Current Views and Controversies in Auditory Processing Disorders

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Definition

• ASHA, 2005
  “(C)APD refers to difficulties in the perceptual processing of auditory information in the central nervous system”
• (Central) Auditory Processing [(C)AP] refers to the efficiency and effectiveness by which the central nervous system (CNS) utilizes auditory information

Nature of APD

ASHA, 2005

• Deficit in neural processing of auditory stimuli
  • Deficit in the CANS per se
  • Not due to higher order language, cognitive, or related factors
  • May coexist with other disorders (e.g., ADHD, language impairment, and learning disability)

Nature of APD

BSA, 2011

• “APD has its origins in impaired neural function”
  • Auditory system afferent and efferent pathways
  • Higher level processing systems - modulation

APD – No Gold Standard

• ’Gold standard’ defined:
  “agreed clinical diagnostic standard with which the sensitivity and specificity of other measures can be compared” BSA, 2011

Current Guidelines and Status

• The American Academy of Audiology
• British Society of Audiology
  www.thebsa.org
APD – Diverse and Heterogeneous

- Auditory processing in the CNS
  - Complex process
  - Serial and parallel processing
  - Shared processing (other sensory/higher order)
  - Diverse levels of impairment

The Central Auditory Nervous System (CANS)

- Consists of nerve fibers and neural sites
- Function: Analysis and transfer of the electrical signal
- Ipsi and contralateral pathways

Neural sites - CANS

1. Cochlear nucleus
   - Probable role: refine the sound as it leaves the peripheral auditory system
   - Ipsi and contralateral pathways

2. Superior olivary nucleus
   - Probable role: locate the source of sound based on time and intensity differences from both ears

CANS - cont.

3. Lateral lemniscus
   - Probable role: preservation of combined information from both ears

4. Inferior colliculus
   - Probable role: communicate the information to other structures

5. Medial geniculate body
   - Probable role: relay to cortex

6. Primary auditory cortex
   - Hisch’s gyrus (BA 41)
   - Probable role: auditory discrimination and perception and connection to language association areas (recognition, interpretation, comprehension)
Overlapping Symptoms

• Non-modularity in the brain

Audition
Vision
Other sensory
Cognitive
Memory
Attention
Language

Overlapping symptoms

Screening for APD

• Aim: to identify individuals “at risk” for APD
  - Questionnaires: not validated, poor specificity, tend to over refer
  - Other tests: SCAN:3 - screening (Keith, 2009)
  - Research needed to develop valid screening tools

SCAN-3 – Screening form

Candidates for APD Testing

Children
• Listening complaints, learning problems, reading problems, or dyslexia, etc
• History of otitis media
• Hearing loss with complaints exceeding what is expected

Adults
• Neurologic disease, disorder, or insult that affects auditory areas
  • History of hyperbilirubinemia
  • Seizure disorders
  • Multiple sclerosis
  • Traumatic brain injury
  • Neurological conditions affecting the CNS

General Considerations Pre-Testing

• Minimum age of seven or eight years (no normative data available for younger children)
• Use of speech and non-speech test stimuli
• Confounding factors: attention, motivation, cognitive status, hearing sensitivity and native language

Test Consideration

• Administered by trained and skilled audiologist
• Choose the specific tests based on the individual’s complaints - not test driven
• Examine different central auditory processes
• Choosing tests with known reliability and validity with normative data
• Know what is considered normal performance, age-wise
• Recommended test duration: 45-60 min
• Assessment should include multi-disciplinary team
APD Assessment

- Comprehensive case history
- Questionnaires
- Peripheral hearing assessment
- Central auditory test battery

APD Case History

- Crucial component
  - Help determine the nature
  - Illuminate the functional difficulties
- Must include:
  - Family / genetic history
  - Pre, peri, postnatal development
  - Listening and auditory behaviors
  - Educational status
  - Therapies/treatments

Common Symptoms

AAA, 2010

Most common:

- Difficulty understanding speech in background noise or in reverberant acoustic environments
- Difficulty localizing the source of a signal
- Inappropriate responses
- Frequent requests for repetitions
- Difficulty following rapid speech
- Difficulty following directions

Peripheral hearing Assessment

- Comprehensive audiometry
- Tympanometry (rule out middle ear dysfunction)
- Otoacoustic emissions (rule out cochlear dysfunction)

Central auditory Assessment

- Behavioral test battery
  - Tests of Temporal Processes
  - The ability to analyze acoustic events over time
  - Dichotic Listening (Speech) Tests
  - The ability to integrate or separate different auditory stimuli presented to both ears simultaneously

Central Assessment – cont.

