Key Principles in Auditory Processing: From Diagnosis to Rehabilitation

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Presentation Outline
- Current Status of (C)APD
- New Diagnostic Measures
- New (and old) (Re)habilitative Approaches
- Case Examples

Historical Perspective
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The truth of the matter...
- Still only a small percentage of audiologists examine APD
- Focus remains on the periphery
- Chermak et al., 2007
- Only 1 hr/week spend evaluating central function

Current Status of (C)APD

Definition
- APD = **efficiency** and **effectiveness** by which the CANS utilizes auditory information.
- What we do with what we hear.
- Katz
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Possible Causes of APD in Pediatrics

- Neurologic
  - Agenesis, Landau-Kleffner
- Neuromorphological
  - Ectopic cells
    - Galaburda
  - Genetic
- Neuromaturational
  - Myelin delay
- “Acquired”
  - Deprivation (CHL or SNHL)
  - TBI
  - Stroke
- Genetic
- Idiopathic

Risk Factors
- Preterm
  (Gozzo et al, 2009)
  - NICU Noise
- Otitis Media
  (Zumach et al, 2009)
- Family Member with APD
  (Morell et al, 2007)
- Dx of Developmental Disorder
  (SL/Psychological) (Sharma et al, 2009)
Dawes et al., (2008)

- 28% of children with APD presented with a Hx of OM (10% in non-APD children)
- 41% of parents reported a close relative with a developmental disorder (23% in non-APD children)
- Deprivation
- Changes in sub-cortical and cortical processing

Sharma et al., 2009
Prevalence of various disorders in children referred for APD evaluation

Differential Diagnosis: A Team Approach

- Adapted from Todd Richards
Scope of Practice
American Academy of Audiology Code of Ethics, 2011

- PRINCIPLE 2: Members shall maintain high standards of professional competence in rendering services.
  - Rule 2a: Members shall provide only those professional services for which they are qualified by education and experience

  - Audiologists
  - Audiologists with specialized training
    - HA’s, Implants, Vestibular...

AAA (2010): Symptoms Consistent with APD

1. difficulty understanding speech in the presence of competing background noise
2. problems with the ability to localize the source of a signal
3. difficulty hearing on the phone
4. inconsistent or inappropriate responses to requests for information
5. difficulty following rapid speech
6. frequent requests for repetition and/or rephrasing of information
7. difficulty following directions
8. difficulty or inability to detect the subtle changes in prosody that underlie humor and sarcasm
9. difficulty learning a foreign language or novel speech materials, especially technical language
10. difficulty maintaining attention
11. a tendency to be easily distracted
12. poor singing, musical ability, and/or appreciation of music
13. academic difficulties, including reading, spelling and/or learning problems

Behavioral Checklists

- Auditory Processing
  - Fisher’s Auditory Problems Checklist
    - “Fishers”
    - Fisher, 1976
  - Children’s Auditory Processing Performance Scale
    - “CHAPPS”
    - Smoski et al., 1992
  - Auditory Processing Domains Questionnaire
    - “APDQ”
    - O’Hare, 2005

- ADHD
  - Brown Attention Questionnaire
  - Snap IV
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SNAP IV
- Swanson, Nolan And Pelham, 1983
- 52 item questionnaire
- Ages 7-17 yo
- Percentile rank based on age norms
- Provides level of risk
- Sub-Domains
  - Auditory Processing
  - Attention
  - Language
  - Targeted Auditory Processing

ADHD
- The American Psychiatric Association states that 3%-7% of school-aged children have ADHD.
- DSM IV
  - Three Subtypes:
    - Attention-Deficit/Hyperactivity Disorder Predominantly Inattentive Type
    - Attention-Deficit/Hyperactivity Disorder Predominantly Hyperactive-Impulsive Type
    - Attention-Deficit/Hyperactivity Disorder Combined Type

ADHD Behaviors

- **Inattention**
  - Often does not give close attention to details or makes careless mistakes in schoolwork, work, or other activities.
  - Often has trouble keeping attention on tasks or play activities.
  - Often does not seem to listen when spoken to directly.
  - Often does not follow through on instructions and has trouble in school, work, or other places (not due to oppositional behavior or failure to understand instructions).
  - Often has trouble organizing activities.
  - Often avoids, dislikes, or doesn’t want to do things that take a lot of mental effort for a long period of time (such as schoolwork or homework).
  - Often loses things needed for tasks and activities (e.g., toys, school assignments, pencils, books, or tools).
  - Is often easily distracted.
  - Is often forgetful in daily activities.

