Perspectives on the Diagnosis and Remediation of Auditory Processing Disorders

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American Auditory Society
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What you might remember

• Listening difficulties have multiple causes, which can be quantified.
• Diagnosing the type(s) and extent of auditory processing disorder present requires quantitative control of the effects of memory, attention, intelligence and language on auditory processing tests.
• Deficit-specific treatment can be highly effective in removing auditory processing deficits.
• Research is needed to:
  • Better understand cause and effect between auditory processing, language and cognition
    → intervention studies;
  • Create differential tests that identify more specific types of auditory processing disorders;
  • Create a more efficient (hierarchical, adaptive) test battery than currently exists.
Talk outline

Concepts

NAL / Macquarie / Melbourne specific data

Literature meta-analysis

What clinicians can do now

What researchers could do
APD concepts and other disorders
Four “controversies”
Controversy 1: What do we call it?
APD by any other name ..... 

**Central auditory processing disorder**  
Sullivan (1976)  

**Auditory processing disorder**  
Jerger & Musiek (2000)  

**Auditory neuropathy**  
Starr et al 1996  

**Hidden hearing loss**  
Schaette & McAlpine (2011)  

Two things in common:  
1. Auditory perception poorer than expected from hearing thresholds  
2. Definition sufficiently broad to include diverse types of deficits
Controversy 2: Does APD exist?
Does APD exist?

1. Do you believe the brain transmits and analyses neural signals after they leave the cochlea, or does auditory perception occur by magic?

2. Can anything ever go wrong with the way the brain transmits and analyses neural signals initiated by sound, or is the system infallible and develops properly in every person?

3. When something does go wrong with the way the auditory system processes the neural signals initiated by sound, what would you like to call such a disorder? 

Language disorder
General developmental disorder
Cognitive disorder

Kaas & Hackett (2000)

Cognitive abilities

Auditory processing abilities

Language abilities

23% shared variance

29% shared variance

35% shared variance

23% shared variance
Controversy 3: What abilities does APD encompass?
"When I use a word,' Humpty Dumpty said in rather a scornful tone, 'it means just what I choose it to mean — neither more nor less."

"The question is," said Alice, "whether you can make words mean so many different things."

ASHA (2005)
“(C)APD is a deficit in neural processing of auditory stimuli that is not due to higher order language, cognitive, or related factors.

Moore, Ferguson et al (2010)
“What is currently called APD, for individuals without known neurologic lesions, should be redefined as primarily a cognitive disorder, rather than a sensory disorder.”
<table>
<thead>
<tr>
<th>Professional Society</th>
<th>Definition</th>
<th>Comment</th>
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<tr>
<td>ASHA (2005)</td>
<td>A deficit in neural processing of auditory stimuli that is not due to higher order language, cognitive, or related factors.</td>
<td>Cognition and language out</td>
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<tr>
<td>AAA (2010)</td>
<td>Difficulties in the perceptual processing of auditory information. (C)APD is frequently comorbid with related language, learning and cognitive disorders.</td>
<td>Cognition and language out</td>
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<td>Danish Medical Audiological Society (2014)</td>
<td>The efficiency with which the central nervous system uses received auditory information.</td>
<td>Cognition and language out</td>
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<tr>
<td>Canadian Interorganizational Steering Group (2012)</td>
<td>A persistent limitation in the performance of auditory activities that originates in the auditory system and is not caused by loss of auditory acuity or disorders of language, attention, memory or cognition.</td>
<td>Cognition and language out</td>
</tr>
<tr>
<td>Belgian International Bureau for Audiophonology (20070)</td>
<td>… difficulties in listening and intelligibility …..can be the consequence of … cognitive and memory functions, but also the functions provided by central auditory pathways.</td>
<td>Cognition and language out</td>
</tr>
<tr>
<td>NAL – Australia (Dillon &amp; Cameron, 2015)</td>
<td>An Auditory Processing Disorder (APD) is a deficit in the way the neural representation of sounds are processed by the brain, resulting in a distorted neural representation of the auditory signal within the auditory nervous system.</td>
<td>Cognition and language out</td>
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<tr>
<td>BSA (2017)</td>
<td>Poor perception of speech and non-speech. Origins include the CANS and neural processing systems for language, reading, speech, attention, executive function, memory, emotion, vision and action.</td>
<td>Cognition and language in</td>
</tr>
<tr>
<td>Dutch position statement (2017)</td>
<td>Listening difficulties can be caused by both disturbed bottom-up processes (sensory processing) and disturbed top-down processes (including cognition and language).</td>
<td>Cognition and language are the most common problem in listening difficulties</td>
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<td>New Zealand (2017)</td>
<td>Auditory processing disorder is a hearing disorder that results from atypical processing of auditory information in the brain.</td>
<td>Doesn’t say</td>
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<td>German (Nikisch et al, 2015)</td>
<td>???</td>
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</table>
Controversy 4: Need APD be unimodal?
Should APD be conceptualized as an auditory-specific disorder or as one aspect of a more generalized disorder?

