Clinical Guidelines for Assessment and Management of Auditory Processing Disorders (APD) in Children and Adults

James W. Hall III, Ph.D.
Clinical Professor
Department of Speech, Language and Hearing Sciences
College of Public Health and Health Professions
University of Florida
Gainesville, Florida
and
Extraordinary Professor
University of Pretoria
South Africa

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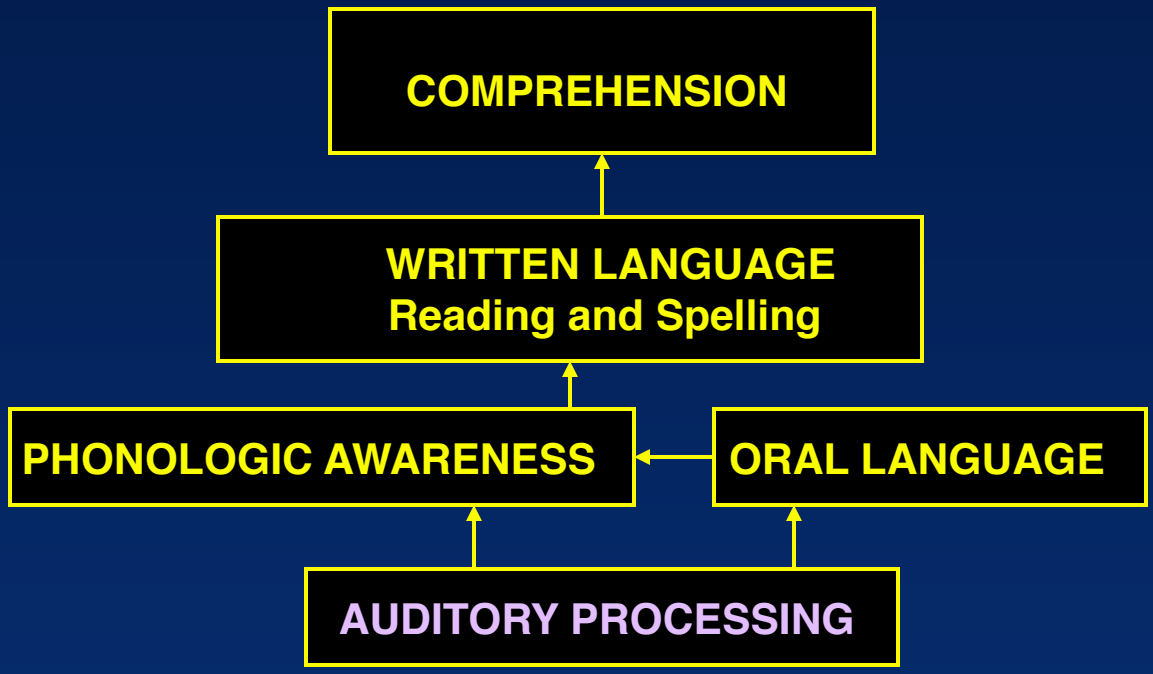
- Definition of APD … why is it important?
- Historical perspective … interest in APD dates back over 50 years
- Neuroscience foundation for APD
- Disorders often co-existing with APD
- Risk factors for APD
- Current and future assessment strategies and procedures
- Effective management strategies and procedures

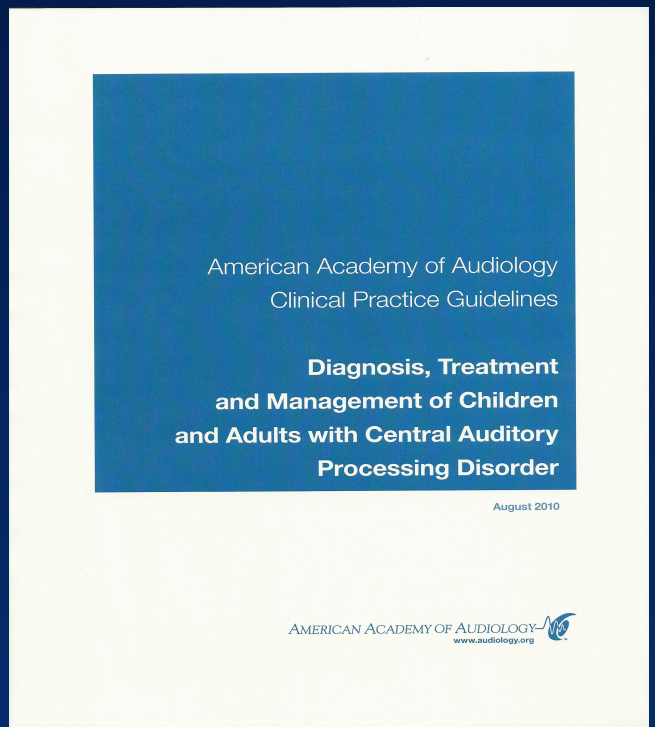
AUDITORY PROCESSING:
Cornerstone of Language and Literacy (Reading)



Definitions of Auditory Processing Disorders (APD)

- "APD is broadly defined as a deficit in the processing of information that is specific to the auditory modality."
  (Bruton Conference in Dallas, 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, 2010)

AAA Clinical Guidelines on Auditory Processing Disorders *(www.audiology.org)*



Consequences of Late Identification of APD

- Reading failure
- Academic failure
- Psychosocial problems
  - Behavioral Assessment System for Children, Volume II (BASC-II)
    - ✓ A profile of adaptive and maladaptive behaviors and emotions of children and adolescents.
  - Children with APD are at risk for or have clinically significant evidence of
    - ✓ Externalizing problems (e.g., aggression, conduct problems)
    - ✓ Internalizing problems (e.g., anxiety, depression)
    - ✓ Behavioral symptoms index (e.g., withdrawal)
    - ✓ Adaptive skills (e.g., social skills, functional communication)
- May require long-term remediation
  - Increased cost and decreased benefit versus early identification and intervention

AAA Clinical Guidelines on Auditory Processing Disorders *(www.audiology.org)*

- Executive summary & Introduction
- Patient History and Selection Criteria
  - Age considerations
  - Cognitive abilities
  - Language status and proficiency
  - Speech intelligibility
  - Peripheral hearing loss

AAA Clinical Guidelines on Auditory Processing Disorders *(www.audiology.org)*

- Diagnosis (Bellis & Hall)
  - Introduction (discussion of evidence grades)
  - Minimum age for testing
  - Speech versus non-speech test stimuli
  - Efficiency and test performance
  - Behavioral tests
  - Auditory electrophysiological tests
  - Interpretation of (C) APD test results
- Intervention

AAA Clinical Guidelines on Auditory Processing Disorders *(www.audiology.org)*

- Intervention
  - Intervention components
    - ✓ Bottom up approaches
    - ✓ Top down approaches
  - Multidisciplinary team
  - Determining goals and documenting improvement
  - Intervention principles
  - Auditory training
  - Individualizing intervention
  - Sources of materials for intervention
  - Alternative sound-based programs
- Professional Issues, Training, and Education

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Carlo Calearo, M.D.
Otorhinolaryngologist
"Italian Pioneer in APD Assessment"

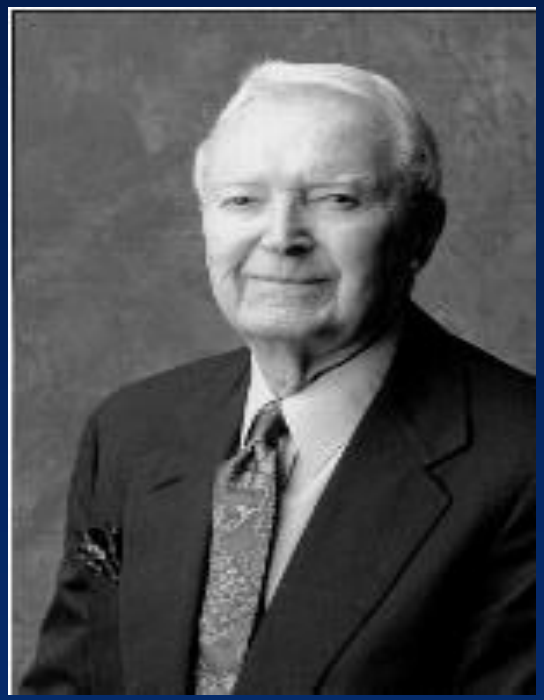
Bocca E, Calearo C, Cassinari V.
A new method for testing hearing in temporal lobe tumors.
***Acta Otolaryngologica* 44: *1954*.**

Helmer Myklebust, Ph.D. (in psychology)
Northwestern University
"Pioneer in APD Assessment"

Myklebust HR. Auditory disorders in children: A manual for differential diagnosis. New York: Grune & Stratton, 1954.

"hearing is a receptive sense … and essential for normal language behavior" (p. 11)

