# Evidence Based Diagnostic Audiology: Enhancing Efficiency and Effectiveness with Value Added Tests


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# Evidence Based Diagnostic Audiology: Enhancing Efficiency and Effectiveness with Value Added Tests

- **Learner Outcomes**
  1. **Define what is meant by the term "value added test"**
  2. **List 3 characteristics value added tests**
  3. **Identify 4 examples of value added tests in diagnostic audiology**

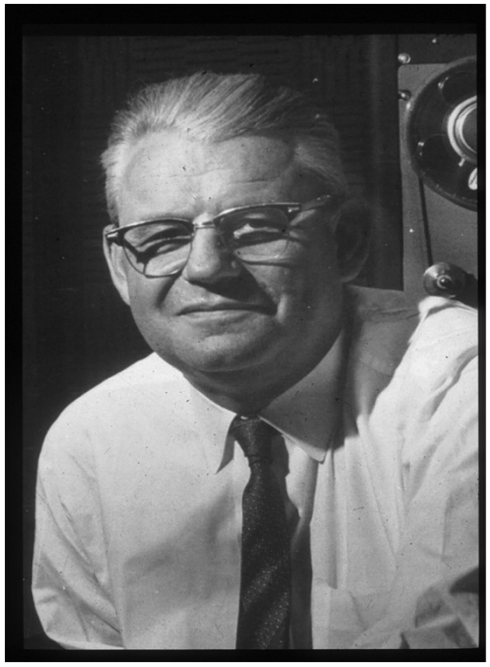
# Evidence Based Diagnostic Audiology: Enhancing Efficiency and Effectiveness with Value Added Tests

- Concept and definition of value added tests *(0—5 min)*
- Value added behavioral tests *(6—20 min)*
- Value added objective tests *(21—40 min)*
- A modern diagnostic test battery *(41—55 min)*
- Summary, Questions and Answers *(55—60 min)*

# Raymond Carhart: Father of Audiology
## *Developed Audiology Test Battery 70 Years Ago*
### *(Audiology Father of James Jerger)*

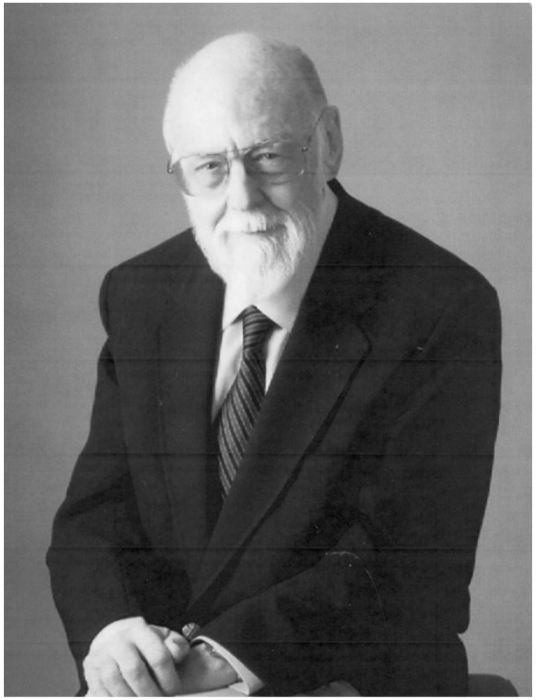
- **Test battery at the beginning of our profession, in order of test administration**
  - **Air-conduction pure tone audiometry**
  - **Bone-conduction pure tone audiometry**
  - **Speech reception thresholds**
  - **Word recognition (PB word lists)**
  - **Uncomfortable loudness level (UCL), i.e.,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

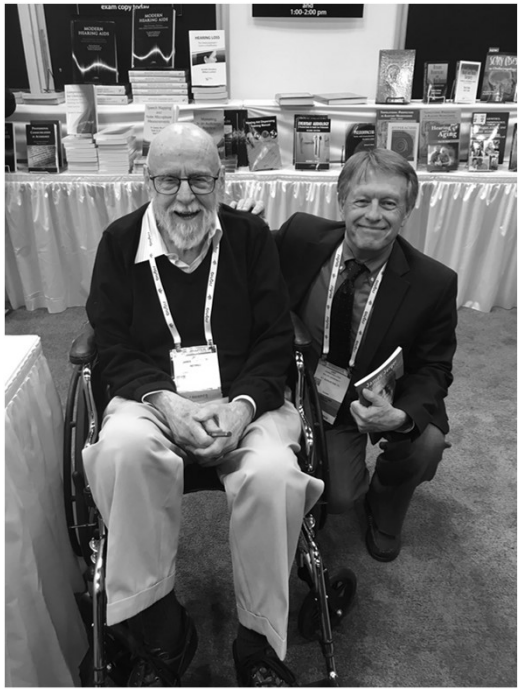
***Source: Wiener F & Miller G. Hearing aids. In Combat Instruments II. Washington, D.C. NDRC Report 117, 216-232, 1946***