- **Hyperactivity**
  - Often fidgets with hands or feet or squirms in seat when sitting is expected.
  - Often gets up from seat when remaining in seat is expected.
  - Often excessively runs about or climbs when and where it is not appropriate (adolescents or adults may feel very restless).
  - Often has trouble playing or doing leisure activities quietly.
  - Is often “on the go” or often acts as if “driven by a motor”.
  - Often talks excessively.

- **Impulsivity**
  - Often blurts out answers before questions have been finished.
  - Often has trouble waiting one’s turn.
  - Often interrupts or intrudes on others (e.g., butts into conversations or games).

State Based Prevalence Data (2007-2008)

ADHD vs. APD

Chelminski et al, 2013
ADHD Diagnosis

- Primary ADHD → Primary APD
- Secondary APD → Secondary ADHD

Other Considerations

- ADHD
  - Medications

Screening for vs. Diagnosis

- Screening
  - SLP, Aud, Psychologist...
  - Questionnaires, checklists...
  - Auditory behaviors
  - No universally accepted screening measures

- Diagnosis
  - Audiologist
  - SLP Role is to collaborate
Pre-Evaluation Considerations

- Requirements:
  - Age: 7 years or older
  - Speech-Language Assessment (children)
  - Psychoeducational or Neuropsychological Testing (children)
- Other Things to Consider
  - Attention
  - Motivation
  - Medications
  - Fatigue
  - Hearing Sensitivity
  - Native Language

Multidisciplinary Team

- Other Subspecialties
  - Cochlear Implants
    - Audiologist
    - Speech-Language Pathologist
    - Otologist
    - Psychologist etc...

History: Children

- Referral
  - Reason & Source
  - History of Tx
  - Psychoeducational Testing
    - Academic Performance
    - Reading/Spelling
    - Family Life
    - Attention
      - Formal or Informal Dx
- Otologic & Hearing History
  - Hearing Loss
  - Hearing in Noise
  - Directions
  - Otitis Media (OM)
  - Repetition
  - Music
- Perceptual/Motor
  - Reversals
  - Space Perception/Coordination
  - Art Skills
- Medical History
  - Hospitalizations
  - Head Injuries
  - High Fevers
- Developmental
  - Speech Acquisition
  - Age of Walking
  - Handedness
  - Pre, Pen, Postnatal Complications
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(C)APD in Adult Populations

- (C)APD not limited to children
- The Adult Patient
  - Head Trauma
  - Neurological Involvement
  - Undiagnosed childhood (C)APD
  - Aging auditory system
  - Veterans

History: Adults

- Referral
  - Reason & Source
- Otologic & Hearing Hx
  - Hearing Loss
  - History of Otologic Involvement
  - Tinnitus
  - Vertigo/Balance
  - Directions
  - Repetition
- Neurolgical Hx
  - Small
  - Vision (changes)
  - Taste
  - Eye Movement
  - Facial Numbness/Paralysis
  - Swallowing
  - Motor Control/Strength
  - Tingling/Weakness in Extremities
  - Hallucinations
  - Cognition/Memory

Nerves | Type | Function
-------|------|---------------
I Olfactory | sensory | smell
II Optic | sensory | Vision
III Oculomotor | motor* | eyelid and eyeball muscles
IV trochlear | motor* | eyeball muscles
V trigeminal | nerve | Sensory: facial and mouth sensation, Motor: chewing
VI abducens | motor* | eyeball movement
VII facial | nerve | Sensory: taste, Motor: facial muscles and salivary glands
VIII Auditory | sensory | Hearing and Balance
IX Glossopharyngeal | nerve | Sensory: taste, Motor: swallowing, efferent cranial nerves
X vagus | nerve | Parasympathetic nervous system
XI Accessory | nerve | Accessory: moving head and shoulder
XII Hypoglossal | motor* | tongue muscles
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Test Principles
10 Golden Rules:
1. Audiologist have knowledge, training & skills
2. Test battery is not test driven, but rather by Hx
3. Tests with good reliability & validity, high sensitivity & specificity