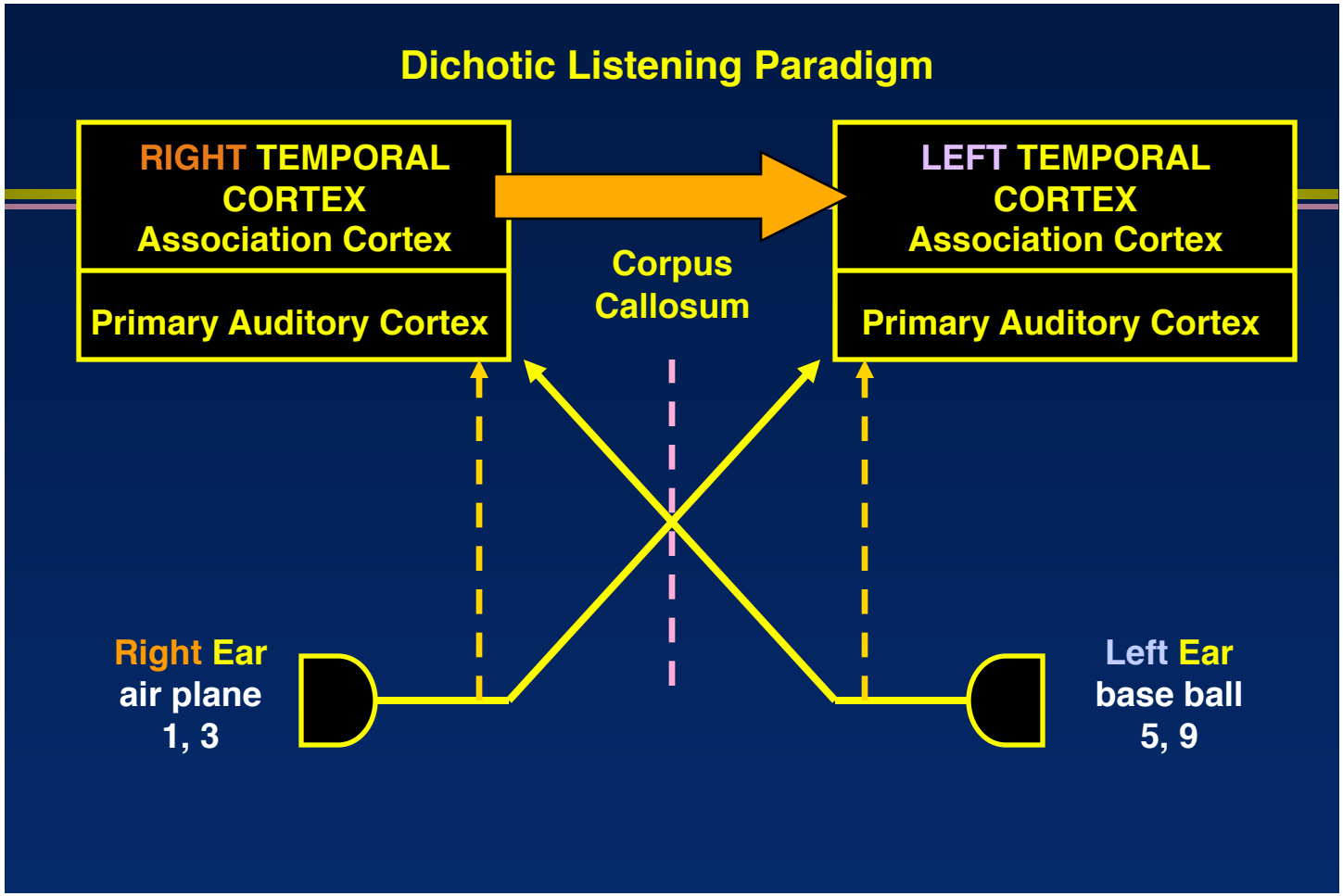
"the diagnostician of auditory problems in children has traditionally emphasized peripheral damage. It is desirable that he (sic) also include central damage." (p. 54)



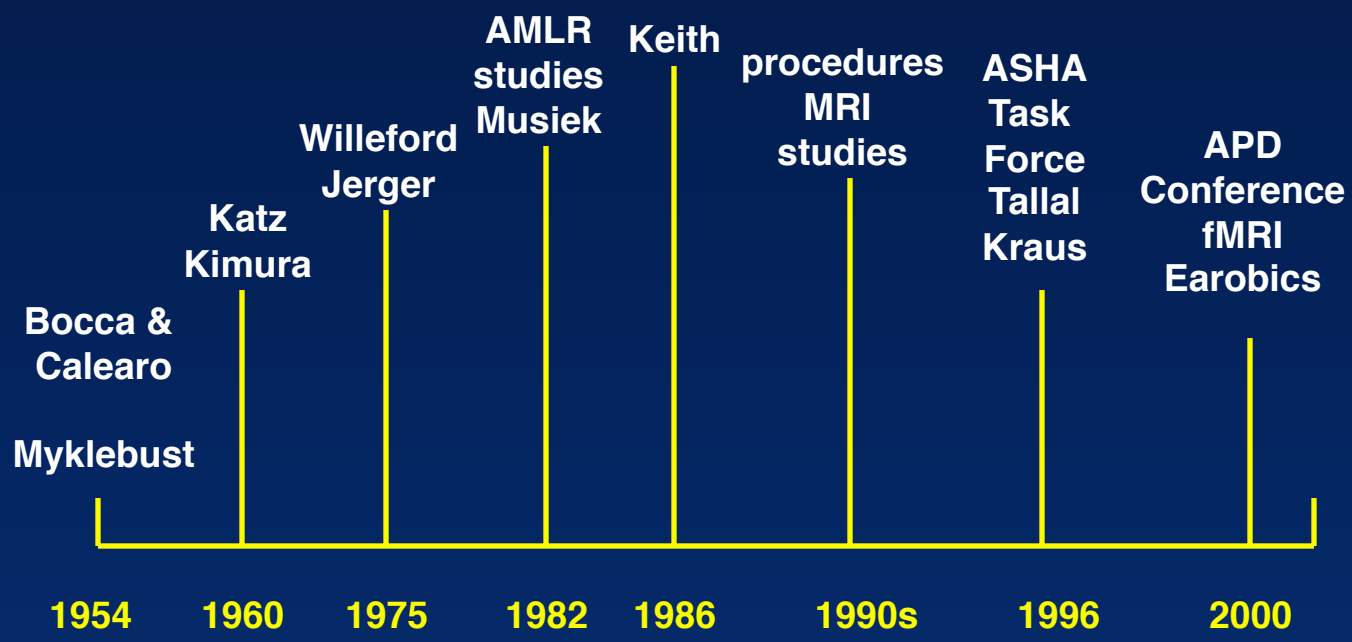
Dichotic Listening Paradigm … A long-standing test strategy for assessment of auditory processing

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

1961: Canadian Psychologist
Doreen Kimura, Ph.D.


Dichotic Listening Paradigm
RIGHT TEMPORAL CORTEX
Association Cortex
Primary Auditory Cortex
Corpus Callosum
LEFT TEMPORAL CORTEX
Association Cortex
Primary Auditory Cortex
Right Ear
air plane
1, 3
Left Ear
base ball
5, 9

Development of APD Assessment & Management: Principles & Procedures



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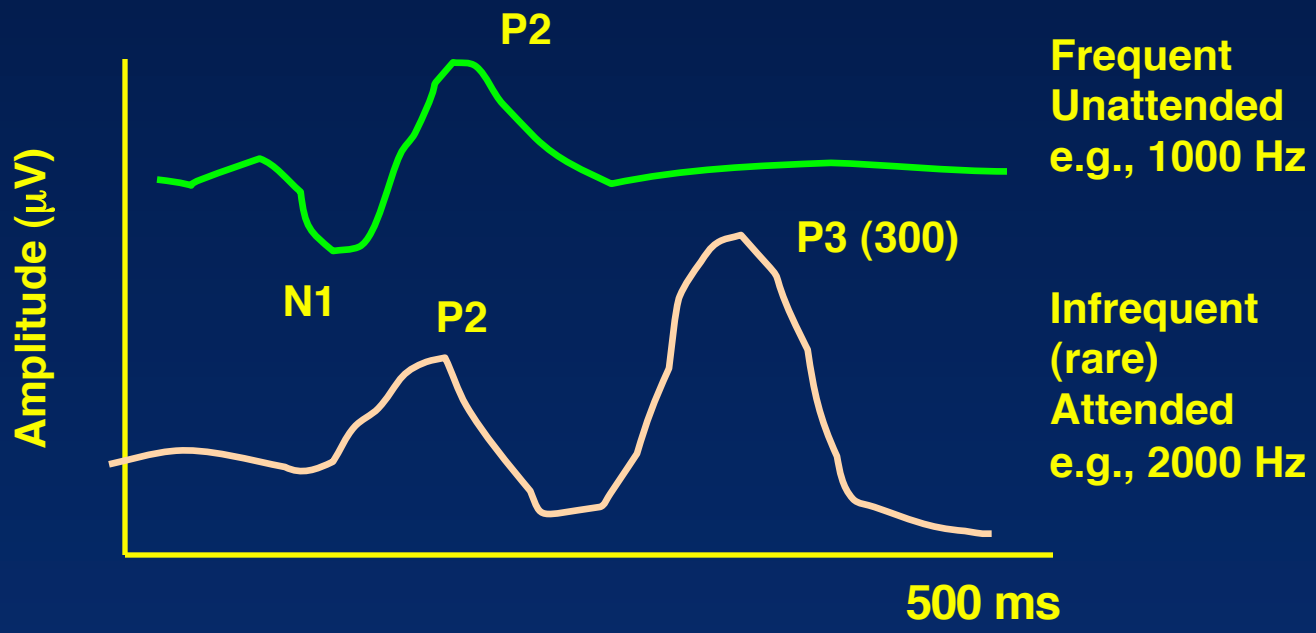
Basic neuroscience advances in the decade of the brain (1990s) impacted understanding of APD

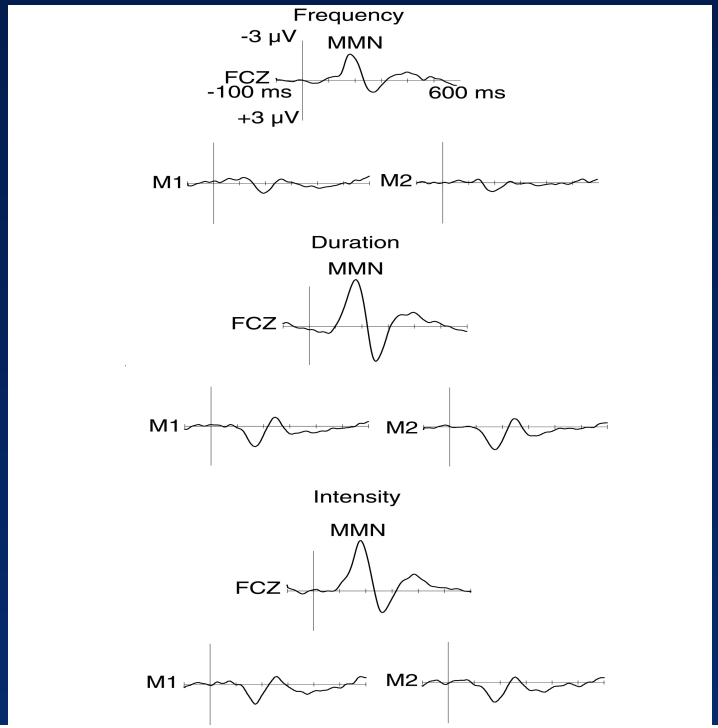
- Different regions mature at different rates
  - Maturation occurs along caudal to rostral gradient
- Development of auditory pathways and centers involves
  - Cell differentiation and migration
  - Myelination
  - Arborization
  - Synaptogenesis
- Consistent and typical auditory stimulation (experience) 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 Late Response and P300 Response



