

## Auditory Processing Disorders (APD) Adults with Traumatic Brain Injury

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## Auditory Processing Disorders (APD) Adults with Traumatic Brain Injury

- Definition (s) of APD
- Rationale for auditory processing assessment in adults
- Neuroscience of APD
- Etiologies of APD in adults
- Risk factors for APD in adults, that is, who should be evaluated?
- Disorders co-existing with adult APD
- Team approach in the assessment and management of adult APD
- Test battery for APD assessment
  - Peripheral auditory function
  - Central auditory function
    - ✓ Behavioral measures
    - ✓ Electro-acoustic measures
    - ✓ Electro-physiologic measures
- Management strategies
  - Counseling and advocacy
  - Appropriate referrals to other professionals
  - FM technology
  - Computerized auditory training programs
  - Other management strategies

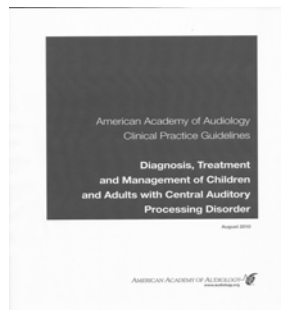
## Definition of Auditory Processing Disorders (APD)

- "APD is broadly defined as a deficit in the processing of information that is specific to the auditory modality." (Jerger & Musiek 2000)
- Auditory processing is "the efficiency and effectiveness by which the CNS utilizes auditory information." (ASHA, 2005)
- "(C)APD is seen in a wide array of populations, including children and adults. It can be the result of a number of different etiologies that involve deficits in the function of the central auditory nervous system. Neurological involvement ranging from degenerative diseases to exposure to neurotoxic substances can result in (C)APD" (AAA, 2009)
- Adult listener variables in the diagnostic assessment of APD
  - hearing sensitivity
  - attention
  - fatigue
  - cognitive variables (e.g., memory, processing speed)
  - medications
  - motivation
  - motor skills
  - native language, language experience, language age
  - visual acuity

## 2000 Consensus Conference on the Diagnosis of APD

- Assumptions in the diagnostic assessment of APD ... possible outcomes
  - A pure APD
  - An APD and a disorder or disorders in other modalities, e.g., multi-sensory
  - A disorder that appears auditory at first, but actually is non-auditory
  - A disorder that appears at first to be non-auditory but is actually auditory

## AAA Clinical Guidelines on Auditory Processing Disorders ([www.audiology.org](http://www.audiology.org))



## Increased Demands for New and Innovative Audiology Services for Military Personnel and Veterans of Current Wars in Iraq and Afghanistan

- Different types and quantity of otologic and brain injuries secondary to noise exposure, trauma, and rapid medevac and acute care, e.g.,
  - Focal injuries (gunshot wounds)
  - Acceleration/deceleration
  - Blast injuries
- Peripheral *and* central auditory dysfunction
- Massive problem with tinnitus and hyperacusis
- Vestibular and balance disorders
- Significant co-existing disorders potentially confounding audiologic assessment, e.g.,
  - Cognitive deficits
  - Post-traumatic stress disorder (PTSD)
  - Language impairment

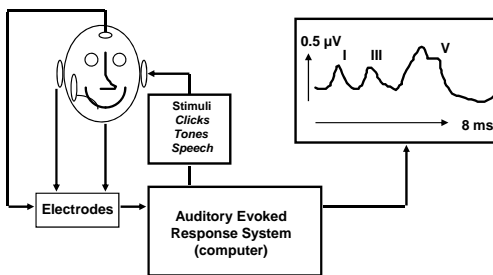
### Assessment of Central Auditory Dysfunction in Traumatic Brain Injury: 25 Years of Experience

- Hall JW III, Huangfu M, Gennarelli TA. Auditory function in acute head injury. *The Laryngoscope* 93: 385-390, 1982.
- Hall JW III, Spielman G and Gennarelli TA. Auditory evoked responses in acute severe head injuries. *Journal of Neurosurgical Nursing* 14: 225-231, 1982.
- Hall JW III, Huangfu M, Gennarelli TA, Dolinskas CA, Olson K, Berry GA. Auditory evoked response, impedance measures and diagnostic speech audiometry in severe head injury. *Otolaryngology Head and Neck Surgery* 91: 50-60, 1983.
- Hall JW III, Mackey-Hargadine J, Kim EE. Auditory brainstem response in determination of brain death. *Archives of Otolaryngology* 111: 613-620, 1985.
- Mackey-Hargadine JR and Hall JW III. Sensory evoked responses in head injury. *Central Nervous System Trauma* 2: 187-206, 1985.
- Hall JW III and Tucker DA. Sensory evoked responses in the intensive care unit: A tutorial. *Ear and Hearing* 7: 200-232, 1986.
- Ghorayeb BY, Yeakley JW, Hall JW III, Jones EB. Unusual complications of temporal bone fractures. *Archives of Otolaryngology-Head and Neck Surgery* 113: 749-753, 1987.
- Hall JW III. Auditory evoked responses in acute brain-injured children and adults. *American Journal of Otolaryngology* 9 (supplement): 36-46, 1988.

### Basic neuroscience advances in the decade of the brain (1990s) impacted understanding of APD

- Different regions mature at different rates
  - Maturation occurs along caudal to rostral gradient
- Development of auditory pathways and centers involves
  - Cell differentiation and migration
  - Myelination
  - Arborization
  - Synaptogenesis
- Consistent and typical auditory stimulation (experience) within the first years after birth shapes nervous system development (plasticity)
- Perinatal and childhood factors influence development of auditory processing, e.g.,
  - Neurological risk factors (e.g., asphyxia, hyperbilirubinemia)
  - Conductive hearing loss
  - Environmental deprivation
- Genetic factors play a role in etiology of auditory processing disorders

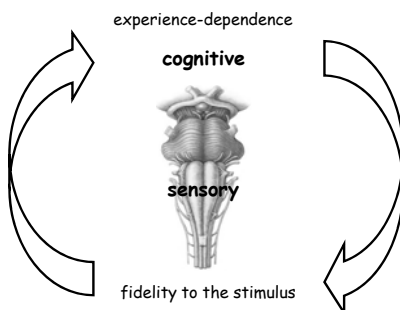
### Auditory Brainstem Response (ABR)