**Not a practically useful question!!!!**

**Child 1**
- Deficit in auditory processing only
- Identify the deficit
- Give training to improve auditory skills in deficit
- Improve input sound SNR
- Manage or treat the other problem(s)

**Child 2**
- Deficit in auditory processing + Deficit in visual processing
Four “controversies” dealt with

1. The name APD, CAPD, or (C)APD?
   - Of course auditory processing happens in the cochlea

2. Does it exist?
   - Duh, yes!

3. Include or exclude deficits in cognition and language?
   - Excludes, by most definitions, but of course perception of speech needs cognition and language as well

4. Limited to unimodal problems?
   - Not limited. Problems involving audition should be identified and helped, irrespective of whether there are similar problems in other modalities

None are productive debates: more semantics than reality
One test, multiple abilities
Deficits (various) in auditory processing

Deficits (various) in cognition

Listening difficulties

Performance on tests of APD
Deficits (various) in auditory processing

Deficits (various) in cognition

Deficits (various) in language

Performance on tests of APD
Example of a test that tests multiple abilities

- Dichotic digits test – Musiek (1983) - 293 citations
- Easy to administer and score
- Often failed by children seeking APD assessment
- In many, many test batteries, including Australian Hearing
Dichotic Free Recall Paradigm

2, 4

1, 8

1, 2, 4, 8
Diotic Paradigm

Dichotic Digits Difference Test
Dichotic versus diotic (%)
Correlations with cognition

- Attention (prudence)
- Attention (vigilence)
- Forward digit span
- Reverse digit span
- Non-verbal IQ

Correlations:
- Attention (prudence) to Free recall dichotic: 0.31
- Attention (vigilence) to Free recall dichotic: 0.21
- Forward digit span to Free recall dichotic: 0.53
- Reverse digit span to Free recall dichotic: 0.36
- Non-verbal IQ to Free recall dichotic: 0.27
Correlations with cognition

- Attention (prudence)
- Attention (vigilence)
- Forward digit span
- Reverse digit span
- Non-verbal IQ

Correlation coefficients:
- Attention (prudence): 0.26
- Attention (vigilence): 0.15
- Forward digit span: 0.52
- Reverse digit span: 0.42
- Non-verbal IQ: 0.24
Dichotic scores and memory

The normal range!

R=0.60
Accounting for variance

Memory

Other non-dichotic factors

Random measurement error

Dichotic factors

27%

9%

Dichotic test scores

64%

64%

+27%

91%
.. And then there’s attention!

Fig 1 from Stavrinos (2018)
Dichotic tests

Testing cognitive ability

Application to brain-lesion patients

Information about hemisphere differences

Application to auditory processing disorder patients

Inferences about auditory processing

- Selective attention
- Working memory
- Executive function
- Aging
- Mental Retardation
Brain “lesions” in Central Auditory Nervous System

Cognitive deficits

Cause

Low dichotic test scores

Indicate
What *not* to do in “sensitising” a test

**Problem:** A test gives ceiling performance for too many people

**Usual solution:** Make the test harder by demanding additional skills:
- dichotic digits – make it two pairs, or three pairs → memory ↑
- speech tests – low-pass filter it → vocabulary ↑, phonetic awareness ↑

**Result:** Scores decrease below ceiling, but cause become uncertain

**An alternative:** Adaptively change inter-aural level
Diagnosing auditory processing disorders
Disentangling the disorders

Publications per year

Year

Cognitive disorder

Auditory processing disorder

Language disorder
Relation between APD and Attention Disorder

101 children with listening difficulties

Gyldenkaerne, Dillon, Sharma and Purdy (2014); JAAA.
Instead of “What disorder(s) does this person have” …. 