Mismatch Negativity (MMN) Response:
"Unconcious Brain Response Elicited by Different Properties of Sound

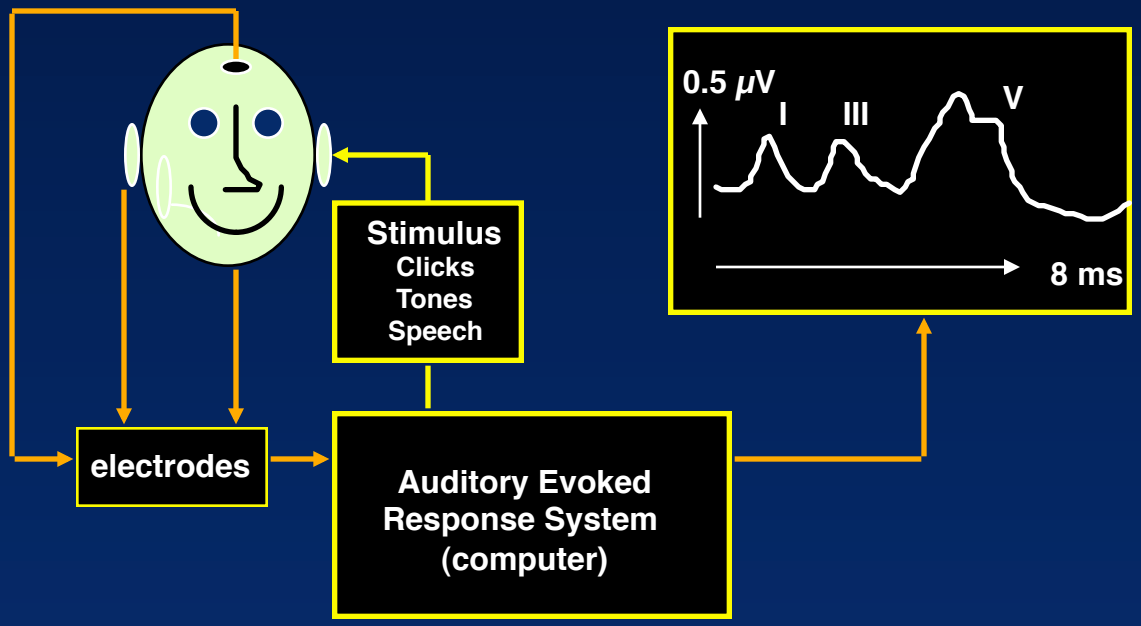
(Courtesy of Catharine Pettigrew, Ph.D.)



MISMATCH NEGATIVITY (MMN) RESPONSE: Investigations in clinical populations

- Assessment of infant speech perception, including children at risk for disorders, e.g., language *(e.g., Leppanen & Lyytinen, 1997)*
- Hearing aid fitting of infants and young children with speech signals *(e.g., Kraus, et al)*
- Cochlear implant fitting infants and young children with speech signals *(e.g., Kraus, et al)*
- Documentation of auditory training and language treatment *(e.g., Kujala et al, 2001)*
- Description of Alzheimer's disease *(e.g., Pekkonen et al, 1994)*
- Electrophysiologic documentation of attention deficit hyperactivity disorder *(e.g., Barry, Johnstone, Clarke, 2003)*
- Prognosis of recovery from coma *(e.g., Kane et al, 1993)*
- Diagnosis of frontal and auditory temporal lobe dysfunction in schizophrenia *(e.g., Michie et al, 2000)*
- Neurophysiologic documentation of auditory processing disorder (APD) and dyslexia in children

Auditory Brainstem Response (ABR)



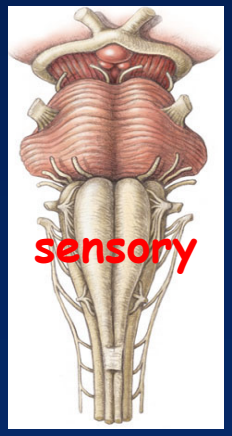
Auditory Processing Deficits in Language Learning and Reading: Neurophysiological Evidence from Northwestern University

- 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.
- Banai 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

experience-dependence

cognitive



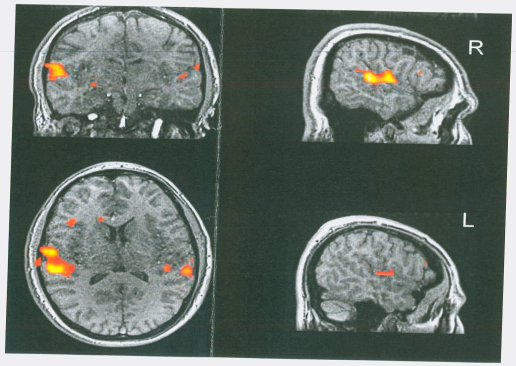
sensory

fidelity to the stimulus

Neuroscience Evidence for APD: Functional Neuro-Imaging (fMRI)

(18 y.o. APD Patient with Right Ear Dichotic Deficit)

Fig. 2 Sectional Views of Activation Maps Superimposed on T1W Images



Patient:
DOB:
Date of I

Exam: Functional MRI to identify auditory area

Task: Listening and repeat the words.

Paradigm: Block (4on/5off, 30 sec/blk)

"fMRI" and "Auditory" Medline Citations: *Thousands of Peer Reviewed Articles*

- Bernal B, Altman NR, Medina LS. Dissecting nonverbal auditory cortex asymmetry: an fMRI study. Int J Neurosci. 2004 May;114(5):661-80
- Rowan A, Liegeois F, Vargha-Khadem F, Gadian D, Connelly A, Baldeweg T. Cortical lateralization during verb generation: a combined ERP and fMRI study. Neuroimage. 2004 Jun;22(2):665-75.
- Okada T, Honda M, Okamoto J, Sadato N. Activation of the primary and association auditory cortex by the transition of sound intensity: a new method for functional examination of the auditory cortex in humans. Neurosci Lett. 2004 Apr 8;359(1-2):119-23.
- Blau V, van Atteveldt N, Ekkebus M, Goebel R, Blomert L. Reduced Neural Integration of Letters and Speech Sounds Links Phonological and Reading Deficits in Adult Dyslexia. Curr Biol. 2009 Mar 11.
- Leff AP, Iverson P, Schofield TM, Kilner JM, Crinion JT, Friston KJ, Price CJ. Vowel-specific mismatch responses in the anterior superior temporal gyrus: An fMRI study. Cortex. 2009 Apr;45(4):517-26. Epub 2008 Feb 7.
- Warrier C, Wong P, Penhune V, Zatorre R, Parrish T, Abrams D, Kraus N. Relating structure to function: Heschl's gyrus and acoustic processing. J Neurosci. 2009 Jan 7;29 (1):61-9.

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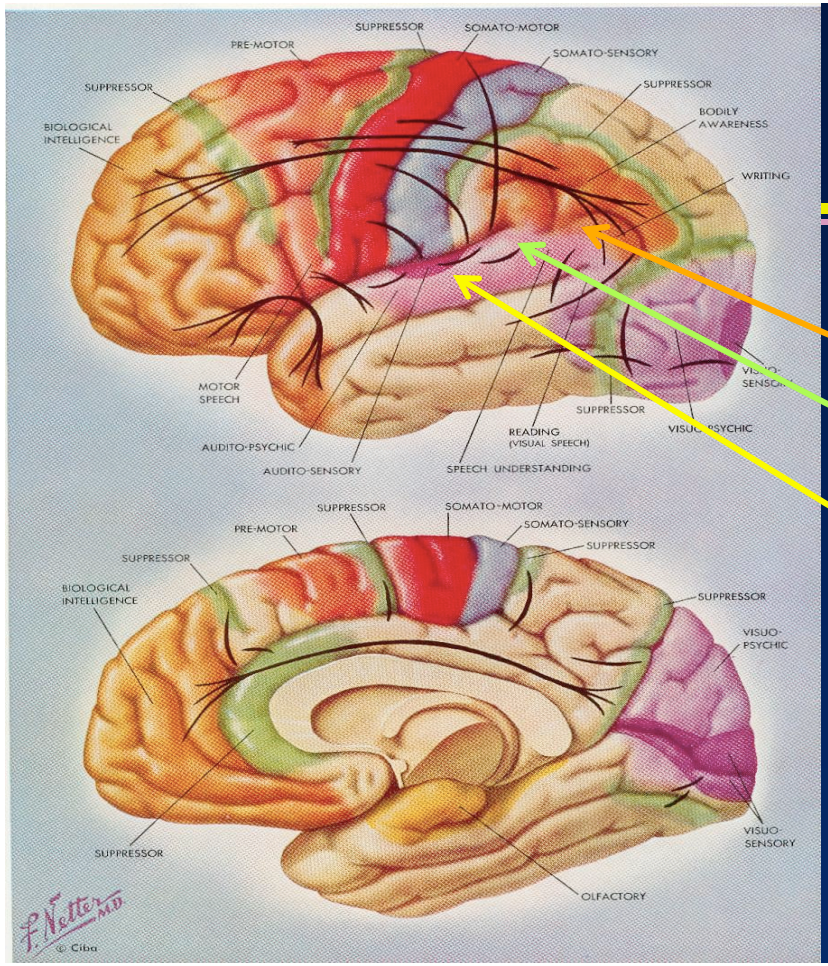
Auditory Processing Disorders: Differential Diagnosis

"**Differential Diagnosis:**

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



Shared Anatomy

Reading

Language

Auditory processing

AUDITORY PROCESSING DISORDERS: Co-existing Disorders (Co-morbidity)

- Peripheral (conductive and sensory) hearing loss
  - Common in older adults and patients with TBI
- Specific language impairment (SLI)
- Learning disabilities (LDs)
- Reading disorders (dyslexia)
- Attention deficit/hyperactivity disorder (ADHD)
- Emotional and psychological disorders
- Developmental delay
- Seizure disorders
- Autism spectrum disorders

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APD:
Screening and Assessment in Pre-School Children

Risk Factors for APD: Team Work in Identification and Assessment

- Neurological dysfunction and disorders *(physicians)*, e.g.,
  - neonatal risk factors (e.g., asphyxia, CMV)
  - head injury
  - seizure disorders
- Chronic otitis media in preschool years *(otolaryngologists)*
- Academic underachievement or failure *(teachers and educational psychologists)*
- Family history of academic underachievement *(parents)*
- Co-existing disorders *(multiple professionals)*

Auditory Processing Disorders: Indicators in Early School Age Population and Screening for At Risk Children

S.I.F.T.E.R.

