Update on Diagnostic and Speech Audiometry in Children and Adults

- The diagnostic auditory test battery needs an update
- Defining “best practices” and “standard of care”
- The concept of value added tests (VATs)
- Modern diagnostic audiology and audiologic rehabilitation
  - Acoustic immittance
  - OAEs
  - Auditory processing tests
  - Audiological rehabilitation
- Speech audiometry today

Audiology Test Battery: 60+ years Ago

- Test battery at the beginning of our profession, in order of test administration
  - Air-conduction pure tone audiometry
  - Bone-conduction pure tone audiometry
  - Speech reception thresholds
  - Word recognition (PB word lists)
  - Uncomfortable loudness level (UCL), i.e., loudness discomfort level (LDL)

Source: Wiener F & Miller G. Hearing aids. In Combat Instruments II. Washington, D.C. NDRC Report 117, 216-232, 1946

Audiology in the 1950s and 1960s: *Equipment*

GSI 162
Speech
Audiometer

GSI E800
Bekesy
Audiometer

Early Maico Audiometer

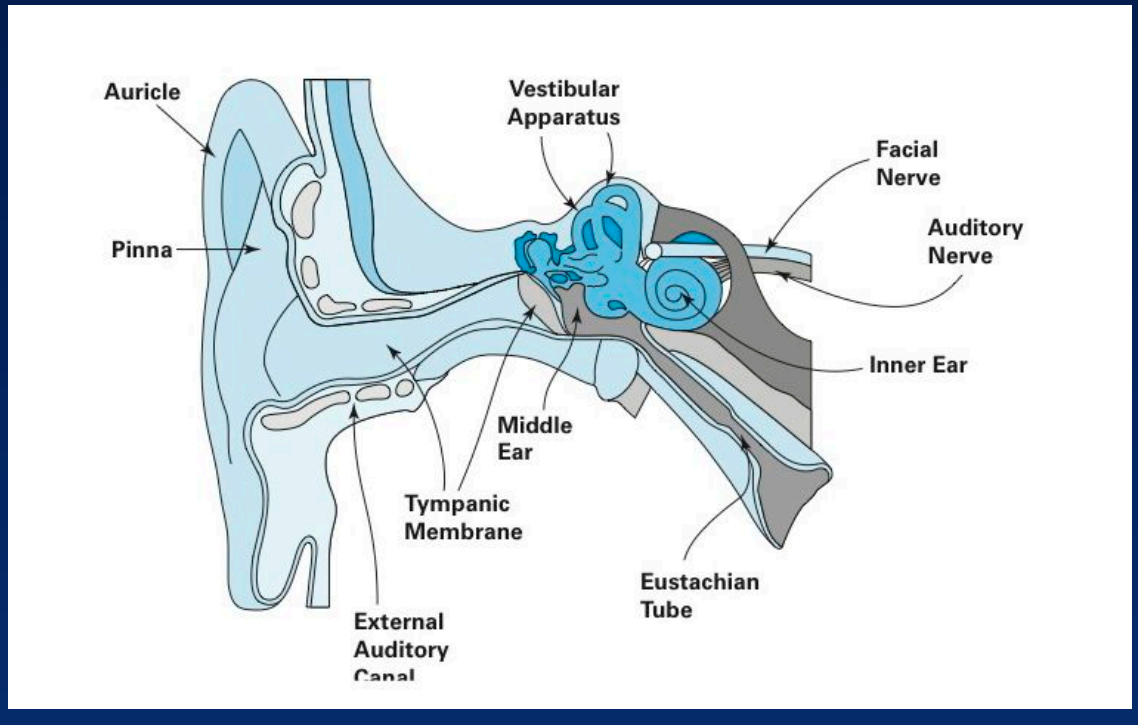
Best Practices in Audiology:
Modern Audiometers

GSI AudioStar Audiometer

KUDUwave Automated Audiometer

Best Practices in Audiology: Efficient and Sensitive Assessment of the Peripheral Auditory System

(Figure: Hall JW III (2014). Introduction to Audiology Today. Boston: Pearson)

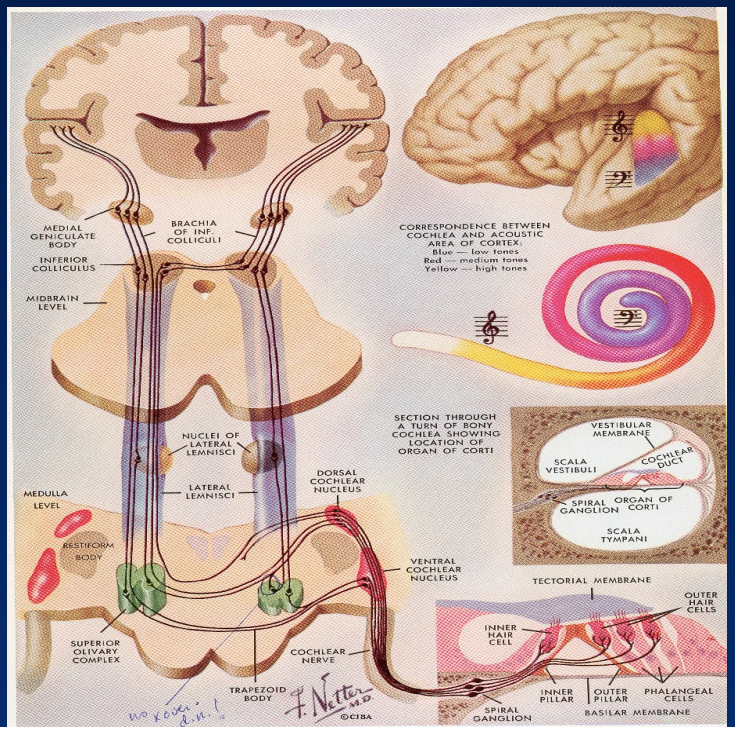


A Modern Diagnostic Audiologic Test Battery

(In the order of testing for new patients. Test time < 1 hour.)

- Objective measures
  - Otoacoustic emissions (OAEs)
  - Aural immittance measures
- Behavioral measures
  - Pure tone audiometry
    - ✓Air conduction
    - ✓Bone conduction *(as indicated)*
    - ✓Automated technique as appropriate
  - Speech audiometry
    - ✓Simple procedures
    - ✓Central auditory procedures *(as indicated)*

We Hear with Our Brain! Efficient and Sensitive Assessment of the Central Auditory Nervous System



Procedures for Central Auditory Assessment *(As Indicated)*

- Behavioral measures
  - Speech-in-noise tests
  - Distorted speech tests
  - Dichotic listening tests
  - Temporal processing and sequencing tests
- Objective measures
  - Auditory brainstem response
    - ✓Non-speech signals (clicks and tone bursts)
    - ✓Speech signals
  - Cortical auditory evoked responses

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Best Practices are Evidence-Based

"Those who fall in love with practice without science are like a sailor who steers a ship without a rudder or compass, and who can never be certain whither he is going."

