Hearing with Your Brain: Auditory Processing Disorder in Children
Christine Rota-Donahue, PhD
Lehman College of the City University of New York
FLASHA, 2016

Disclosure
• Employed by the City University of New York
• Grant from the American Hearing Research Foundation
• Author of several articles and presentations on auditory perception

Introduction to Auditory Processing
- Comprehension
- Identification
- Motivation
- Working memory
- Emotions
- Attention
- Cognitive skills
- Language
- Discrimination
- Detection
- Vision
- Vision
### Outline

**Auditory skills development:**
- Structural maturation
- Behavioral responses to sounds

**Definition:**
- How is Auditory Processing Disorder (APD) defined today?
- Behavioral and brain bases of APD

**Assessment and Treatment of pediatric APD:**
- Case presentation supporting a multidisciplinary approach

---

### Ascending auditory pathways

![Image of ascending auditory pathways](image.from.neuroville.com)

---

### Decussation of the auditory pathways

![Image of decussation of the auditory pathways](image.from.neuroville.com)
Behavioral auditory milestones

Stage 1: 0-6 months

**Newborns and young infants**
- react to loud sounds
- can discriminate between speech sounds
- recognize voices

However
- representations of sound are coarser than adults'
- elevated detection thresholds
- ability to separate sounds of different frequencies is immature
- limited precision in representation of speech
Stage 2: 6 months - 5 years

Young children
- show interest in sounds
- follow stories

However
- detection thresholds still elevated
- listen in broad band way
- difficulty listening in noisy environment until age 5

Stage 3: 6 years - adolescence

School-aged children
- have mastered selective listening
- speech perception becomes automatic

However
- less consistent than adults in categorization of speech sounds.
- need multiple cues to identify phonemes
- requires attention

Models of speech perception
- Traditional models
- More recent model
- The McGurk effect
Auditory processing disorder:

- 3% of school-aged children (Musiek & Chermak, 2014)
- Often associated with language impairment (e.g., Rota-Donahue, 2014)
- Other higher order deficits in attention and memory (e.g., Sharma et al., 2014)
- ‘Is a deficit in neural processing of auditory stimuli’ (Musiek and Chermak, 2014)

Definition:

- How is Auditory Processing Disorder (APD) defined today?
- Behavioral and brain bases of APD
Symptoms of APD – ASHA 2005 and AAA 2010

Include difficulty in one or more of the following:
• sound localization and lateralization
• auditory discrimination
• auditory pattern recognition
• temporal aspects of audition
• auditory performance in competing acoustic signals
• auditory performance with degraded acoustic signals

Auditory Processing Disorder is NOT
• Poor sound detection
• Cognitive deficit
• Language impairment
• Age appropriate listening
• Attention deficit

Behavioral assessment

Pediatric APD is typically diagnosed if one of the following skills is affected:
- Perception of physical dimensions of sounds
- Localization or spatial listening
- Dichotic listening
- Speech in noise
Brain bases of APD

- Electroencephalography (EEG)
  - P1N1P2 and Mismatch Negativity (MMN)
- fMRI

What is EEG?

- Recording of electrical activity at the level of the scalp
- Using caps with electrodes
- Spontaneous EEG
- Responses time locked to an event

Spontaneous EEG activity - waveform
EEG spectral analysis

Brainwaves, Frequencies and Functions

<table>
<thead>
<tr>
<th>Unconscious</th>
<th>Conscious</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delta</td>
<td>Delta</td>
</tr>
<tr>
<td>0.5 – 4 Hz</td>
<td>0.5 – 4 Hz</td>
</tr>
<tr>
<td>Theta</td>
<td>Theta</td>
</tr>
<tr>
<td>4 – 8 Hz</td>
<td>4 – 8 Hz</td>
</tr>
<tr>
<td>Alpha</td>
<td>Alpha</td>
</tr>
<tr>
<td>8 – 13 Hz</td>
<td>8 – 13 Hz</td>
</tr>
<tr>
<td>Beta</td>
<td>Beta</td>
</tr>
<tr>
<td>13 – 30 Hz</td>
<td>13 – 30 Hz</td>
</tr>
<tr>
<td>Gamma</td>
<td>Gamma</td>
</tr>
<tr>
<td>30 – 50 Hz</td>
<td>30 – 50 Hz</td>
</tr>
</tbody>
</table>

- **Instinct**
  - Survival
  - Deep sleep
  - Cortical

- **Emotion**
  - Feeling
  - Trance
  - Dreams

- **Consciousness**
  - Awareness of the body
  - Integration of feelings

- **Thought**
  - Perceptual
  - Concentration
  - Mental activity

- **Will**
  - Cognitive focus
  - Energy
  - Ecology

---

P1-N1-P2 complex

P1-N1-P2 waveform in children with APD or SLI

---
Differences in the P1N1P2 in children with APD

AEP responses at FCZ at 500Hz and at 3000Hz for TD children (8-10 y.)
- Large ∆f expected response clearly visible.
- ∆f threshold: between .5 % and 1% of the base frequency

