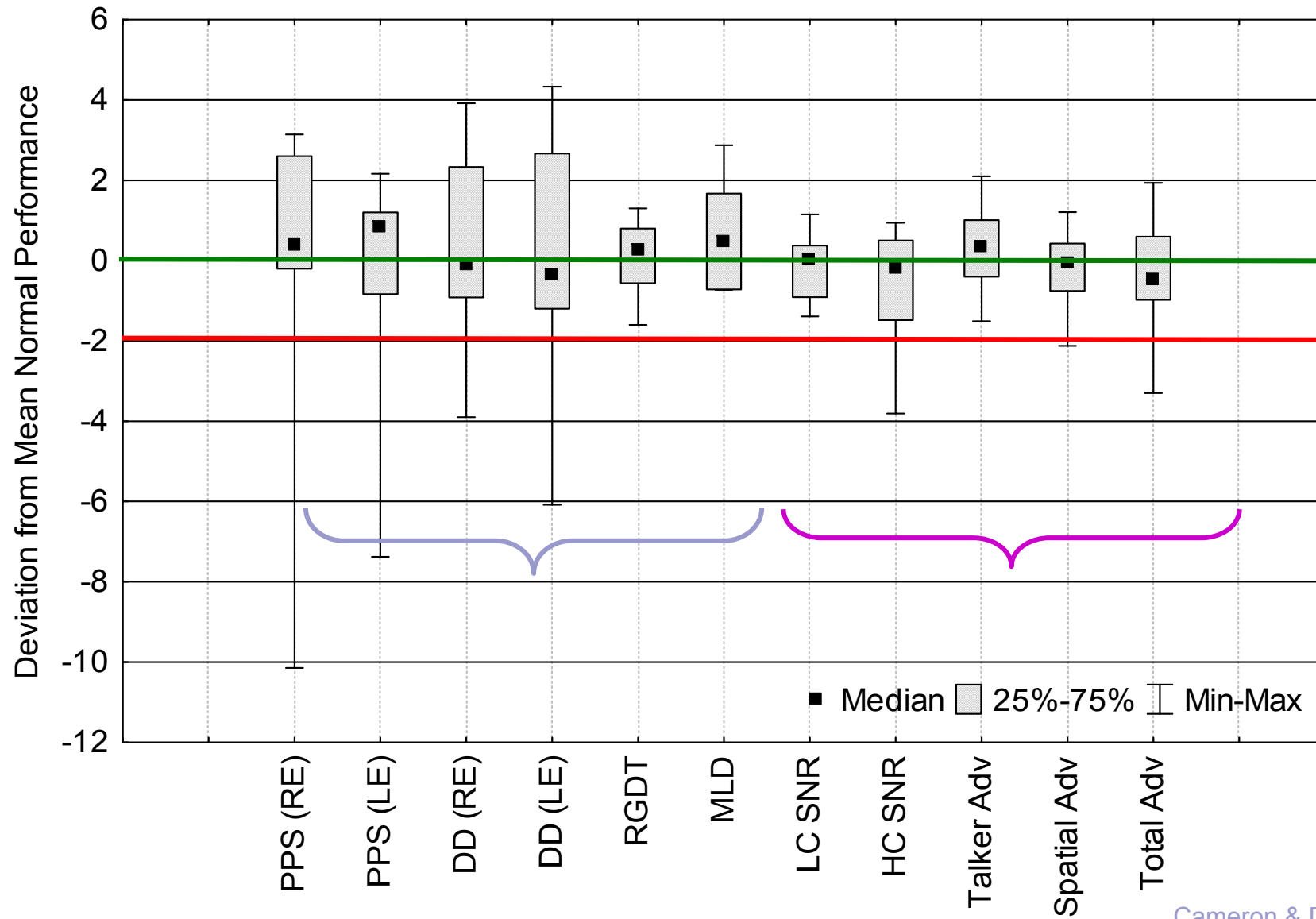
Current effect: $F(12, 72) = .81714, p = .63220$



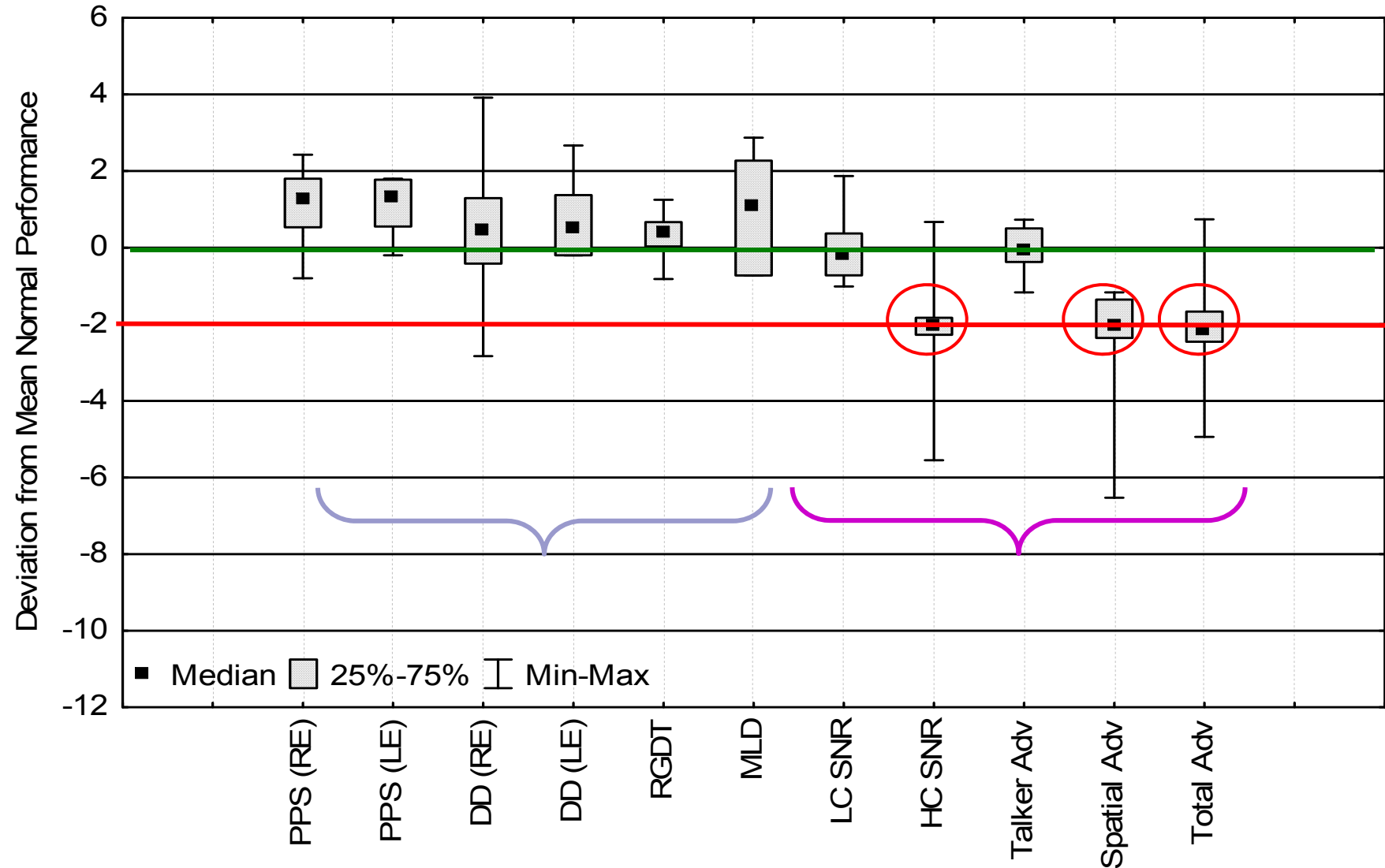
Children with Spatial Processing Disorder

- 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

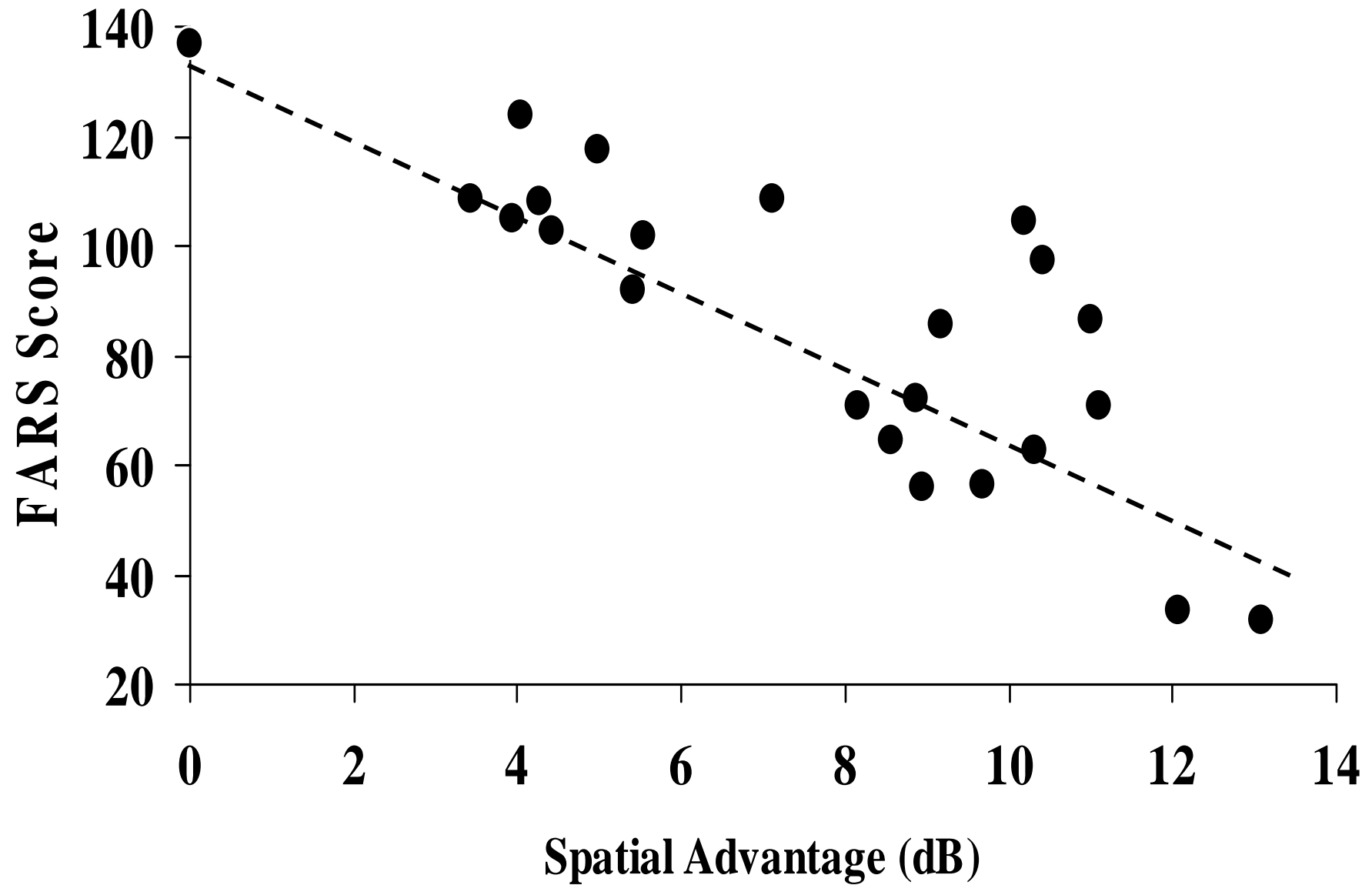
LiSN-S vs. Traditional Battery (LD Group)