Leonardo Da Vinci (1452-1519)

General Definitions of Standard of Care

- Consistent with local, regional or national clinical practice
- Follows guidelines or recommendations on clinical practice approved by national multi-disciplinary professional committees or panels, e.g., Joint Committee on Infant Hearing or NHS 2013
- Follows guidelines]on clinical practice approved by national professional organizations, e.g., AAA or BSA
- Is consistent with statements of
  - Scope of Practice
  - Code of Ethics
- Is in compliance with Federal guidelines for clinical practice and services

Best Practices in Audiology: Specific Sources for Practice Guidelines (Standard of Care in the USA)

- Guidelines for different clinical practices, e.g.,
  - Diagnostic audiometry in adults
  - Pediatric diagnostic audiology
  - Preschool hearing screening
  - Hearing aids and amplification
  - Ototoxicity monitoring and assessment
  - APD assessment and management
  - Tinnitus assessment and management
  - Cochlear implants

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The Concept of Value Added Tests (VATs): Fundamental Criteria for Inclusion in a Test Battery

- Value added tests (VATs)
  - The procedure adds value to the description of auditory status for the patient … information that's
    - ✓Not available from other procedures,
    - ✓Obtained quicker than with another procedure
    - ✓Useful in managing the patient
    - ✓Contributes to better outcome for the patient
- OAEs are an example of a VAT
- Some traditional test procedures do *not* alwats add value, e.g.,
  - Speech recognition threshold (SRT)
  - Bone conduction pure tone audiometry
  - Word recognition only in quiet at 40 dB SL

Update on Diagnostic and Speech Audiometry in Children and Adults

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Linkage between Diagnostic Procedures and Intervention Outcome: *Aural Immittance Measurement*

- Diagnostic information
  - Middle ear versus sensory auditory dysfunction
  - Objective confirmation of sensory hearing loss
  - Objective evidence of retrocochlear auditory dysfunction
  - Objective evidence of central nervous system dysfunction
- Impact on Intervention Outcome
  - Prompt medical management of middle ear disorder
  - Cost effective and lower risk decisions regarding further diagnostic test procedures (e.g., ABR under anesthesia)
  - Referral for otologic consultation and MRI referral
  - Referral for APD assessment or neurological consultation

Update on Diagnostic and Speech Audiometry in Children and Adults

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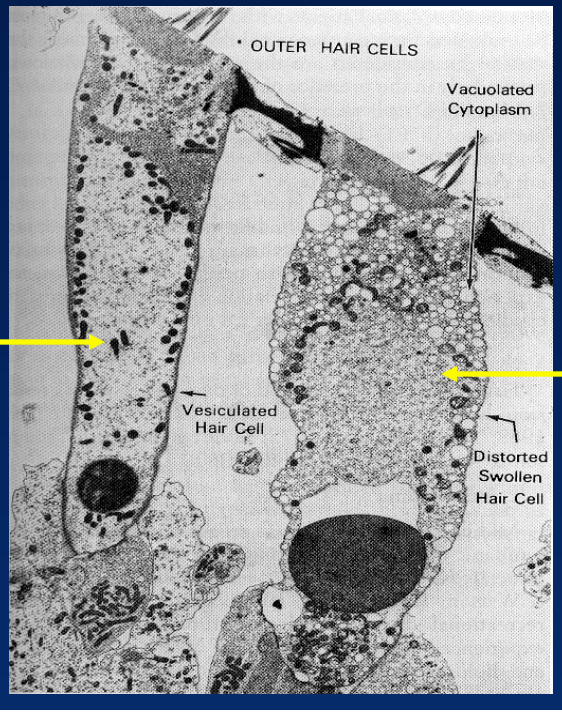
OAEs in Early Detection of Outer Hair Cell Dysfunction

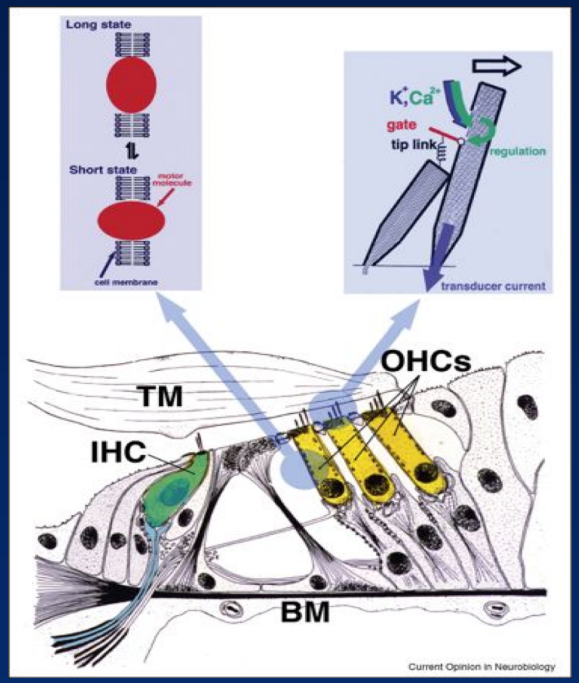
Normal OHC (OAEs)



Abnormal OHC (OAEs)

Cochlear Origins of OAEs

- Outer hair cell motility
  - Prestin motor protein
- Stereocilia
  - Motion
  - Stiffness
- Tectorial membrane
- Basilar membrane mechanics
  - Dynamic interaction with outer hair cells
- Stria vascularis
- Middle ear (inward and outward propogation)
- External ear canal
  - Stimulus presentation
  - OAE detection

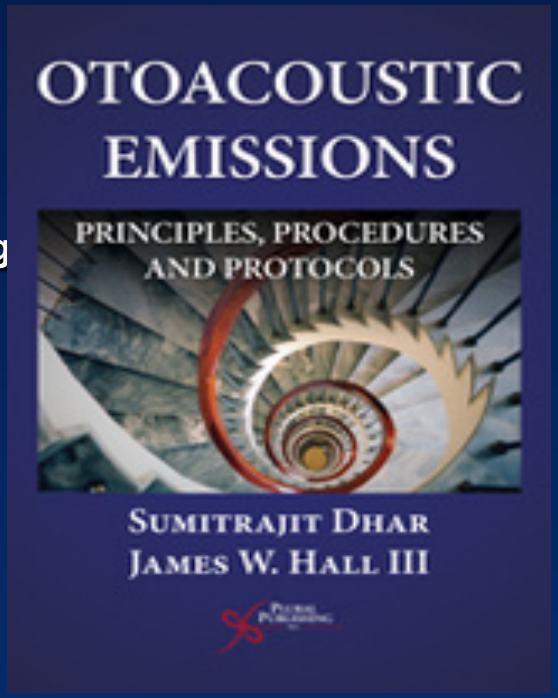


Best Practices in Audiology: Evidence-Based Clinical Applications of OAEs in Pediatric Populations

- Pediatric Applications
  - Infant hearing screening
  - Diagnosis of auditory dysfunction in infants and young children
    - ✓ Identification of auditory neuropathy spectrum disorder
  - Monitoring ototoxicity
  - Pre-school/school screenings
  - Identification of pseudohypacusis

Best Practices in Audiology: Evidence-Based Clinical Applications of OAEs in Adult Populations

- Sensitive measure of middle ear status
- Sensitive and specific measure of auditory dysfunction in noise/music exposure
- Diagnosis of false or exaggerated hearing loss
- Cochlear versus retrocochlear dysfunction
- Assessment of tinnitus & hyperacusis
- Auditory processing disorders (r/o cochlear deficit)
- Industrial hearing screening and conservation



Linkage between Diagnostic Procedures and Intervention Outcome: *Otoacoustic Emissions (OAEs)*

- Diagnostic information
  - Early detection of cochlear (outer hair cell) dysfunction
  - Objective confirmation of sensory y dysfunction in infants
  - Frequency specific details on cochlear dysfunction
- Impact on Intervention Outcome, e.g.,
  - Preventative measures for persons at risk for sound hearing loss
  - Preventative measures or modification of drug therapy for persons at risk for ototoxicity related hearing loss
  - Effective and appropriate management of pseudohypacusis
  - Effective and appropriate management of tinnitus
  - Early intervention for permanent infant hearing loss
  - Early intervention for ANSD