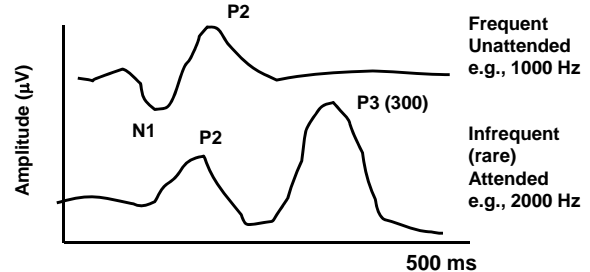
### Auditory Processing Deficits in Language Learning and Reading: Neurophysiological Evidence from Northwestern University

- Kraus N, McGee TJ, Carrell TD, Zecker SG, Nicol TG, Koch DB. (1996) Auditory neurophysiologic responses and discrimination deficits in children with learning problems. *Science* 273: 971-973.
- Cunningham J, Nicol T, Zecker S, Kraus N. (2000) Speech-evoked neurophysiologic responses in children with learning problems: development and behavioral correlates of perception. *Ear and Hearing* 21: 554-568.
- Hayes E, Warrier CM, Nicol T, Zecker SG, Kraus N. (2003) Neural plasticity following auditory training in children with learning problems. *Clinical Neurophysiology* 114: 673-684.
- Hornickel J, Skoe E, Nicol T, Zecker S, Kraus N. (2009) Subcortical differentiation of voiced stop consonants: relationships to reading and speech in noise perception. *Proceedings of the National Academy of Science* 106(31): 13022-13027.
- Chandrasekaran B, Hornickel J, Skoe E, Nicol T, Kraus N. (2009) Context-dependent encoding in the human auditory brainstem relates to hearing speech in noise: Implications for developmental dyslexia. *Neuron* 64: 311-319.
- Abrams D, Nicol T, Zecker S, Kraus N. (2009) Abnormal cortical processing of the syllable rate of speech in poor readers. *Journal of Neuroscience* 29: 7686-7693.
- Banal K, Hornickel JM, Skoe E, Nicol T, Zecker S, Kraus N. (2009) Reading and subcortical auditory function. *Cerebral Cortex* 19(11): 2699-2707.

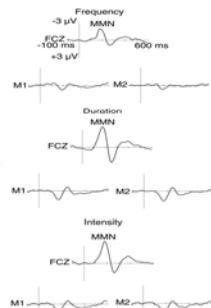
### Bottom Up and Top Down Influences on Auditory Processing



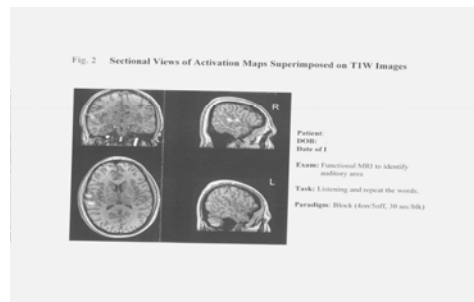
### Auditory Late Response and P300 Response



**Mismatch Negativity (MMN) Response:**  
 "Unconscious Brain Response Elicited by Different Properties of Sound"  
 (Courtesy of Catharine Pettigrew, Ph.D.)



**Neuroscience Evidence for APD:  
 Functional Neuro-Imaging (fMRI)**  
 (18 y.o. APD Patient with Right Ear Dichotic Deficit)



**Auditory Processing Disorders in Adults:  
 Some of the Etiologies**

- Aging of the central auditory nervous system
  - Longstanding evidence
  - Recent findings
- Combined peripheral and central auditory disorders
  - Central auditory dysfunction with progressive peripheral hearing loss
  - Peripheral hearing loss with progressive central auditory dysfunction
- Psychiatric/Neurological disorders, e.g.,
  - Neoplasms
  - Cardiovascular disease
  - Dementias (Alzheimer's dementia)
  - Schizophrenia?
  - Parkinson's Disease
- Traumatic head injury
  - Motor vehicle accidents
  - Gunshot wounds
  - Military blasts and explosions

**SCAN-C and SCAN-A (Robert Keith, 1986):  
 Undefined sensitivity and specificity**

- Low pass filtered words subtest
  - 40 monosyllabic words (20 for each ear)
  - low pass filtered at 1000 Hz
- Auditory figure-ground subtest
  - 40 monosyllabic words (20 for each ear)
  - multi-talker babble noise at + 8 dB SNR
- Competing words
  - 40 monosyllabic words (20 for each ear)
  - inter-word interval of  $\leq 5$  ms
  - initial response to right then left ear words
- Competing sentences
  - 15 target and competing sentences
  - initial response to right then left ear sentences

**Auditory Processing Disorders in Adults:  
 Risk Factors and Clinical Indications**

- Medical history (recall etiologies in previous slide)
- Audiological history
  - Communication complaints greater than expected by audiogram
  - Deterioration in communication abilities with stable audiogram
  - Unusually poor benefit from amplification
- Audiological findings
  - Abnormality for crossed versus uncrossed acoustic reflexes
  - Speech audiometry
    - ✓ Very poor speech perception
    - ✓ Rollover on PI PB functions
    - ✓ Problems with speech in noise
  - Slow response time and processing speed
  - Poor benefit from amplification

**Auditory Processing Disorders:  
 Differential Diagnosis**

"Differential Diagnosis:

Diagnosis based on comparison of symptoms (signs) of two or more similar diseases (disorders) to determine which the patient is suffering from."