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



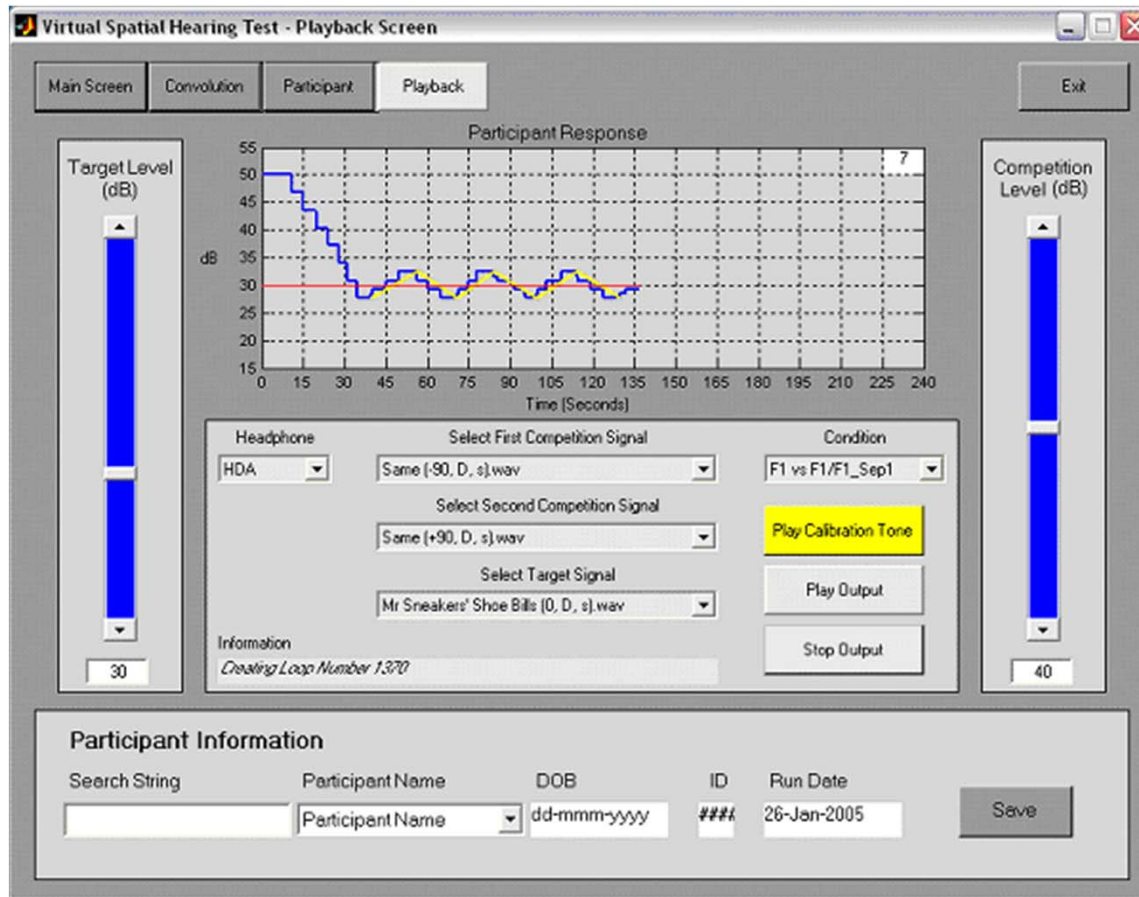
Friedreich Ataxia Rating Scale vs LiSN-S spatial advantage



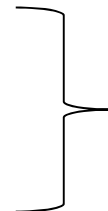
Source: Rance (Neuroscience, 2012)