Validity & Reliability
- Validity
  - How well a test actually measures what it’s suppose to measure
- Reliability
  - Stability and/or Repeatability of a measure
  - Consistency over time

Sensitivity & Specificity
- Sensitivity
  - Probability of a positive test among patients with a disease
- Specificity
  - Probability of a negative test among patients without a disease

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Efficiency of (C)APD Tests

Golden Rules cont..
4. (C)APD battery should examine different central processes
5. Be sensitive to the attributes/behavior of the individual (fatigue, motivation...)
6. Know test normative information (i.e. don’t give the FPT to a 7 yo)
7. Understand mental age
8. Test methods should be consistent with original research method
9. The test duration should be appropriate
10. Assessment should be collaborative and multi-disciplinary

Peripheral Auditory (Dys)Function
- Know what the periphery is doing because it will influence the central processing!!!
- Know the effect of hearing loss on each of the tests
- Can be done but...
- Must interpret test results with caution!
3 typical situations...

- What if the (C)APD eval is normal.... In light of PHL?
- What if the PHL is symmetrical & the (C)APD eval demonstrates asymmetrical results?
- What if the PHL is asymmetrical & there is “poorer” performance in the better ear?

What if AP is normal.... In light of PHL?

What if the PHL is symmetrical & the (C)APD demonstrates asymmetrical? results?
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What if the PHL is asymmetrical & there is “poorer” performance in the better ear?

Jennifer’s Opinion
- By definition all individuals with peripheral hearing loss have an auditory processing deficit….
- The questions is…. Is it central?

More Resistant
- Dichotic Digits
- Mild to moderate PHL
- Duration Patterns
- GIN

Studies to remember…
- Miltenberger et al., 1978
- Filtered speech often abnormal in PHL
- Speaks et al., 1985
- DDT, DW, DCVs
  - DDT most resistant
  - CVs least resistant

General Rule
- The greater the hearing loss… the more influence the periphery will have on central test results.
- May be able to perform electrophysiology… With up to a moderate PHL if symmetrical
Assessment

- Peripheral assessment
- Central Battery
  - Behavioral = Functional
  - Electrophysiological = Neural Integrity

Equipment?

- Sound Suite
- 2 channel audiometer
- CD player
- Tests
- Forms
  - Electro-acoustic/physiology equipment
  - Or access to someone who has it

Minimal Test Battery

- Questionnaires (adults)
  - APDQ (Auditory Processing Domains Questionnaire)
  - SNAP IV (Swanson, Nolan and Pelham)
- Peripheral
  - Comprehensive Audiological Evaluation
  - Tympanometry
  - Otoacoustic Emissions
- Central
  - Behavioral
    - Dichotic Task
    - Pattern Sequencing Task
    - Temporal Resolution Task
  - Electrophysiological: When appropriate & Feasible
    - Auditory Brainstem Response
    - Auditory Middle Latency Response
    - Auditory Late Response
What do some of these processes do?

- Preserve the rapid changes in the auditory sound over time (temporal processing)
- Ability to attend to a speech in one ear while speech competition is presented to the other ear (dichotic processing – binaural separation)
- Ability to locate a sound and place its location within a much larger auditory scene (binaural interaction)
- Ability to extract meaningful information from a degraded auditory signal (auditory closure)

Behavioral Evaluation

Dichotic Tasks

- Binaural Integration and Separation
- Sensitive to cortical pathology and inter-hemispheric compromise

**Dichotic Digits**
**Staggered Spondaic Words**
**Competing Sentences**
**Dichotic Rhyme**
Neuromaturational Course

Dichotic Digits

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<thead>
<tr>
<th>Age</th>
<th>Left</th>
<th>Right</th>
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<tbody>
<tr>
<td>7-7.11</td>
<td>55%</td>
<td>75%</td>
</tr>
<tr>
<td>8-8.11</td>
<td>65%</td>
<td>75%</td>
</tr>
<tr>
<td>9-9.11</td>
<td>75%</td>
<td>80%</td>
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<tr>
<td>10-10.11</td>
<td>75%</td>
<td>85%</td>
</tr>
<tr>
<td>11+ (Adult)</td>
<td>90%</td>
<td>90%</td>
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Competing Sentences