### APD in Adults May Co-Exist with Other Disorders

- Peripheral hearing loss, e.g.,
  - Age related (presbycusis)
  - Noise induced hearing loss
  - Hearing loss secondary to otologic trauma
- Cognitive deficits
  - Memory
  - Attention
  - Processing speed
  - Executive functions
- Dementia (e.g., Alzheimer's)
- Language impairment
- Attention deficits
- Emotional disorders
- Motivational concerns (including malingering)
- Post-traumatic stress disorder (PTSD)

### APD in Adults May Co-Exist with Other Disorders: Psychosocial Problems ... Co-existing or secondary to APD?

- Aggression
- Conduct problems
- Anxiety
- Depression
- Internalizing problems
- Withdrawal
- Attention problems
- Adaptive skills
- Functional communication

### Assessment of Central Auditory Dysfunction in Cognitive Deficits and Alzheimer's Dementia

- Strouse A, Hall JW III & Burger M. (1995). Central auditory processing in Alzheimer's disease. *Ear & Hearing*, 16, 230-238
  - Subjects
    - ✓ 10 with mild to moderate AD
    - ✓ 10 control subjects matched for age, gender, hearing loss
  - Procedures
    - ✓ Pure tone audiogram; DPOAEs
    - ✓ Synthetic sentence identification-ipsilateral competing message (SSI-ICM)
    - ✓ Dichotic sentence identification (DSI)
    - ✓ Dichotic digits
    - ✓ Pitch pattern sequence (PPS)
    - ✓ Duration pattern sequence (DPS)
  - Conclusions
    - ✓ AD group scored significantly lower than the matched control group on four of the five measures utilized. Differences for right versus left ear performance were found among AD subjects. Overall patterns in findings cannot be easily explained as artifacts of cognitive decline. Results support screening for central auditory dysfunction in the AD population, since impaired processing could influence psychiatric assessment of cognitive deficit as well as audiologic management of peripheral hearing loss in this population.

### Assessment of Central Auditory Dysfunction in Cognitive Deficits and Alzheimer's Dementia

- Gates GA et al. (2008) Central auditory dysfunction in older persons with memory impairment or Alzheimer's dementia. *Arch Otolaryngol Head Neck Surg*, 134, 771-777
  - "Central auditory function was affected by even mild memory impairment. The Dichotic Sentence Identification test in the free report mode was the most sensitive test for the presence of memory impairment. We recommend that central auditory testing be considered in the evaluation of older persons with hearing complaints as part of a comprehensive, individualized program to assist their needs in both the aural rehabilitative and the cognitive domains."

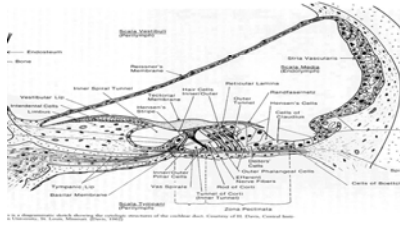
### Diagnosis of and Intervention for APD in Children and Adults Requires a Team Approach

- Audiology
- Speech pathology
- Psychology (e.g., neuropsychology)
- Physical and occupational therapy
- Medical specialties
  - Otolaryngology
  - Neurology
  - Psychiatry
  - Radiology
  - Physical medicine/rehabilitation

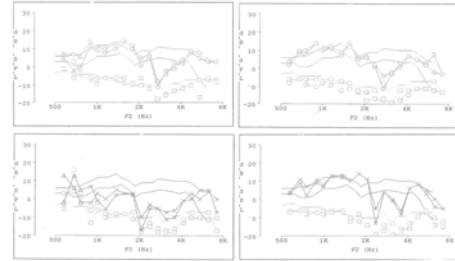
### Assessment of APD: Peripheral Auditory Test Battery (≤ 30 minutes)

- Otoacoustic emissions (OAEs)
- Aural Immittance measures
  - Tympanometry
  - Acoustic reflexes (technically central auditory assessment)
    - ✓ crossed vs. uncrossed conditions ... initial measure of CNS function
- Pure tone audiometry
  - Inter-octave frequencies (e.g., 3000 and 6000 Hz)
  - High frequency (> 8000 Hz) audiometry (as indicated)
- Electrophysiologic estimation of auditory thresholds as indicated with
  - Tone-burst auditory brainstem response (ABR)
  - Auditory steady-state response (ASSR)
- Speech audiometry
  - Word recognition (use CD materials with 10 most difficult words first)

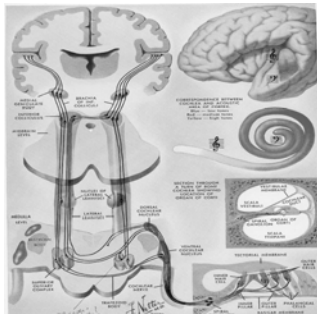
**Otoacoustic Emissions: Highly Sensitive and Specific Measure of Cochlear (Outer Hair Cell) Integrity**



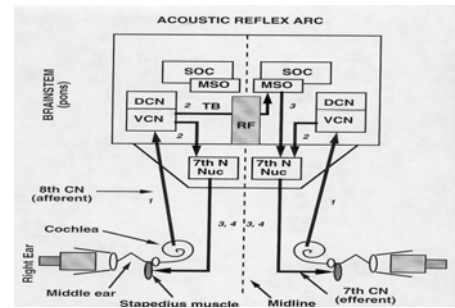
**DPOAEs in APD: Detection of subtle cochlear deficits in 2 of 3 triplets with normal audiograms**



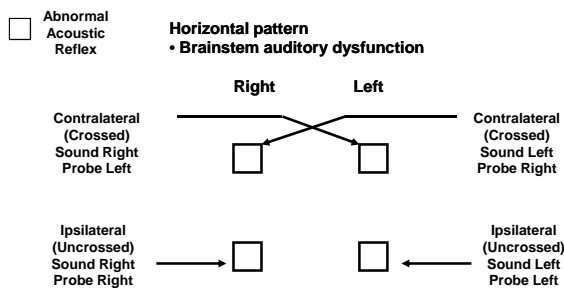
**Assessment of Central Auditory Nervous System Function: We Hear with Our Brain!**