**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

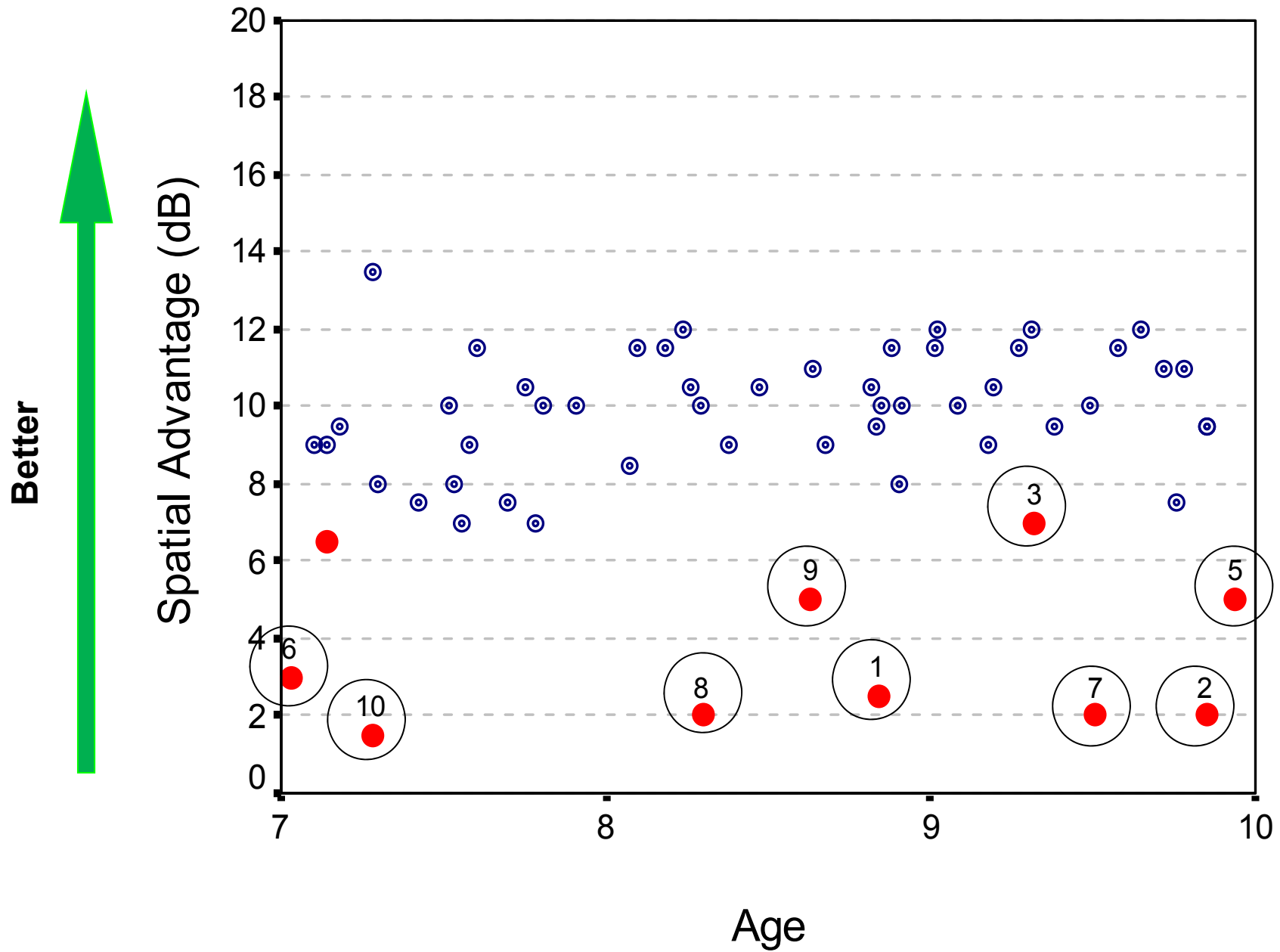


Just understand



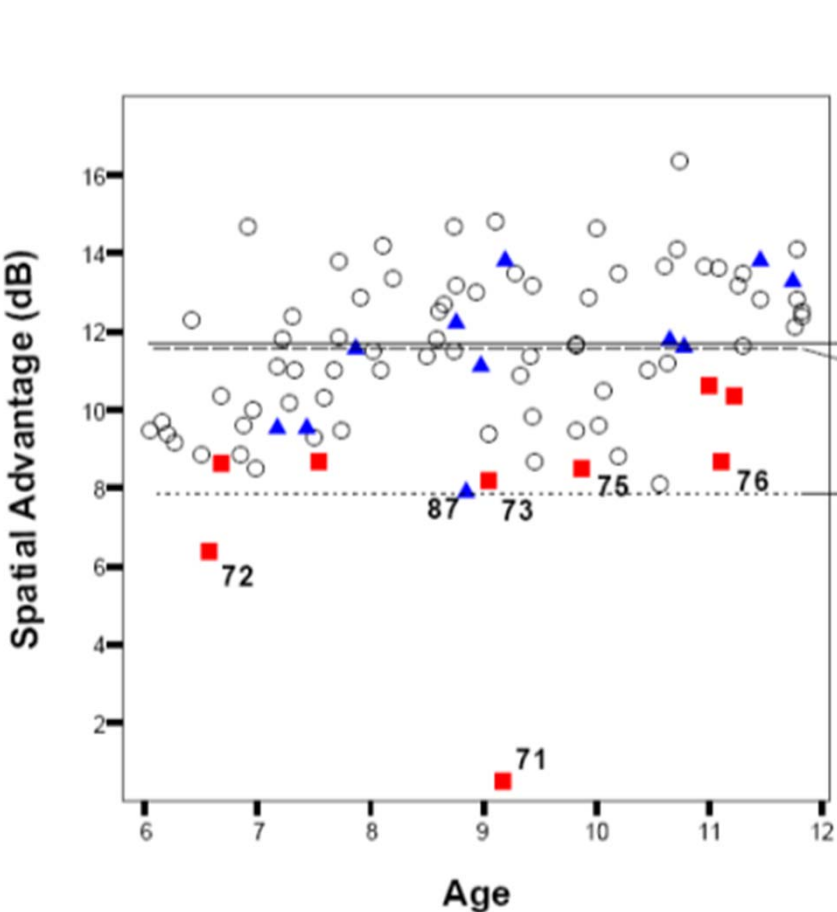
Too hard to understand

LISN - CD

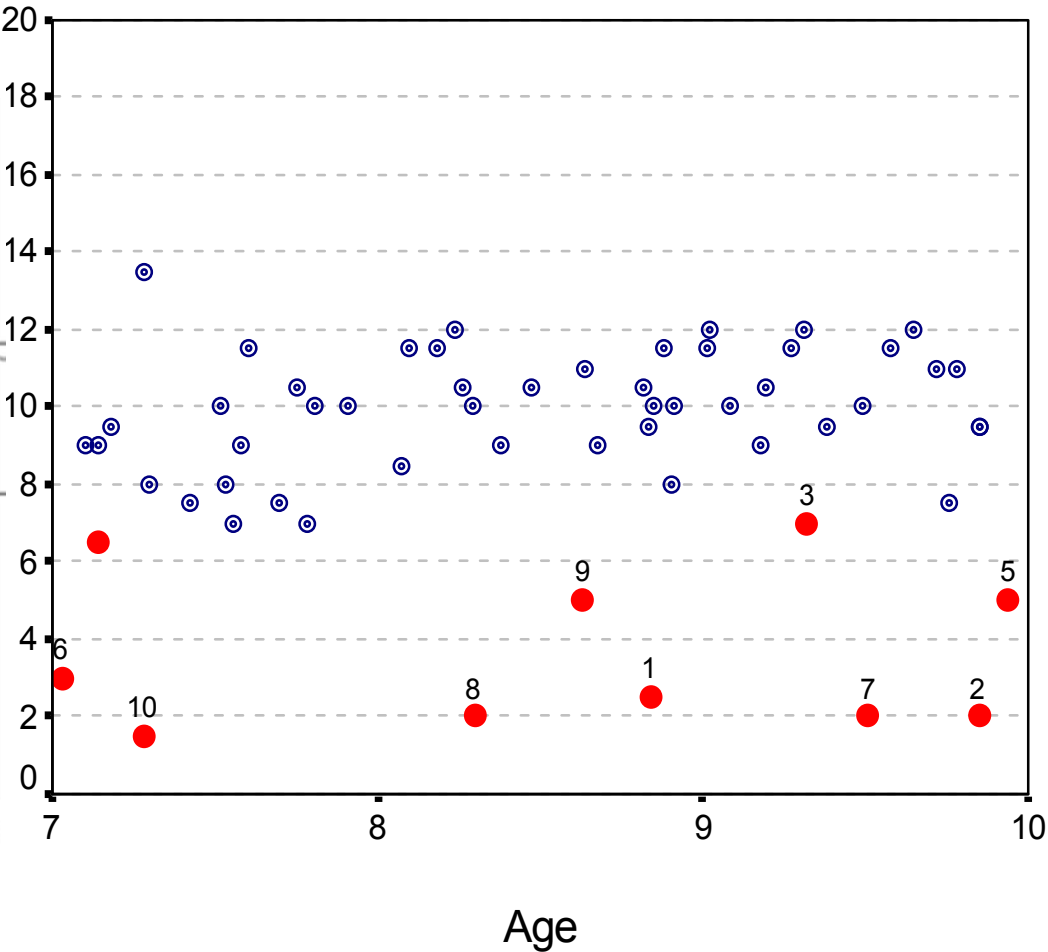


Impact of task on spatial processing deficit

LiSN - S



LiSN - CD

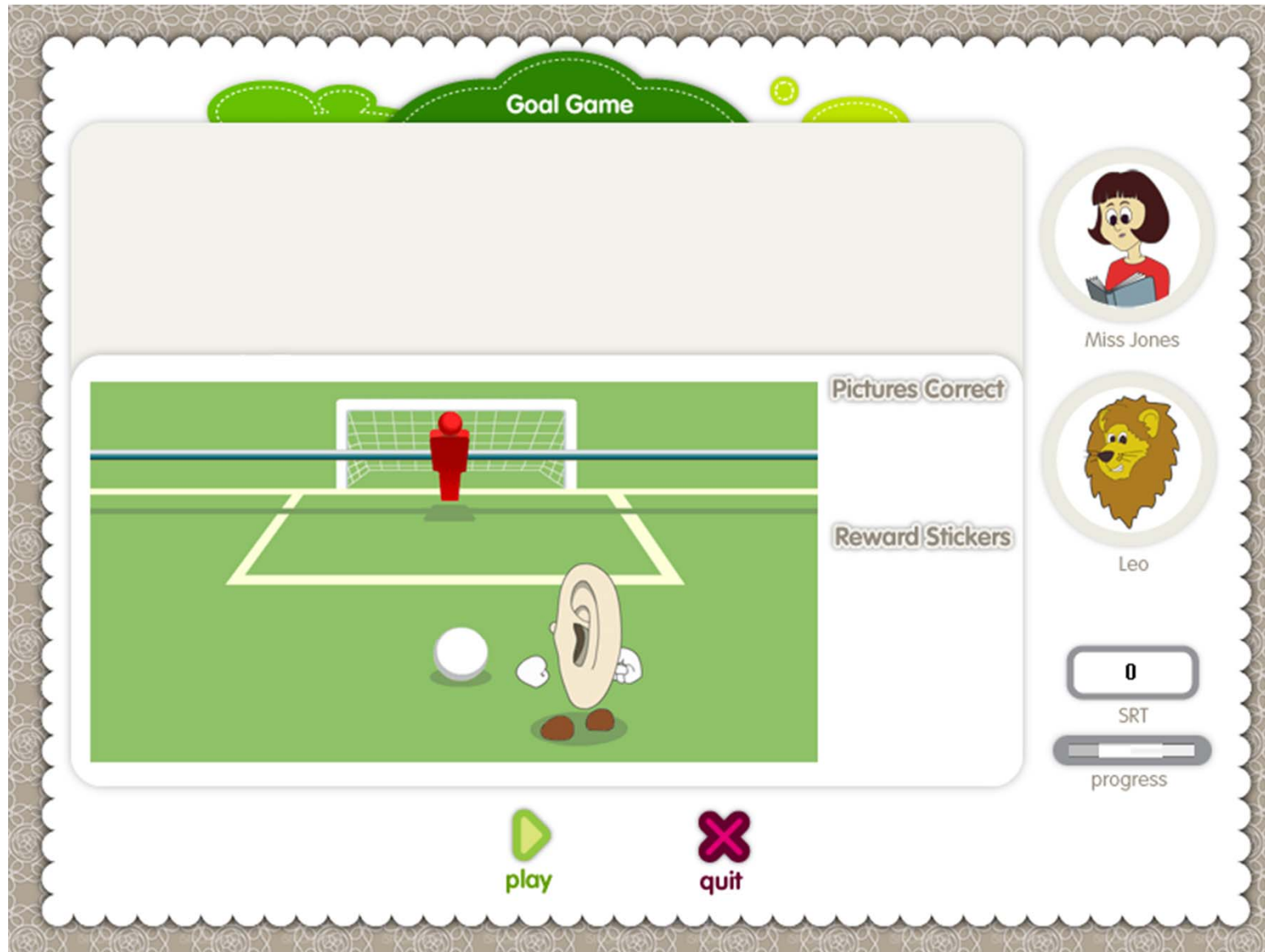


REMEDICATION OF SPATIAL PROCESSING DISORDER

LISN & Learn game

- Five games presented on PC over headphones
- Target sentences at 0° azimuth (initially 62 dB SPL)
- Competing stories at $\pm 90^\circ$ 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 shoes

Goal Game

Miss Jones

Leo

-23.0

SRT

progress


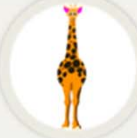
pause

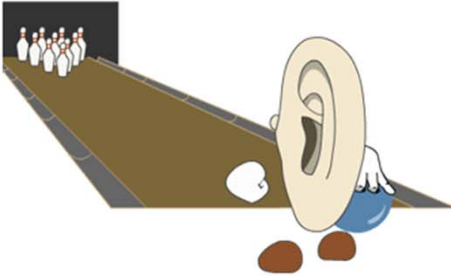
quit

Pictures Correct

Reward Stickers

Answer Alley

4 7   ?