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<th>Age</th>
<th>Left</th>
<th>Right</th>
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<tbody>
<tr>
<td>7-7.11</td>
<td>n/a</td>
<td>n/a</td>
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<tr>
<td>8-8.11</td>
<td>40%</td>
<td>82%</td>
</tr>
<tr>
<td>9-9.11</td>
<td>75%</td>
<td>90%</td>
</tr>
<tr>
<td>10-10.11</td>
<td>90%</td>
<td>90%</td>
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<tr>
<td>11+ (Adult)</td>
<td>90%</td>
<td>90%</td>
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Monaural Low Redundancy Speech Tests
- Recognition of degraded speech stimuli presented to one ear at a time
- Ecologically Valid

Filtered Speech
Time Altered Speech
Speech in Competition

Monaural Low-Redundancy Tests cont...
- Stimuli are degraded
- "classroom environment"/ecological validity
- Evaluate how well the CANS can take poor information and unify it into one event

Examples
- Filtered Speech
- Compressed Speech
- Speech In Noise

Filtered Speech Test

Right | Left
--- | ---
7.7.11 | 60% 60%
8.8.11 | 70% 70%
9.9.11 | 70% 70%
10-10.11 | 70% 70%
11+ (Adult) | 70% 70%
Speech-In-Noise

- Stimuli
- Setup
- Instructions
- Norms

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<thead>
<tr>
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<th>Right</th>
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<tbody>
<tr>
<td>7-7.11</td>
<td>70%</td>
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<td>8-8.11</td>
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<td>70%</td>
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Temporal Processing:
The ability to analyze acoustic elements over time

- Temporal Resolution
- Temporal Ordering

Gaps-In-Noise Test
Random Gap Detection Test
Frequency Patterns Test
Duration Pattern Test

Temporal Processing
- Auditory **temporal processing** can be defined as the perception of sound or the alteration of sound within a restricted or defined time domain. Musiek et al., 2005
- Functional Deficits
  - poor musical skills
  - lack of prosody during speech and reading
  - poor emotional tone
  - difficulty understanding poetry
  - difficulty understanding jokes
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4 Types of Temporal Processing
1) temporal ordering or sequencing
2) temporal resolution or discrimination
3) temporal integration or summation
4) temporal masking

Frequency Pattern Test
- Stimuli: 880 Hz, 880 Hz, 1122 Hz
- Setup: 150 ms, 150 ms, 150 ms
- Instructions:
- Norms:
  - 7-7.11: n/a
  - 8-8.11: 40%
  - 9-9.11: 65%
  - 10-10.11: 72%
  - 11+ (Adult): 75%

Duration Pattern Test
- Stimuli: 250 msec, 250 msec, 500 msec
- Setup: S, S, L
- Instructions:
- Norms:
  - 7-7.11: n/a
  - 8-8.11: n/a
  - 9-9.11: n/a
  - 10-10.11: n/a
  - 11+ (Adult): 70%
Gaps-In-Noise (GIN)

1. 5 sec ISI
2. 5 sec ISI
3. No Gap

Scoring

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<tr>
<th>Threshold</th>
<th>2 mSec</th>
<th>3 mSec</th>
<th>4 mSec</th>
<th>5 mSec</th>
<th>6 mSec</th>
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<td>17%</td>
<td>50%</td>
<td>67%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>72%</td>
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Total % Score

ATh = 5 msec
72% Correct

Scatter Plot Based on Individual Data

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<th>20%</th>
<th>15%</th>
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<th>5%</th>
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X = LE
O = RE

Normal

Brainstem Cortical

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<th>20%</th>
<th>15%</th>
<th>10%</th>
<th>5%</th>
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X = LE
O = RE
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Individual Data Points

Psychometric Functions

Psychometric Functions

Screening
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Interpretation: Behavioral

- General Rules
  - Norm-Based Interpretation
  - Poor Performance on 1 test does not make for (C)APD
  - Unless it’s more than 3 SD
  - Administer other tests to further investigate
  - Be cautious of depressed scores across tests

Other things to consider...
- Redirect/Encouragement may indicate a more global or motivational issue...

