Diagnosis of Amblyaudia: A Binaural Integration Type of APD
Deborah Moncrieff, Ph.D., CCC-A
University of Pittsburgh
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Financial Disclosure
• I am the owner of Dichotics Inc, the developer of a software program that can be used to assess individuals for binaural integration deficits with dichotic listening tests. The software program can also be used to provide ARIA training.

Overview
• Auditory Processing Disorder (APD)
• Clinical assessment
• Amblyaudia as a type of APD
• Deficit patterns from DL tests
• Estimated prevalence of risk and severity in general and at-risk populations
• Prevalence and severity in clinical populations
• Conclusions and cautionary comments

Auditory Processes
• Underlying neural mechanisms that are revealed through auditory behaviors
• Clinically assessed with a battery of tests
Deficits in Auditory Processing

- Problems with auditory processing are co-morbid with language and learning difficulties (Bellis, 2003; Delloms & Moncrieff, 2008; Moore, 2011)
- Debate whether focus in these children should be on
  - Academic weakness, i.e. phonemic awareness, reading, spelling, language (Kahmi, 2011; Wallach, 2011)
    - These are processes that depend upon activations in cortical brain regions
  - The underlying auditory processing weakness (Moncrieff, 2006; Medwetsky, 2011)
    - These are the processes that are initiated in the auditory brainstem and ascend to the thalamus

Bottom-up or Top-down?

- Pattern recognition tests
  - Monaural or binaural
  - Frequency Pattern Test
- Dichotic speech tests
  - Binaural separation
    - Competing Sentences
  - Binaural integration
    - Dichotic CVs, words, digits
- Auditory discrimination tasks
  - Monaural word recognition
- Low-redundancy speech tests
  - Monaural or binaural
  - Speech-in-noise
  - Time-compressed speech
  - Filtered words
APD Test Battery Criticisms

- “Consensus Conference” on APD produced no consensus (Jerger & Musiek, 2000)
- No “gold standard” approach and multiple, heterogeneous behaviors to consider (DeBonis & Moncrieff, 2008)
- Heterogeneity of results may make the diagnosis of “APD” unworkable (Wilson, et al., 2013)

Characterizations of “APD”

- Case 1: Poor in LE on Dichotic Digits and poor in RE on Gaps in Noise, poor in RE on AFG in SCAN-3
- Case 2: Poor in both ears on Speech-in-Noise and Frequency Pattern Test
- Case 3: Poor in both ears on Dichotic Digits and Masking Level Difference
- Case 4: Poor in LE on Dichotic Digits and both ears on Speech-in-Noise
- Case 5: Poor SCAN composite score, poor both ears on Dichotic Digits, poor in both ears on Compressed Words
- Under current standards with ASHA and AAA, all of these heterogeneous results lead to a single diagnosis of APD

Typical Diagnosis of APD

- Below normal performance on any two tests
- Can be same or different auditory processing skills
- NO specificity for ear (unilateral left, unilateral right, bilateral)
- How can this diagnosis guide treatment?

Amblyaudia is a type of APD

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

Amblyaudia is identified through dichotic listening tests as part of an APD battery

- DL tests are the most commonly used assessment tools in the APD battery (Emanuel, 2011, American Journal of Audiology)
- Competing stimuli are presented simultaneously to the left and right ears
  - “10, 5”
  - “6, 3”
- Listener is asked to repeat everything that has been heard

Most listeners produce an “ear advantage”

- The listener’s “dominant ear” performs better than “non-dominant ear”
  - The dominant ear is defined as the ear that is contralateral to language-dominant cerebral hemisphere (Emanuel, 1981, Canadian Journal of Psychology)
  - The dominant 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, Brain and Cognition)
- Results consistent with larger left-hemisphere planum temporale in 67% of post-mortem brains (Geschwind & Levitsky, 1967)

Magnitude of ear advantage can vary

- Maturation (structural theory)
  - Magnitude decreases with increasing age
- Response bias (attention theory)
  - Higher performance in ear toward which listener is directed
  - Increased performance in LE when asked to repeat words heard on that side first
- Stimulus (temporal theory)
  - Long VOT favors the LE when paired with short VOT presented to the RE (Rimol, Eichele, & Hugdahl, 2006; Moncrieff, Dubyne, & Hugdahl, in preparation)
- Method of measurement can also affect magnitude of ear advantage
  - Traditional method (RE,LE) vs. Alternative method (Dominant – Non-dominant) (Moncrieff, 2011)

Traditional Ear Advantages (RE – LE)