SCREENING INSTRUMENT FOR TARGETING EDUCATIONAL RISK

by Karen L. Anderson, Ed.S., CCC-A

STUDENT _____ TEACHER _____ GRADE _____

DATE COMPLETED _____ SCHOOL _____ DISTRICT _____

The above child is suspect for hearing problems which may or may not be affecting his/her school performance. This rating scale has been designed to sift out students who are educationally at risk possibly as a result of hearing problems.

Based on your knowledge from observations of this student, circle the number best representing his/her behavior. After answering the questions, please record any comments about the student in the space provided on the reverse side.

1. What is your estimate of the student's class standing in comparison of that of his/her classmates?	UPPER 5	4	MIDDLE 3	2	LOWER 1				ACADEMICS	☐
2. How does the student's achievement compare to your estimation of her/her potential?	EQUAL 5	4	LOWER 3	2	MUCH LOWER 1					
3. What is the student's reading level, reading ability group or reading readiness group in the classroom (e.g., a student with average reading ability performs in the middle group)?	UPPER 5	4	MIDDLE 3	2	LOWER 1					
4. How distractible is the student in comparison to his/her classmates?	NOT VERY 5	4	AVERAGE 3	2	VERY 1				ATTENTION	☐
5. What is the student's attention span in comparison to that of his/her classmates?	LONGER 5	4	AVERAGE 3	2	SHORTER 1					
6. How often does the student hesitate or become confused when responding to oral directions (e.g., "Turn to page . . .")?	NEVER 5	4	OCCASIONALLY 3	2	FREQUENTLY 1					
7. How does the student's comprehension compare to the average understanding ability of her/her classmates?	ABOVE 5	4	AVERAGE 3	2	BELOW 1				COMMUNICATION	☐
8. How does the student's vocabulary and word usage skills compare with those of other students in his/her age group?	ABOVE 5	4	AVERAGE 3	2	BELOW 1					
9. How proficient is the student at telling a story or relating happenings from home when compared to classmates?	ABOVE 5	4	AVERAGE 3	2	BELOW 1					
10. How often does the student volunteer information to class discussions or in answer to teacher questions?	FREQUENTLY 5	4	OCCASIONALLY 3	2	NEVER 1				CLASS PARTICIPATION	☐
11. With what frequency does the student complete his/her class and homework assignments within the time allocated?	ALWAYS 5	4	USUALLY 3	2	SELDOM 1					
12. After instruction, does the student have difficulty starting to work (looks at other students working or asks for help)?	NEVER 5	4	OCCASIONALLY 3	2	FREQUENTLY 1					
13. Does the student demonstrate any behaviors that seem unusual or inappropriate when compared to other students?	NEVER 5	4	OCCASIONALLY 3	2	FREQUENTLY 1				SCHOOL BEHAVIOR	☐
14. Does the student become frustrated easily, sometimes to the point of losing emotional control?	NEVER 5	4	OCCASIONALLY 3	2	FREQUENTLY 1					
15. In general, how would you rank the student's relationship with peers (ability to get along with others)?	GOOD 5	4	AVERAGE 3	2	POOR 1					

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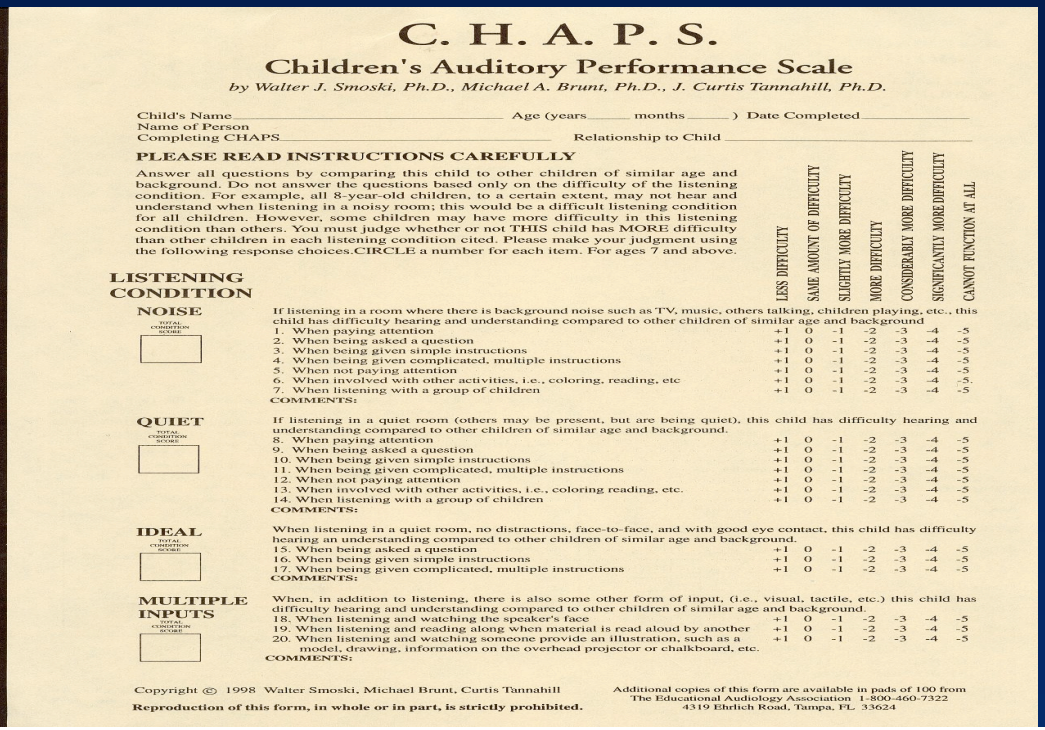
The Educational Audiology Association 1-800-460-7322
4319 Ehrlich Rd., Tampa, FL 33624
ISBN 0-8134-2845-9

Auditory Processing Disorders: Indicators in Early School Age Population and Screening for At Risk Children



C. H. A. P. S.

Children's Auditory Performance Scale

by Walter J. Smoski, Ph.D., Michael A. Brunt, Ph.D., J. Curtis Tannahill, Ph.D.

Child's Name _____ Age (years_____ months_____) Date Completed _____
Name of Person
Completing CHAPS _____ Relationship to Child _____

PLEASE READ INSTRUCTIONS CAREFULLY

Answer all questions by comparing this child to other children of similar age and background. Do not answer the questions based only on the difficulty of the listening condition. For example, all 8-year-old children, to a certain extent, may not hear and understand when listening in a noisy room; this would be a difficult listening condition for all children. However, some children may have more difficulty in this listening condition than others. You must judge whether or not THIS child has MORE difficulty than other children in each listening condition cited. Please make your judgment using the following response choices.CIRCLE a number for each item. For ages 7 and above.

LISTENING CONDITION	LESS DIFFICULTY	SAME AMOUNT OF DIFFICULTY	SLIGHTLY MORE DIFFICULTY	MORE DIFFICULTY	CONSIDERABLY MORE DIFFICULTY	SIGNIFICANTLY MORE DIFFICULTY	CANNOT FUNCTION AT ALL
NOISE TOTAL CONDITION SCORE ____	If listening in a room where there is background noise such as TV, music, others talking, children playing, etc., this child has difficulty hearing and understanding compared to other children of similar age and background						
1. When paying attention	+1	0	-1	-2	-3	-4	-5
2. When being asked a question	+1	0	-1	-2	-3	-4	-5
3. When being given simple instructions	+1	0	-1	-2	-3	-4	-5
4. When being given complicated, multiple instructions	+1	0	-1	-2	-3	-4	-5
5. When not paying attention	+1	0	-1	-2	-3	-4	-5
6. When involved with other activities, i.e., coloring, reading, etc	+1	0	-1	-2	-3	-4	-5
7. When listening with a group of children	+1	0	-1	-2	-3	-4	-5
COMMENTS:							
QUIET TOTAL CONDITION SCORE ____	If listening in a quiet room (others may be present, but are being quiet), this child has difficulty hearing and understanding compared to other children of similar age and background.						
8. When paying attention	+1	0	-1	-2	-3	-4	-5
9. When being asked a question	+1	0	-1	-2	-3	-4	-5
10. When being given simple instructions	+1	0	-1	-2	-3	-4	-5
11. When being given complicated, multiple instructions	+1	0	-1	-2	-3	-4	-5
12. When not paying attention	+1	0	-1	-2	-3	-4	-5
13. When involved with other activities, i.e., coloring reading, etc.	+1	0	-1	-2	-3	-4	-5
14. When listening with a group of children	+1	0	-1	-2	-3	-4	-5
COMMENTS:							
IDEAL TOTAL CONDITION SCORE ____	When listening in a quiet room, no distractions, face-to-face, and with good eye contact, this child has difficulty hearing an understanding compared to other children of similar age and background.						
15. When being asked a question	+1	0	-1	-2	-3	-4	-5
16. When being given simple instructions	+1	0	-1	-2	-3	-4	-5
17. When being given complicated, multiple instructions	+1	0	-1	-2	-3	-4	-5
COMMENTS:							
MULTIPLE INPUTS TOTAL CONDITION SCORE ____	When, in addition to listening, there is also some other form of input, (i.e., visual, tactile, etc.) this child has difficulty hearing and understanding compared to other children of similar age and background.						
18. When listening and watching the speaker's face	+1	0	-1	-2	-3	-4	-5
19. When listening and reading along when material is read aloud by another	+1	0	-1	-2	-3	-4	-5
20. When listening and watching someone provide an illustration, such as a model, drawing, information on the overhead projector or chalkboard, etc.	+1	0	-1	-2	-3	-4	-5
COMMENTS:							

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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 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