Pictures Correct
0

Score to beat: 0

Coins earned

-7.0
SRT
progress

pause quit help




start game

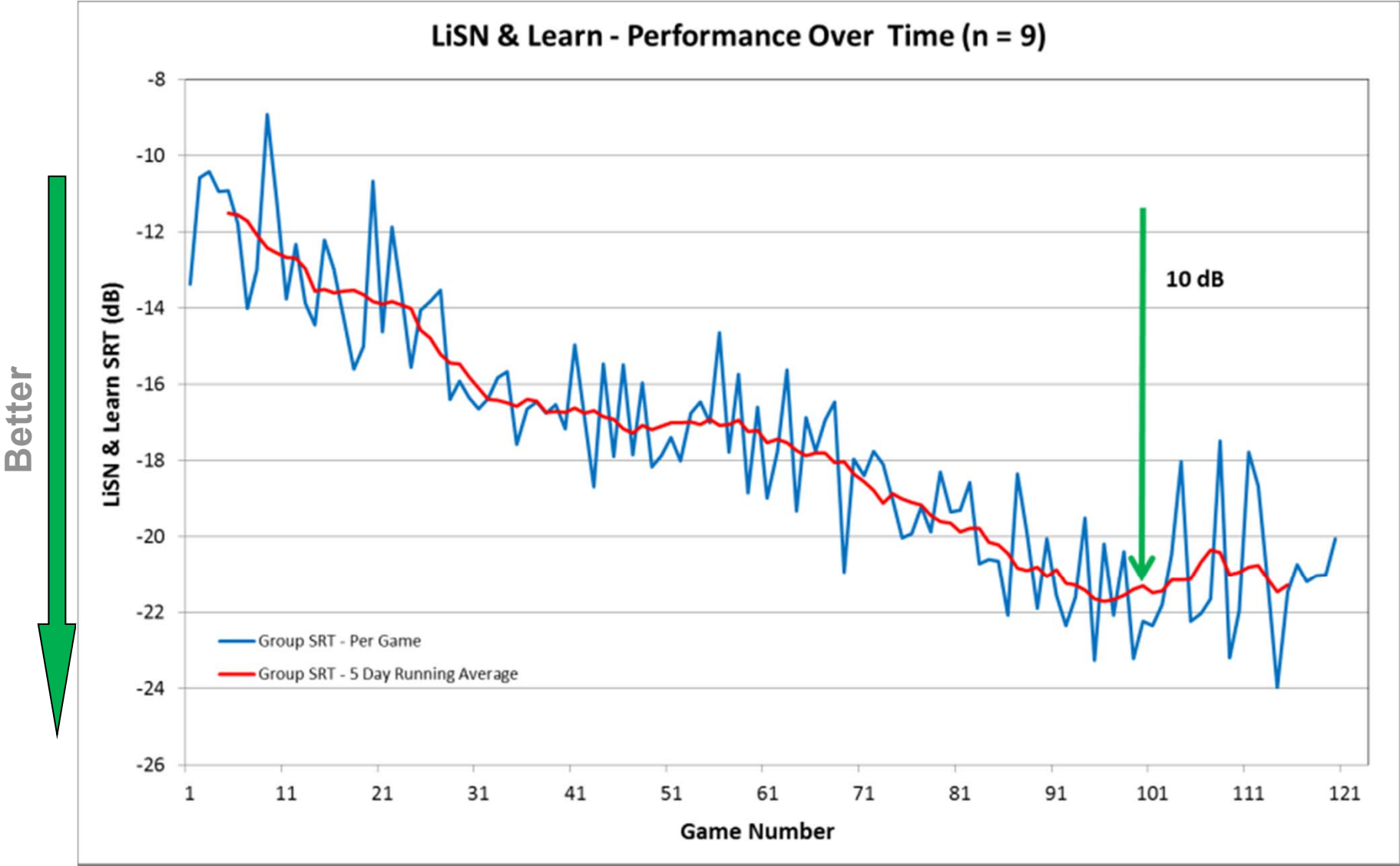
Sound calibration start demo game reward shop

change my details progress report help quit

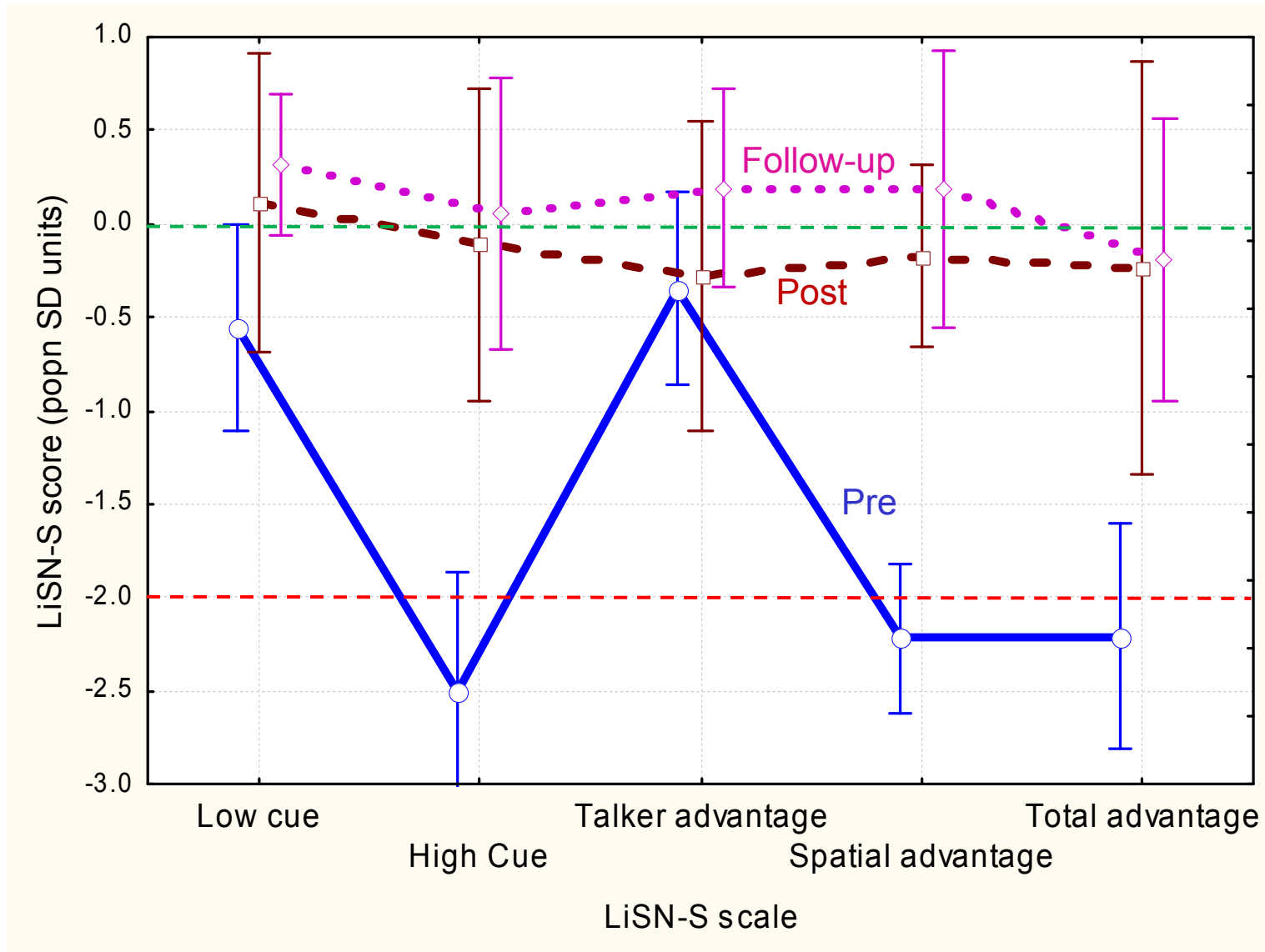
Method

- 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

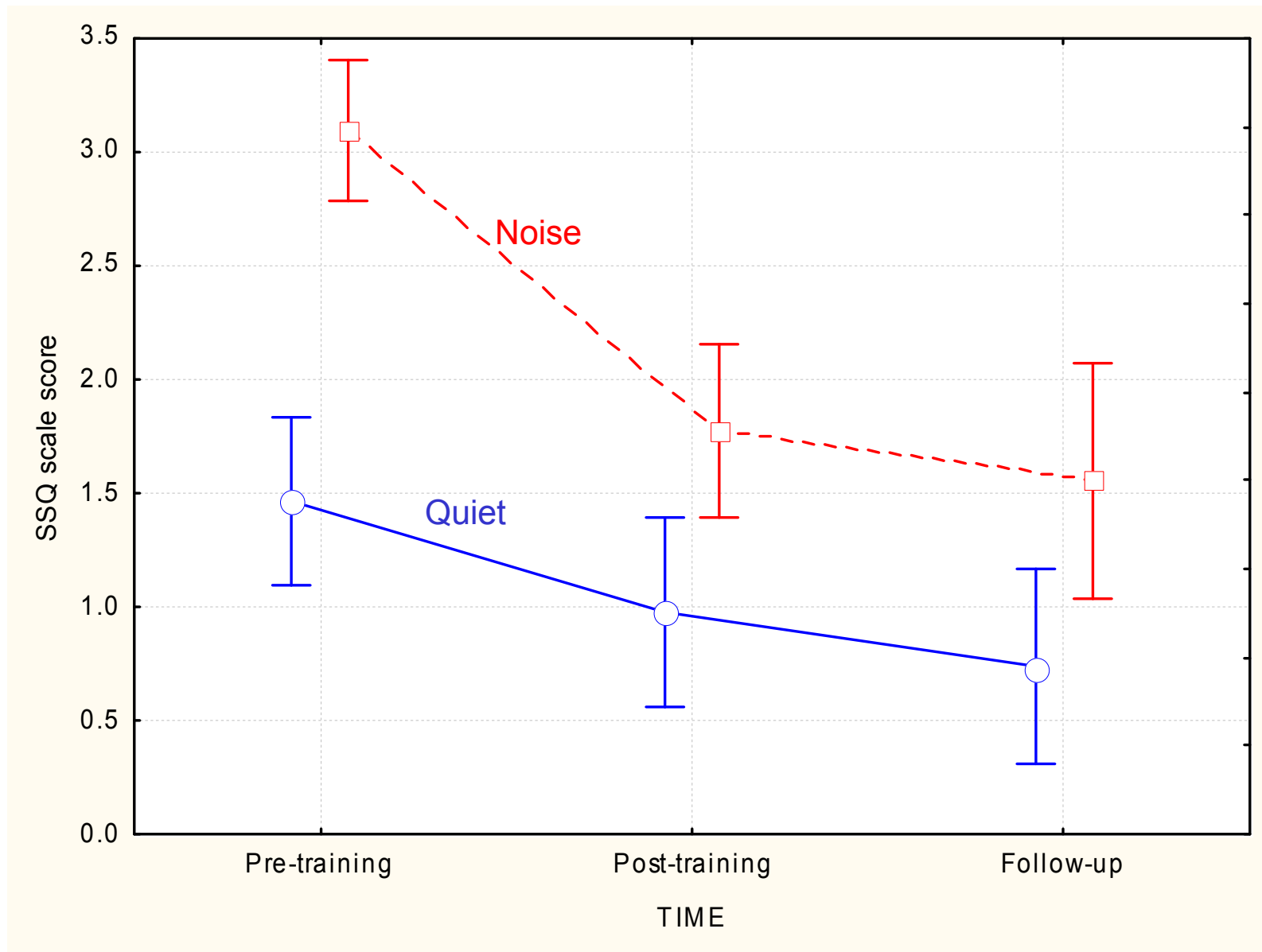
LiSN & Learn - Performance Over Time (n=9)