Update on Diagnostic and Speech Audiometry in Children and Adults

- The diagnostic auditory test battery needs an update
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- The concept of value added tests (VATs)
- Modern diagnostic audiology and audiologic rehabilitation
  - Acoustic immittance
  - OAEs
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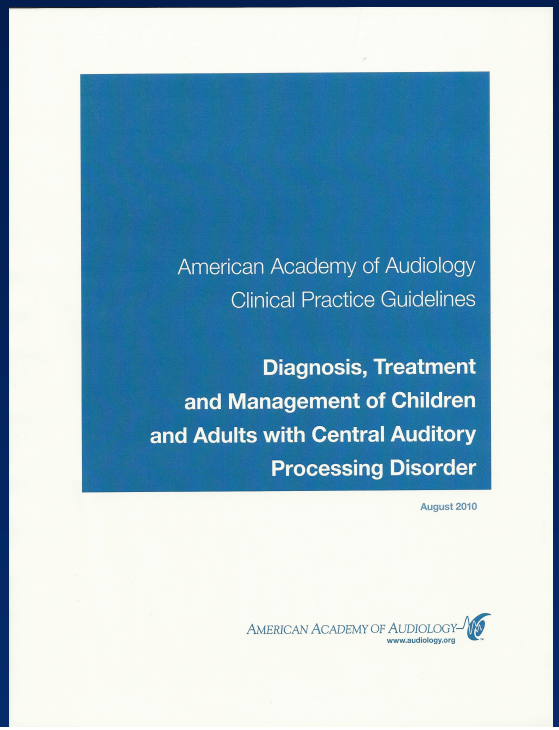
AAA Clinical Guidelines on Auditory Processing Disorders *(www.audiology.org)*



Risk Factors for APD in Children: Team Work for Early 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)*
- Language disorders resistant to treatment *(speech pathologists)*
- Older siblings with APD *(parents, teachers)*
- Academic underachievement or failure *(pre-school and Head Start teachers, classroom teachers, and educational psychologists)*
- Poor listeners *(pre-school and Head Start teachers, classroom teachers, and educational psychologists)*
- Family history of academic underachievement *(parents)*
- Co-existing disorders *(multiple professionals)*

Auditory Processing Disorders in Adults: *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
- Dementia and 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

Auditory Processing Disorders in Adults: Risk Factors and Clinical Indications

- Medical history (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

Consequences of Late Identification of Auditory Processing Disorders (APD)

- Children
  - Reading failure
  - Academic failure
  - Psychosocial problems
  - May require long-term remediation
- Adults
  - Unemployment
  - Under employment
  - Psychosocial problems
  - Incorrect diagnosis, e.g.,
    - ✓ Dementia
  - Mismanagement
  - Poor quality of life

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* Pure tone audiometry
  - Inter-octave frequencies (e.g., 3000 and 6000 Hz)
  - High frequency (> 8000 Hz) audiometry (as indicated)
- Speech audiometry
  - Word recognition (10 most difficult words first)

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

- **Auditory Discrimination Tests:** Tests with 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:** Tests of 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:** Tests of 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

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

- **Monaural Low-Redundancy Speech Tests:** 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-Sentences (LiSN-S) 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)

Linkage between Diagnostic Procedures and Intervention Outcome
Measures of Auditory Processing

- Diagnostic information
  - Identification of central auditory nervous system dysfunction
  - Differentiation among types of auditory processing deficits
- Impact on Intervention Outcome
  - Timely referrals for
    - ✓ Comprehensive APD assessment
    - ✓ Speech-language consultation
    - ✓ Neurological consultation
    - ✓ Neuro-psychological consultation
  - Implementation of treatment, including:
    - ✓ Auditory training, e.g., Earbobics or LACE (Listening and Communication Enhancement)
    - ✓ FM technology
    - ✓ Amplification

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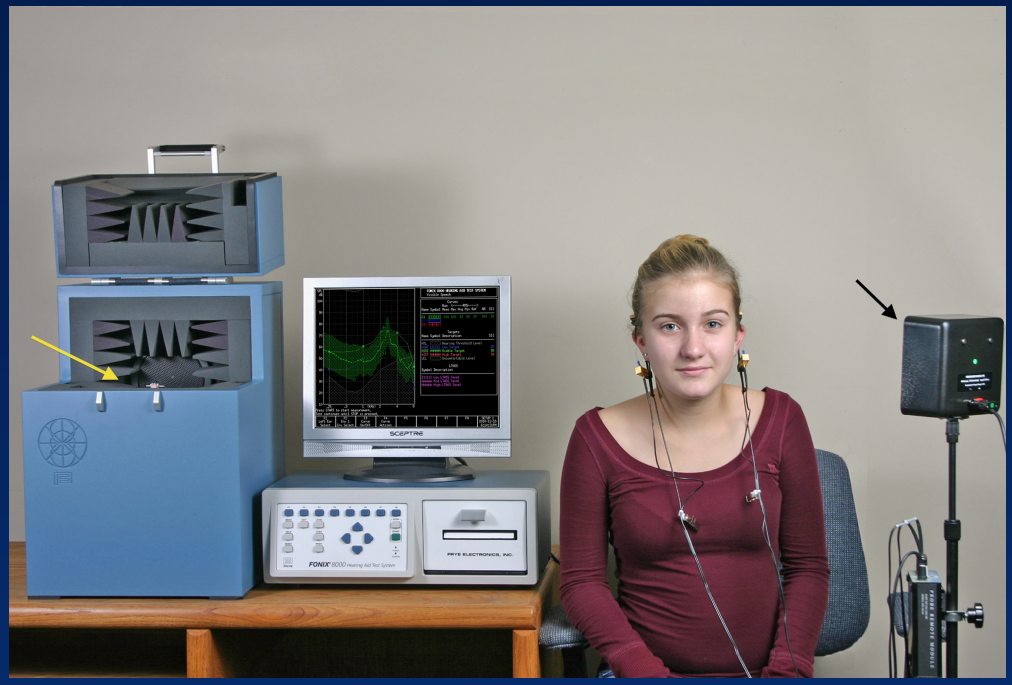
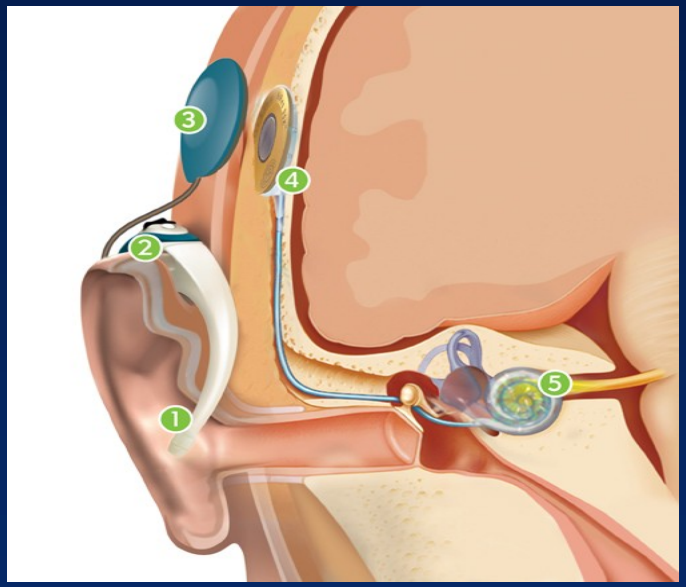
Best Practices in Audiology:
Hearing Aid Technology in Rehabilitation