- Positive values for REA
- Lower average ear advantage value

Alternative Ear Advantages (Dom-Nondom)

- Positive values for LEA
- Larger average ear advantage value

Children with learning difficulties show abnormally large ear advantages

- Aylward (1984)
- Kershner & Morton (1990)
- Lamm & Epstein (1994)
- Morton (1994)
- Kershner & Graham (1995)
- deMaddalena, Watzlawick-Schumacher & Arold (2001)
- Moncrieff & Black (2008)
There are 4 typical DL patterns

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Amblyaudia is evidenced in 2 patterns

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

The primary feature in BOTH cases is an abnormally large interaural asymmetry

Dichotic Dysaudia

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

Advantages of the amblyaudia diagnosis

- Ear specificity (right-dominant or left-dominant)
- Degree of severity (discrepancy from normal cut-off)
- Consistency across 2 or more measures for cross-check
- Familiarity with amblyopia or “lazy eye”

DL results in typically developing children

401 children tested with the Randomized Dichotic Digits Test (RDDT) (Strouse & Wilson, 1996)

411 children tested with the Dichotic words Test (DWT) (Moncrieff, 2015)

Prevalence of risk in typically developing children
Many TD children show borderline deficits

12.9% of TD children showed greater than borderline deficits in their dominant ears
20.9% of TD children showed greater than borderline deficits in their non-dominant ears

Classification of DL test results

Diagnosis requires matched deficit on 2 tests

Average test scores in each category

A large interaural asymmetry is the distinctive feature of amblyaudia

Diagnosis of Amblyaudia in Children Referred for Auditory Processing Assessment

- Moncrieff, D, Keith, W, Abramson, M, Swann, A (in press)
- n = 141
- 56 females, 85 males
- Ages 6 to 12
- Tested with a full auditory processing battery that included dichotic listening tests with digits and words
Many clinically-referred children also show borderline deficits

- 18.4% of clinically-referred children showed greater than borderline deficits in their dominant ears
- 36.2% of clinically-referred children showed greater than borderline deficits in their non-dominant ears

Some risk factors have been suggested

- Genetics strongly associated with DL patterns (Morrell et al., 2007, Human Genetics)
- Family history of learning disability
- Family history of amblyopia
- OME with conductive hearing loss (Whitton & Polley, 2011, Journal of the Association for Research in Otolaryngology)

Neural mechanisms have also been proposed

- Poor interhemispheric transfer of information through corpus callosum (Westerhausen, Grüner, Specht, & Hugdahl, 2010, Cerebral Cortex)
- Abnormal suppression of neural activation from information presented to non-dominant ear by activation in dominant ear pathway (Popescu & Polley, 2010, Neuron)
- Reduced inhibition in sub-lenticular auditory pathways (Schmithorst, Holland, & Plante, 2011, Ear and Hearing)
- Abnormal cellular development in auditory thalamus on non-dominant side (Galaburda, Menard, & Rosen, 1994, PNAS)

Electrophysiologic Evidence in Children with Amblyaudia

- Lack of correlation between the two ears in late evoked potential in dyslexic children with amblyaudia
Larger Left-ear MLR Response in Children without Amblyaudia

- Na amplitude
- Peak-to-peak amplitude

Right-ear MLR Differences Appear Only When You Separate AMB and AMB Plus

Evidence of Undiagnosed Auditory Processing and Language Deficits in Adjudicated Adolescents

Deborah W. Moncrieff, Ph.D., CCC-A
National Symposium on Juvenile Services September 30, 2015
School of Health and Rehabilitation Sciences
Department of Communication Sciences and Disorders

Overview

- Background
  - Juvenile justice in US
  - Language, learning and reading disabilities in incarcerated adolescents
- Amblyaudia
  - Definition and diagnosis
  - Relationship to language, learning and reading disabilities
- Clinical services at Shuman Juvenile Detention Center in Pittsburgh
  - Partnerships and methods
  - Clinical findings
- Interpretations and conclusions

Juvenile Incarceration

- Juvenile Arrest Rates 1980-2012
- Juvenile incarceration rate in US is much higher than in any other nation (Hazel, 2008)

Effect of Incarceration on Education

- Incarceration decreases the chance of high school graduation by 13.39%
- Once incarcerated, juveniles are unlikely ever to return to school
  - More likely to be classified for special education services due to behavioral/emotional disorders rather than a cognitive disability
- Aizer & Doyle, 2013
Schools to Prison Pipeline

- Policies and practices that push at-risk children from classrooms into the juvenile justice system
- Reflects a prioritization of incarceration over education
  - Inadequate resources at local schools
  - Schools may even encourage low-performing children to drop out in order to maintain higher scores on test-based accountability measures

Is low performance at school possibly due to language impairment (rather than emotional/behavioral issues)?