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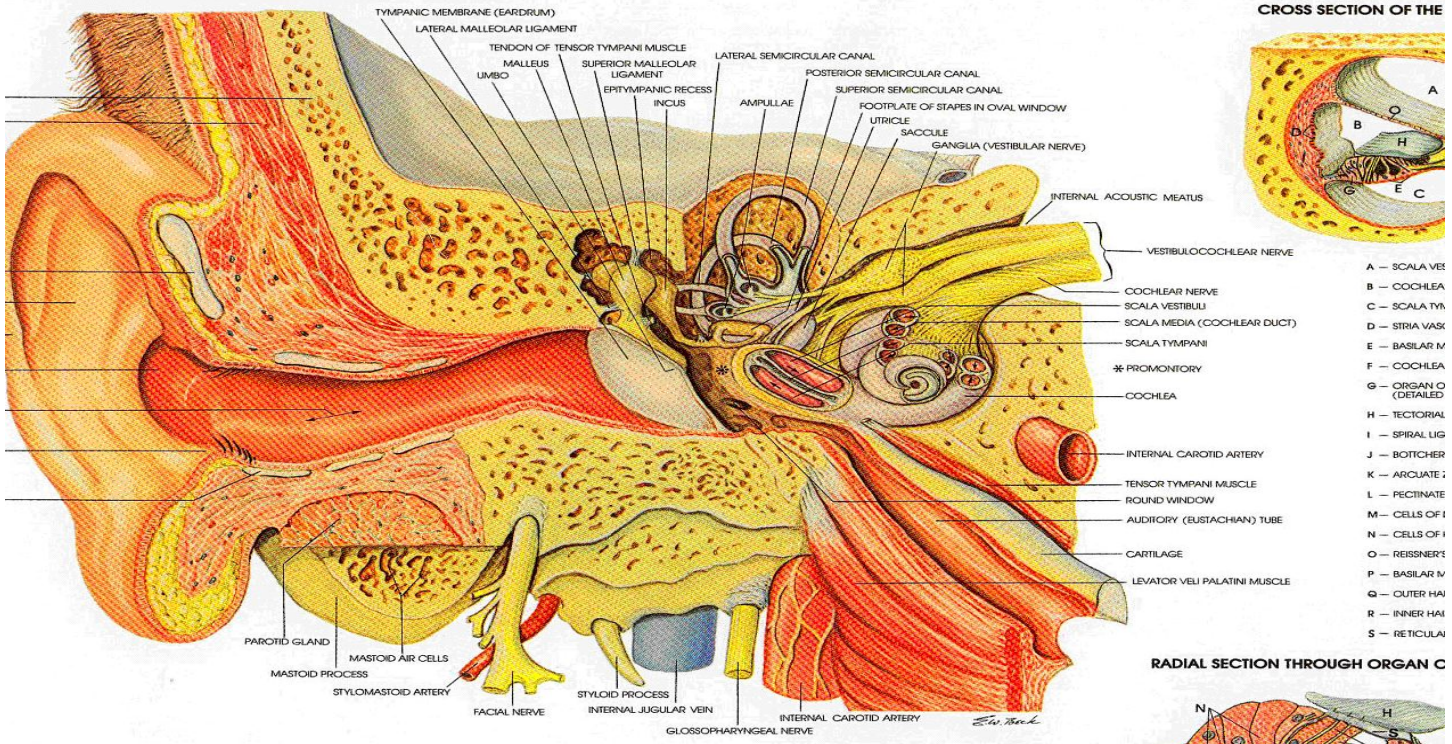
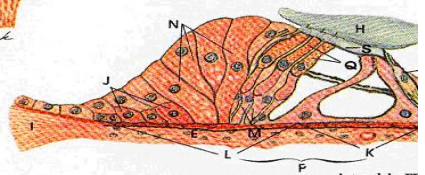


CROSS SECTION OF THE

A — SCALA VES
B — COCHLEA
C — SCALA TYM
D — STRIA VASC
E — BASILAR M
F — COCHLEA
G — ORGAN O (DETAILED
H — TECTORIAL
I — SPIRAL LIG
J — BOTTCHER
K — ARCUATE
L — PECTINATE
M — CELLS OF
N — CELLS OF
O — REISSNER'S
P — BASILAR M
Q — OUTER HA
R — INNER HA
S — RETICULA

RADIAL SECTION THROUGH ORGAN C



Artwork by E

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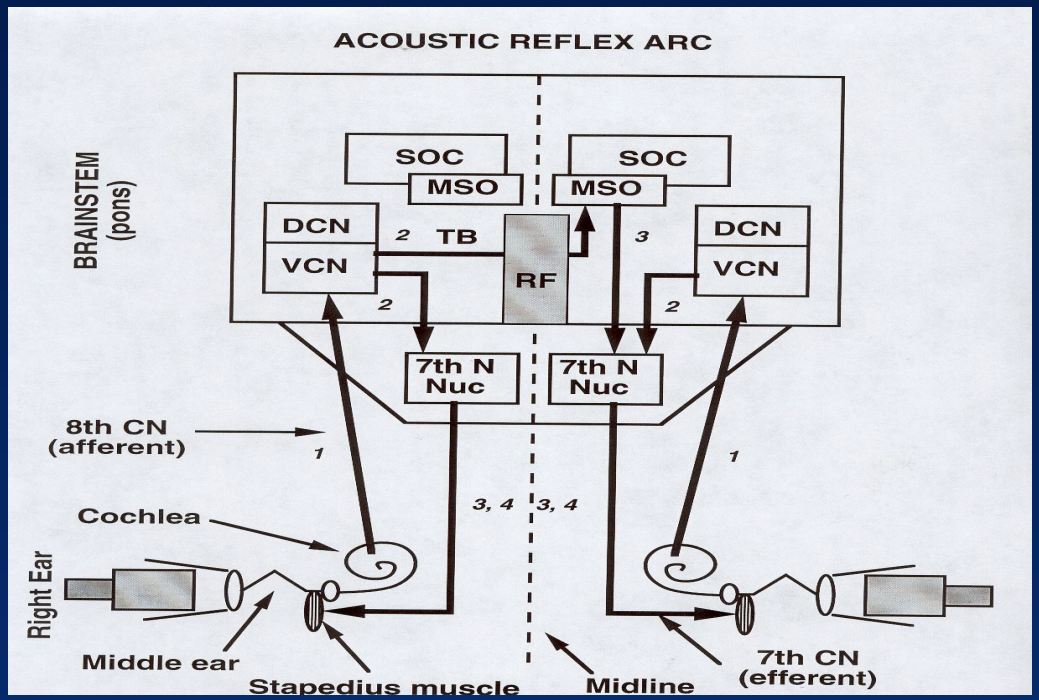
Assessment of APD: Peripheral Test Battery (< 20 minutes)

- Otoacoustic emissions (OAEs)
  - Diagnostic protocol, e.g.,
    - ✓ 500 to 8000 Hz
    - ✓ ≥ 5 frequencies per octave
  - OAEs are abnormal in 35% of children undergoing APD assessment
- Aural immittance measures
  - Tympanometry
  - Acoustic reflexes
    - ✓ *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)
- Speech audiometry
  - Word recognition (use CD materials with 10 most difficult words first)

Tympanometry and Acoustic Reflex Measurement: Objective Information on Peripheral Auditory System and Auditory Brainstem

