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 ±90° azimuth at 55 dB SPL
5. Runs on a PC with specified headphones
6. Four LiSN-S conditions
(LiSN-S) Conditions

Same Voice - 0° Condition

Different Voices - 0° Condition

Same Voice - ±90° Condition

Different Voices - ±90° Condition

Talker Advantage

Spatial Advantage

Total Advantage

Low cue

High cue

Difference scores remove effects of language, memory, and cognition
LiSN-S Diagnostic Screen
Results profile: spatial processing disorder

### Results

<table>
<thead>
<tr>
<th>Measure</th>
<th>Average Score for Age</th>
<th>Client’s Score (dB)</th>
<th>Normal Limits</th>
<th>Variance from Average in StdDev</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low-Cue SRT</td>
<td>-1.4</td>
<td>-1.0</td>
<td>Within</td>
<td>-0.4</td>
</tr>
<tr>
<td>High-Cue SRT</td>
<td>-15.3</td>
<td>-9.5</td>
<td>Outside</td>
<td>-3.9</td>
</tr>
<tr>
<td>Talker Advantage</td>
<td>4.1</td>
<td>3.8</td>
<td>Within</td>
<td>-0.2</td>
</tr>
<tr>
<td>Spatial Advantage</td>
<td>12.4</td>
<td>7.6</td>
<td>Outside</td>
<td>-2.7</td>
</tr>
<tr>
<td>Total Advantage</td>
<td>14.0</td>
<td>8.5</td>
<td>Outside</td>
<td>-3.8</td>
</tr>
</tbody>
</table>

### Variance from mean

![Graph showing variance from mean](image)

- Low Cue SRT
- High Cue SRT
- Talker Advantage
- Spatial Advantage
- Total Advantage
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

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 distractor stories presented at a fixed intensity of 55 dB SPL. The distractor 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
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.
High Cue SRT

Age Group

High Cue SRT (dB)

Better
Spatial Advantage (≡ Spatial Release from Masking)

Australia

Nth America
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)

Deviation from Mean Performance

Median
25%-75%
Min-Max

PPS (RE)  PPS (LE)  DD (RE)  DD (LE)  RGDT  MLD  LC SNR  HC SNR  Talker Adv  Spatial Adv  Total Adv

Cameron & Dillon (2008)
LiSN-S vs. Traditional Battery (sus CAPD Group)

Deviation from Mean Normal Performance

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
Impact of task on spatial processing deficit

LiSN - S

LiSN - CD

Age

Spatial Advantage (dB)

72

71

87

73

75

76

6

8

10

12

14

16

18

20
REMEDIATION 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 ±90° 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
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

- **SSQ scale score**
  - **Noise**
  - **Quiet**

- **TIME**
  - Pre-training
  - Post-training
  - Follow-up
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

Group: LiSN & Learn

N = 5

Earobics

Low Cue
High Cue
Talker Adv
Spatial Adv
Total Adv

LiSN-S Score (Population Standard Deviation Units)

Pre-training
Post-training

Group: LiSN & Learn
RBCG Study
LiSN & Learn - Performance Over Time (n = 5)

LiSN & Learn SRT (dB)

Game number

-26 -24 -22 -20 -18 -16 -14 -12 -10 -8

Group SRT - Per Game
Group SRT - 5 Day Running Average

9 dB
Questionnaire results

Parents

Current effect: $F(1, 8) = .78788, p = .40064$

Vertical bars denote 0.95 confidence intervals

Children

Current effect: $F(1, 8) = 1.7524, p = .22215$

Vertical bars denote 0.95 confidence intervals

Teachers

Current effect: $F(1, 8) = 4.9181, p = .05739$

Vertical bars denote 0.95 confidence intervals
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

Executive control

CAPD

SO / IC / A1

ILD
ITD

L
R

Sensorineural hearing loss

CN

CN
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 advantage

LiSN-S High Cue

SPD

......

LiSN & Learn

FM

.......
SPATIAL PROCESSING FOR NON-SPEECH SOUNDS

→ 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


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

Background Noise

- 0°
- ±90°
Age Matched Control - Passive Task
N1 and P2 to Standard Stimulus at Cz

17 January 2013
Sharon Cameron
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

- 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