Best Practices in Audiology:
Hearing Aid Technology in Rehabilitation

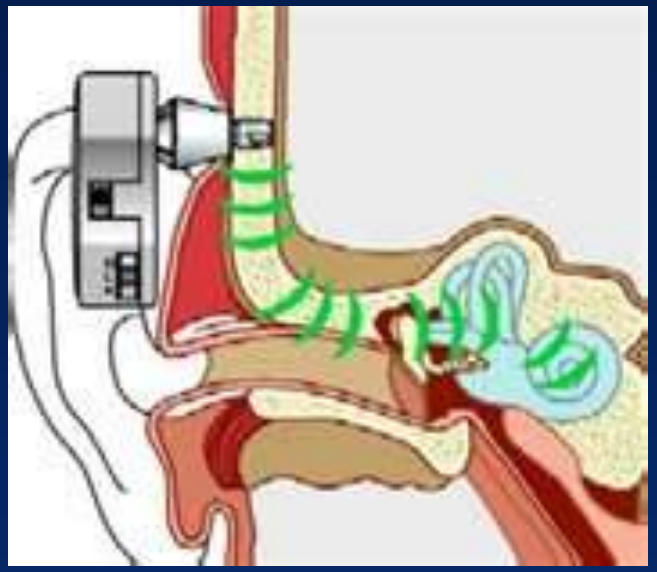


Best Practices in Audiology:
FM Technology in Rehabilitation

Best Practices in Audiology:
Implant Technology and Rehabilitation

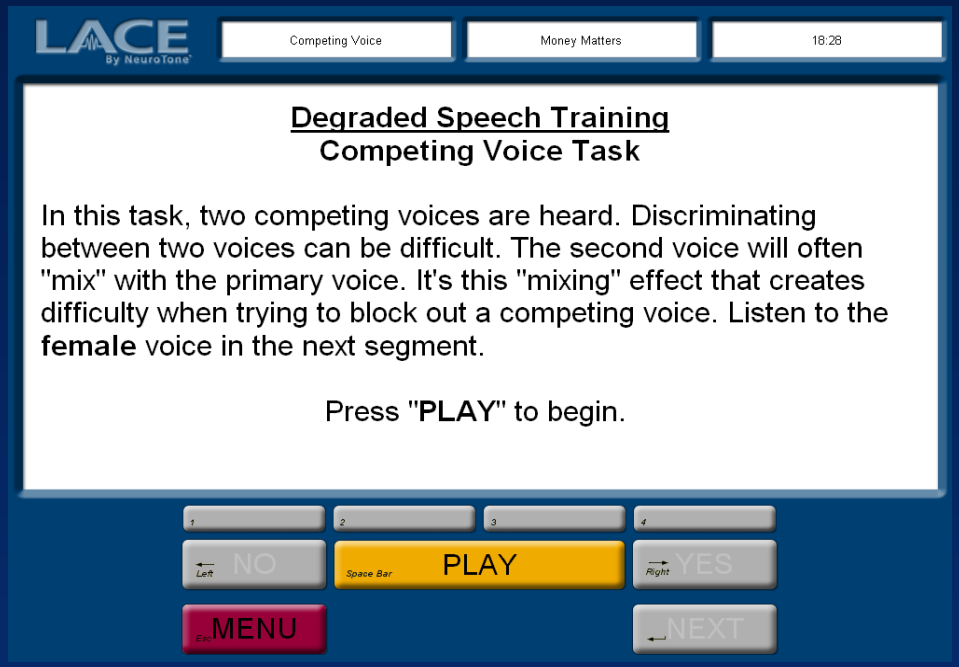


Cochlear Implants



Bone Anchored Hearing Devices

Best Practices in Audiology:
Auditory and Cognitive Training in Rehabilitation



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Update on Diagnostic and Speech Audiometry in Children and Adults: Speech Audiometry Today

- Historical perspective
- Speech audiometry is important
  - An essential component in a diagnostic test battery
  - Types of speech audiometry procedures
  - Advantages of recorded test materials

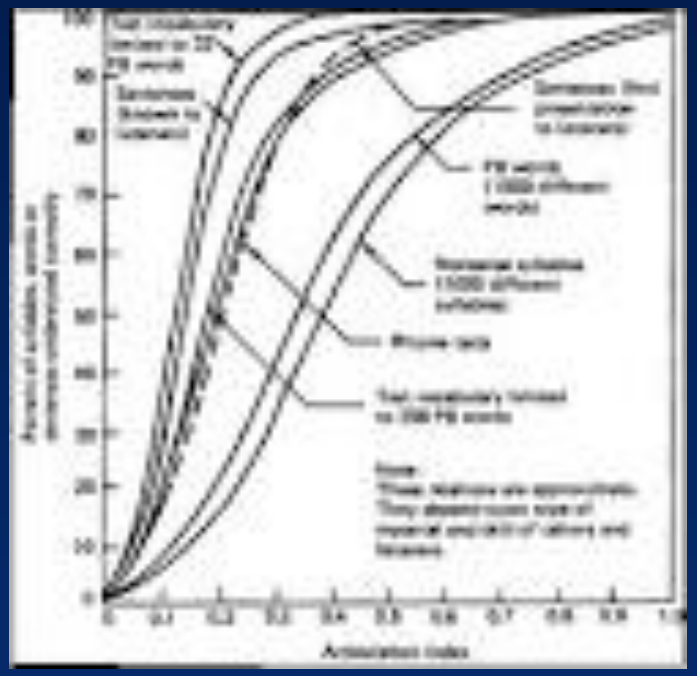
Foundation of Speech Audiometry: Bell Telephone Laboratories

Harvey Fletcher
(1884-1981)

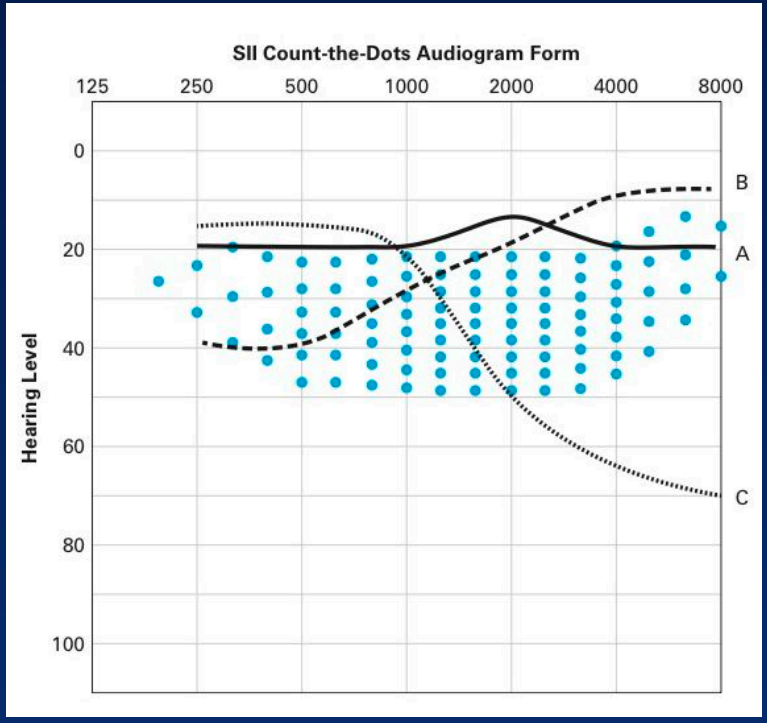
Western Electric Speech Audiometer
Bell Labs

Foundation of Speech Audiometry: Bell Telephone Laboratories

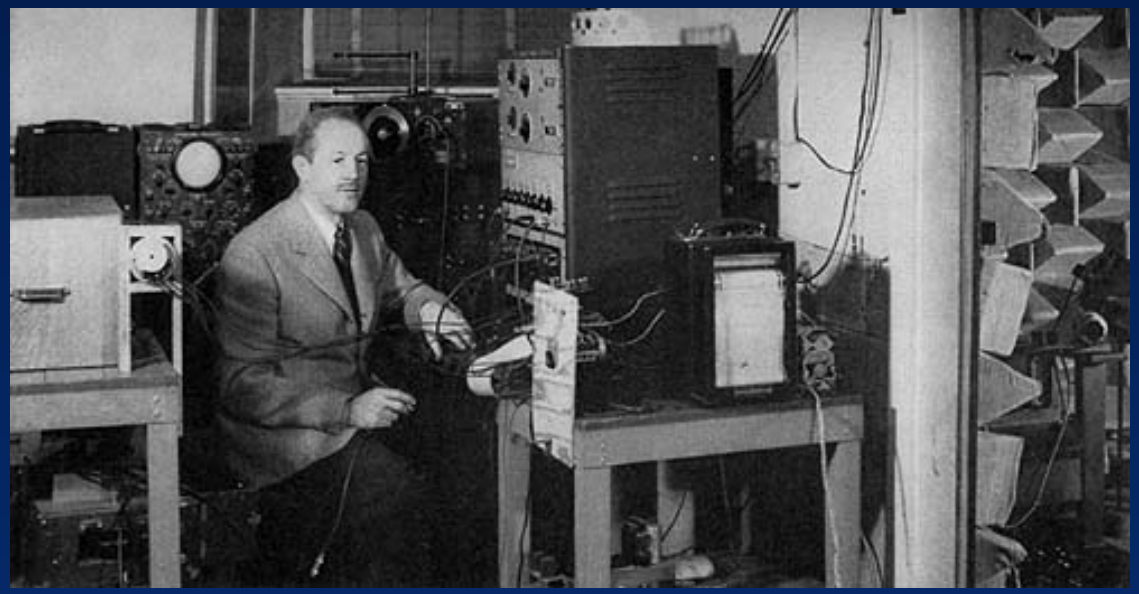
- Fletcher H (1929). Speech and Hearing. New York: D Van Nostrand
- Fletcher H & Steinberg JC (1929). Articulation testing methods. Bell System Technical Journal, 8, 806-854