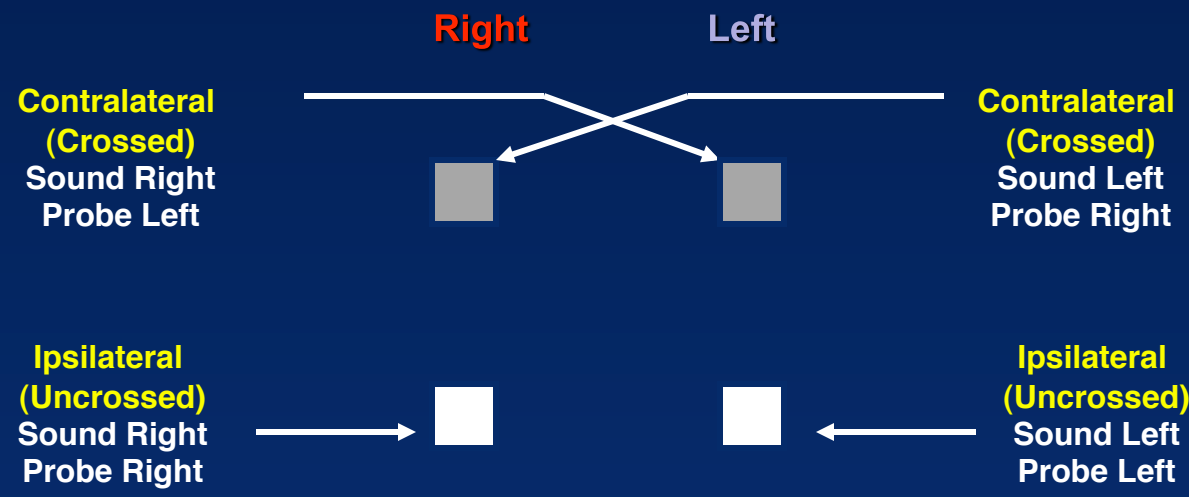


Acoustic Reflex Confirmation of Central Auditory Nervous System Dysfunction

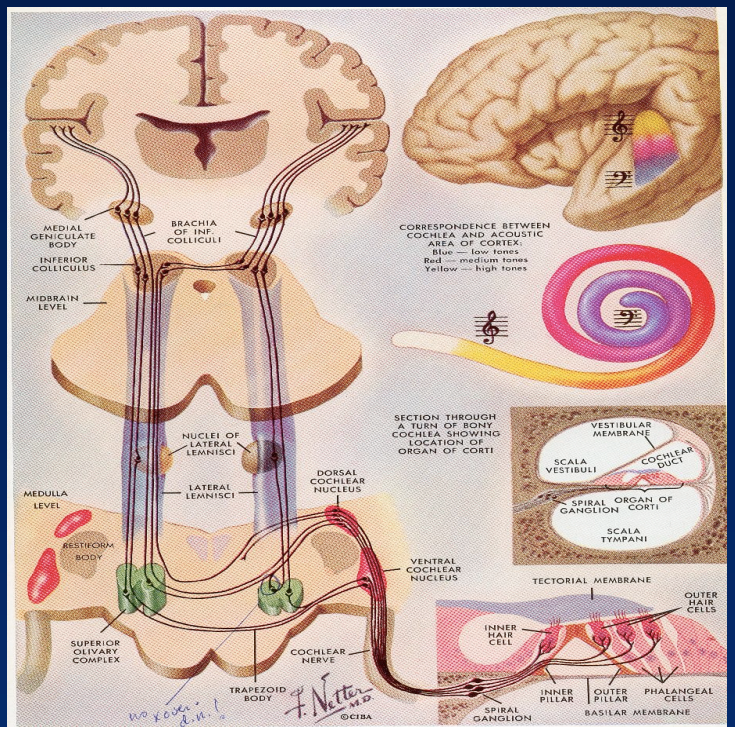
Abnormal Acoustic Reflex

Horizontal pattern

- Brainstem auditory dysfunction

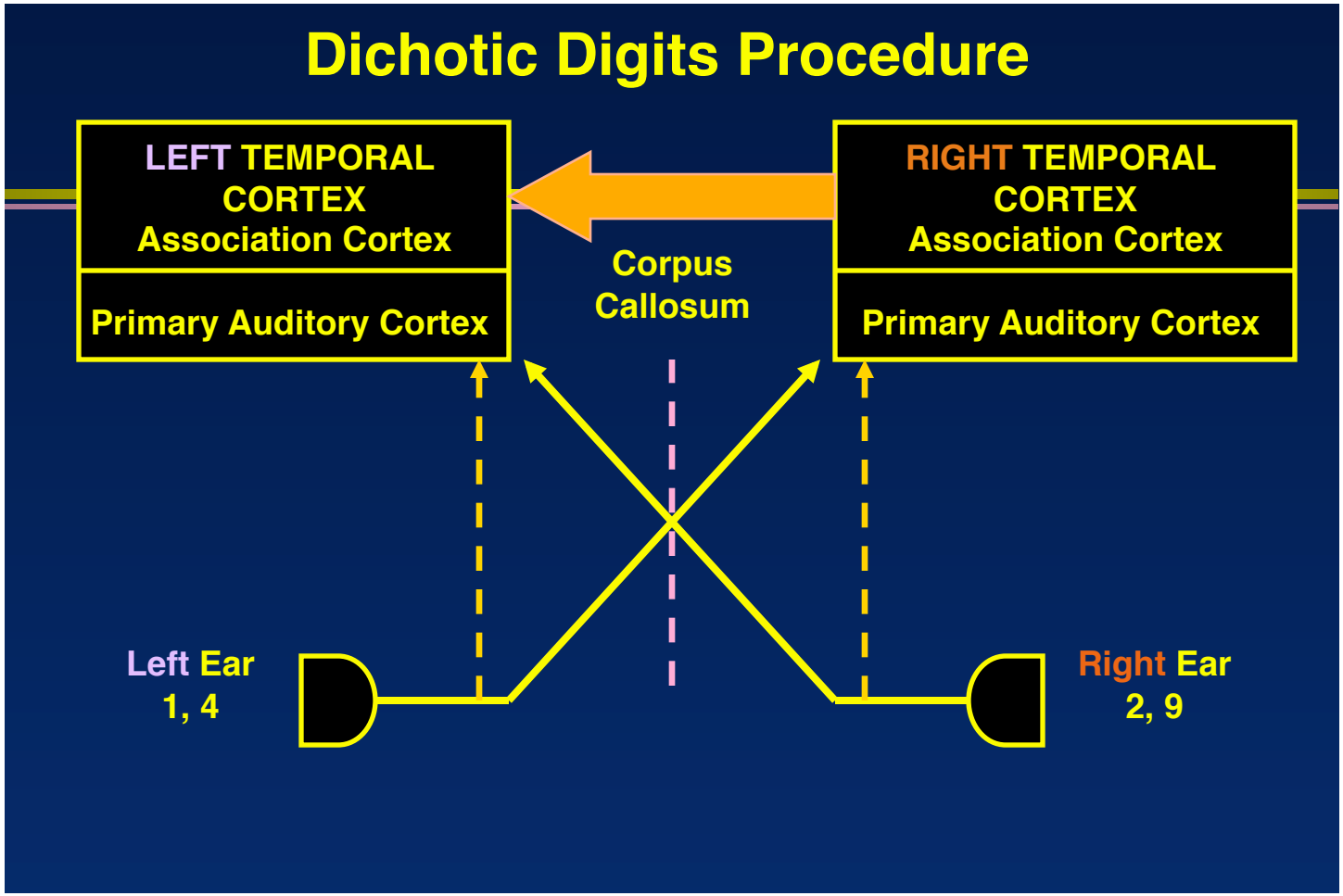


Assessment of APD:
Central Auditory Test Battery (~ 80 minutes)



APD ASSESSMENT:
Behavioral Test Battery for Auditory Processes (1)
(ASHA, 2005; AAA, 2010)

- **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 Digits Procedure
LEFT TEMPORAL CORTEX
Association Cortex
Primary Auditory Cortex
Corpus Callosum
RIGHT TEMPORAL CORTEX
Association Cortex
Primary Auditory Cortex
Left Ear
1, 4
Right Ear
2, 9

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)

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: Creative Non-Verbal Test Procedures and Protocols … the LISN-S

- 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

APD ASSESSMENT:
Additional Components of Test Battery (as indicated)

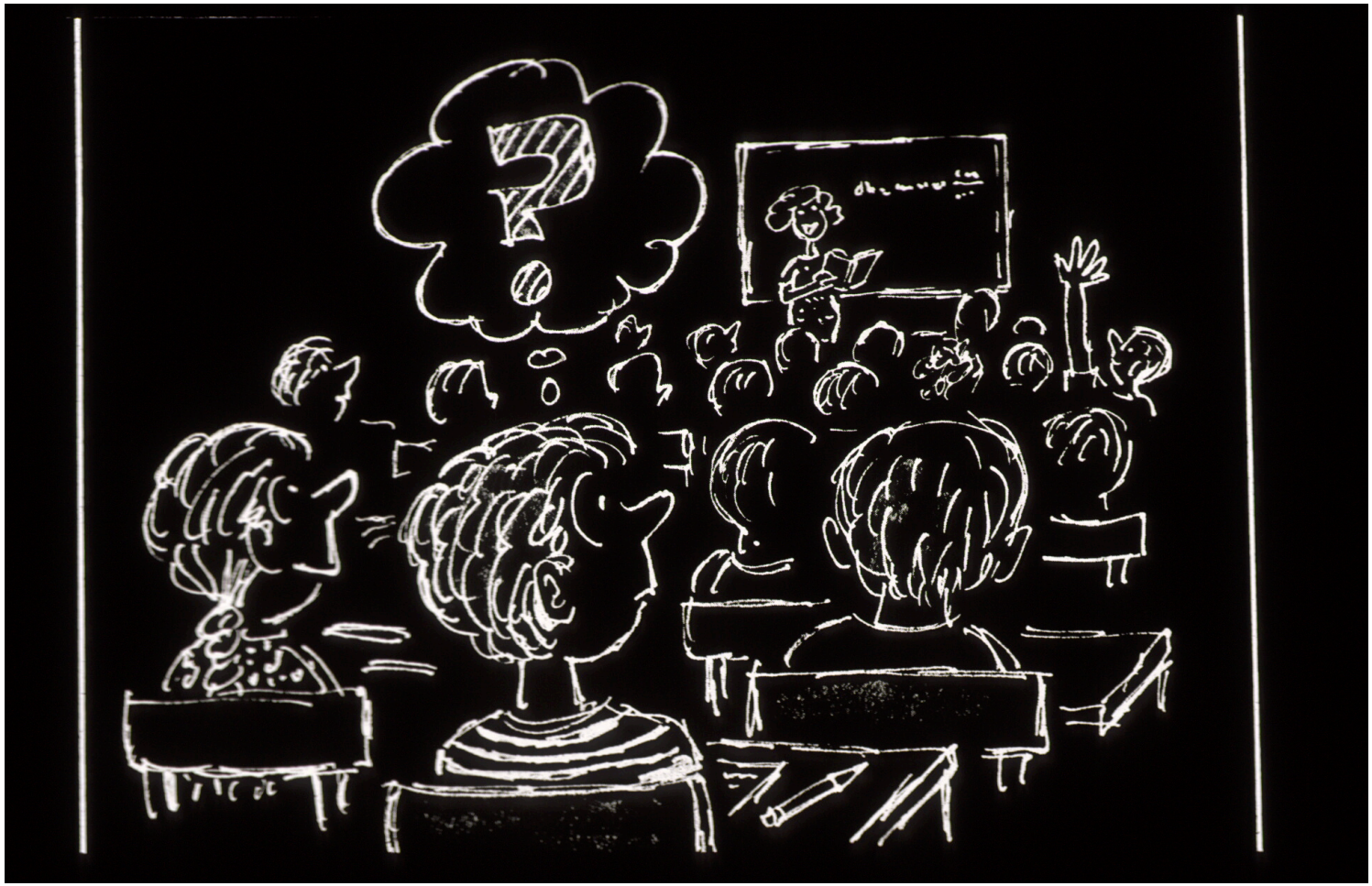
- Auditory Continuous Performance Test (ACPT)
  - developed by Robert Keith
  - for children with suspected or diagnosed AD/HD
  - rapid presentation of words
  - task is to respond to target word "dog" only
  - analog to visual continuous performance tests
- Screening of phonologic awareness skills
  - Phonemic synthesis test
    - ✓ developed Jack Katz
  - Test of Auditory Analysis Skills (TASS)
    - ✓ Say the word *baseball* … now say it again but don't say *base*
    - ✓ Say the word *smack* … now say it again but don't say */m/*

2000 Consensus Conference on the Diagnosis of APDs

- Listener variables in the diagnostic assessment of APD
  - Attention
  - Auditory neuropathy
  - Fatigue
  - Hearing sensitivity
  - Intellectual and developmental age
  - Cognitive variables (e.g., memory, processing speed)
  - Medications
  - Motivation
  - Motor skills
  - Native language, language experience, language age
  - Visual acuity