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 – $p = 0.0004$

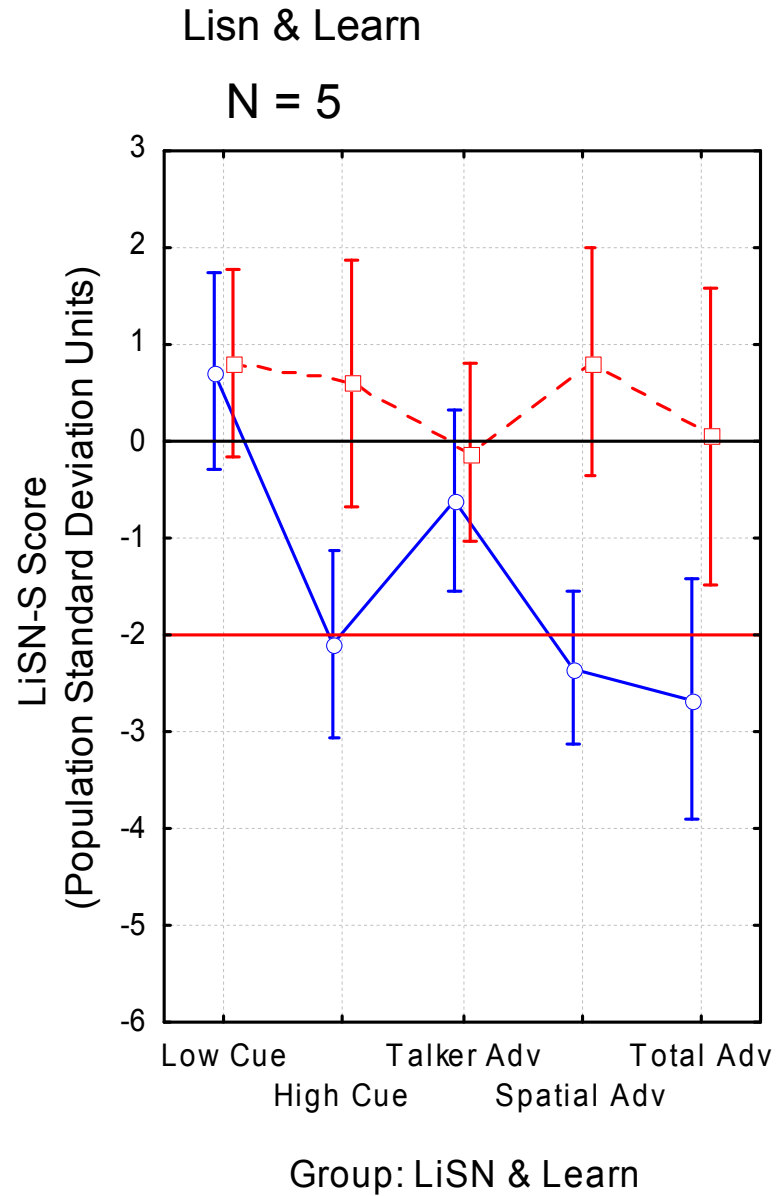
■ TAPS-3

- Memory Index – $p = 0.003$

Phase II Clinical Study

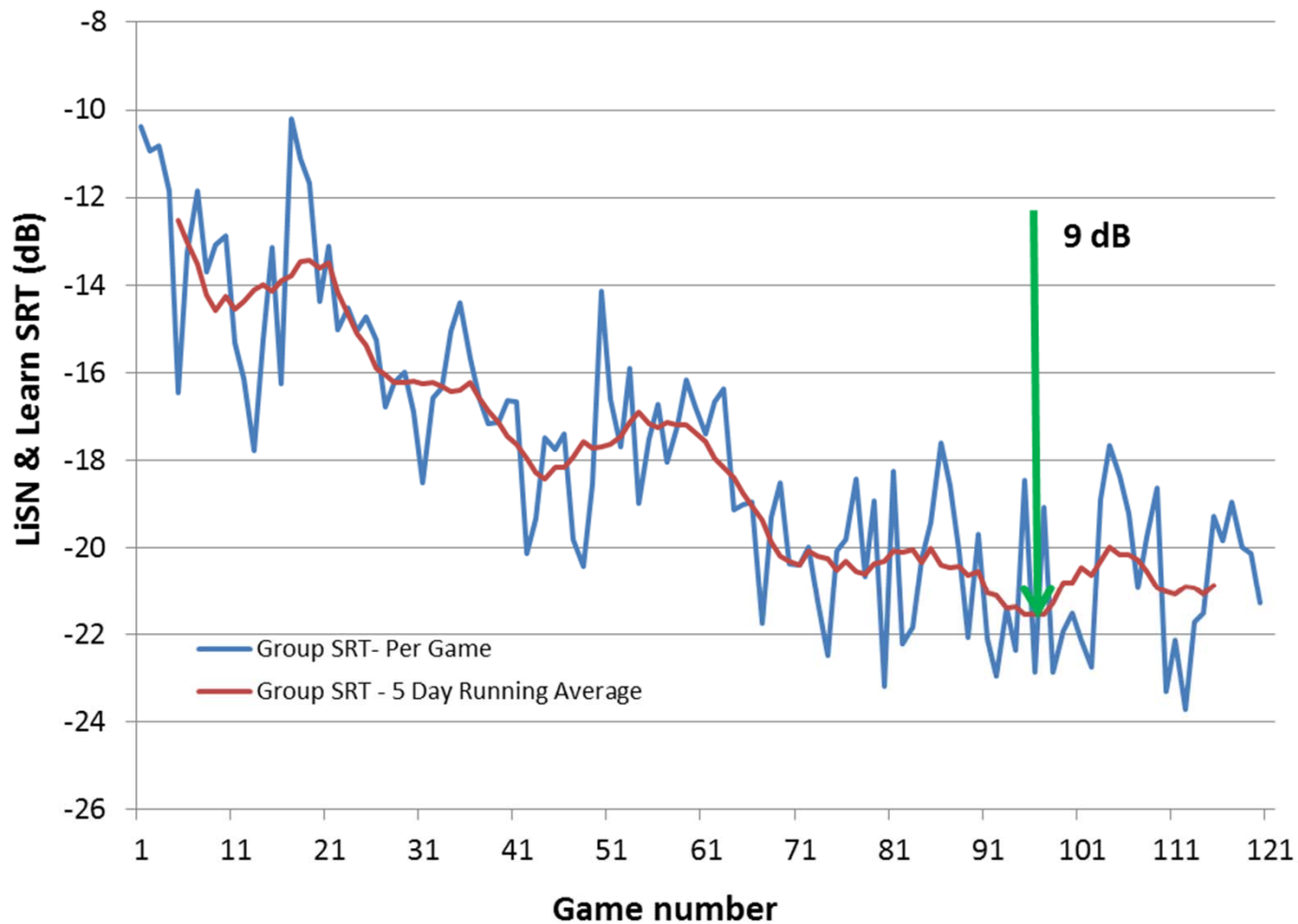
1. 16 children - LISN-S spatial advantage $>2SD$ from mean
 - a) 8 x *LiSN & Learn* (experimental group) \rightarrow 5
 - b) 8 x *Earobics* (control group) \rightarrow 5
2. Questionnaire
 - a) Participant (LIFE)
 - b) Parent (Fishers)
 - c) Teacher (LIFE)
3. *LiSN & Learn* or *Earobics* training – 15 minutes per day
4. Re-evaluate LiSN-S and questionnaires post-training
5. Offer *LiSN & Learn* to control group.

Randomized Control Trial

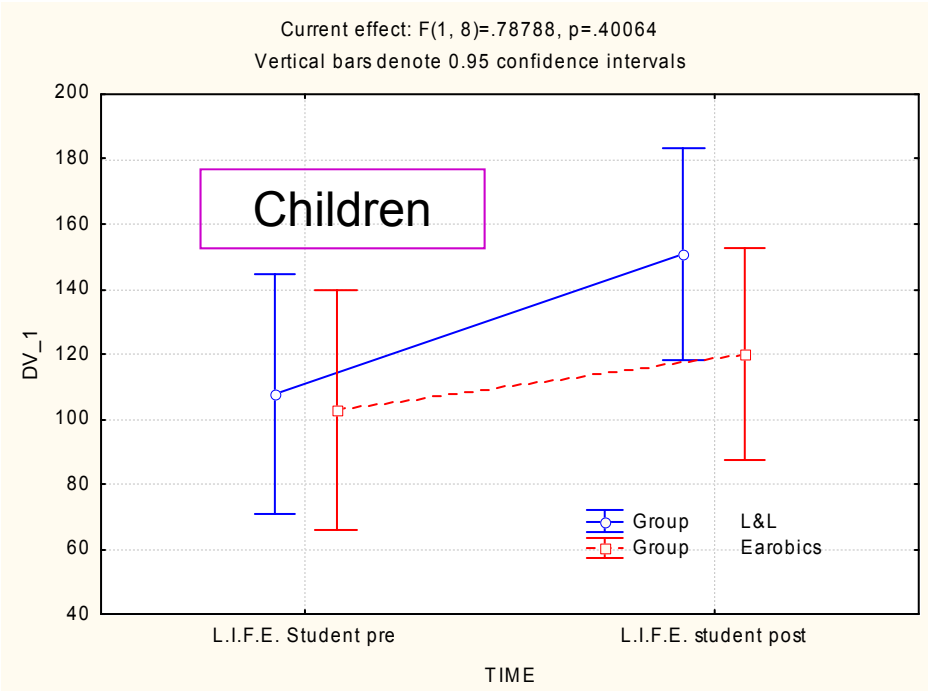
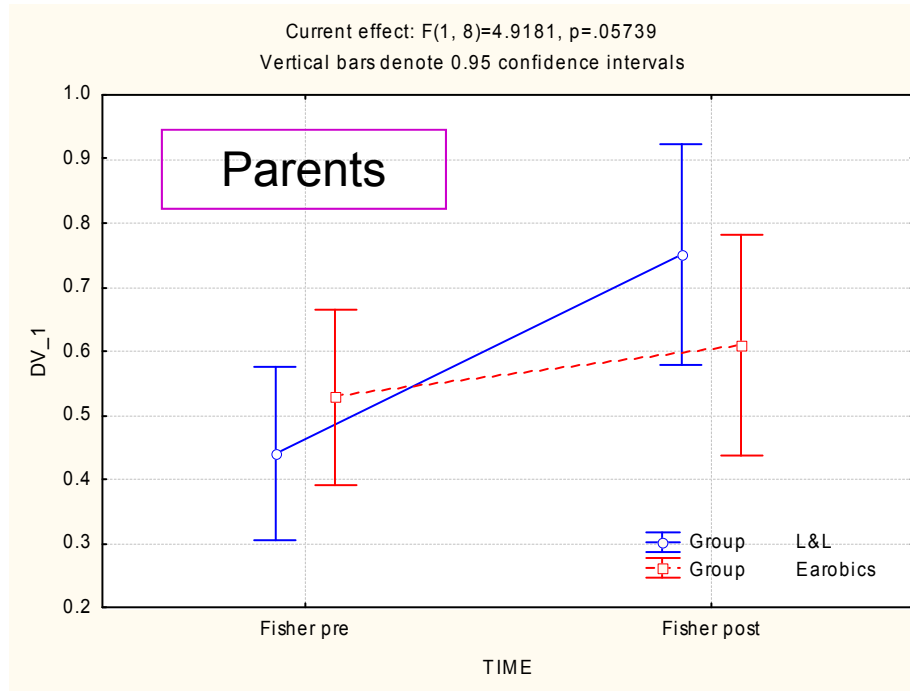
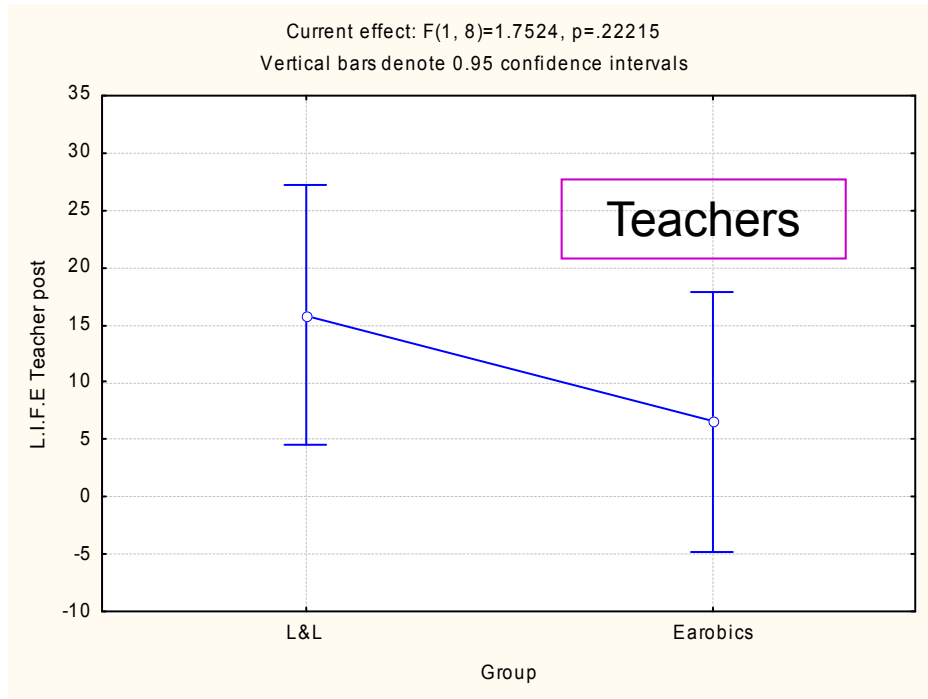