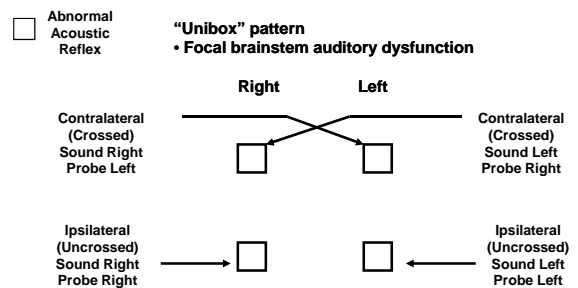
**Measurement of Acoustic Reflexes: Objective Information on Peripheral Auditory System and Auditory Brainstem**



**Plotting the Results of Acoustic Reflex Measurements**



**Plotting the Results of Acoustic Reflex Measurements**



**APD ASSESSMENT:  
Behavioral Test Battery for Auditory Processes (1)**  
(ASHA, 2005; AAA, 2009)

- **Auditory Discrimination Tests:** Assess the ability to differentiate similar acoustic stimuli that differ in frequency, intensity, and/or temporal parameters, e.g.,
  - Difference limens for frequency, intensity, and duration
  - Psychophysical tuning curves
  - Phoneme discrimination)
- **Auditory Temporal Processing and Patterning Tests:** Assess the ability to analyze acoustic events over time, e.g.,
  - Sequencing and patterns
  - Gap detection (Gaps in Noise, GIN, test)
  - Forward and backward masking)
- **Dichotic Speech Tests:** Assess the ability to separate (i.e., binaural separation) or integrate (i.e., binaural integration) disparate auditory stimuli presented to each ear simultaneously, e.g.,
  - Dichotic CVs
  - Dichotic digits
  - Dichotic words
  - Dichotic sentence identification

**Dichotic Listening Paradigm ... A long-standing test strategy for assessment of auditory processing**

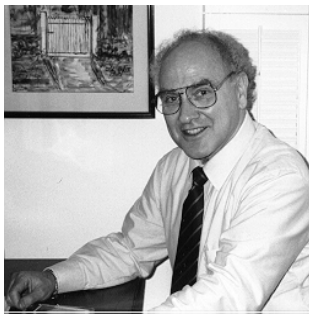
1956: British Psychologist  
Donald E. Broadbent, Ph.D.



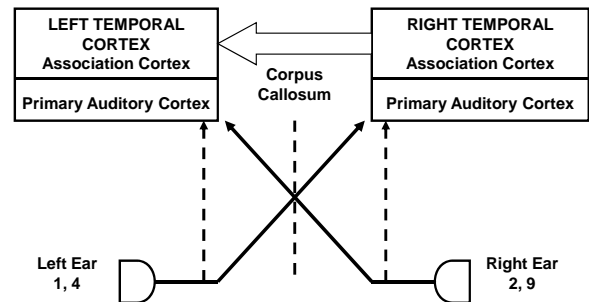
1961: Canadian Psychologist  
Doreen Kimura, Ph.D.



1962: Jack Katz, Ph.D.  
Developed the staggered spondaic word (SSW) test



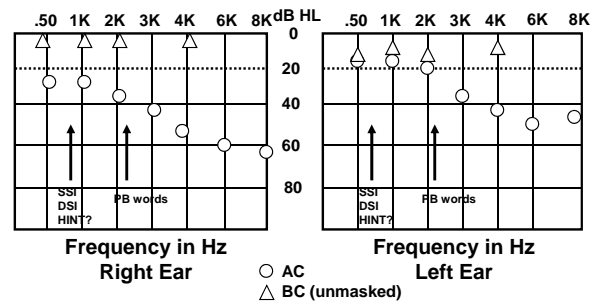
**Dichotic Digits Procedure**



**APD ASSESSMENT:  
Behavioral Test Battery for Auditory Processes (2)**  
(ASHA, 2005; AAA, 2009)

- **Monaural Low-Redundancy Speech Tests:** Assess recognition of degraded speech stimuli presented to one ear at a time (e.g., filtered, time-altered, intensity- altered, e.g.,
  - Performance-intensity PI-PB functions
  - Speech-in-noise or speech-in-competition
    - ✓ Synthetic sentence identification with ipsilateral competing message (SSI-ICM)
    - ✓ Listening in Spatialized Noise (LISN) procedure
  - Hearing In Noise Test (HINT)
  - Speech In Noise (SIN or QuickSIN) test
- **Binaural Interaction Tests:** Assess binaural (i.e., diotic) processes dependent on intensity or time differences of acoustic stimuli, e.g.,
  - Masking level difference
  - Localization & lateralization (e.g., LISN-S)

**Peripheral Hearing Loss and  
Speech Audiometry Procedures**  
(Hearing Loss from Cox et al, 2008)



**APD ASSESSMENT IN ADULTS:  
Influence of Peripheral Hearing Loss**

Cox LC et al (2008). Monotic auditory processing disorder tests in the older adult population. *JAAA*, 19, 293-308

"The purpose of this study was to determine if peripheral hearing loss of varying degrees in elderly subjects affected performance on monotic auditory processing disorder (APD) tests. A battery of monotic APD tests was administered to a group of well-educated and high-functioning older adults who were divided into three subgroups based on hearing acuity but similar in age: (1) normal hearing out to 4000 Hz with a slight high-frequency slope above that point, (2) normal hearing in the speech range but greater high-frequency loss (sloping configuration), and (3) hearing loss in both the low and high frequencies (low/high).

**APD ASSESSMENT IN ADULTS:  
Influence of Peripheral Hearing Loss  
(Cox et al, 2008)**

Mean Scores for Each Group on Each APD Procedure\*

|                            | Normal  | Sloping SNHL | Low/High SNHL |
|----------------------------|---------|--------------|---------------|
| Low-pass filtered speech   | 69%     | 56%          | 54%*          |
| Pitch pattern sequence     | 97%     | 98%          | 94%           |
| QuickSIN                   | 2.7 SNR | 4.0 SNR      | 3.8 SNR       |
| SSI-ICM (-10 MCR)          | 75%     | 75%          | 69%           |
| Time-compressed speech     | 91%     | 92%          | 90%           |
| Random Gap Detection Task) |         |              |               |