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

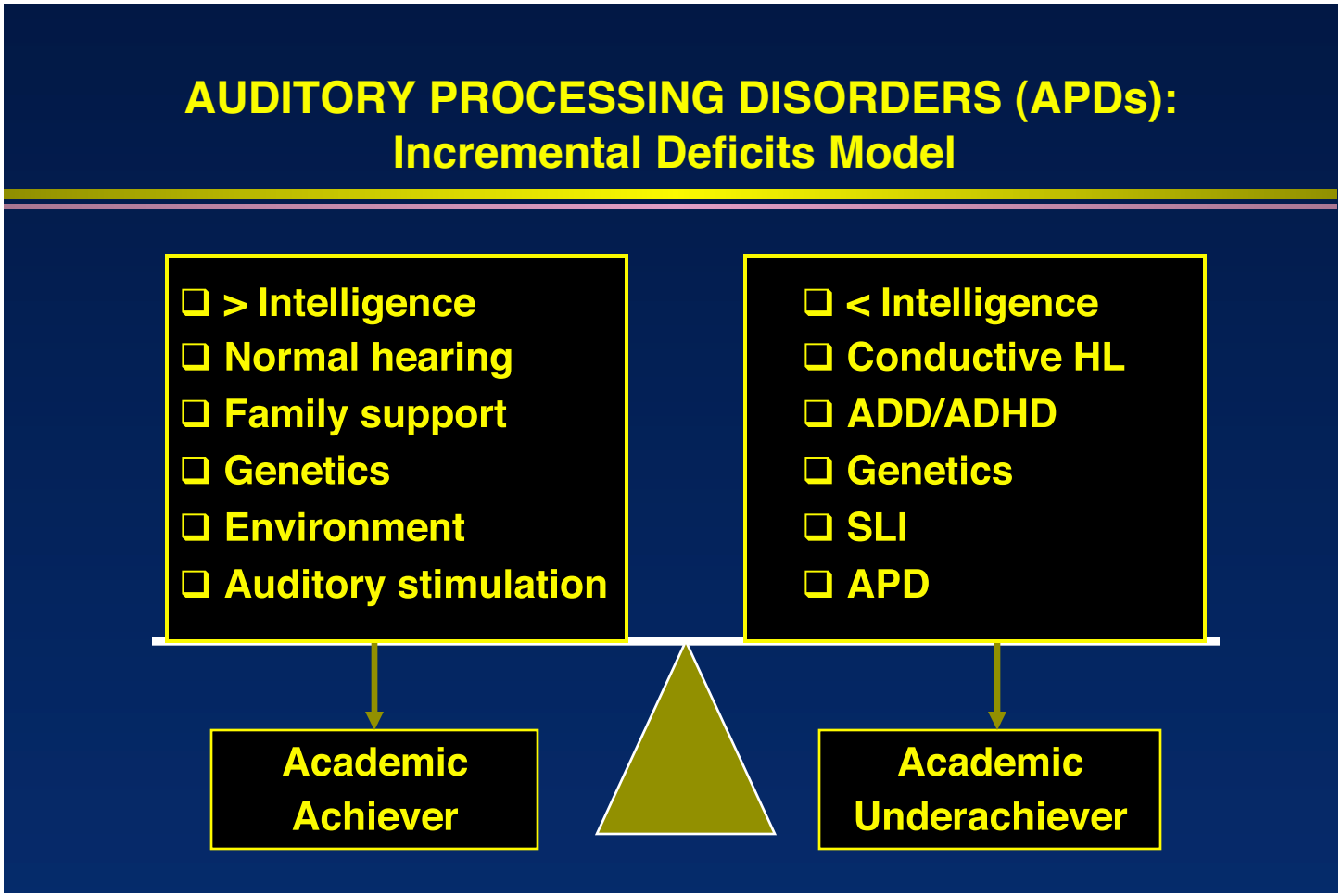
- Auditory evoked responses
  - Auditory brainstem response (ABR)
    - ✓ Click stimulation
    - ✓ Speech stimulation
  - Auditory steady state response (ASSR)
  - Auditory middle latency response (AMLR)
  - Auditory P300 response
    - ✓ oddball paradigm
    - ✓ active or passive subject
  - Mismatch negativity (MMN) response



Clinical Guidelines for Assessment and Management of Auditory Processing Disorders (APD) in Children and Adults

- Definition of APD … why is it important?
- Historical perspective … interest in APD dates back over 50 years
- Neuroscience foundation for APD
- Disorders often co-existing with APD
- Risk factors for APD
- Current and future assessment strategies and procedures
- Effective management strategies and procedures

AUDITORY PROCESSING DISORDERS (APDs): Incremental Deficits Model



Assessment and Management of Auditory Processing Disorders (APD)

- Historical perspective … interest in APD dates back over 50 years
- How APD became a household phrase in audiology
- Neuroscience foundation for APD
- Disorders often co-existing with APD
- Risk factors for APD
- Current and future assessment strategies and procedures
- Effective management strategies and procedures
  - Computer based auditory training
  - Targeted auditory training
  - FM technology

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

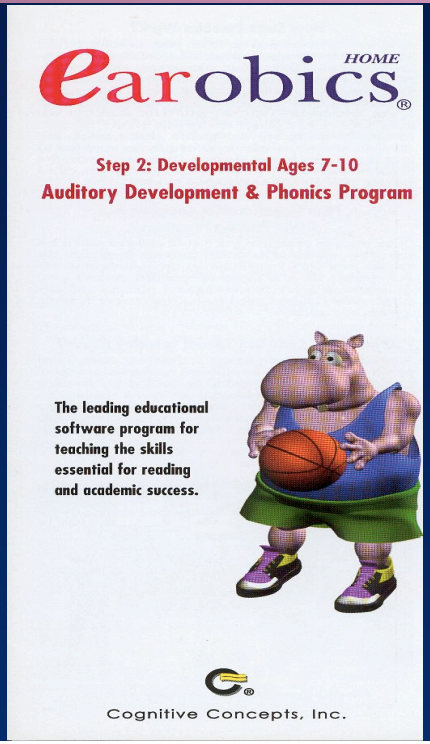
- **Intervention**: "…encompassing term referring to one or more actions taken in order to produce an effect and to alter the course of a disease, disorder, or pathological condition."
- **Treatment:** "…any specific procedure used to prevent, remediate (I.e., cure), or ameliorate a disease, disorder,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

Management of APD with Computer-Based Techniques: Scientific Bases of FastForword

Tallal P, Miller S, Merzenich M, et al. Language comprehension in language-learning impaired children improved with acoustically modified speech. Science 271: 81-84, 1996.

"A speech processing algorithm was developed to create more salient versions of the rapidly changing elements in the acoustic waveform of speech that have been shown to be deficiently processed by language-learning impaired (LLI) children … LLI children received extensive daily training with listening exercises ..."

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

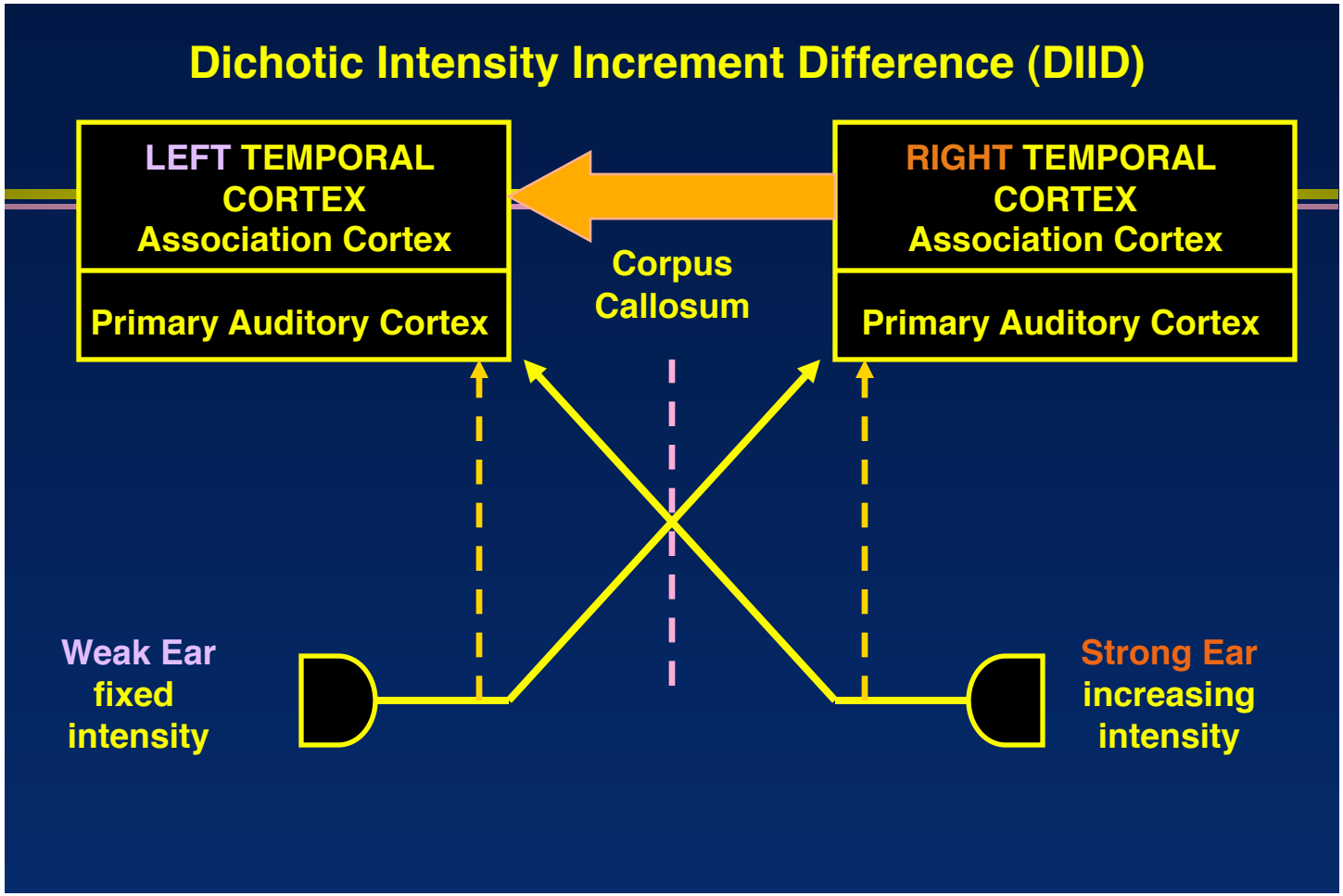
Earobics: Comments from Website (www.cogcon.com)

Earobics is widely considered to be one of the most validated and quantifiable reading intervention programs. States across the country have reviewed the program and approved its use in their schools to quickly and effectively build student reading achievement.