Foundation of Speech Audiometry: Articulation Index Research is Applied in the "Count-the-Dots" Audiogram



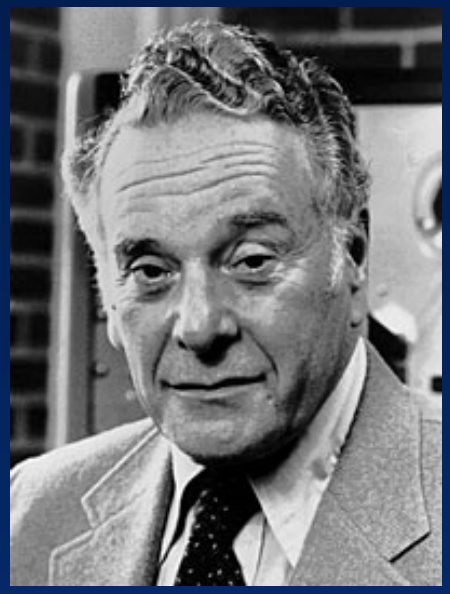
Foundation of Speech Audiometry: Psychoacoustics Laboratory (PAL) Harvard University (1940s and 1950s)



SS Stevens
(1906-1973)

Foundation of Speech Audiometry: Psychoacoustics Laboratory (PAL) Harvard University (1940s and 1950s)

Hallowell Davis
(1896-1992)



Ira Hirsh
(1922-2010)

Foundation of Speech Audiometry
Psychoacoustics Laboratory (PAL)
Harvard University (1940s and 1950s)

- Davis H (1948). The articulation area and the social adequacy index for hearing. Laryngoscope, 58, 761-778
- Egan JP (1948). Articulation testing methods. Laryngoscope, 58, 955-991
- Hirsh IJ, Davis S, Silverman et al (1952). Development of matierals for speech audiometry. Journal of Speech & Hearing Disorders, 17, 321-337
- Hudgins CV, Hawkins JE, Karlin JE & Stevens SS (1947). The development of recorded auditory tests for measuring hearing loss for speech. Laryngoscope, 40, 57-89

Audiology Test Battery: 60+ years Ago

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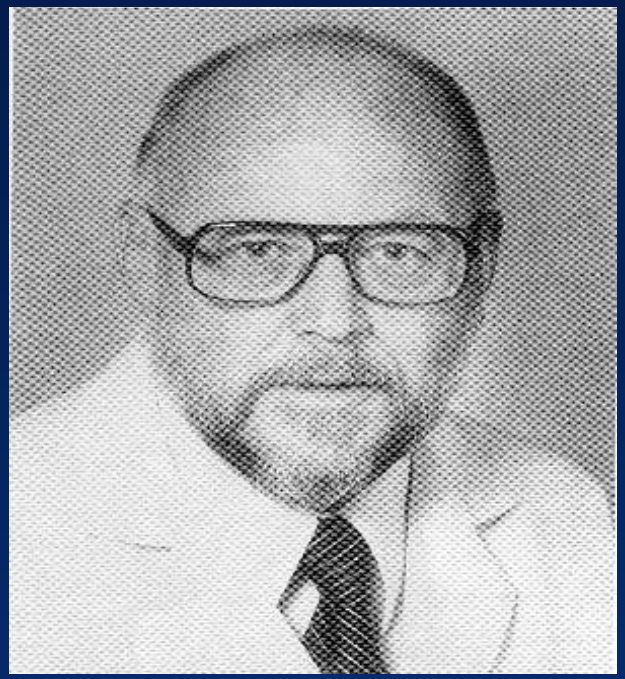
  - Word recognition (PB word lists)
  - Uncomfortable loudness level (UCL), i.e., loudness discomfort level (LDL)

Source: Wiener F & Miller G. Hearing aids. In Combat Instruments II. Washington, D.C. NDRC Report 117, 216-232, 1946

Raymond Carhart

James Jerger
"Father of Diagnostic Audiology"
Developed Speech Audiometry Procedures in the 1960s