\* Significant effect

**APD ASSESSMENT:  
The GIN .... A Creative New Non-Verbal Test Procedure**

- Gaps-in-Noise (GIN) test (Musiek, Shinn, Jirsa, Bamiou, Baran & Zaidan. The GIN (Gaps-in-Noise) Test performance in subjects with confirmed central auditory nervous system involvement. *Ear & Hearing*, 26, 2005.)
  - Noise signals with gaps of silence
    - ✓ Gaps of different durations and locations within noise
    - ✓ Non frequency specific signals
    - ✓ Scores not influenced by hearing loss
  - Simple button pushing response
    - ✓ Signal with either gap or no gap
    - ✓ Yes or no response judgment
    - ✓ Minimal influence of cognition (for patient and tester)
  - Gap detection is a traditional and accepted measure of *temporal processing*

**APD ASSESSMENT:  
The GIN .... A Creative New Non-Verbal Test Procedure**

Samelli AG & Schochat E. (2008) The gaps-in-noise test: gap detection thresholds in normal-hearing young adults. *Int J Audiol*, 47, 238-245

The aim of this study was to establish parameters for the gaps-in-noise test in normal-hearing young adults. One hundred subjects (50 males and 50 females) received an audiological evaluation to rule out hearing loss and auditory processing disorder. The gaps-in-noise test was then conducted on all subjects. The mean gap detection threshold was 4.19 ms. A psychometric function by gap duration was constructed, revealing that the percentage of correct responses was less than or equal to 5% for a gap duration of 2 ms, 10-30% for a gap duration of 3 ms, 60-70% for a gap duration of 4 ms, and over 96% for gap durations of 5 ms or longer. The results suggest that the data obtained can be applied as reference values for future testing. In the subjects evaluated, the gaps-in-noise test proved to be consistent with low variability

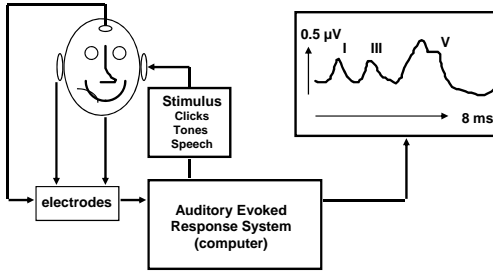
**APD ASSESSMENT:  
Creative Non-Verbal Test Procedures and Protocols  
LISN**

- Cameron S, Dillon H & Newall. The Listening in Spatialized Noise Test: An auditory processing disorder study. *JAAA*, 17, 2006.
- Cameron & Dillon. The Listening in Spatialized Noise-Sentences Test (LISN-S): Comparison of the prototype LISN and results from children with either suspected (central) auditory processing disorder or a confirmed language disorder. *JAAA* 19, 2008.
  - Virtual sound field simulated under earphones
  - Understanding of a story (continuous discourse) presented at 0° azimuth judged (three alternative forced choice adaptive procedure) as:
    - ✓ Easy to understand
    - ✓ Just understandable
    - ✓ Too difficult to understand
  - Distracter sentences presented at 0° (low cue) or 90° (high cue) azimuth
    - ✓ Distracter sentences read by same female speaker or different female speakers
  - Speech perception in competition is a traditional, accepted, and practical measure of *auditory processing*
  - LISN-S software available from Phonak

**OBJECTIVE ELECTROPHYSIOLOGIC APD ASSESSMENT:  
Auditory Evoked Responses Evoked with  
Non-speech and Speech Signals**

- Auditory brainstem response (ABR)
- Auditory steady state response (ASSR)
- Auditory middle latency response (AMLR)
- Auditory late response (N1, P2, N2)
- Auditory P300 response
  - oddball paradigm
  - active or passive subject
- Mismatch negativity (MMN) response

### Auditory Brainstem Response (ABR)



### Auditory Evoked Responses in APD

- Auditory brainstem response (ABR)
  - A measure of brainstem auditory timing with click stimuli
  - Can be recorded with commercially-available devices (since 1975)
  - New research (Kraus and colleagues) on speech evoked ABR measurements in APD assessment
  - Bio-Mark software for clinical application of speech evoked AERs

### Speech-Elicited ABR (Nina Kraus and Colleagues)

- Commercially available with Bio Logic "BioMark" device
- Electrophysiological response that follows or "mimics" the characteristics of the speech signal /da/
- Normative data are available for adults and children between ages of 8 to 12 years
- Test protocol
  - Patient sits quietly in chair
  - Quiet subject condition enhanced by watching video
  - Test time of about 20 minutes
  - Three trials each averaged for 2000 stimuli
  - Three waveforms are averaged

### Analysis

#### Timing

- Compared to stimulus
- Each peak
- Between peaks

#### Magnitude

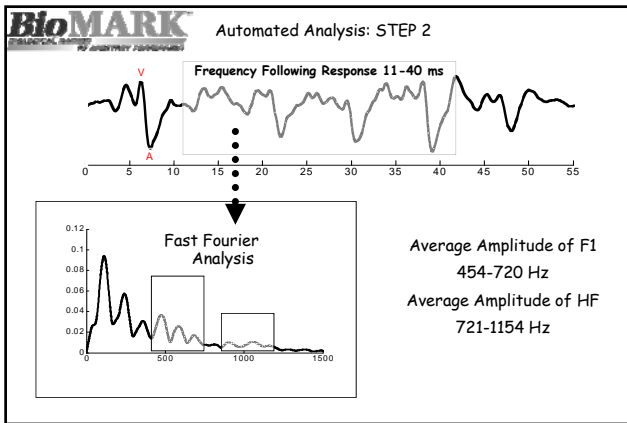
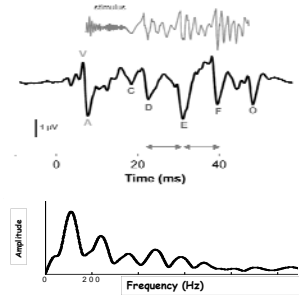
- Each peak
- A chunk of time (RMS)
- Compared to baseline (SNR)