RBCG Study

LiSN & Learn - Performance Over Time (n = 5)



Questionnaire results

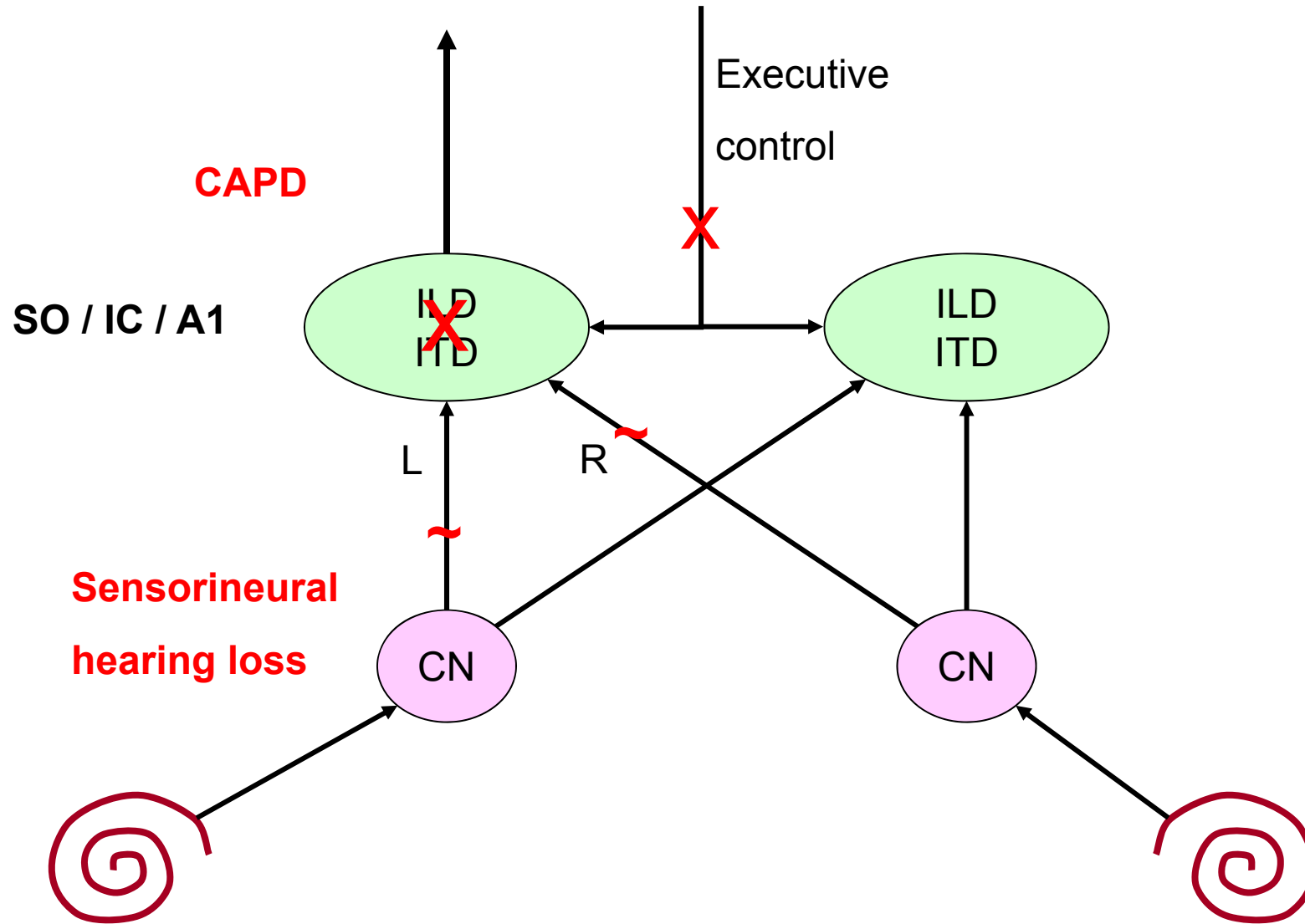


Conclusion

- *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.

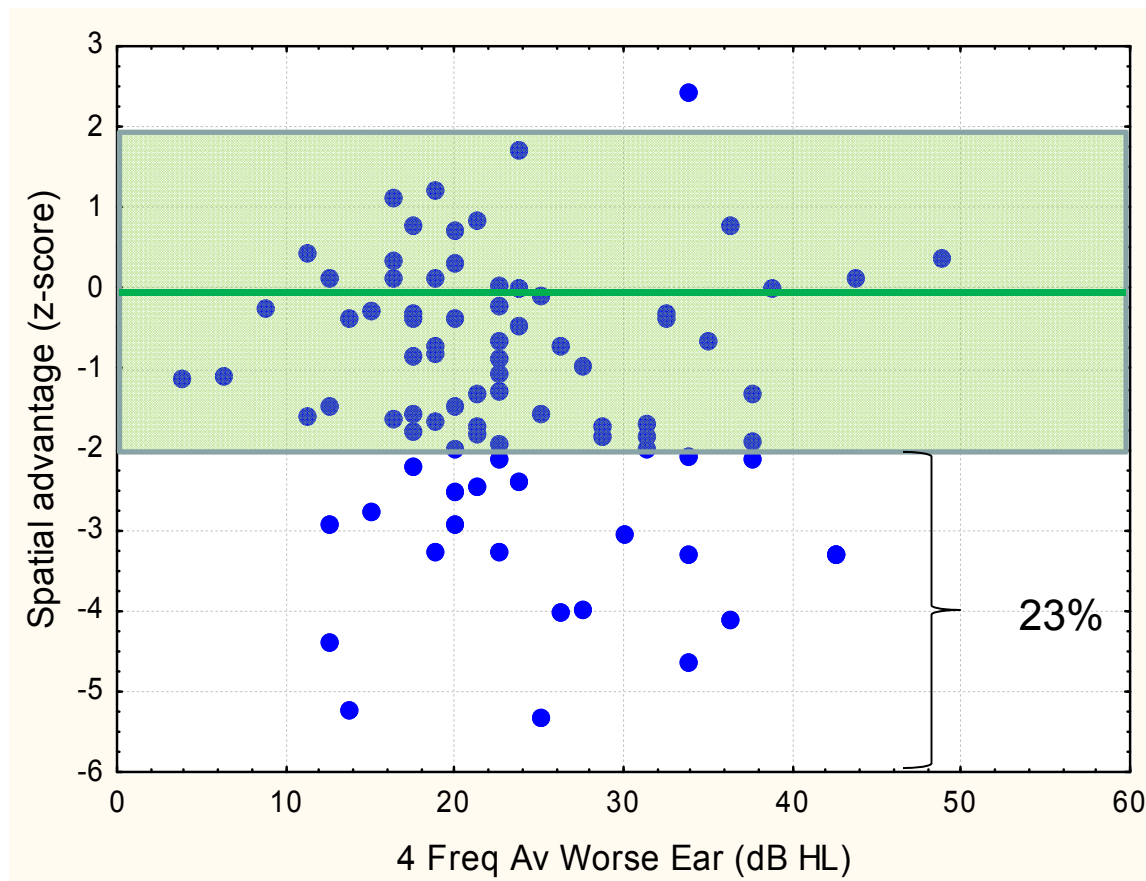
**MECHANISMS IN SPATIAL
PROCESSING AND ITS
DISORDERS**