“How strong are the deficits in each of: cognition, auditory processing, and language”

With a common unit of measure!
Reported Listening difficulties

Suspected Auditory Processing Disorder

Suspected Language Disorder

Suspected Cognitive Disorder

References:

Bornstein & Musiek (1992)
Dawes, Bishop, Sirimanna, Bamiou (2008)
Sharma, Purdy & Kelly (2009)
Rosen, Cohen, Vanniasegaram (2010)
Umat, Mukari, Ezan & Din (2011)

Gyldenkaerne, Dillon, Sharma, Purdy (2014)
Boothalingam, Allan, Allen & Purcell (2015)
Saxena, Allan & Allen (2015)
Ahmed & Ahmed (2016)
Neijenhuis, de Wit, Luinge (2017)
Children diagnosed with APD reported similar symptoms and similarly had high rates of co-morbid learning problems.

Dawes, Bishop, Sirimanna, Bamiou (2008): “Children diagnosed with APD reported similar symptoms and similarly had high rates of co-morbid learning problems”.

CHAPS questionnaire results – Great Ormond Street APD Clinic, London

Parents

Teachers

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CHildren’s Auditory Performance Scale

CHildren’s A uditory P erformance S cale
Speech understanding – what could go wrong?

Auditory processing
- Auditory filtering
- Envelope analysis
- Temporal fine structure
- Spatial analysis

Speech processing
- Comparison to stored templates (phonemes, syllables or words)

Language processing
- Morphology knowledge
- Syntactic knowledge
- Semantic knowledge
- Prosody knowledge
- Working memory
- World knowledge

Degrade the input
- Noise
- Spatial cues
- Reverb
- Rate

Phonemic and lexical neighbourhood density

These enable auditory closure

Percent understanding
SNR

Attention, Memory

Reverb

Message length

Semantic cues

Prosodic cues

SNR

Morphology knowledge

Syntactic cues

Semantic cues

Prosodic cues

Phonemes, syllables or words identified

Understanding

Working memory
Speech recognition – what has gone wrong?

Auditory processing
- Auditory filtering
- Envelope analysis
- Temporal fine structure
- Spatial analysis
- Pitch contour analysis

Speech processing
- Comparison to stored templates (phonemes, syllables or words)

Language processing
- Morphology knowledge
- Syntactic knowledge
- Semantic knowledge
- Prosody knowledge
- Working memory
- World knowledge

Test of auditory and speech processing

Test of auditory processing

Test of auditory and speech and language processing

Understanding

Phonemes, syllables or words identified

Phonemic and lexical neighbourhood density

Attention, Memory

Complex Signals analysed

Auditory (speech) input

Noise

Reverb

Spatial cues

Rate

Syntactic cues

Semantic cues

Prosodic cues

Message length

Under-standing
Observations in relation to model

- APD **should** be able to cause poor speech perception and language delay (imagine consequences of a complete APD).
- Listening difficulties can be caused by any of auditory processing, speech processing, language processing or cognitive deficits, either alone or in combination.
- A deficit in language processing or auditory/speech processing can be expressed as an equivalent SNR loss.
Importance of SNR: 1. Age

Sound Scouts

LiSN-S

LiSN-U

Sentences in competing babble

Nonsense syllables in competing nonsense syllables

1.3 dB/year

1.0 dB/year

2.4 dB/year
**Importance of SNR: 2. Hearing loss or APD**

<table>
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<tr>
<th>Condition</th>
<th>Effect</th>
<th>Increase in SRT</th>
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<tbody>
<tr>
<td>Mild hearing loss (35 dB 4FAHL)</td>
<td>1 dB increase for each 10 dB of 4FAHL above 5 dB</td>
<td>+3 dB</td>
</tr>
<tr>
<td>Spatial processing disorder</td>
<td>Same-age population standard deviation is 1.6 dB</td>
<td>+3.2 dB</td>
</tr>
</tbody>
</table>

**Conclusion:** A 6 year old, with mild hearing loss, or spatial processing disorder just outside normal limits needs $3 + 9 = 12$ dB better SNR than an average adult.

SNR = -4 dB

SNR = -14 dB
So,

top-level testing to find the strength of deficit in each area,

but ....

How do we find the specific deficit(s)?
How do we find the specific deficit(s) causing listening difficulties?