Comparison ∆f thresholds TD vs. APD
Stimuli

Frequency changes (Rota-Donahue et al., JAAA, 2016)

Frequency discrimination, the detection of $\Delta f$

APD or SLI status affected frequency discrimination

Small $\Delta f$ vs. Large $\Delta f$

The literature

Sensitivity index

- Hit rate ($H$) and false alarm rate ($F$) calculated for each participant for both tasks
- $d'$ determined for each participant using the formula $d' = z(H) - z(F)$
- Bias criterion $c$ also calculated using the formula $c = -1/2 \{z(H) + z(F)\}$
Preliminary data

- Mean $d'$ for Three Frequency Changes

**Auditory skills development:**
- Structural maturation
- Behavioral responses to sounds

**Definition:**
- How is Auditory Processing Disorder (APD) defined today?
- Behavioral and brain bases of APD

**Assessment and Treatment of pediatric APD:**
- Case presentation supporting a multidisciplinary approach

**fMRI**

Boiocchi et al., 2011
Test battery used in my lab

- Questionnaire to rule out known neurological deficits such as epilepsy or ASD
- Hearing screening
- Checklist to rule out ADHD based on the Connors’ checklist
- Test of non-verbal intelligence. TONI – 4

Clinical Evaluation of Language Fundamentals CELF – 5
Word Class, Formulated Sentences, Recalling Sentences and Semantic Relations to get a core language score (CLS)

FOUR TESTS of AUDITORY PROCESSING
- LiSN-S
- DDT
- GIN
- SCAN3-C – A/F ground subtest

Preliminary data for 12 participants

<table>
<thead>
<tr>
<th>Group</th>
<th>TONI-4</th>
<th>CELF-5 CLEF</th>
<th>LI-5 SCL</th>
<th>Dichotic Digits (%)</th>
<th>Gaps in Noise (ms)</th>
<th>SCAN (AFG)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical (TD)</td>
<td>109.9</td>
<td>112.1</td>
<td>9.9</td>
<td>R: 93.6</td>
<td>L: 87.4</td>
<td>R: 4.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>R: 4.4</td>
<td>L: 4</td>
<td></td>
</tr>
<tr>
<td>Atypical</td>
<td>99.3</td>
<td>74.7</td>
<td>5.3</td>
<td>R: 67.3</td>
<td>L: 54</td>
<td>R: 12.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>R: 12.7</td>
<td>L: 12</td>
<td>8.7</td>
</tr>
</tbody>
</table>
Case presentation supporting a multidisciplinary approach

Jane

Vanessa

Assessment

• Questionnaire: known neurological deficits were ruled, medical history was unremarkable
• Hearing screening: pass bilaterally between 500Hz and 4000Hz
• Checklist to rule out ADHD based on the Connors’ checklist: pass
• Test of non-verbal intelligence. TONI – 4

Assessment (continued)

Clinical Evaluation of Language Fundamentals - CELF 5
Core Language Standard Score: 55

<table>
<thead>
<tr>
<th>Subtests</th>
<th>Scaled Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>Word Classes</td>
<td>3</td>
</tr>
<tr>
<td>Formulated Sentences</td>
<td>3</td>
</tr>
<tr>
<td>Recalling Sentences</td>
<td>4</td>
</tr>
<tr>
<td>Semantic Relations</td>
<td>0</td>
</tr>
</tbody>
</table>
Assessment (continued)

Tests of Auditory Processing
• LiSN-S: below norms
• DDT: 54%, AD, 44% AS
• GIN: 20ms AU
• SCAN3-C – A/F ground subtest scaled score: 8

Treatment of processing problems
Treating the symptoms at each level: acoustic, phonemic, linguistic

Differential Processing Training Program
by Kerry Winget (LinguiSystem)

Book 1 Acoustic Tasks
• Dichotic Listening
• Temporal Patterning
• Auditory Discrimination

Book 2 Acoustic-Linguistic Tasks
• Phonemic Manipulation
• Phonetic Manipulation

Book 3 Linguistic Tasks
• Word Relationships
• Prosodic Interpretation
• Language Organization
Jane’s first sessions of auditory training
Monaural in noise

After 2 months of Auditory Training

SOAP notes from the SLP:
- Jane is more attentive during sessions
- The mother is more motivated
- Jane is able to follow 3 steps commands (> 80% after 2 months of auditory training)
- However, Jane’s language comprehension and her reading skills are still very poor
- CTOPP, phonological memory (memory for digits and non word repetition), score: 88
- Future goals include working on word relationships and semantics

What can we learn from this case?
- Jane has both APD and SLI
- Auditory perception vs. language processing
- Speech perception
Conclusion

Brain basis of APD and SLI

References


References (continued)

• Rota-Donahue C. et al. (2016) in press
Thank you 😊