A New Protocol for APD Testing and Therapy

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Auditory Processing

- Auditory processes are neural mechanisms that begin with peripheral acuity and are modified and encoded through central neural pathways.
- Auditory processes manifest through auditory behaviors.
- ASHA defines Auditory processing as "the efficiency and effectiveness by which the central nervous system (CNS) utilizes auditory information. Narrowly defined, (C)AP refers to the perceptual processing of auditory information in the CNS and the neurobiologic activity that underlies that processing and gives rise to electrophysiologic auditory potentials."

Defining APD

- Lack of consensus within the field regarding specific APD definition.
- APD vs. CAPD.
- Compounding factors such as autism, speech disorders, learning disabilities, and language processing disorders can complicate APD identification and severity.
- “(C)APD is a deficit in neural processing of auditory stimuli that is not due to higher order language, cognitive, or related factors” ASHA (2005).
- ICARD may co-exist with other disorders, but is not caused by these disorders.
Defining APD

- ASHA suggests that "(C)APD is best viewed as a neural deficit in the neural processing of auditory stimuli that may co-exist with, but is not the result of, dysfunction in other sensory "domains."
- APD includes disordered processing within one or more of the following domains:
  - Sound localization and lateralization
  - Auditory discrimination
  - Auditory sound recognition
  - Temporal aspects of audition (including temporal integration, temporal discrimination (gap detection), temporal variability, temporal masking)
  - Auditory performance in competing signals
  - Auditory performance in degraded signals

History of APD Assessments

- Early assessments of APD relied heavily on tests used for identifying a site of lesion
- Physicians relied on audiologists to create behavioral assessments that could reliably identify central auditory deficits in neuro-otology patients
- Behavioral tests were designed to validate functional deficits with known peripheral and central sites of lesion
- The same tests were then applied to measure functional deficits in children similar to those seen in neurologic patients

Identifying APD: Screening Tools

- APD screening tools may help identify children in need of comprehensive APD testing
- Several tools exist, but there is no one generally accepted screening tool
- Behavioral Checklists:
  - Fisher’s Auditory Processing Checklist
  - Children’s Auditory Performance Scale
  - Evaluation of Classroom Listening Behavior
  - Children’s Home Inventory for Listening Difficulties
- Behavioral Screening Instruments
  - SCAN-A
  - SCAN-D
Current “Standards” for Identifying APD

- Clinical APD assessment batteries were created in the 1960’s and 1970’s to evaluate different auditory processing skills
- Buffalo Model (Katz, 1957, 1961, 1966); Jerger (1965); Willeford (1977); Bellis-Fette (1999); Musiek/Chermak (1977, 1983); SCAN-C (Keith, 1986)
- Poor standardization exists among APD assessments and the test battery varies depending on the clinical site and audiologist administering the test.

APD Diagnostic Requirements

- ASHA (2005) and AAA (2010) standards diagnose APD from below normal performance on any two tests from any battery
- Generally requires performance deficits of at least two standard deviations below the mean on two or more tests in the test battery (Chermak & Musiek, 1997).
- If poor performance on only one test, the audiologist should withhold diagnosis unless scores fall three standard deviations below the mean or if an additional functional difficulty is assessed.

Problems with this type of APD Assessment

- APD test battery is large and heterogeneous
- Lack of consistency and standards in which APD subtests are administered
- Audiologists tend to use the APD test battery that they were trained to use in graduate school
Previous MSHC Protocol for APD:
Areas of Assessment

- Frequency Discrimination
- Temporal Ordering
- Binaural Integration
- Binaural Separation
- Auditory Memory
- Auditory Closure
- Binaural Interaction
- Auditory Fusion
- Hemispheric Communication
- Auditory Figure Ground
- Localization