Independent industry reviewers, including the Florida Center for Reading Research (FCRR), confirm these findings. As a vital source for districts and schools, FCRR regularly reviews reading programs to help teachers, principals, and district administrators make informed choices on effective instruction.

Earobics was among the select few programs in the supplemental, intervention, and technology-based program categories to achieve the FCRR's highest ranking in all five reading areas.

NOTE: FCRR = Florida Center for Reading Research (www.fcrr.org)


Dichotic Intensity Increment Difference (DIID)
LEFT TEMPORAL CORTEX Association Cortex
Primary Auditory Cortex
Corpus Callosum
RIGHT TEMPORAL CORTEX Association Cortex
Primary Auditory Cortex
Weak Ear fixed intensity
Strong Ear increasing intensity

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

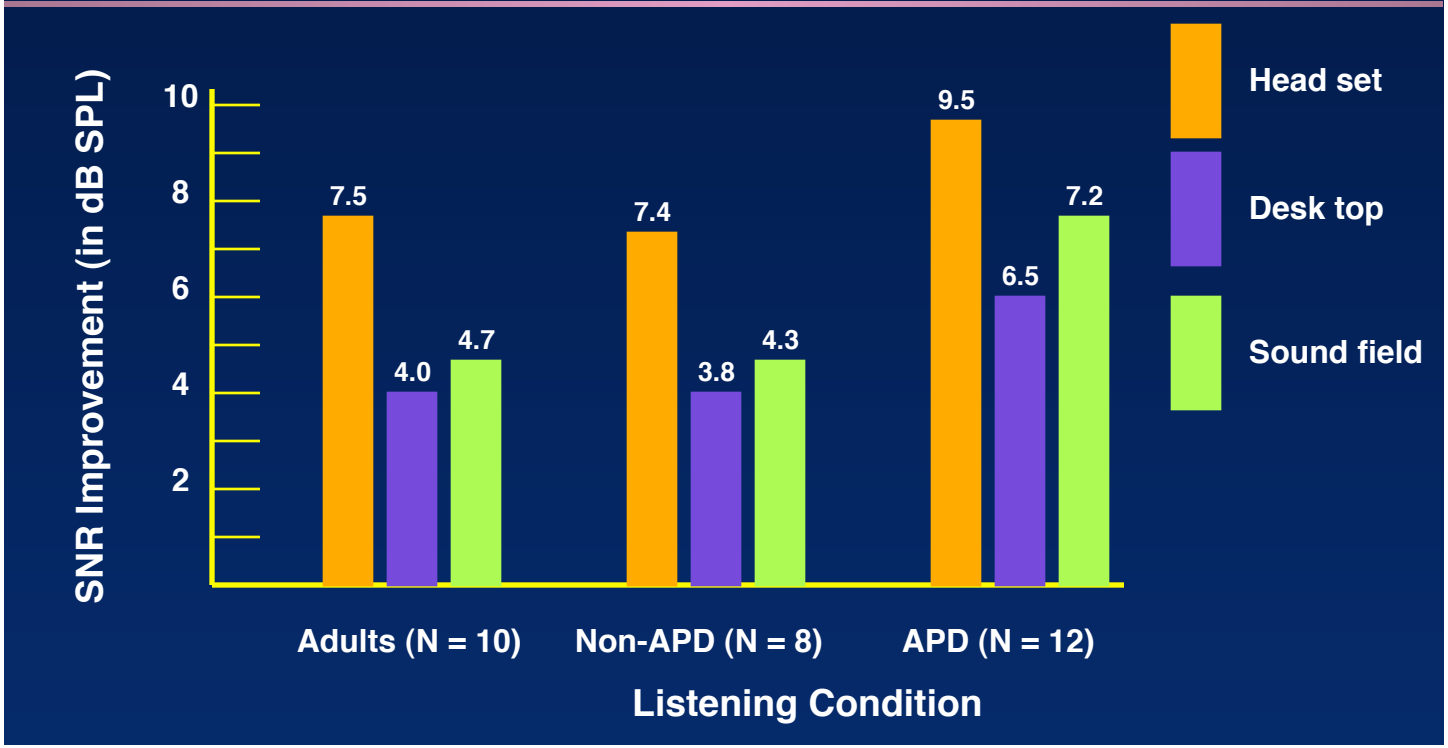
Deborah W. Moncrieff*
Diane Wertz

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

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

Carl Crandell, Ph.D.
1958 - 2005

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

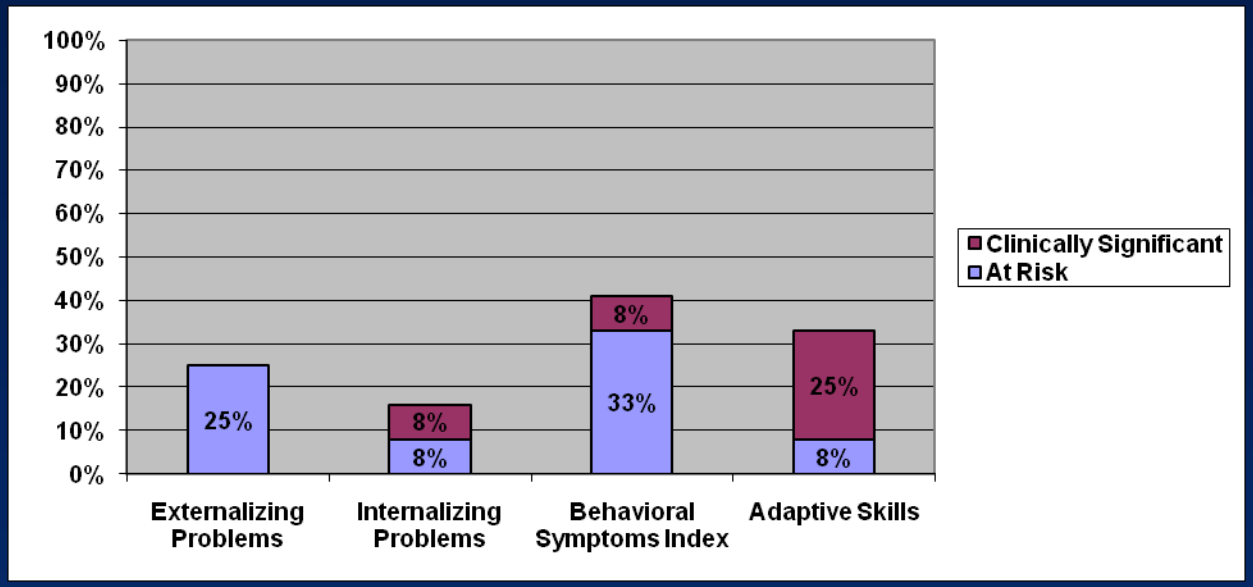
Hearing in Noise Test (HINT) Results
(Mean SNR values without and with EduLink)

	Group	
Test Condition	**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*

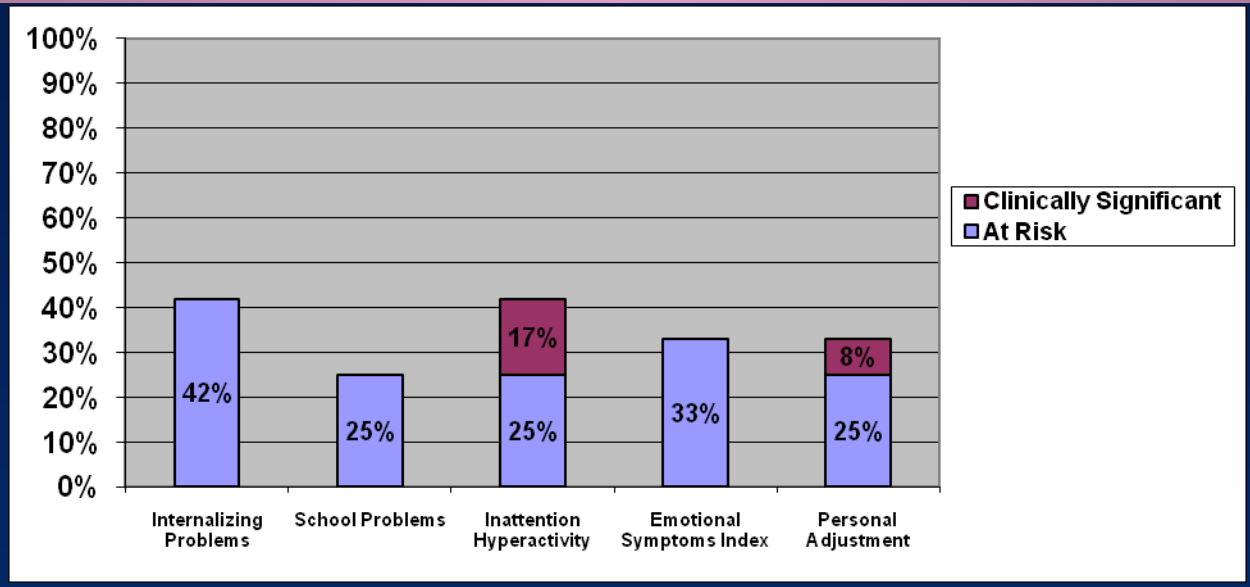
Typical Classroom SNR Range: +5 to -7 dB
Markides (1986); Finitzo-Hieber (1988); Crandell and Smaldino (1995)

Psychosocial Function in Children with APD: Initial BASC II Parent Report



- ***Externalizing Prob:*** **Hyperactivity, Aggression, Conduct Problems**
- ***Internalizing Prob:*** **Anxiety, Depression, Somatization**
- ***BSI:*** **Atypicality, Withdrawal, Attentional Problems**
- ***Adaptive Skills:*** **Adaptability, Social Skills, Leadership, Activities of Daily Living, Functional Communication**

Psychosocial Function in Children with APD: Initial BASC II Child Self Report



- *Internalizing Prob:* Atypicality, Locus of Control, Social Stress, Anxiety, Depression, Sense of Inadequacy, Somatization
- *School Prob:* Attitude to School, Attitude to Teachers, Sensation Seeking
- *ESI:* combination of Social Stress, Anxiety, Depression, Sense of Inadequacy
- *Personal Adjustment:* Relations with Parents, Interpersonal Relations, Self-Esteem, Self Reliance

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

	Normal Findings per Group (%)	
Domain	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

	Normal Findings per Group (%)	
Domain	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*

Auditory Processing Disorders (APD): Diagnosis is Feasible and Management is Effective