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

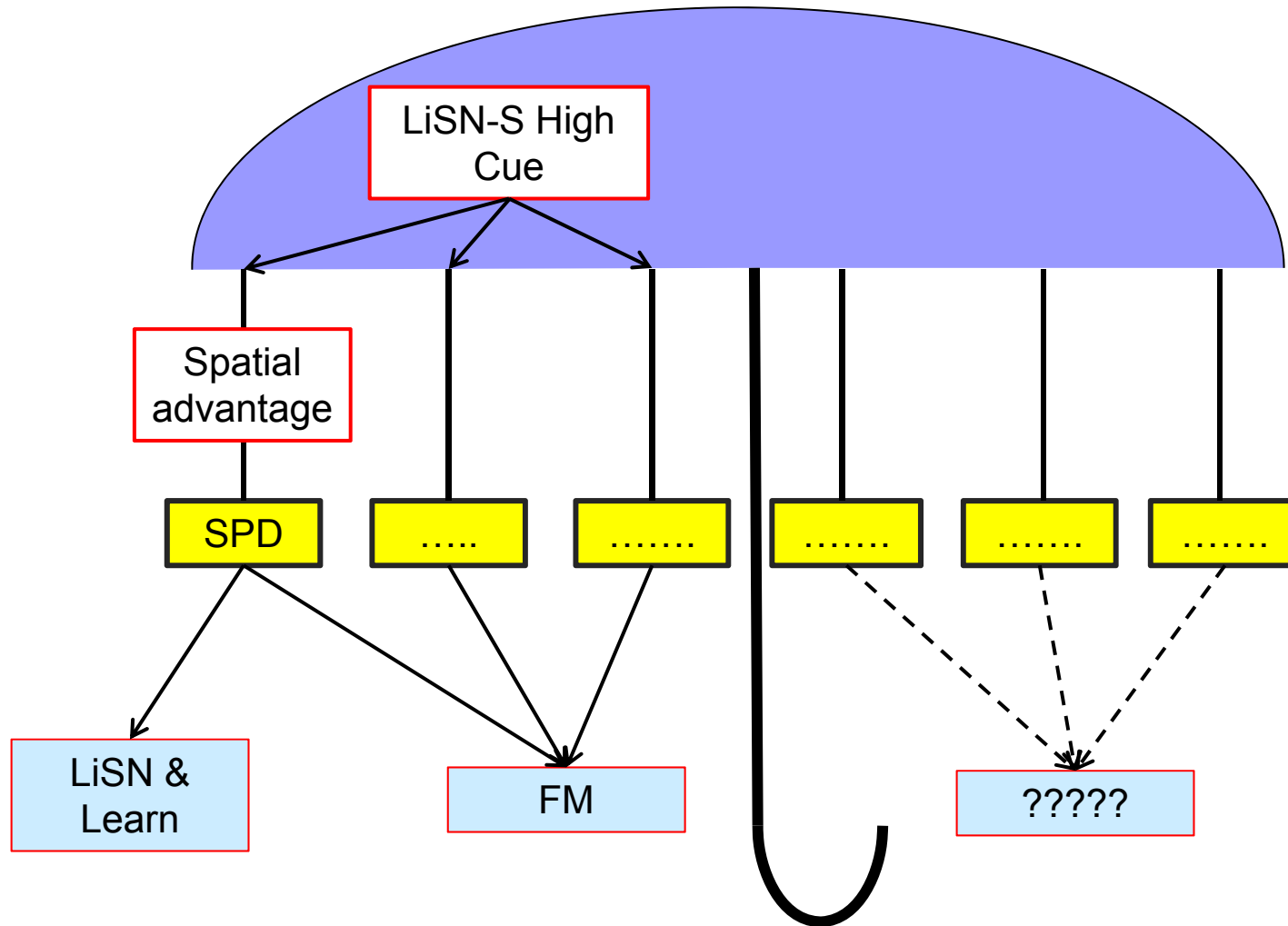
→ 10% had SPD profile

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

→ 7% had SPD profile

SPD ≠ CAPD

C A P D



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 or 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

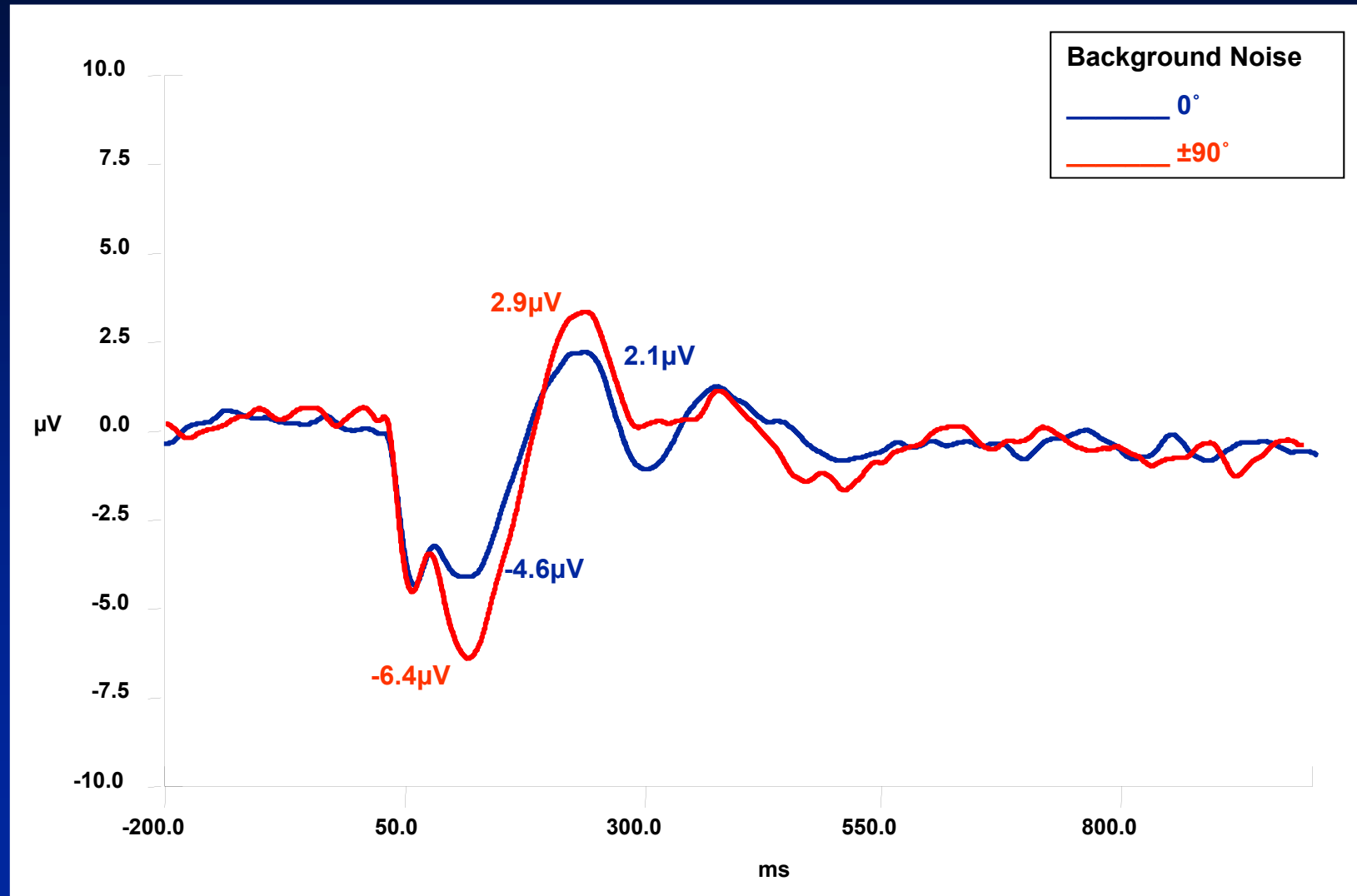


The support of the Commonwealth Department of Aging is greatly appreciated

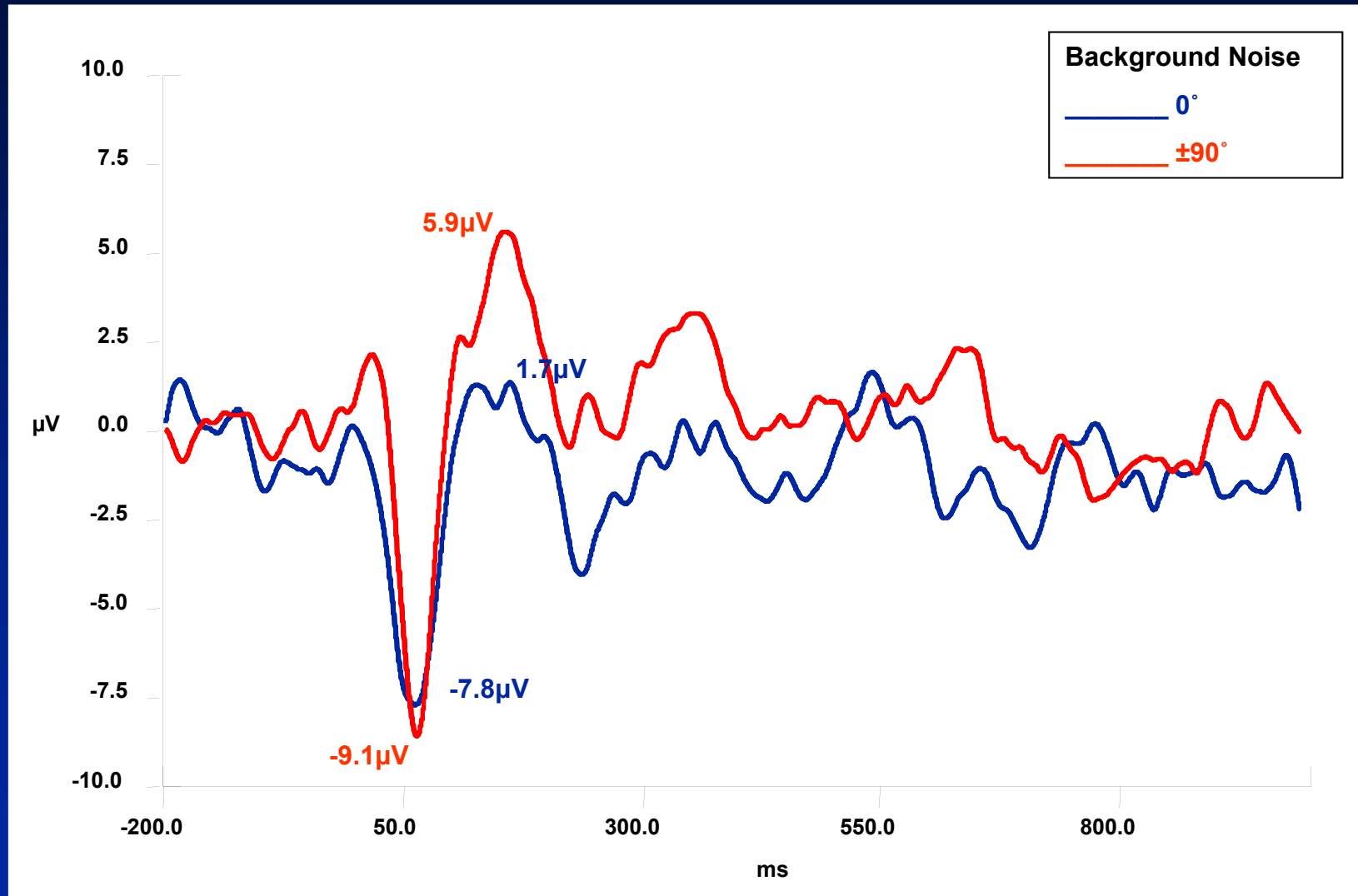
capd.NAL.gov.au - *TV news story*
- *science TV show*