- Tests of Monaural Low-Redundancy Speech Perception
  - Recognition of speech stimuli presented monaurally in degraded way
- Auditory Discrimination Tests
  - The ability to distinguish between similar acoustic stimuli that differ in frequency, intensity, or duration
Tests of Temporal Processes

<table>
<thead>
<tr>
<th>Temporal resolution</th>
<th>Temporal sequencing</th>
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<tbody>
<tr>
<td>Gaps-in-Noise (GIN) Test</td>
<td>The Frequency (or Pitch) Pattern Sequence Test</td>
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<tr>
<td>Sensitivity and specificity to cortical and brainstem lesions</td>
<td>The Duration Patterns Test</td>
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<tr>
<td>Random Gap Detection Test</td>
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The Duration Patterns Test

- 1000 Hz tones
- Repeat the pattern verbally (S-S-L)

Sensitivity and specificity to cortical and brainstem lesions

Random Gap Detection Test

The Duration Patterns Test

- 1000 Hz tones
- Repeat the pattern verbally (S-S-L)

Sensitive to cerebral lesion and dysfunctional corpus callosum

Dichotic Listening Tests

- Binaural Integration and Separation
  - Dichotic digits
  - Staggered Spondee Word Test (SSW) competing words
  - Competing sentences

Sensitive to cortical and interhemispheric lesions

Dichotic Test Procedure

RIGHT TEMPORAL CORTEX

Non-Dominant Hemisphere

Primary Auditory Reception Area, Lang. Dominant Hemisphere

LEFT TEMPORAL CORTEX

Corpus Callosum

Non-Dominant Hemisphere

Primary Auditory Reception Area, Lang. Dominant Hemisphere

The Dichotic Listening Test Procedure

Competing Words – SCAN:3

- 20 word pairs presented dichotically
- Count correct responses from Rt ear, then from Lt ear
- Ear advantage: correct Rt – correct Lt
- Refer to normative data
Monaural Low-Redundancy Speech Perception

Aim: Reduce the natural redundancy in speech signals using:
- High- or low-pass filtering
- Time compression
- Embedding speech in background noise

Less sensitive to APD than other tests
Language and cognitive status might affect the results

Other Tests

Localization and Lateralization
Auditory Discrimination

Discrimination of: frequency, intensity and duration

How to select the test battery?

Test Battery Selection

- Tests targeting the individual’s complaints
- Appropriate to the individual’s age and cognitive status
- Assess different auditory processes
- Assess various regions and levels within the CANS

Interpretation

- Performance must be compared to:
  - Age-appropriate norms
  - Performance across tests (Intertest analysis)
- APD Diagnosis:
  - Poor performance (2 SD below the mean) on 2 or more tests in the battery
  - Poor Performance (more than 3 SD) on 1 test

Watch out for inconsistencies across tests – might indicate non-auditory confounds

The SCAN-3 Test Battery

Keith, 2009

- Contains the major tests recommended by position papers (ASHA, AAA).
- Normed on 775 subjects
- Provides standardized scores, cut-off scores, Auditory composite score and prevalence of ear advantage for all tests
- Have the highest level of sensitivity and specificity of any auditory processing test or battery (Friburg & McNamara, 2010)
The SCAN-3 Test Battery
Keith, 2009

Screening Tests
- Gap Detection—examines temporal processing ability which may influence the ability to comprehend continuous speech
- Auditory Figure Ground (+6dB)—Tests ability to listen in background noise
- Competing Words (Free Recall) — Dichotic listening task (poor performance may indicate lack of maturation or abnormality of the auditory nervous system)

Diagnostic Tests
- Filtered Words—tests the ability to process speech when distorted or compromised
- Competing Words (Directed Ear)—Dichotic listening task that examines a child’s auditory maturation
- Competing Sentences—Provides information about the maturation of the CANS