Reported Use of Various Tests

Emanuel et al., 2001
### Electroacoustic & Electrophysiological Evaluation

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<th>Tests cont...</th>
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<td>Electroacoustic</td>
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<tr>
<td>OAEs</td>
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<tr>
<td>Electrophysiologic</td>
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<tr>
<td>ABR, MLR, Corticals</td>
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### Electroacoustic Evaluation

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<th>DPOAEs</th>
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<tr>
<td>TEAEBE</td>
<td>Cochlear vs. Retrocochlear Involvement</td>
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</table>
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Auditory EPs
- Auditory Brainstem Response (ABR)
- Middle Latency Response (MLR)
- Late Auditory Response (LAR)

Sensitivity and Specificity

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<thead>
<tr>
<th>EP</th>
<th>Sensitivity</th>
<th>Specificity</th>
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<tbody>
<tr>
<td>ABR</td>
<td>87%</td>
<td>92%</td>
</tr>
<tr>
<td>MLR</td>
<td>50-85%</td>
<td>85%</td>
</tr>
<tr>
<td>N1,P2</td>
<td>70%</td>
<td>75%</td>
</tr>
<tr>
<td>P300</td>
<td>80%</td>
<td>68%</td>
</tr>
<tr>
<td>MMN</td>
<td>No Established</td>
<td></td>
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When?
- ABR
  - Children – Adults
- MLR through Late Potentials
  - Adolescence – Adults
Detectability of the MLR in Children

Krause et al.

EPs into your CAPD battery?

- Objective measures of CANS integrity
- Monitoring changes
- Correlations between behavioral and electrophysiological results
- Hearing Loss
- Non-verbal

Electrode Placement
Effects: Amplitude

- Electrode Effect:
  - The electrode closest to the lesion site will reflect the greatest deficit.

- Ear Effect:
  - At times, the ear contralateral to the lesion hemisphere will demonstrate a deficit.

- Intensity Effects:
  - At times, there will be a significant difference between the behavioral threshold and the electrophysiological threshold.

Patient as norm

Ear Effect

Electrode Effect
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Intensity Effect
- Sensitivity of ABR in Acoustic Neuroma is around 90% (larger than 1 cm)
- Sensitivity drops to 58-80% for Acoustic Neuromas less than 1 cm
- MRI has become the gold standard in AN diagnosis
- MRI obstacles?
  - cost, availability, and patient comfort
- Increasing ABR sensitivity is desirable since it can be cost effective as a screening tool not as the primary diagnostic tool.

Case example
- Hx
  - 44 year old female
  - imbalance, lightheadedness and vertigo
  - husband reports concerns regarding a decrease in her hearing sensitivity
  - some hypersensitivity to sound
  - severe headaches, and unilateral left sided tinnitus.

Quick look at the ABR
- Left Ear
  - Absolute V: 6.0 msec
  - I-V: 4.3 msec
  - I-III: 2.2 msec
  - III-V: 2.1 msec
- Right Ear
  - Absolute V: 5.8 msec
  - I-V: 4.0 msec
  - I-III: 2.1 msec
  - III-V: 1.9 msec
  - ILD: 0.2 msec
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Can we do it better?

- **Patient Selection:**
  - Prospective analysis of 7 patients with MRI-proven acoustic neuromas being followed clinically and radiographically.
  - 3 mm to 1.6 cm with a mean of 7.8 mm.

- **Audiologic Battery:**
  - Pure tone audiometry and word recognition testing.
  - ABR Behavoiural click threshold bilaterally
  - Neurodiagnostic ABR in bilaterally
  - ABR threshold

---

**Behavioral vs. ABR Threshold Comparisons**

**Index Sensitivity**

![Behavioral vs. ABR Threshold Comparisons](image1)

![Index Sensitivity](image2)
A closer look at the ABR

Behavioral Threshold = 10 dB HL  Behavioral Threshold = 10 dB HL

The UK Way...

- Every patient undergoing a neurodiagnostic ABR (or MLR) gets both Supra- and Threshold testing (yes, even adults).
- Any difference between the behavioral threshold and the electrophysiological threshold greater than 25 dB is suggesting of retrocochlear involvement.

*Jirsa et al.*
So... what do we do with patients diagnosed with (C)APD...