1. Differential testing
   - DDdT (Dichotic digits difference test, Cameron et al, 2016)
   - SPIN (Speech in noise test; Kalikow, Stevens & Elliott, 1977)
   - LiSN-S (Listening in spatialized noise sentences test, Cameron & Dillon, 2007)

2. Allow for other abilities that affect test scores (just like we allow for age)

3. Use tests that rely only minimally on other abilities
Differential testing (e.g. SPIN – Kalikow, Stevens & Elliot, 1977)

Test of auditory and speech and language processing (with semantic cues)

Test of auditory and speech and language processing (with no semantic cues)

ΔSRT = SRT₂ - SRT₁

Auditory processing
- Auditory filtering
- Envelope analysis
- Temporal fine structure
- Spatial analysis
- Pitch contour analysis

Speech processing
- Comparison to stored templates (phonemes, syllables or words)

Language processing
- Morphology knowledge
- Syntactic knowledge
- Semantic knowledge
- Prosody knowledge
- Working memory
- World knowledge

Auditory (speech) input
- Noise
- Spatial cues
- Reverb
- Rate

Complex Signals analysed

Phonemes, syllables or words identified

Phonemic and lexical neighbourhood density

Attention, Memory

Attention, Memory

Message length

SRT₁

SRT₂

Pichora-Fuller (2008)
Diagnosing spatial processing disorder with the Listening in Spatialized Noise Sentences (LiSN-S) test

Disclosure
Licensed to Phonak
Four LiSN-S Conditions

Same Voice

Different Voices

Same Direction

Different Directions

Talker Advantage

Total Advantage

Spatial Advantage

Low Cue SRT

High Cue SRT

Difference measures!
Spatial Advantage (≡ Spatial Release from Masking)

Australia

Nth America
**LiSN-S 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>
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<tr>
<td>High-Cue SRT</td>
<td>-15.3</td>
<td>-9.5</td>
<td>Outside</td>
<td>-3.9</td>
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<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

The variance from the mean is indicated by the green and red zones. The red zone indicates values outside the normal limits, and the green zone indicates values within the normal limits.

### Diagnostic Session

Client: [Client Name]

Diagnostic: [Diagnostic Information]

Different voices ±90°

Same voice ±90°

Different voices 0°

Same voice 0°

Results

Explanations

Reports
LiSN-S vs. Traditional Battery

Deviation from Mean Normal Performance

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

-12
-10
-8
-6
-4
-2
0
2
4
6

Cameron & Dillon (2008)
Link between SPD and Chronic Otitis Media (COM)
SPD and chronic otitis media (COM)

• 50% of children (24/49) **diagnosed with SPD** at NAL reported (unsolicited) a history of COM. (Dillon et al., 2012).

• 18% of children (18/82) **previously diagnosed with COM** at University of Melbourne were diagnosed with SPD. (Graydon et al., 2017).

• Degree of spatial loss at primary school age increases with **degree of threshold elevation** due to COM in infancy. (Graydon et al, 2015)

• Spatial processing deficit **worse for early onset age and longer duration** of COM (n=35; Tomlin & Rance, 2014).

• 6 yo children with history of COM have **below average spatial advantage** (n=17; z= -1.0) (Kapadia et al, 2012).

• 13-17 yo adolescents with history of COM have **below average spatial advantage** (n=20; z= -0.75) (Kapadia et al, 2014).

• 10% of a **population sample** (9/90) of Aboriginal children from remote Australia diagnosed with SPD. (Unpublished data).

• 7% of a **population sample** (10/144) of Aboriginal children from regional Australia diagnosed with SPD. (Cameron et al., 2014).
Spatial Processing Disorder –

Unique amongst forms of APD because we:

• Know its major cause
• Can diagnose it, unrelated to cognitive ability
• Have extensive normative and reliability data
• Can remediate it (blinded, randomized trial)
• Remediation generalizes to real life
Not all differential tests give immunity from cognitive deficits!

Right ear advantage in dichotic tests
An analogy

\[
\frac{3}{+4} \quad ?
\]

\[
3,148 - 1,659 = ?
\]
An analogy

Percent correct

Cognitive resources applied to task

Right

Left

100%

0%
How do we find the specific deficit(s) causing listening difficulties?