MSHC Protocol - Test Battery

- Pitch Pattern (frequency discrimination, temporal ordering, hemispheric communication)
- Competing Sentences (binaural integration, binaural separation, auditory memory)
- Dichotic Digits (binaural integration, binaural separation, auditory memory)
- Compressed Speech (auditory closure monaural low redundancy speech)
- Low Pass Filtered Speech (auditory closure monaural low redundancy speech)
- GIN (temporal resolution, duration discrimination)
- RAS (auditory figure ground, localization, auditory memory, auditory fusion, binaural integration)
- MLD (auditory figure ground, localization, auditory memory, auditory fusion, binaural integration)
- RASP (auditory figure ground, localization, auditory memory, auditory fusion, binaural integration)

Pitch Pattern

- Frequency Discrimination: the ability to detect a change in the frequency of a pure tone
- Temporal Ordering: a arrangement of events in time
- Hemispheric Communication: communication that occurs between the two hemispheres of the brain
Competing Sentences

- **Binaural Separation**: ability to ignore differing stimuli presented simultaneously to each ear.
- **Auditory Memory**: ability to take in information that is presented orally, process it, retain it in one’s mind, and then recall it.

Dichotic Digits

- **Binaural Integration**: cognitive process that involves the “fusion” of different auditory information presented binaurally.
- **Auditory Memory**: ability to take in information that is presented orally, process it, retain it in one’s mind, and then recall it.

Compressed Speech

- **Auditory Closure**: ability to utilize intrinsic and extrinsic redundancy to fill in missing or distorted portions of the auditory signal and recognize the whole message.
Low Pass Filtered Speech

- **Auditory Closure** - ability to utilize intrinsic and extrinsic redundancy to fill in missing or distorted portions of the auditory signal and recognize the whole message.

GIN: Gaps in Noise

- **Temporal Resolution** - ability of the auditory system to resolve temporal changes in an acoustic signal.
- **Duration Discrimination** - ability to discriminate between durations of auditory signals.

MLD: Masking Level Difference

- **Auditory Figure Ground** - ability to understand speech in the presence of noise.
- **Localization** - ability to identify the location or origin of a detected sound.
- **Binaural Interaction** - assesses binaural fusion, which is the ability to take incomplete information presented to each ear and fuse the information into an understandable message.
- **Auditory Fusion** - ability to distinguish paired acoustic events from single acoustic events.
- **Auditory Memory** - ability to take in information that is presented orally, process it, retain it in one's mind, and then recall it.
### RASP: Rapidly Alternating Speech Perception

- **Auditory Figure Ground**: Ability to understand speech in the presence of noise.
- **Localization**: Ability to identify the location or origin of a detected sound.
- **Binaural Interaction**: Assesses binaural fusion, which is the ability to take incomplete information presented to each ear and fuse the information into an understandable message.
- **Auditory Fusion**: Ability to distinguish paired acoustic events from single acoustic events.
- **Auditory Memory**: Ability to take in information that is presented orally, process it, retain it in one’s mind, and then recall it.

### Scoring

Scoring is calculated by comparing results to age-based normative data on each sub-test.

### Concerns with this Approach

- Current test battery employed by most audiologists produces heterogeneous results and lacks defect specificity (Emmanuel et al., 2011).
- ASHA (2005) and AAA (2010) standards declare that abnormal performance on any two tests from any battery qualify an individual for an APD diagnosis.

Outcomes might provide:
- Ear specificity
- Measure of severity
- Type of processing deficit (there is no requirement that the two tests have to match)

Leads to diagnosis of APD and general recommendations for preferential seating and use of an FM system.
Criticism of APD Battery

- Primary Criticism: APD diagnosis is multi-modal and not auditory specific
- Tests in the APD battery are not sensitive to auditory perceptual deficits because they tap into multi-modal processes such as attention, working memory and cognition (Cacace & McFarland, 1995)
- Unlike confirmations with known lesions of the CNS, unimodal APD tests can’t be validated from multi-modal tests in school-age children (Cacace & McFarland, 1998)
- APD tests can be improved by assessing auditory perceptual dysfunction only (Cacace & McFarland, 2005) and some propose that diagnosis should be made only with non-speech stimuli since they are less likely to tap into these supra-modal factors (Moore, 2006)
- Non-auditory factors could be better controlled by testing under an adaptive forced-choice alternative method (Cacace & McFarland, 2013)