Clinical Practice Guidelines: Diagnosis, Management, and Treatment of Children and Adults with APD

- Characteristics of an effective APD Treatment
  - Proper referral for additional testing
  - Work as part of a multi-disciplinary team
  - Individualized intervention, which may include:
    - Auditory training
      - CBAT
    - Formal vs. informal directed training
    - Speech-language therapy
    - Classroom modification
    - Assistive listening device
    - Establishing outcome goals and timeline

- Auditory Plasticity Defined
  - "The alteration of nerve cells to better conform to immediate environmental influences, with this alteration often associated with behavioral change."
  - Musiek & Berge
Types of plasticity
- Developmental
- Compensatory (Injury Related)
- Learning Related Plasticity

Mechanisms underlying plasticity
1) Activation of neural substrate “in-reserve”
2) Formation of new neural connections

Most important concept...
- Therapy must be deficit driven...
  1. Compensatory Strategies
     1. i.e. chunking information
  2. Environmental Modifications
     1. FM trainer
  3. Auditory Training
     1. Changing neural network and auditory behavior
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Multidisciplinary Team
- SLP
- Neuropsychologist
- School Psychologist
- Pediatric Neurologist
- ADHD specialist

Formal & Informal Auditory Training
- Formal
  - Fast ForWord
  - Earobics
- Informal
  - AME Procedure
  - Simon Game
  - Etc....

LiSN & Learn
- National Acoustic Lab
- Cameron & Dillon 2010
- Spatial Processing Disorders (SPD)
  - Diagnosed with LiSN-S
  - Children with difficulty hearing in noise
D I I D Training

**Dichotic Interaural Intensity Difference**

Training

<table>
<thead>
<tr>
<th>LE Deficits for Dichotic Listening in Children</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digits</td>
</tr>
<tr>
<td>-------------------------</td>
</tr>
<tr>
<td>R &gt; L = 76.2 %</td>
</tr>
<tr>
<td>L &gt; R = 14.3 %</td>
</tr>
<tr>
<td>R = L = 10.5 %</td>
</tr>
<tr>
<td>** R &gt; L = 23.8 %</td>
</tr>
<tr>
<td>** = &gt; 20%</td>
</tr>
</tbody>
</table>

[Musiek]

Physiology of Binaural Integration
Key Principles in Auditory Processing: From Diagnosis to Rehabilitation
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Physiology of Binaural Integration

Constraint Induced Therapy

- Edward Taub, Ph.D. and collaborators at the University of Alabama at Birmingham
- Patients can "learn" to improve the ability to move the weaker parts of their bodies and therefore not rely primarily on the stronger extremities.
- It is the only rehabilitation technique shown to produce a marked change in brain organization and function.
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**DIID Training**

**CONDITIONS**
- UNDER EARPHONES
- SOUND FIELD

**MATERIALS**
- Words, Digits, Sentences...

---

**Prelim. Data**

Mean % Dichotic Improvement from DIID Training

- #1 = Musiek
- #2 = Wertz, Moncrieff, Musiek (30 min/3 times/wk/4wks)

---

**What does DIID do?**

Abnormal Dichotic Listening Function Before Training

---

**Abnormal Dichotic Listening Function**

Before Training

---

---
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Improved Dichotic Listening Function

What does DIID do?

Other deficit-based therapies
- Let's think about some other deficits...
  - Temporal Processing
  - Auditory Closure

Temporal Training
- Fast ForWord
- Gap discrimination
- Simon and other commercial games
- Keyboard, Cadence training
  - Frequency, length, speed change
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Temporal Cueing

- The doctor said that **nosedrops** will help the cold.
- The doctor said he **knows drops** will help the cold.
- You should read the **newsprint** carefully.
- When you write the **news print** carefully.

Simon Game

Keyboard Training

- Frequency cues/ non frequency cues
- Pattern length
- ISI speed, element duration
- Target segments
- Cadence
Missing Exercises

- Add in competition once mastered in quiet.

Vocabulary Building

- Contextual derivation [new word = pilfered]

The robber broke out of jail. He needed some money. He saw a jewelry store and walked into the store. When the clerk wasn’t looking, the robber pilfered a gold ring from the shelf and ran out of the store. Later he sold the ring he had pilfered for some money.