GSI 162 Speech Audiometer

Audiometers for Speech Audiometry from the 1970s to the Present

GSI 10

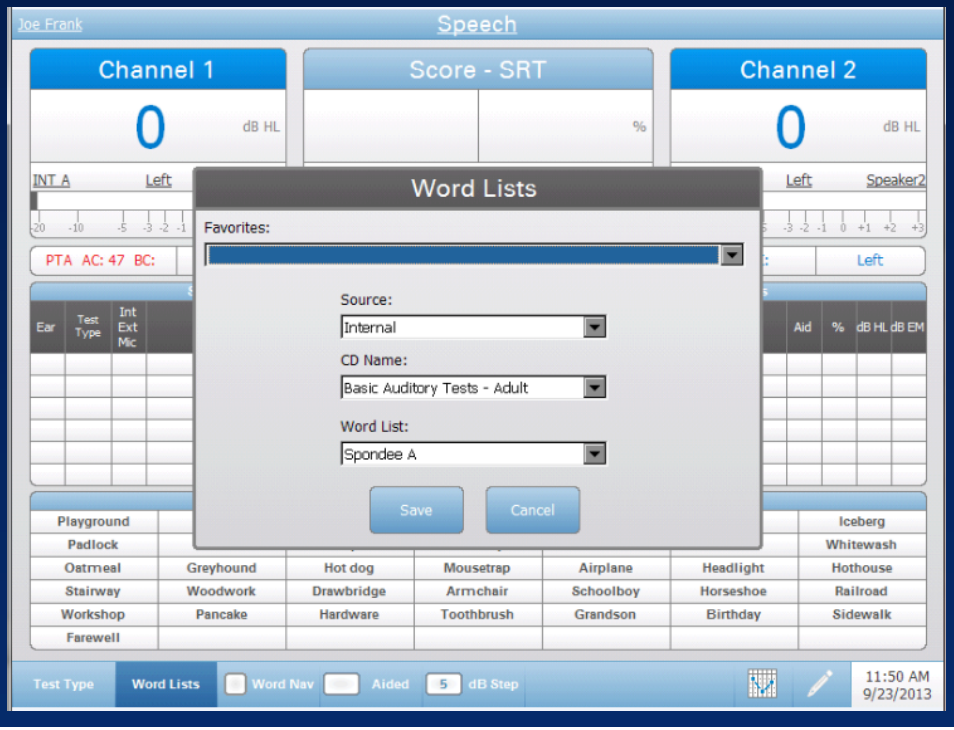
GSI 61

GSI 16

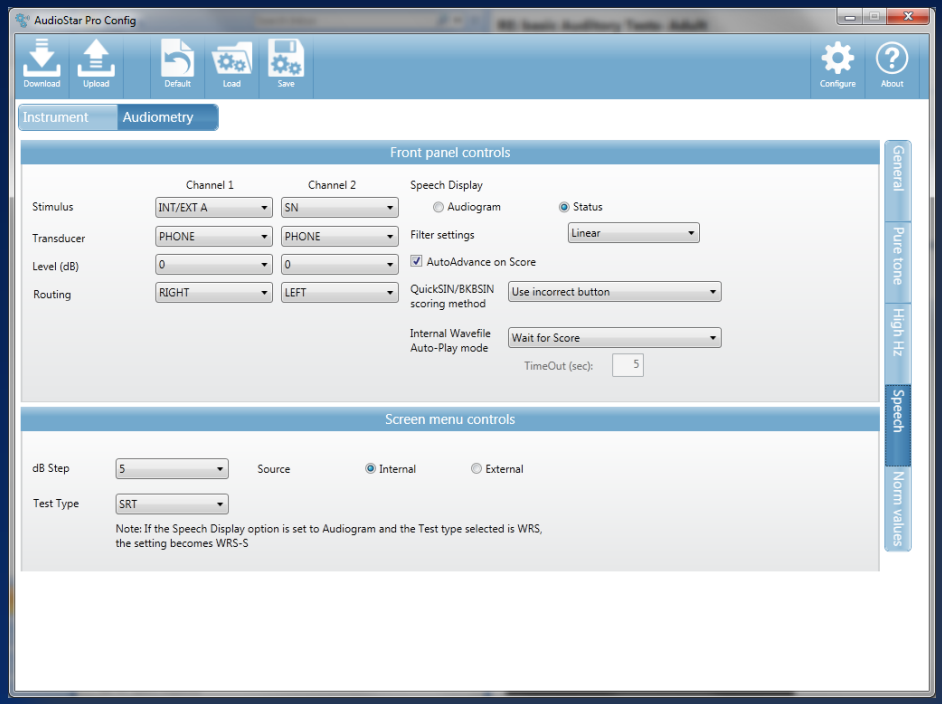
GSI AudioStar

A Modern Audiometer for Speech Audiometry
GSI AudioStar Pro

A Modern Audiometer for Speech Audiometry
GSI AudioStar Pro
(Speech Reception Threshold)

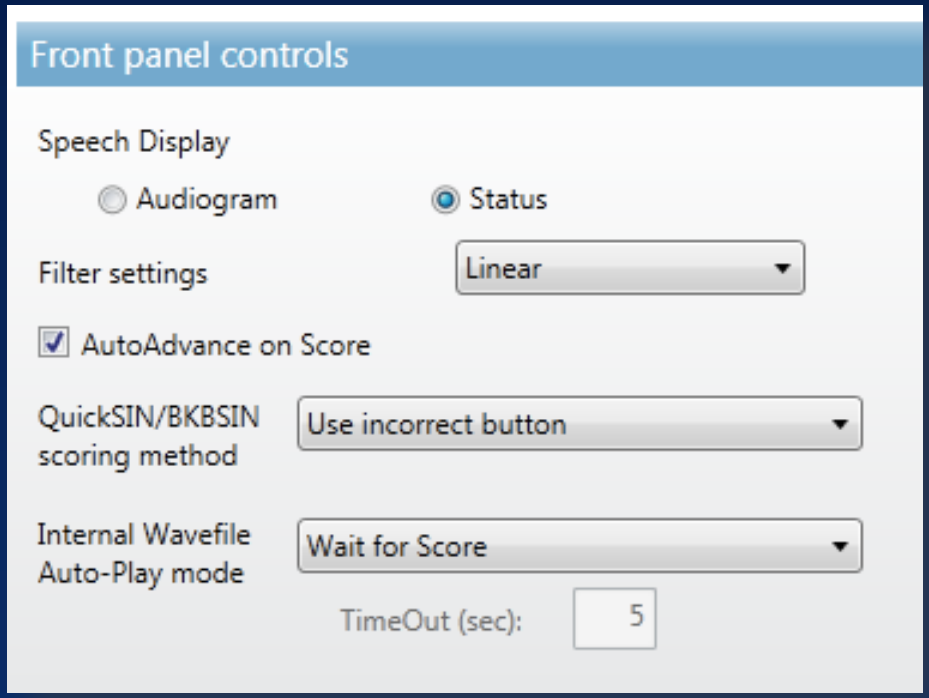


A Modern Audiometer for Speech Audiometry
GSI AudioStar Pro
(Speech Reception Threshold)

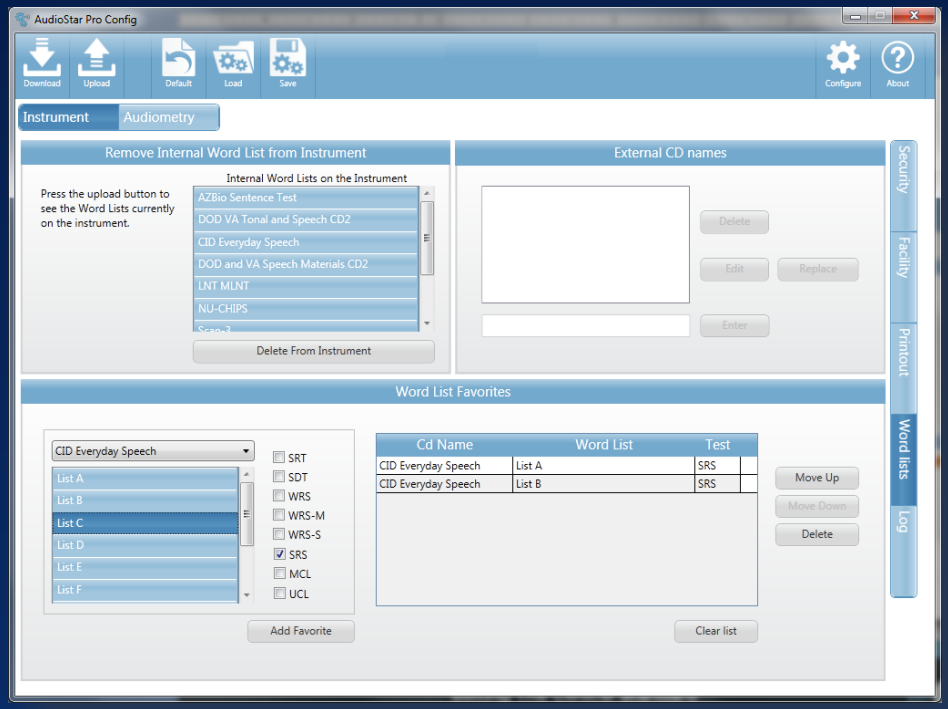


A Modern Audiometer for Speech Audiometry
GSI AudioStar Pro
(Word Reception)

A Modern Audiometer for Speech Audiometry
GSI AudioStar Pro
(Automatic Scoring in Speech Testing)