1. Differential testing
   - DDDt
   - SPIN
   - LiSN-S

2. Allow for other abilities that affect test scores (just like we allow for age)

3. Use tests that rely only minimally on other abilities
A common recommendation:

Multi-disciplinary evaluation

Practicality!
Allowing for related abilities

APD test z-score = AP ability + c.(memory) + d.(attention)

Therefore:

AP ability = APD test z-score – c.(memory) – d.(attention)
Dichotic scores and memory

Dichotic free recall (z score)

Clinic
School

Number memory forward (z score)
Dichotic scores and memory

Clinic
School

Dichotic free recall (z score)
Number memory forward (z score)
Allowing for related abilities

AP ability = APD test z-score – c.(memory) – d.(attention)

But ........

• Which type of “memory”?
  • Echoic
  • Working memory

• Which type of attention?
  • Sustained?
  • Switching?
  • Selective?

• What are the values of c and d for each auditory processing test?
• Are the effects of memory and attention linear or non-linear?
• How accurately do we need to know memory and attention?
• Do we need to add non-verbal IQ or language ability to the modifiers?
Cognitive ability (of some sort)

Auditory processing test score

[Diagram showing a line graph with two markers: one with an 'X' indicating a lower score and one with a checkmark indicating a higher score.]
But which cognitive or language abilities affect which auditory processing tests?
Correlations!
# Cognitive (NVIQ, memory, attention)

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# APD (dichotic, non-speech)

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# APD (speech tests)

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# Outcomes (reading, questionnaires, language)

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<td>-0.03</td>
<td>0.01</td>
<td>-0.03</td>
</tr>
<tr>
<td>Vis. &amp; Aud. Tec.</td>
<td>0.27</td>
<td>0.16</td>
<td>0.15</td>
<td>0.08</td>
<td>0.13</td>
<td>0.08</td>
<td>0.02</td>
<td>0.02</td>
<td>-0.02</td>
<td>-0.02</td>
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<tr>
<td>Math.</td>
<td>0.30</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
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<tr>
<td>Overall academic ability</td>
<td>0.30</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
</tr>
</tbody>
</table>

Constrained SEM Model

Path strength scale

- 0.1
- 0.2
- 0.3
- 0.4
- 0.5
How do we find the specific deficit(s) causing listening difficulties?

1. Differential testing
   • DDdT
   • SPIN
   • LiSN-S

2. Allow for other abilities that affect test scores (just like we allow for age)

3. Use tests that rely only minimally on other abilities
   • LiSN-U
Speech without language?

Auditory and speech processing

**Auditory processing**
- Auditory filtering
- Envelope analysis
- Temporal fine structure
- Spatial analysis
- Pitch contour analysis

**Complex Signals analysed**

**Speech processing**
- Comparison to stored templates (phonemes, syllables or words)

**Phonemic and lexical neighbourhood density**

**Language processing**
- Morphology knowledge
- Syntactic knowledge
- Semantic knowledge
- Prosody knowledge
- Working memory
- World knowledge

**Understanding**

**Attention, Memory**

**Message length**

**Syntactic cues**

**Semantic cues**

**Prosodic cues**
LiSN-U

Listening in Spatialised Noise - Universal
LiSN-U

Listening in Spatialised Noise - Universal
LiSN-U preliminary data

(Test still under development)
Building an assessment battery
Traditional approach to APD testing

History

Audiometry

Is there a problem that APD might explain?

No

Exclude APD; Refer elsewhere

Yes

Detailed test battery

Test result interpretation & diagnosis

Non-specific remediation and management:
- Classroom placement
- FM use
- Instruction style
- Soundfield amplification
- Auditory training

Deficit-specific remediation

Caveats:
1. Diagnosis may be needed to get the funding needed for management
2. Diagnosis may help teachers and/or parents “understand” reason for problems
Why diagnose APD at all?

To *Manage* it?

To *Treat* it?  
(i.e. remediate, cure)

To *Compensate* for it?  
(i.e. train some useful skill)
Hierarchical assessment

Test of auditory and speech and language processing

Test of auditory and speech processing

Test of auditory processing

Auditory processing
- Auditory filtering
- Envelope analysis
- Temporal fine structure
- Spatial analysis
- Pitch contour analysis

Speech processing
- Comparison to stored templates (phonemes, syllables or words)

Language processing
- Morphology knowledge
- Syntactic knowledge
- Semantic knowledge
- Prosody knowledge
- Working memory
- World knowledge

Phonemic and lexical neighbourhood density

Attention, Memory

Understand:
- Phonemes, syllables or words identified
- Syntactic cues
- Semantic cues
- Prosodic cues
- Message length