#### Correlations

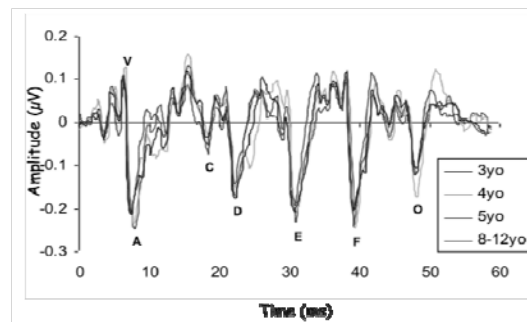
- With another signal
  - stimulus
  - response to another condition
- With itself

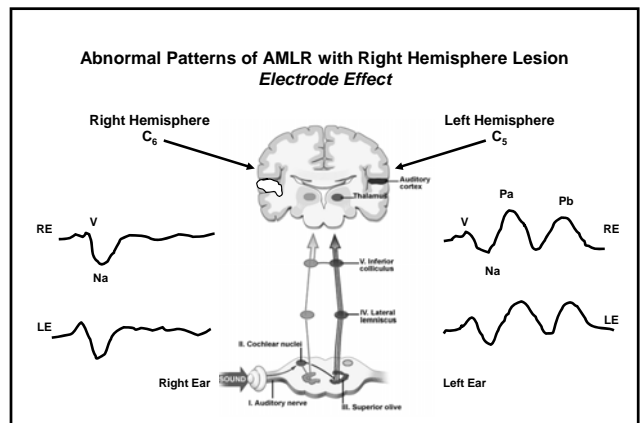
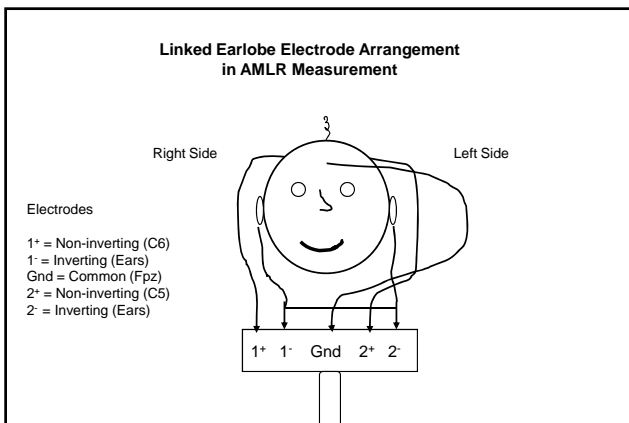
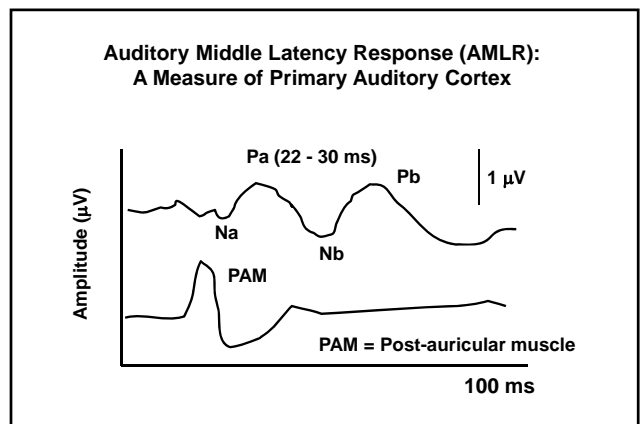
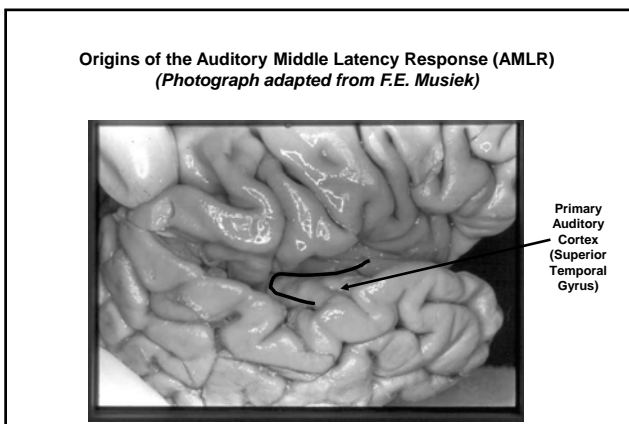
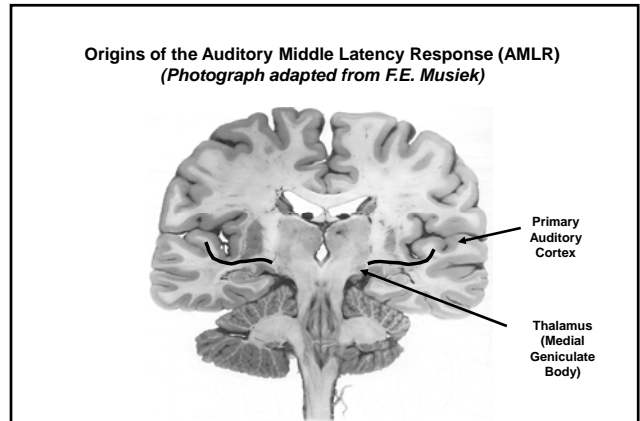
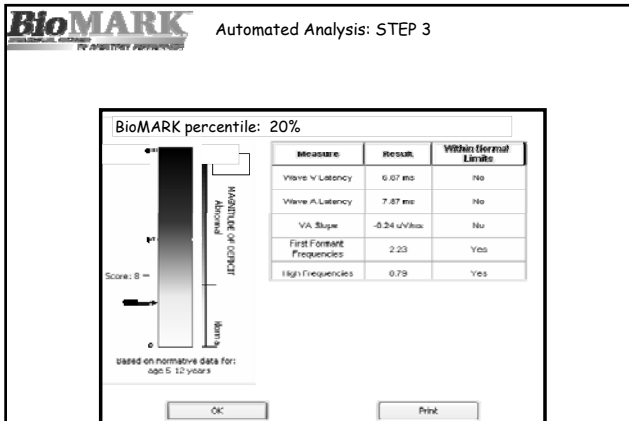
#### Frequency Composition