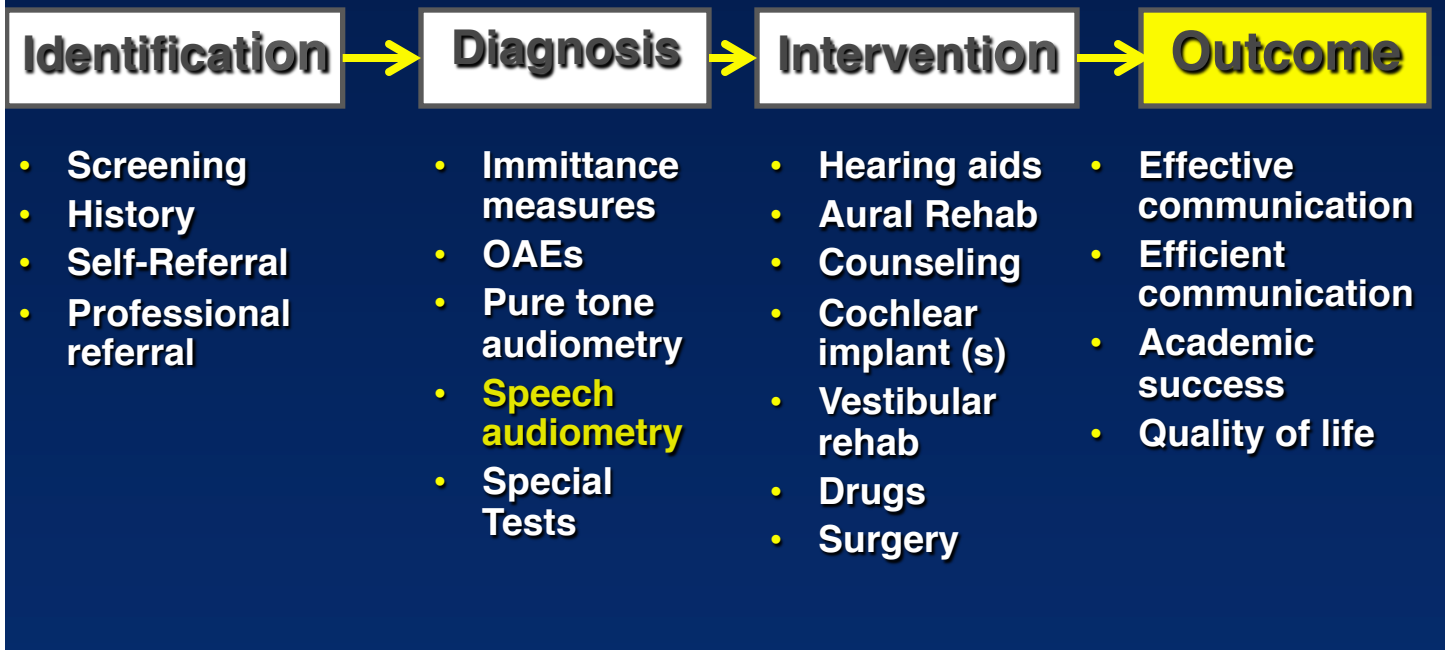
A Modern Audiometer for Speech Audiometry
GSI AudioStar Pro
(A Variety of Speech Test)



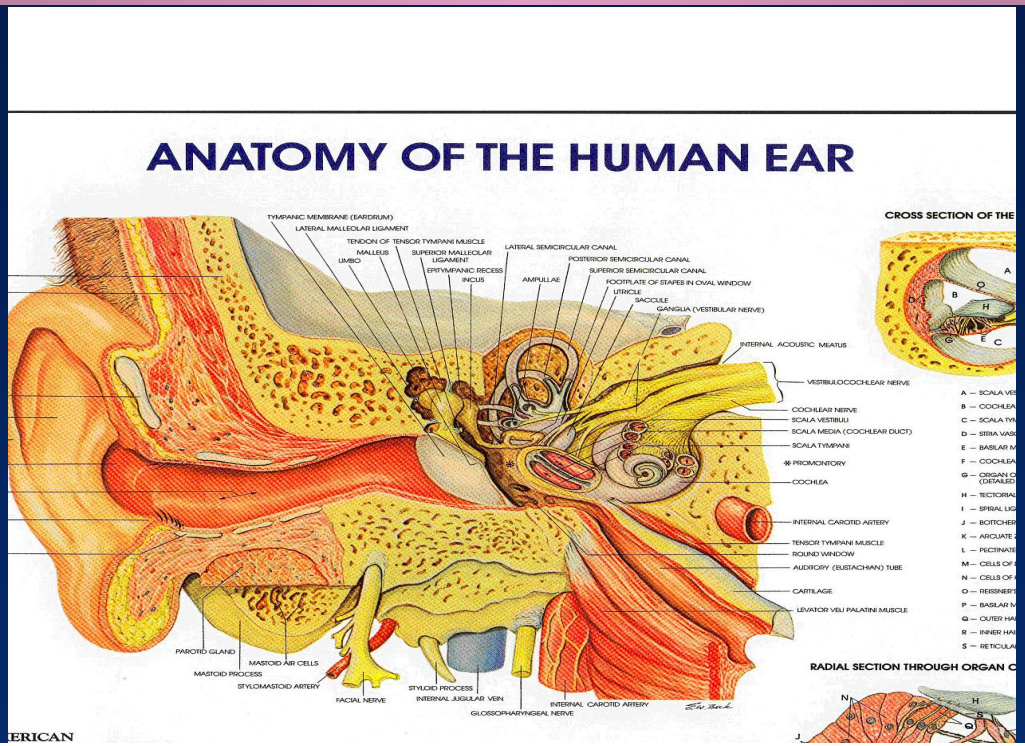
Update on Diagnostic and Speech Audiometry in Children and Adults: Speech Audiometry Today

- Historical perspective
- Speech audiometry is important to evaluate communication
  - Types of speech audiometry procedures
  - Advantages of recorded test materials

Speech Audiometry in Evidence-Based Practice: Categories of Research Evidence (ASHA, 2004)



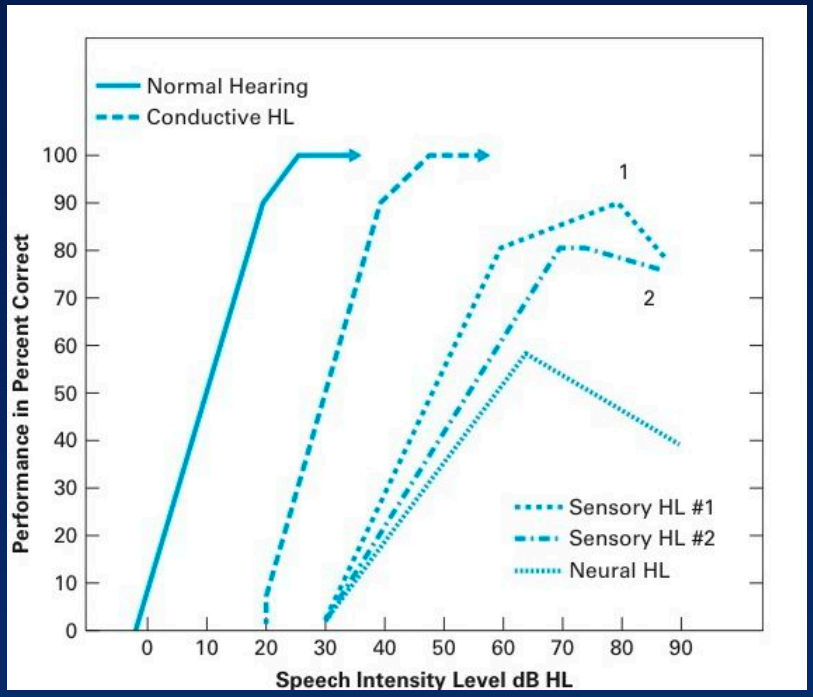
Speech Audiometry Assessment of the Peripheral Auditory System



Speech Audiometry Procedures for General Auditory Assessment

- Threshold measures
  - Speech awareness or detection tests (SAT or SDT)
  - Speech recognition threshold (SRT)
- Word recognition tests
  - Phonetically balanced word lists (≥ 25 words)
  - Verbal or picture pointing response mode
  - Efficiency is increased with 10 most difficult words first
  - Performance intensity functions are most accurate measure
- Speech-in-noise tests, e.g,
  - Speech-in-noise (SIN) or QuickSIN
  - Hearing in Noise Test (HINT