APD doesn't represent a clinical entity

- There is no "gold standard" approach across multiple, heterogeneous behaviors (DeBonis & Moncrieff, 2008)
- Current test battery fails to provide diagnostic specificity (Cacace & McFarland, 2005)
- There is no true clinical entity for APD (AAA, 2010; Moore, et al., 2013; Wilson & Arnott, 2013)
- Challenging to differentiate between auditory processing and learning difficulties (Bell, 2003; DeBonis & Moncrieff, 2008; Moore, 2013)

A NEW FOCUS!

- MSHC changes
- Protocol
- Delivery model
- Recommendations
A New Focus in APD Testing: Amblyaudia

- Amblyaudia is a specific type of Auditory Processing Disorder
- Amblyaudia is a deficit in binaural integration, characterized by an abnormal interaural asymmetry during dichotic listening tasks (Moncrieff, 2010; Moncrieff, et al., 2016)
- It is an auditory equivalent of amblyopia in the visual system
- Binocular integration deficit (convergence failure) commonly known as “lazy eye”

Revised MSHC APD Protocol Summary

- SCAN-C/SCAN-A
- Filtered Words
- Auditory Figure Ground
- Competing Words
- Competing Sentences
- Dichotic Digits
- Dichotic Words
- Words in Noise (WIN)
- LiNS
- Dichotic Consonant-Vowels (adults and older children)

MSHC Current APD Protocol

- New protocol aims to provide a more deficit-specific assessment to facilitate the implementation of more evidence-based intervention for specific auditory processing disorders
Dichotic Listening

- "Dichotic listening refers to listening to different acoustic events presented to each ear simultaneously."
- Dichotic listening tasks measure binaural integration in the central auditory system by presenting competing stimuli to the right and left ears simultaneously and the listener is asked to relay what was heard.
- Most listener's results reveal a slight "ear advantage" demonstrating a dominant ear preference for most listeners.
- The dominant ear is defined as the ear that is contralateral to the language-dominant cerebral hemisphere (Kimura, 1961, Canadian Journal of Psychology).
- The common ear is connected to the cortex via abundant neural fibers that comprise the contralateral auditory pathway.

Ear Advantage Evidence

- REA prevalence in adults is 75-80% (Hiscock, et al., 2000).
- Many children produce a LEA or no EA, especially with words (Moncrieff, 2011).
- Results consistent with larger left-hemisphere planum temporale in 67% of post-mortem brains (Geschwind & Levitsky, 1967).

Identification of Amblyaudia

- Dichotic listening tests are used to identify amblyaudia.
- Dichotic listening forms one of the most widely researched and used behavioral tests to assess the central auditory system (Musiek et al., 2015).
- Dichotic listening is the most commonly used assessment tool in the APD battery (Musiek et al., 2015).
- Competing stimuli are presented simultaneously to the left and right ear.
- Listener is asked to repeat everything that he/she has heard.

"10, 5"
Identification of Amblyaudia

- Amblyaudia is characterized by a large interaural asymmetry which manifests on behavioral dichotic listening tests.

Four Dichotic Listening Patterns

- **WNL**
- **Dichotic Dysaudia**
- **Amblyaudia**
- **Amblyaudia Plus**

Pattern of Amblyaudia in DL tests

- **AMBLYAUDIA**: Normal performance in dominant ear, below normal performance in non-dominant ear.
- **AMBLYAUDIA PLUS**: Below normal performance in both ears, above normal interaural asymmetry.
**Dichotic Dysaudia**

- Poor performance in both ears seen during dichotic listening tests
- Not currently known if both ears would show deficit on monaural word recognition tests
- Deficit may only be apparent when the two ears are put into competition

**Classification of Dichotic Listening Test Results**

- Amblyaudia diagnosis requires matched deficit on two tests
- Improves sensitivity of diagnosis