- Language impairments are linked to:
  - Weak verbal expression
  - Limited vocabulary
  - Inability to ask appropriate questions
  - Inability to understand figurative language
  - Difficulty with organizational skills
- All of these could reduce performance in school

Poor language skills in juvenile offenders

- Childhood communication disorders are a good predictor for future criminal activity (Stattin & Klackenburg-Larsson, 1993)
  - Better predictor for male than for female subjects
- 66-90% of incarcerated juveniles performed below normal on tests of language (Bryan & Freer, 2014)
  - 46-67% were in the poor to very poor group
  - 62% had not achieved level 1 in literacy

Earlier evidence of high prevalence of language impairment in incarcerated population

- 38% with Test of Adolescent Language – 2 (Davis, Singer, & Morris-Friehe, 1991) Sanger, Hux & Belau, 1997 (TLC-E) (14.3%)
- 22% with Test of Language Competence – Expanded Edition (Sanger, Creswell, Dworak, & Schultz, 2000)
- 19.4% with CELF-3 and WORD Adolescent Test (Sanger, Moore-Brown, Magnuson, & Svoboda, 2001)
- 21% with CELF-3 (Blanton, 2003)
- Higher prevalence than in general population, but may underestimate the true prevalence among incarcerated youth

Language and learning depend upon good auditory skills

- Without adequate auditory intervention, children with hearing impairment often failed to advance beyond the 4th grade in reading skills
- Even with normal hearing acuity, some children may not process the auditory signal normally
  - “I can hear it, but I don’t fully understand what I’m hearing”
  - Indicates a problem with auditory processing of the signal
- Diagnosis of auditory processing disorder has been controversial, primarily because the standard clinical approach involves a large battery of tests that is too heterogeneous (Wilson & Arnott, 2013)
  - Failure of diagnosis to specify a type of processing problem means that intervention cannot be specific
- Diagnosis and treatment of auditory processing problems are improved with identification of specific type/s of auditory processing deficit/s (DeBonis & Moncrieff, 2008)

Our work at Shuman Juvenile Detention Center

- Our mission was to
  - Provide hearing assessments and clinical training for graduate student clinicians in the AuD program at Pitt
  - Gather information about the prevalence of auditory processing weaknesses and language impairment in the population of adjudicated adolescents at Shuman
Hearing Testing at Shuman

- Juveniles must have hearing screened during each detention
- Screenings are performed in the medical department
- The medical department is linked to Adolescent Medicine at Children’s Hospital of Pittsburgh
- Memorandum of understanding was arranged between Adolescent Medicine and P.I. to perform hearing assessments and other screenings

Methods at Shuman

- Screenings are conducted by first-year AuD students under direct supervision of their clinical supervisor (P.I.)
- Hearing assessments
  - Otoscopy, tympanometry, otoacoustic emissions, pure tone audiometry at 0.5, 1, 2 and 4 kHz
- Auditory processing screening
  - Randomized Dichotic Digits Test administered through a laptop computer with Bose noise-cancellation earphones
- Language screening
  - Face-to-face administration of Clinical Evaluation of Language Fundamentals

Data Population

- n = 835
- 11 to 18 years
- 149 females
- 686 males

Summary of results from RDDT

- Adjudicated adolescents as a group scored very low in both the dominant and non-dominant ears on this dichotic listening test
- They also produced a much higher difference between their ears
- This is strong evidence of binaural integration weakness in this group
RDDT Results

- n=313 (37%) normal results in both ears
- n=163 (20%) abnormal results in one ear
- n=359 (43%) abnormal results in both ears
  - n=259 (33%) abnormal asymmetry between ears
  - n=84 (10%) normal symmetry between ears

Prevalence of Amblyaudia Risk at Shuman

- Abnormal results in the non-dominant ear
  - 20% at risk of Amblyaudia
- Abnormal results in both ears with abnormal asymmetry
  - 33% at risk of Amblyaudia +
- Overall risk of Amblyaudia in this population is 53%

Severity of risk can also be estimated

- If the listener’s asymmetry score is 10-19% higher than the cut-off for normal, the severity is low
- If the listener’s asymmetry score is more than 30% higher than the cut-off for normal, the severity is much higher
  - This means that one ear is performing at 30% or more higher than the other ear