- Fourier Analysis



### Normative Data for Speech-Evoked ABR are Appropriate for Children Within Age Range of 3 to 12 Years: Automated Statistically Based Analysis







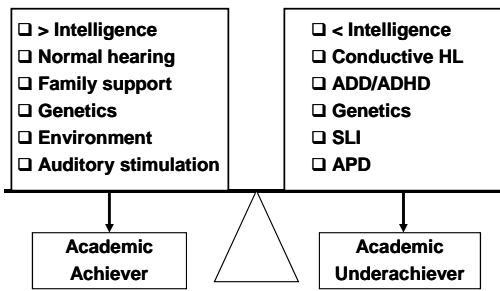
**AAA Clinical Guidelines on Auditory Processing Disorders:  
Terminology for Habilitation/Rehabilitation**

- ❑ **Intervention:** "...encompassing term referring to one or more actions taken in order to produce an effect and to alter the course of a disease, disorder, or pathological condition."
- ❑ **Treatment:** "...any specific procedure used to prevent, remediate (i.e., cure), or ameliorate a disease, disorder, or pathological condition."
- ❑ **Management:** "...refers to compensatory approaches (e.g., strategies, technologies) used to reduce the impact of deficits that are resistant to remediation."

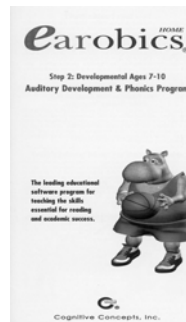
**Management Options and Strategies for APD in Adults**

- ❑ **Prevention**
  - Improved hearing protection devices
  - Improved combat headgear for military personnel
- ❑ **Counseling and advocacy**
- ❑ **Appropriate and timely referral to other professionals (recall team)**
- ❑ **Assistive technology**
  - Hearing aids
  - FM technology
  - Combination of amplification and FM technology
- ❑ **Computer-based auditory training programs**
  - Earobics
  - LACE (Listening and Communication Enhancement)
- ❑ **Other auditory training methods, e.g.,**
  - DIID (Dichotic Intensity Increment Difference) Counseling and advocacy

**AUDITORY PROCESSING DISORDERS (APDs):  
Incremental Deficits Model**



**APD MANAGEMENT: Computer-based Auditory Therapy  
(www.cogcon.com)**



Earobics comes in two versions:

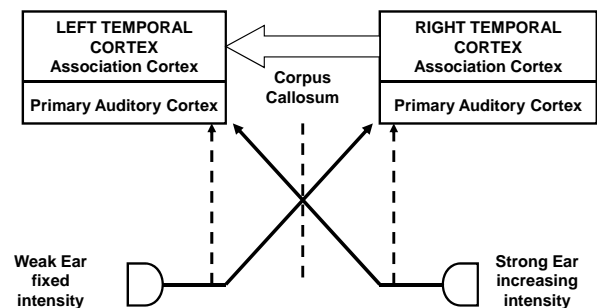
- Earobics Foundations for pre-kindergarten, kindergarten, and first grade students
- Earobics Connections for second and third grade students, and other struggling readers

Instructions available in 10 languages

**Auditory, Phonological, and Pre-Reading Skills  
Addressed by Earobics Program**

- ❑ Rhyming
- ❑ Phoneme identification
- ❑ Blending
- ❑ Segmentation
  - Ability to break word down into individual sounds
- ❑ Phonological manipulation
- ❑ Discrimination
- ❑ Auditory performance in competing noise
- ❑ Auditory sequential memory

**Dichotic Intensity Increment Difference (DIID)**



### Dichotic Intensity Increment Difference (DIID) Tasks

- Binaural separation
- Ear directed targets (monaural)
- Ear directed targets (binaural)
- Ear directed manipulations
- Ear directed judgments
- Intensity, clarity
- Materials should be a mixture of dichotic materials
  - Digits
  - Spondee words
  - Single syllable words
  - Sentences

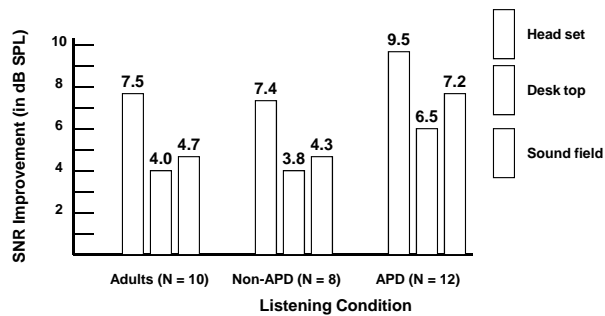
### Dichotic Intensity Increment Difference (DIID) Tasks

Deborah W. Moncrieff\*  
Diane Wertz

\* Department of Communication  
Science and Disorders, University of  
Pittsburgh, USA

*International Journal of Audiology 2008; 47:84* Auditory rehabilitation for interaural asymmetry: Preliminary evidence of improved dichotic listening performance following intensive training

SNR improvement on the HINT in normal hearing adults and children without and with APD: Three different FM system types



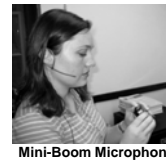
### Phonak EduLink FM System Use Improves Academic Performance and Psychosocial Status in Children with APD

Johnston, John, Kreisman, Hall & Crandell. (2009). Multiple benefits of personal FM system use by children with auditory processing disorder (APD). *International Journal of Audiology, 48*, 371 - 383

EduLink Receivers



Campus S Transmitter



Mini-Boom Microphone



### Hearing in Noise Test (HINT) Results (Mean SNR values without and with EduLink)

| Test Condition                  | Group    |          |
|---------------------------------|----------|----------|
|                                 | Control  | APD      |
| Unaided in Noise (SNR)*         | 7.9 dB   | 6.1dB    |
| Aided in Noise (SNR) **         | - 0.3 dB | - 4.2 dB |
| Advantage in Noise with EduLink | 8.2 dB   | 10.3     |

\*  $t = p < .08$ ; \*\*  $t = .002$

Typical Classroom SNR Range: +5 to -7 dB  
Markides (1986); Finitzo-Hieber (1988); Crandell and Smaldino (1995)