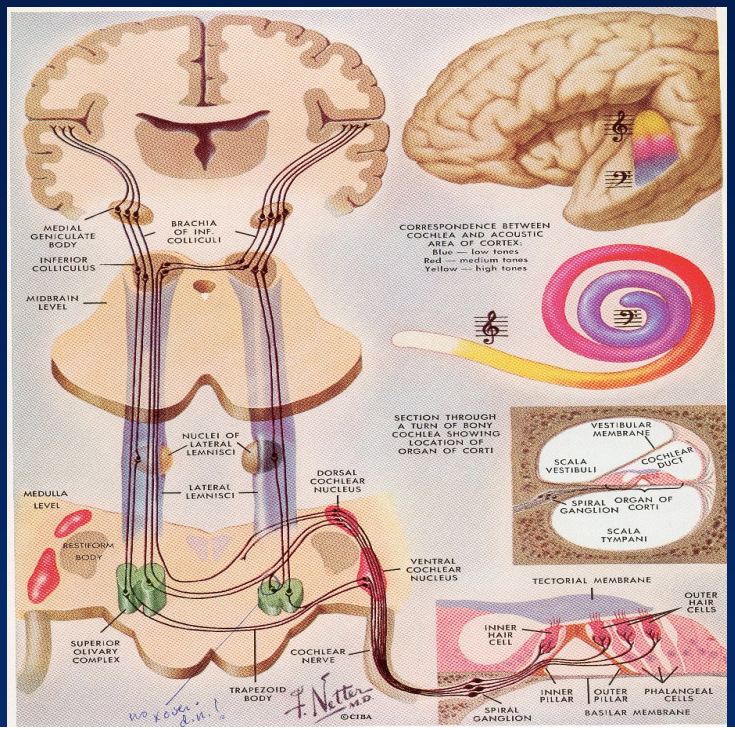
Speech Audiometry Procedures for Performance Intensity Functions for PB Words



Hall JW III. *Introduction to Audiology Today*

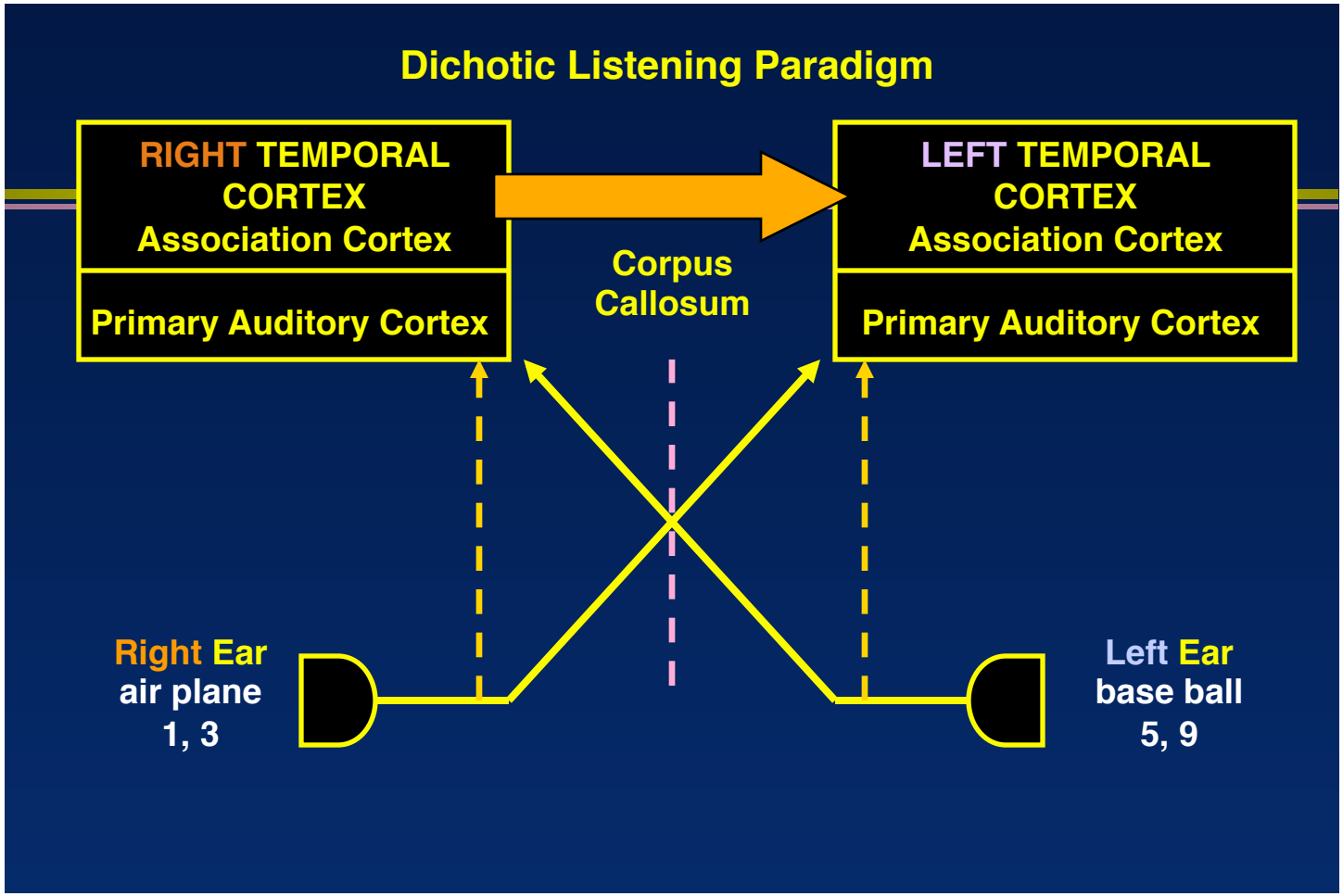
A Modern Audiometer for Speech Audiometry
GSI AudioStar Pro with QuickSIN

We Hear with Our Brain!
Speech Audiometry Permits Efficient and Sensitive Assessment of the Central Auditory Nervous System



Speech Audiometry Procedures for Central Auditory Assessment

- Behavioral measures
  - Speech-in-noise tests
  - Distorted speech tests
    - ✓Filtered speech materials
    - ✓Time compressed speech materials
  - Dichotic listening tests
- Objective measures
  - Speech evoked auditory brainstem response (ABR)
  - Speech evoked cortical auditory evoked responses


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

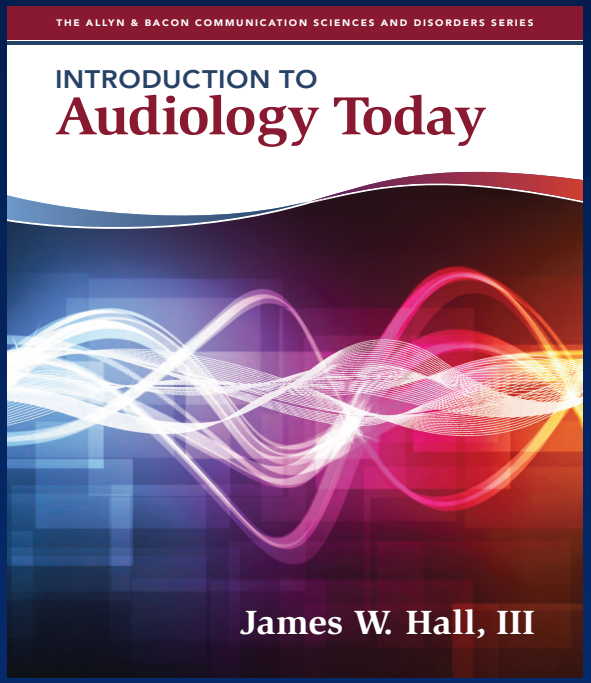
Update on Diagnostic and Speech Audiometry in Children and Adults: Speech Audiometry Today

- Historical perspective
- Speech audiometry is important to evaluate communication
  - Types of speech audiometry procedures
  - Advantages of recorded test materials

Speech Audiometry Tests: Advantages of Recorded Test Materials

- Tests consist of carefully selected words spoken by a single person without a distinct dialect
- Materials are available for male or female speakers
- Speech is professionally recorded in a sound studio with high quality equipment
- Speech intensity level is calibrated with an audiometer and presented consistently throughout the test
- Variability in patient performance is minimized permitting comparison of test results over time
- Speech materials are the same
  - Each time they are used in a clinic
  - From one clinic to the next

Source of More Information of Speech Audiometry and Much More: Thank You! … *Questions?*



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