Significance of Findings

- A large proportion of adolescents at the juvenile detention center are at risk of amblyaudia
- Amblyaudia is likely to be interfering with their communication skills
  - Most listening is binaural and a deficiency in binaural integration can lead to confusions in comprehension
- Amblyaudia is a disorder of auditory processing that can be remediated with a short-term treatment protocol
  - There are means for these adolescents to be diagnosed and treated for amblyaudia, but none have sought them to date
Language screening at Shuman

- $n = 523$
- 11 to 18 years
- 153 females
- 370 males
- Screened with the Clinical Evaluation of Language Fundamentals – 4 and 5

CELF

- RTI Level 1 assessment
  - Following instructions
  - Sentence repetition
  - Sentence construction (semantics and syntax)
  - Problem solving (vocabulary and reasoning)
  - Word pairings (vocabulary and relationships)

Difficulties noted on the CELF

- Sentence construction
  - Task requires each to create two different sentences from a set of visually presented words
- Problem solving
  - Problems are spoken so each must listen carefully and reason to derive two correct answers

Many adolescents fail to reach criterion on language screening

How do results correlate?

<table>
<thead>
<tr>
<th>Correlations</th>
<th>CELF4</th>
<th>CELF4</th>
<th>CELF4</th>
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<td>.000</td>
<td>.438</td>
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</tbody>
</table>

** Correlation is significant at the 0.01 level (2-tailed).
**Correlational Results**

- Very strong correlations between language screening score and both individual ear scores and asymmetry
- When individual ear scores are low, so too is the CELF score
- When ear asymmetry is high, CELF score is low
- All dichotic listening results are related to poor language scores

**Amblyaudia and Language**

- Among those with amblyaudia ONLY
  - 39% did not achieve criterion on CELF
- Among those with bilateral DL weakness ONLY
  - 61% did not achieve criterion on CELF
- Among those with amblyaudia and bilateral DL weakness
  - 68% did not achieve criterion on CELF
- Among those with normal DL performance
  - 34% did not achieve criterion on CELF

**SUMMARY**

- Adolescents with amblyaudia alone are as likely to show weaknesses in language as children with no dichotic listening deficits
- Adolescents with dichotic listening deficits in their dominant ears are the most likely to show language weaknesses
  - Whether with or without co-morbid amblyaudia

**What next?**

- Children with evidence of auditory processing or language weakness should be referred for a diagnostic evaluation
- Children diagnosed with amblyaudia should be referred for ARIA therapy
- Children diagnosed with language disorders should be referred for language intervention
  - Those with amblyaudia should receive ARIA training first before intervention for language

**What alternatives are there?**

- Could the court mandate follow-up evaluations after screening results demonstrate risk?
  - Diagnostic evaluations and therapy could be made part of probation requirements
  - Focus would be on rehabilitation for a diagnosed communication disorder that is likely to interfere with adolescent’s ability to comprehend
Amblyaudia in Children with Hearing Loss

Demographics and Methods

- 30 children attending DePaul School for Hearing and Speech
- Ages 5 to 14 years
- 16 females, 15 males
- Assessed with RDDT in sound field while wearing amplification

Expectations

- Children will perform more poorly than normal in both ears
  - Consistent with general difficulties with verbal working memory and language
  - Would more likely produce the DD pattern
- RDDT has a low lexical load
- Primary goal was to identify children with amblyaudia pattern of performance

Outcomes

- None of the children were able to achieve criterion on the RDDT
  - Criteria based on testing under earphones
  - In young adults, sound field testing was no poorer than under earphones for non-dominant ear and only slightly poorer for dominant ear (1.3%)

Role of the SLP

- ASHA (2005) did not fully address the role of the SLP
- Current draft of revised scope of practice for SLP includes
  - Auditory Habilitation/Rehabilitation
    - Speech, language, communication, and listening skills impacted by hearing impairment, deafness
    - Auditory processing

- Most of the children performed equally poorly in both ears, like children with dichotic dysacusia
- 5 children showed AMB+ and 1 child showed AMB pattern across both RDDT and DWT
Conclusions: Diagnosis

- Comprehensive audiologic evaluation is critical when assessing a child for amblyaudia
  - Including monaural word recognition, acoustic reflex thresholds and comprehensive OAEs with suppression
  - Rule out ANSD
  - What about hearing loss?
- SLPs could screen for auditory processing and then refer to an audiologist for a comprehensive evaluation
- Diagnostic software is newly available to assist with identifying children at risk for amblyaudia
  - www.dichoticsinc.com