### BASC II Parent Report Results After EduLink Use (6 to 7 months): APD versus Control Subjects

| Domain                   | Normal Findings per Group (%) |     |
|--------------------------|-------------------------------|-----|
|                          | Control                       | APD |
| Aggression               | 92                            | 100 |
| Conduct problems         | 92                            | 100 |
| Anxiety                  | 84                            | 100 |
| Depression               | 92                            | 100 |
| Internalizing problems   | 77                            | 71  |
| Withdrawal               | 84                            | 71  |
| Attention problems       | 92                            | 29  |
| Adaptive skills          | 92                            | 71  |
| Functional communication | 92                            | 57  |

**BASC II Student Report Results After EduLink Use  
(6 to 7 months): APD versus Control Subjects**

| Domain                   | Normal Findings per Group (%) |     |
|--------------------------|-------------------------------|-----|
|                          | Control                       | APD |
| Attitude toward teachers | 100                           | 86  |
| Attitude toward school   | 100                           | 57  |
| School problems          | 100                           | 71  |
| Conduct problems         | 92                            | 100 |
| Atypicality              | 100                           | 100 |
| Anxiety                  | 100                           | 100 |
| Social stress            | 92                            | 100 |
| Depression               | 100                           | 86  |
| Internalizing problems   | 100                           | 100 |
| Sense of inadequacy      | 100                           | 86  |
| Parent relationship      | 92                            | 100 |
| Self esteem              | 100                           | 100 |

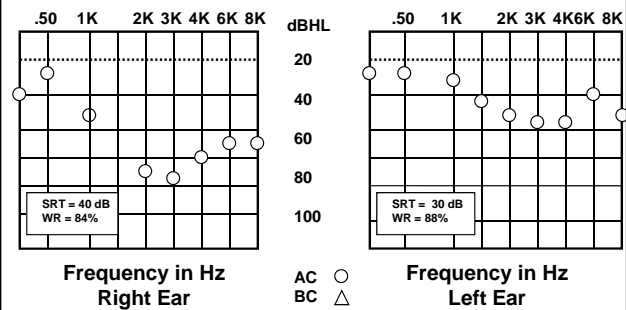
**Multiple Benefits of Personal FM System Use by Children with APD**  
(Johnston, John, Kreisman, Hall, Crandell. 2009. *International Journal of Audiology*, 48, 371-383)

- APD in school age children can have significant negative impact on:
  - Academic performance
  - Psychosocial status
  - Quality of life
- Early intervention for auditory processing deficits is indicated for all children, despite the age of identification
- The Phonak EduLink system is a feasible option for FM technology with adolescents (and persons of other ages)
- Management of APD with FM technology (enhancing the signal-to-noise ratio) improves:
  - Speech perception in noise (with EduLink FM system)
  - Academic performance
  - Psychosocial status
  - Speech perception in noise without the benefit of FM technology

**Peripheral and Central Auditory Processing Disorder in an Adult: Case Report**

- 62 year old male
- Successful lawyer in state capitol
- US Army veteran from Vietnam Conflict
  - Noise exposure as Morse code operator (with right ear)
- Perceives tinnitus in both ears
- No ear disease or pathology by otolaryngology exam and MRI
- Fit with hearing aids bilaterally (Phonak) at VAMC
- Experiencing considerable difficulty understanding speech in everyday listening settings

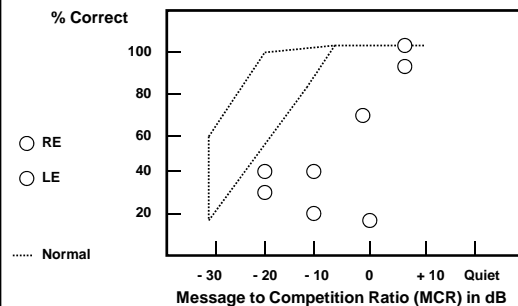
**Peripheral and Central Auditory Dysfunction: Case Report  
Initial Audiogram**



**Peripheral and Central Auditory Processing Disorder in an Adult: Case Report  
Tinnitus Evaluation**

- Ringing tinnitus in both ears, but mostly in right ear
- Threshold for BBN
  - Right ear: 25 dB
  - Left ear: 25 dB
- Pitch matched to 4000 Hz NBN
- Loudness matched to + 0 dB SL
- Tinnitus "masked" with BBN of:
  - 65 dB HL to left ear
  - 65 dB HL to right ear
  - 60 dB HL binaurally
- Tinnitus Handicap Inventory (THI)
  - ✓ Total score = 38

**Case Report: Synthetic Sentence Identification with Ipsilateral Competing Message (SSI-ICM)**



### Peripheral and Central Auditory Processing Disorder in an Adult: Case Report

| Test       | Findings (Sound Field) |
|------------|------------------------|
| HINT       |                        |
| +20 dB SNR | 100%                   |
| +10 dB SNR | 79%                    |
| +5 dB SNR  | 74%                    |
| 0 dB SNR   | 33%                    |
| -5 dB SNR  | 17%                    |

### Peripheral and Central Auditory Processing Disorder in an Adult: Case Report Counseling and Management

- Explained hearing test results
  - Noted central auditory dysfunction
- Described mechanisms of tinnitus
- Described tinnitus evaluation results, with emphasis how:
  - “Soft” the tinnitus is (0 dB!)
  - Tinnitus may be enhanced by stress in communicating in work settings due to extreme difficulty with speech perception in background noise
  - FM technology coupled with amplification would be an effective management of his tinnitus and hearing

### Auditory Processing Disorders (APD) Adults with Traumatic Brain Injury: Conclusions

- Multiple adult patient populations are at risk for auditory processing disorder (APD)
- APD may be a component of neurological, psychiatric, and degenerative disorders, e.g.,
  - Parkinson's Disease
  - Alzheimer's dementia
  - Schizophrenia
- APD can be identified and diagnosed in adults, even those with peripheral hearing loss
- Peripheral and central auditory dysfunction may interact dynamically, and in combination contribute to serious communication impairment
- Management options are available for adult patients with APD