Adult Control Group – Active Task

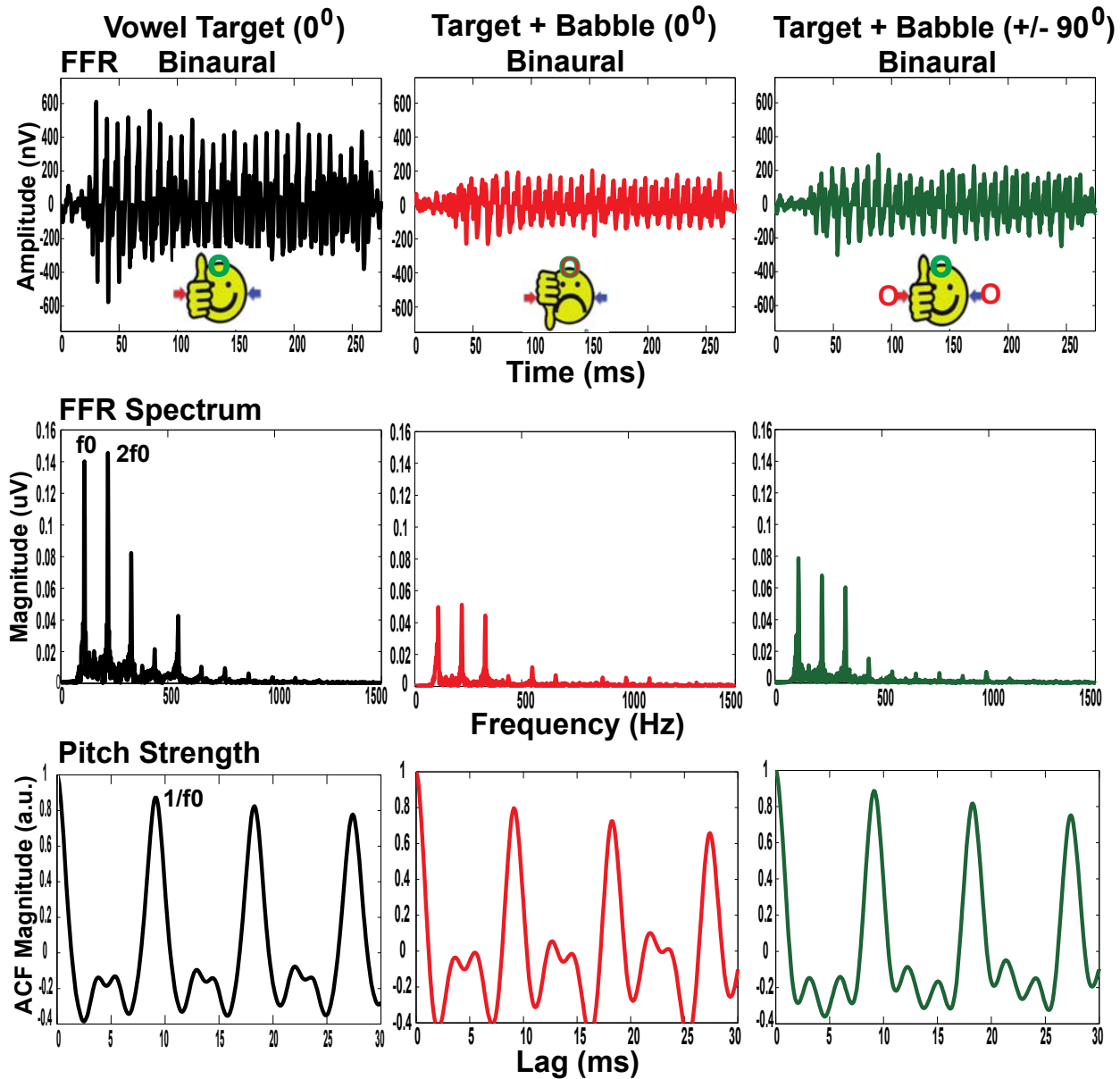
N1 and P2 to Standard Stimulus at Cz



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



Frequency following response



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:

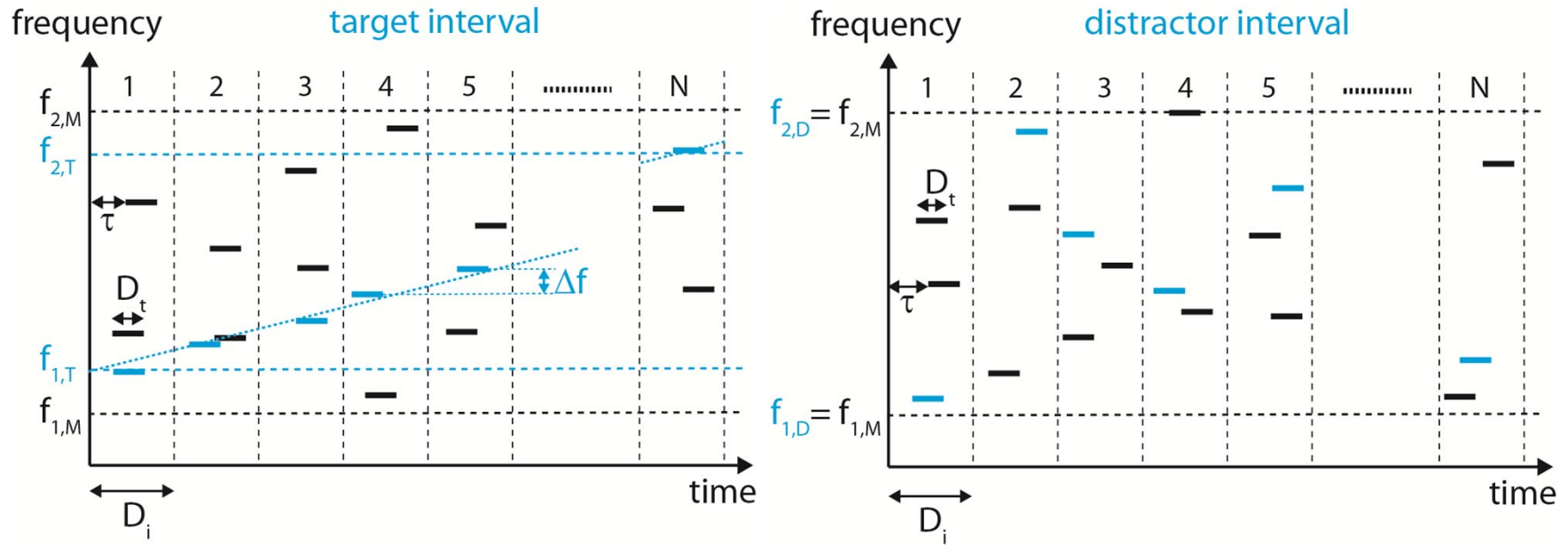
1. Is a proven treatment for children with CAPD
2. Reliably enables a child to perform better on the LiSN-S diagnostic test
3. Provides a near-instantaneous cure
4. Enables improved listening in noise in real life for children with SPD

Some more review questions

LiSN & Learn:

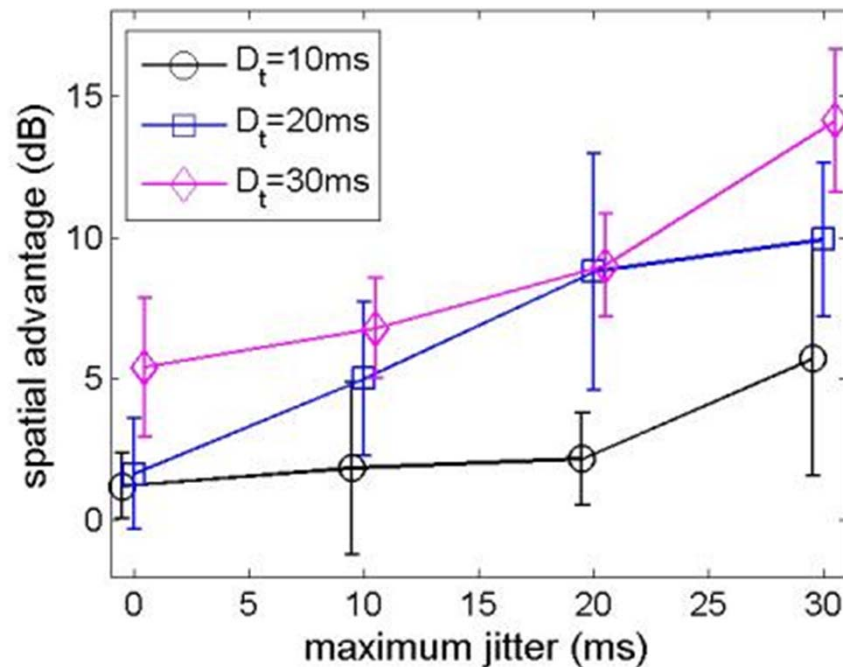
1. Is a proven treatment for children with CAPD - F
2. Reliably enables a child to perform better on the LiSN-S diagnostic test - T
3. Provides a near-instantaneous cure - F
4. Enables improved listening in noise in real life for children with SPD - T

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