Auditory (speech) input
- Noise
- Reverb
- Spatial cues
- Rate

Complex Signals analysed

Message length
Dealing with **listening difficulties**

- **Questionnaire / history**
  - **Audiometry**
  - **Measure of speech understanding in noise (TOLD-U)**
  - **Measure of speech sound recognition in noise (~ LiSN-U)**
  - **Measure of attention**
  - **Measure of working memory**
  - **Evaluate results**

### Cognitive testing & interventions

- **Language testing & interventions**

### Auditory processing testing

<table>
<thead>
<tr>
<th>Cognitive abilities</th>
<th>Speech understanding</th>
<th>Speech sound recognition</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good</td>
<td>Good</td>
<td>Good</td>
<td>None</td>
</tr>
<tr>
<td>Good</td>
<td>Good</td>
<td>X</td>
<td>Should not occur</td>
</tr>
<tr>
<td>Good</td>
<td>X</td>
<td>Good</td>
<td>Language testing &amp; intervention</td>
</tr>
<tr>
<td>Good</td>
<td>X</td>
<td>X</td>
<td>Auditory processing testing &amp; intervention</td>
</tr>
<tr>
<td>X</td>
<td>Good</td>
<td>Good</td>
<td>Should not occur</td>
</tr>
<tr>
<td>X</td>
<td>Good</td>
<td>X</td>
<td>Should not occur</td>
</tr>
<tr>
<td>X</td>
<td>X</td>
<td>Good</td>
<td>Cognitive testing &amp; intervention</td>
</tr>
<tr>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Cognitive testing &amp; intervention</td>
</tr>
</tbody>
</table>
Dealing with **listening difficulties**

- Questionnaire / history
- Audiometry
  - Measure of speech understanding in noise (TOLD-U)
  - Measure of speech sound recognition in noise (~ LiSN-U)
  - Measure of attention
  - Measure of working memory
- Evaluate results

- Temporo-frequency resolution
  - Gap detection
  - Order detection
- Spatial processing
  - Dichotic
  - Localization

- Auditory processing testing

- Cognitive testing & interventions
- Language testing & interventions

- No auditory problem?

---

**Temporo-frequency resolution**

**Gap detection**

**Order detection**

**Spatial processing**

**Dichotic**

**Localization**

**Auditory processing testing**
Dealing with **listening difficulties**

- **Questionnaire / history**
  - **Audiometry**
    - Measure of speech understanding in noise (TOLD-U)
    - Measure of speech sound recognition in noise (~ LiSN-U)
    - Measure of attention
    - Measure of working memory
  - **Evaluate results**
    - Auditory processing & interventions
    - Language testing & interventions

- **No auditory problem**

- **Cognitive testing & interventions**

- **Non-specific remediation and management:**
  - Classroom placement
  - FM use
  - Instruction style
  - Soundfield amplification

- **Deficit-specific remediation**

- **Temporo-frequency resolution**
  - Gap detection
  - Order detection

- **Spatial processing**

- **Dichotic**

- **Localization**
Criteria for selecting an assessment test

1. **Established test validity**, meaning that scores below the cut-off value chosen are usually associated with listening problems in real life.

2. **Adequate normative data** and information on retest reliability and critical differences.

3. **Minimal or controlled effects** of memory, attention and non-verbal intelligence

4. The existence of **remediation options specific to the deficit** revealed by the test, and for which evidence of benefit in real-life exists.

5. Affected by known **lesions** in the brainstem or auditory cortex.
Are listening difficulties *mostly*: Language, Auditory processing, or Cognition?

**University of Melbourne**

*SPD: 3 / 105*

3%  

**Australian Hearing**

*SPD: 130 / 666*

P=0.000 000 000 000 1  
20%  
Cameron et al (2015)
Questionnaires
Diagnosing APD by symptoms?

*Questionnaires* (or other ways to gather symptoms) might be able to confirm there is a problem, but can’t tell us the cause.