Supplementary Tests
- Auditory Figure Ground (+0 dB and +12 dB)
- Time Compressed Sentences

Electroacoustic Measures
- DPOAEs
- TEOAEs
- Acoustic reflex thresholds and decay

Aim: to differentiate between Cochlear and Retrocochlear Involvement

Electrophysiologic measures
Used to measure neuro-electrical activity from the auditory system when an individual is stimulated with sound

- Auditory Brainstem Response (ABR)
  - Information about the auditory nerve and brainstem pathways
  - Early maturation of the response (18 months)
  - Click-evoked ABR: limited sensitivity
  - Speech-evoked ABR: recent promising method in diagnosing and monitoring intervention effects

- Auditory Middle Latency Response (AMLR)
- Auditory Late Response (ALR)
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<tr>
<th>Auditory Middle Latency Response (AMLR)</th>
<th>Auditory Late Response (ALR)</th>
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<tr>
<td>• Generators: thalamo-cortical pathways, primary auditory cortex</td>
<td>• Origins: both the primary and secondary auditory cortices</td>
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<tr>
<td>• Maturation: &gt;10 years old</td>
<td>• Damage to the auditory cortex compromise the N1-P2 complex</td>
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<tr>
<td>• Need to consider many interacting factors: stimulus rate, electrode effect, ear effect...</td>
<td>• Age and stimulation rate can affect the response</td>
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<td>• No well-defined protocols for APD testing</td>
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<th>The Mismatch Negativity (MMN)</th>
<th>When to use AEP’s?</th>
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<tr>
<td>• Used to test discrimination between similar acoustic stimuli</td>
<td>• Behavioral responses not conclusive</td>
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<td>• Present in response to deviant stimulus in between frequent stimuli</td>
<td>• Younger children</td>
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<td>• Elicited passively from individual</td>
<td>• Confounds by other factors</td>
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<tr>
<td>• Generators: primary and association auditory cortex, some frontal lobe regions</td>
<td>• Behavioral measures not available in native language</td>
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<th>APD Diagnosis</th>
<th>Intervention</th>
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<td>Once APD is diagnosed what is the next step?</td>
<td>• When: as soon as APD diagnosis is made and CANS is involved</td>
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<td>• Aim: to exploit the brain’s plasticity and cortical reorganization and to reduce functional deficits</td>
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Neural Plasticity
• The brain’s ability to change; functionally and structurally in response to stimulation, deprivation or experience

Intervention, Training & Plasticity
• Intensive intervention can cause formation of new neural networks by forming new connections between brain cells.
• Stimulation and practice can induce cortical reorganization leading to change in behavior

Intervention Components
• Bottom-up
  - Stimulus driven
  - Auditory training
  - Environmental modification
    - assistive listening systems
    - clear speech
    - improved room acoustics
• Top-down
  - Strategy driven
  - Language & cognitive strategies training
  - Instructional modifications
  - Environment accommodations

Treatment
1. Auditory training:
   - Computer-based:
     - Fast Forward®
     - Earobics
     - LACE®

Computer-based Auditory Training (CBAT)
- Engaging, multisensory stimulation
- Control specific deficits, task difficulty and training schedule
- Customized based on age & general cognitive state

Key factors:
- Intensive training
- Deficit driven
- Task difficulty

Auditory Training
Abnormal findings of interhemispheric transfer based on pattern test and dichotic listening test results
• Dichotic Auditory Training (DAT)
• Multimodal exercises (e.g., linking emotion of facial expression to prosody of a message, sound-symbol association)
Auditory Training – cont.

Deficits identified on auditory performance in competition or degraded conditions

Speech recognition in noise exercises to strengthen closure skills

Other Treatment Options

2. FM systems:
   - For deficits on monaural low-redundancy and/or dichotic speech tests (e.g., speech in noise, filtered or compressed speech)

3. Clear speech
   - Slower rate, emphasizing key words, and pausing

How do we examine plasticity changes?

- Improved behavioral scores
- Improved electrophysiological responses
- Improved functional ability
- Use neuroimaging techniques to monitor changes

Effect Of Auditory Training

kraus et.al., 1995

Selected References