**Finally!**

- We can treat APD
Amblyaudia Intervention: ARIA

- ARIA: Auditory Rehabilitation for Interaural Asymmetry
- Amblyaudia diagnosis is based on interaural asymmetry from abnormal ear dominance (Moncrieff, et al., 2016)
- ARIA can facilitate performance in weaker non-dominant ear (Moncrieff, et al., 2017)
- Premise of ARIA is to strengthen the weaker ear in order to achieve a smaller discrepancy

ARIA benefits after 4-6 weeks of training

Dichotic Digits Test Results

<table>
<thead>
<tr>
<th>Time of Test</th>
<th>Percent Correct</th>
<th>Right Ear</th>
<th>Left Ear</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Training</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post-Training</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Phase 1 Results

Competing Words Test Results

<table>
<thead>
<tr>
<th>Time of Test</th>
<th>Percent Correct</th>
<th>Right Ear</th>
<th>Left Ear</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Test</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post-Test</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Brigance Results

<table>
<thead>
<tr>
<th>Subgroup and Subtest</th>
<th>Grade-equivalent Score</th>
<th>Pre-test</th>
<th>Post-test</th>
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<tbody>
<tr>
<td>LC WR</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BLD</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

ARIA Outcomes at 5 clinical sites, n = 125 children; Moncrieff, et al., 2017

ARIA benefits after 4-6 weeks of training

Reduced hemispheric activation during dichotic listening after 4 weeks of ARIA in 9 children

- Evidence suggests amblyaudia responds to treatment and reduces the neurophysiologic resources involved in complex listening tasks
- Image shows change from pre-ARIA activation levels for dichotic, monaural listening in these children (different words versus same words)
- Blue areas signify reductions in activity in regions where activity was much greater before treatment

ARIA Testing Protocol

- Sound field presentation of dichotic material
- Intensity in non-dominant ear held constant
- Intensity in dominant ear reduced at first and then increased systematically across training sessions
- Listener asked to repeat all stimuli (binaural integration) or to ignore one side and repeat material presented toward other side (binaural separation)

ARIA Testing Protocol

1. Binaural Integration
   - VA double or triple digits, single syllable words, spondaic words
   - Participants are told to repeat everything from both sides as 1 time
2. Binaural Separation
   - Segments from different fairytales stories, Little Red Riding Hood, Cinderella, Snow White
   - Segments presented in normal sequence, staggered between two ears
   - Half of the segments have one “oddball” word inserted that doesn’t make sense
   - Participants ignore one side and repeat the segments from directed side, including the oddball word
ARIA Testing Protocol

- Set non-dominant ear output to 50 dB HL
- Set dominant ear output to 30 dB HL
- Intensity in non-dominant ear held constant at 50 dB HL through training
- Intensity in dominant ear increased systematically across training sessions based on performance in non-dominant ear
- Intensity increased in dominant ear only when performance in non-dominant ear is better than dominant ear or same as dominant ear within 10% difference
- Goal: increase symmetry in performance while edging up the interaural intensity difference toward 0 dB HL.

ARIA Week 1 Summary

- VA double digits (50 items) 50/30 dB HL
- VA double digits (50 items) 50/35 dB HL
- Dichotic words (20 items) 50/40 dB HL
- Dichotic words (20 items) 50/45 dB HL
- Dichotic Spondees (20 items) 50/50 dB HL
- Va double digits (50 items) 50/55 dB HL

ARIA Week 2 Summary

- VA Double Digits (50)
- Dichotic Words (20)
- Dichotic Words (20)
- Dichotic Words (20)
- VA double digits (50)
ARIA Week 3 Summary

- VA Digits (Double or Triple) (50 or 75)
- Fairy Tales (ND then D)
- Fairy Tales (D then ND)
- Dichotic Words (20)
- Dichotic Spondees (15)

ARIA Week 4 Summary

- Dichotic Words (20)
- Dichotic Words (20)
- VA Digits (Double or Triple) (50 or 75)
- Fairy Tales (D then ND)
- Fairy Tales (ND then D)
- Dichotic Spondees (35)
- Dichotic Words (20)