Auditory Memory Enhancement

- Gestalt
- Memory & analytic processes
- Engages both hemispheres
- Reading Comprehension
- Note taking
- Define a segment
- Sketch that segment
  - Key concept
- Review and retell
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Reported Use of Various Therapies

Which has the biggest impact on success?
- Type of training program
- Attitude of the patient
- Knowledge of the therapist
- Equipment and resources
- Sufficient time in therapy
- The degree and type of deficit

An important note about therapy!
- Intensity is the Key!!!
- 2-3 hours/week
- 4-6 weeks
- 30/70 Rule

Emanuel et al., 2001

Audiologists
N=1195
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**Bottom Line...**
- Move beyond environmental modification
- Need to Evidence Based Practice

---

**How do we monitor neural changes?**
- Behavioral Re-assessment
- Functional Improvement
- Electrophysiological Monitoring
  - Jirsa
    - Increased amplitude and decreased latency in P300 in children who underwent general AT
    - Changes not observed in the control group
  - fMRI?

---

**Another Population to Consider: Hearing Aid Users**
- Binaural HAs
  - Advantages
    - Improved localization
    - Improved ability to hear in noise
  - However...
    - 8-10% of HA users experience binaural interference
      - Allen et al., 2000
      - Also... Carter, Nye and Wilson, 2001; Walden and Walden, 2005; Herkin, Waldman and Kishon-Rabin, 2007; Kobler et al., 2010

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(C)APD in HA users...
- May be contraindicated
- Jerger 1993
  - Asymmetrical word rec
  - Poor word rec when binaurally stimulated
- Jerger 2001
  - Larger asymmetry in dichotic listening as we age
  - Independent of hearing loss
  - Inter-hemispheric transfer across the corpus callosum

Walden and Walden (2005)
- Evaluated patients on both the QuickSIN and the Dichotic Digits Test.
- They demonstrated that in many instances, older patients actually performed better on the QuickSIN, as well as listening to speech recognition in noise with unilateral as opposed to bilateral amplification.

Schoepflin (2007)
- Report of a child who demonstrated asymmetric word recognition.
- When bilaterally amplified, the child began to demonstrate adverse behaviors.
- Binaural interference was clearly documented when unilateral-aided (90% vs. 36%) and bilateral-aided (56%) scores were compared.
Corpus Callosum
- 200-350 Million Nerve Fibers
- 95% myelinated
- Information superhighway connecting the right and left hemispheres

**Corpus Callosum Myelinization**

Early Adolescence | Late Adulthood

**Physiology of Binaural Integration**

Language Processing | Contour Recognition
Key Principles in Auditory Processing: From Diagnosis to Rehabilitation
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Physiology of Binaural Integration

Recommendation
- Dichotic Digits test on all adult patients to
  1. Screen for APD
  2. Determine if binaural amplification is the most appropriate fitting choice.
  3. Use post-fitting if binaural rejection

Coding
- CAP 1st 60 min: 92620
- CAP +15 min: 92621
- Comprehensive Eval: 92557
- Tymps: 92567
- OAEs: 92588
- ABR: 92585

Don’t forget...
Note your time!!!
Pediatric Case Study 1

Audiologist Referral
- 7 yo male
- Severe Articulation Deficits
- Reading & Spelling Difficulties
- OM
- Family Hx of LD
- *Unable to “break-down” sounds*
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(C)APD Hx
- No concerns re: hearing sensitivity
- Oral Directions: Fair
- Repetition: Constant
- Music Appreciation: Good
- Hearing in Noise: Poor
- Localization: Poor
- Memory: Poor
- Attention: Fair (or Fair if you're from KY)

(C)APD Evaluation
- Peripheral Assessment
  - Hearing WNL
  - DPOAEs WNL

Peripheral Assessment
Hearing WNL
DPOAEs WNL

= Normal Range
O = Right Ear
X = Left Ear
SFv = Sound Field Verbal Response
Key Principles in Auditory Processing: From Diagnosis to Rehabilitation
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Initial Recommendations
- Comprehensive (re)hab program
  - FM system
  - Auditory closure activities
    - Missing word, syllable & phoneme exercises
  - Reading
  - Vowel and consonant identification and discrimination training

FM System
- Improved signal-to-noise ratio within the classroom
- Soundfield FM
- Modification

Auditory Closure
- "Missing" exercises
  - Phoneme
    - Category: Colors
      - _brown
      - Brown
  - Syllable
    - Category: Sports
      - Foot_
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From Diagnosis to Rehabilitation
Recorded November 29, 2012

Reading
- Drop 1-2 grade levels
- Parents read aloud
- "Jimmy" to read aloud
- Nightly before bed