**Event**
- Child fails to understand an instruction

**Response by child**
- Acts (inappropriately) based on what was heard
- Asks for repetition of instruction
- Does nothing
- Misbehaves

**Interpretation by observer**
- Is not very smart
- Can’t follow instructions
- Poor concentration
- Daydreams
- Badly behaved

Cognition

Auditory processing

Language
Questionnaires (self-report, other-report)

- APDQ
- BMQQ
- CHAPS
- CHILD
- CCC-2
- ECLiPS
- FAPC
- LIFE
- SAB
- SIFTER
- TEAP
- TLI
The **Auditory Processing Domains Questionnaire**

O’Hara and Mealings (submitted)

50 items, 3 scales
Separation of groups using the attention and auditory processing scales
Electrophysiology testing

Yes, probably!
Remediation of auditory processing disorders

1. Deficit-specific training
2. Generalised auditory training + Management by improved SNR
LISN & Learn Game

Target at 0°: 94
Target: The horse kicked six wet shoes
LiSN & Learn – Preliminary Study

- 9 children with SPD (6 to 11 years)
- LiSN & Learn – 2 games/day, 5 days/week, 12 weeks

Average SRT
First vs Last 30 Days
p = 0.000052

Cameron & Dillon (2011)
Experiment 1: Effect of training on LiSN-S scores

<table>
<thead>
<tr>
<th>LiSN-S score (popn SD units)</th>
<th>Pre</th>
<th>Post</th>
<th>Follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low cue</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High cue</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Talker advantage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spatial advantage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total advantage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LiSN-S scale</td>
<td>-3.0</td>
<td>-2.5</td>
<td>-2.0</td>
</tr>
</tbody>
</table>

The graph shows the effect of training on LiSN-S scores for different conditions. The y-axis represents the LiSN-S score in population standard deviation units, and the x-axis represents different conditions: Low cue, High cue, Talker advantage, Spatial advantage, and Total advantage. The graph includes data points for Pre, Post, and Follow-up testing, with error bars indicating variability.
Experiment 2: Blinded randomized controlled trial

Earobics (n = 5)

Lisn & Learn (n = 5)

Cameron, Glyde & Dillon (2012)
Questionnaire results

Effectiveness of remediation
Cameron & Dillon (2011)
Cameron et al (2012)
Cameron et al (2014)
Cameron et al (2015)
Graydon et al (2018)
Necessary steps to show that remediation is effective

• Test scores increase

• Increase in test scores is *not* due to:
  • Practice effects on the test → known test-retest statistics
  • Regression to the mean → double baseline testing
  • Placebo effect → randomized controlled trial
  • Increase in age → age-adjusted scores, control group
  • Similarity of training to test → independent outcome test

• Improved listening ability generalizes to real life, evidenced by
  • Speech understanding in realistic acoustic conditions, and/or
  • Self-report or others-report
Research suggestions
Test of Listening Difficulties (ToLD-U)

Auditory, speech and language processing (Told-U)

Test must require:

- All the signal analysis skills needed to identify speech
- Attention, working memory and language skills needed to understand speech

Test could comprise:

- Sentence material, with syntactic, semantic & prosodic cues available
- Competing talkers, spatially separated from target
- Fast speaking rate
- Reverberation (typical amount)
2. Objective versus subjective assessment of listening difficulties

- Test of speech understanding (ToLD-U)
- Self- or parent report (APDQ, ECLiPS)
- Electrophysiological measure (cABR, CAEP in noise)
3. Create and norm new adaptive tests (where needed)
4. Which types of auditory processing deficits correlate with poor speech perception and listening difficulties?

Test of speech understanding (ToLD-U)

Self- or parent report (APDQ, ECLiPS)

Temporo-frequency resolution

Gap detection

Order detection

Spatial processing

Dichotic

Localization
5. Correcting AP test results for cognition and language

- Determine impact of memory and attention (and IQ and language) on each age-corrected test.
- Derive corrections needed for each APD test in battery.

Diagram showing relationships between AP ability, memory z-score, attention z-score, non-verbal IQ, language z-score, and AP tests.
Causation ........ unknown

- Cognitive abilities
- Auditory processing abilities
- Language abilities
- Academic abilities
- Reported listening ability

Reported listening ability

Causation is unknown.
6. What is the effect of cognitive vs auditory training?

Does Cog $\rightarrow$ APD, or APD $\rightarrow$ Cog, or something else cause both?

Ditto for language training
7. Miscellaneous ideas

• Create a clinical test of backward masking, and measure normative performance and performance in kids with SLI.

• Create a sensitive dichotic test without challenging memory or executive function

• Compare behavioural results to electrophysiological results for stimuli chosen to expose specific deficits & examine sensitivity for individuals

• Explore relationship between temporal order perception (FPT and DPT), cognitive abilities, speech intelligibility, and reported listening difficulties.
Thanks for listening

Thanks to Australian Department of Health for sustained funding.

Questions?

CAPD.NAL.gov.au