Case Study 1: Dichotic Dysaudia

- 8 year old, male
- Passed NBHS
- Risk factors for hearing loss (>5 day stay in hospital, maternal substance abuse)
- Multiple ear infections
- Speech disorder, developmental delay, learning disability
Case Study 1: Dichotic Dysaudia

- Parental Questionnaires
- Auditory Processing Checklist
  - Auditory Decoding (67%)
  - Integration type of APD (67%)
  - Prosodic type of APD (65%)
- Children’s Auditory Performance Scale (CHAPS)
  - Difficulties in noise, quiet, memory, and attention

Case Study 1: Dichotic Dysaudia

- Audiologic Evaluation
  - Healthy tympanic membranes with present PETs, bilateral
  - Hearing within normal limits left ear and a mild rising to normal conductive hearing in right ear
  - 100% word recognition in quiet (PBK)

Case Study 1: APD Evaluation

- Dichotic Listening Tests
  - RD: DDT
  - DWT
  - SCAN: CW

- Ear Advantage
  - Speech in Noise Test (Words in Noise)
  - 2.2 dB S/B

- SCAN Standard Scores
  - FW (2), AFG (11), CW (7), CS (6)
Case Study 1: ARIA Treatment Summary

- Progress from weeks 1 - 4

Case Study 1: Dichotic Dysaudia

- 3 months post evaluation
  - Random Dichotic Digits
    - Left ear 50 (Initial score 44)
    - Right ear 66 (Initial score 58)
  - Dichotic Words
    - Left ear 64 (Initial score 52)
    - Right ear 48 (Initial score 40)
  - SCAN-C
    - Competing Words: IMPROVED
    - Competing Sentences: IMPROVED

Case Study 1: 3 Months Post Evaluation
Case Study 2: Amblyaudia

Background
- 11 year old, male
- Multiple ear infections, PE tubes as infant
- Speech disorder diagnosis at 2 years
- Autism diagnosis at 6 years
- ADD diagnosis at 7 years (takes ADHD medication)

Parental Questionnaires
- Auditory Processing Checklist
  - Difficulties noted in all listening situations
- Children’s Auditory Performance Scale (CHAPS)
  - Difficulties in noise, quiet, memory and attention

Audiologic Evaluation
- Healthy tympanic membranes, Type C tympanograms
- Hearing within normal limits both ears
- 96% word recognition in quiet (CID W-22)
Case Study 2: APD Evaluation

Case Study 2: Amblyaudia

ARIA Treatment

Summary of Scores Weeks 1-4

WHAT'S GOING ON?
Forgot to take his ADHD medication

Case Study 2: Amblyaudia

2 months post evaluation
Random Dichotic Digits
- Left ear: WNL, Initial score WNL
- Right ear: ABN, Initial score ABN

Dichotic Words
- Left ear: WNL, Initial score WNL
- Right ear: ABN, Initial score ABN

SCAN-C
- Number Words: ABN, Initial score ABN
- Auditory Figure Ground BRL: Initial score WNL
- Competing Sentences: BRL, Initial score WNL
- Competing Words: WNL, Initial score WNL
Case Study 2: 3 Months Post-Evaluation

WHAT IS GOING ON?
Forgot to take his ADHD medication

Case Study 3: Amblyaudia

Background
- 8 year old, male
- Diagnosed learning disability summer 2018
- Above average intelligence
- Multiple ear infections with multiple sets of PEBs
- Anxiety

Audiologic Evaluation
- Healthy tympanic membrane right ear with Type A tym; PE tube noted in left ear with Type B tym
- Hearing within normal limits both ears
- 100% word recognition in quiet (CID-W-22)
Case Study 3: APD Evaluation

Case Study 3: Amblyaudia

Case Study 3: 3 Months Post-Evaluation
References

- Moncrieff, D. (July 2018) What is auditory processing disorder and how can we diagnose and treat it? Lecture.ppt.