Vowel and consonant identification and discrimination training
- Identify vowels & consonants in isolation in a quiet environment
- Know long vs. short vowel
- Supply sounds with visual letter
- Vowel said by therapist and child provides corresponding letter
- CVs, CVCs
- Discrimination
  - Same different judgments
  - Work up to pairs and triads

Timeline
- 6-8 weeks
- 3 hours of training/week both at home and school
- 1 months off
- Return to clinic for re-evaluation

Return Visit
- Parents crying
- "Oh No! What have I done?"
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Summary Improvements
- Behavioral (C)APD test results
- Functional improvement in school
  - Articulation
  - Peers
  - Self Esteem
  - Reading

Pediatric Case Study 2
Hx

- 8 yo wf
- Normal hearing
- 4 yo seizure
- General academic difficulty
- ?ADHD
- ?Processing

Hemimegalencephaly

- Abnormally large brain
- Very rare
- Large range of presentations
Key Principles in Auditory Processing:
From Diagnosis to Rehabilitation
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Coronal

Axial

Axial
DIID Training
- 6 weeks
- 2/week
- 30 min
- Integration RE & Separation LE

Post-Tx

O = Right Ear
X = Left Ear
SFv = Sound Field Verbal Response

SFv

Comp.
Sp.
LPFS

O2
X2

O
X

= Normal Range

Adult Case Study
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Otolaryngology Referral (Outside UK)

Recommendations
- Word Rec: 90% AU

Audiologist: Monitor Hearing

ENT: (G)CAPD Evaluation

General Hx
- 49 yo wf
- Migraines
- Intermittent facial weakness with migraines
- Hx of learning disability
- OR nurse

Auditory Hx
- Difficulty hearing since childhood
- Chronic problems with hearing sensitivity and understanding speech in the right ear
- Bilateral tinnitus
- No vertigo
- No previous Hx of otologic infections, trauma, or surgery

CAPD Hx
- Constantly asks for repetition
- Particular difficulty hearing in background noise
- Difficulty in the OR
- Poor Localization
- Poor Memory
- Acquired stuttering/reversals
- Poor attention
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**Audiogram**

- **Word Rec:** 100% AU
- **DPOAEs:** Present AU

**DPOAEs:**
- Present AU

**Word Rec:**
- 100% AU

**Efficiency of (C)APD Tests**

- **Sensitivity:**
  - 100% AU
  - 80%
  - 60%
- **Specificity:**
  - 100%
  - 80%
  - 60%

**DPOAEs:**
- 100%

**ABR**
- Neural Integrity of the CANS

**Dichotic Digits**
- Binaural Integration
- Dichotic Rhyme
- Control for Attention

**Duration Patterns**
- Temporal Processing

**Low-Pass Filtered Speech**
- Ecological Validity

**ABR**
- Neural Integrity of the CANS
Key Principles in Auditory Processing: From Diagnosis to Rehabilitation
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- MRI to assess possible retrocochlear involvement
- Neuro-Otologic Consultation

Recommendations
Radiology

- No Mass Lesion
- No Vestibular Schwannoma
- Neuro-Otologic Consultation
  - Dr. Raleigh Jones
  - Neurologist
- Normal EAC, TM's
- Remainder of ENT exam normal
- Normal Romberg, Gait, Tandem walk
- CN II-XII intact

MRI:

- Right Sided Vascular Loop
  - Janetta 1975
  - Anomalous vascular loop within the IAC, mostly the AICA, which can compress the 7th/8th nerve complex
  - Symptoms
    - Tinnitus
    - SNHL
    - Vertigo
    - Hemifacial spasm
  - Meniere's
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Management
- Surgery?
  - Decompression
- Mild Gain HA
- Speech-in-Noise training

Quick look at another VLS case...
Rehab Success

Therapy...
- Intensity is the Key!!!
- 2-3 hours/week
- 4-6 weeks
- 30/70 Rule
- 2 months
- Dichotic Interaural Intensity Difference (DIID) Training
- Musiek
- LACE®
- Neurotone Inc
Not A Unitary Disorder
• Diverse Etiologies, Symptoms, & Deficits
• Analogy
  - Conductive or Sensorineural Hearing Loss
• Caveat: APD testing generally does not reveal etiology, though test results and history can “suggest”

Take Home Message
› (C)APD DOES have a place in everyday practice.
› It’s NOT just about the periphery!!!
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Out of the box thinking!

Thank you...