**Raymond Carhart**

# Scientific Foundation of Audiology
# James Jerger, PhD … My Audiology Father
***Father of Diagnostic Audiology; Founder of American Academy of Audiology***





# Evidence Based Diagnostic Audiology: Enhancing Efficiency and Effectiveness with Value Added Tests

***Martin, Champlin & Chambers. Seventh survey of audiometric practices in the United States. JAAA 9, 95-101, 1998***

| Procedure | % Performing Procedure |
|---|---|
| Pure tone audiometry: air conduction | 100% |
| Pure tone audiometry: bone conduction | 73%* |
| Word recognition | 91% |
| Speech reception threshold | 99.5% |
| Tympanometry | 96% |
| Acoustic reflexes | 81% |
| Otoacoustic emissions (OAEs) | 33% |

* *Most audiologists routinely perform bone pure tone audiometry. Merely 6% administer BC pure tone audiometry only when warranted based on abnormal aural immittance findings*

## The Concept of Value Added Tests (VATs):
## *Rationale for Inclusion in a Test Battery*

- ❑ Contributes to understanding of patient's auditory status
- ❑ Provides information not available from other procedures and/or
- ❑ Information obtained quicker than another procedure and/or
- ❑ Poses less risk than an alternative procedure and/or
- ❑ Costs less than a comparable procedure
- ❑ Findings are more reliable or valid than an alternative test
- ❑ Highly sensitive to auditory dysfunction
- ❑ Provides site-specific information on auditory dysfunction
- ❑ Contributes to more accurate diagnosis
- ❑ Provides information useful in managing the patient and/or
- ❑ Information leads to better outcome for the patient

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- Concept and definition of value added tests
  *(0—5 min)*
- Value added behavioral tests
  *(6—20 min)*
- Value added objective tests
  *(21—40 min)*
- A modern diagnostic test battery
  *(41—55 min)*
- Summary, Questions and Answers
  *(55—60 min)*

## The Concept of Value Added Tests (VATs):
## *Traditional Behavioral Test Procedures Do Not Invariably Add Diagnostic Value and Squander Precious Test Time*

- ❑ **Speech awareness or detection threshold (SDT or SAT)**
- ❑ **Speech recognition threshold (SRT)** ***99.5%***
- ❑ **Bone conduction pure tone audiometry** ***73%***
- ❑ **Word recognition performance** ***91%***
  - **25 word lists with random difficulty**
  - **Words presented under earphones**
  - **Words presented in quiet**
  - **Words presented at 40 dB SL**
  - **Fixed time interval (~ 2 seconds) between words**
  - **Carrier phrase precedes each word (“Say the word …”)**

## The Concept of Value Added Tests (VATs): A Critical Look at Three Traditional Behavioral Tests *Speech Recognition Threshold (SRT)*

- Study of 1000 pediatric and adult patients (Roscher & Hall, 2005)
- SRT rarely contributed to diagnosis of hearing loss
- Factors in significant differences between PTA vs. SRT
  - Age
    - ✓Children (< 20 years)
    - ✓Older adults ( > 66 years)
  - Hearing loss
    - ✓No value in persons with normal hearing thresholds
    - ✓Greater PTA-SRT difference for SNHL
    - ✓Greater PTA-SRT difference for sloping hearing loss

# The Concept of Value Added Tests (VATs): A Critical Look at Three Traditional Procedures *Speech Recognition Threshold (SRT)*

**TABLE 2. Age distribution for all complete records and for patients with repeat tests excluded**

| | Age | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | <10 | 10s | 20s | 30s | 40s | 50s | 60s | 70s | 80s | 90s | No age | Total |
| All records | | | | | | | | | | | | |
| N | 2461 | 2535 | 1810 | 2607 | 2850 | 2674 | 2522 | 2222 | 942 | 57 | 3118 | 23798 |
| % | 10 | 11 | 8 | 11 | 12 | 11 | 11 | 9 | 4 | 0 | 13 | 100 |
| Patients | | | | | | | | | | | | |
| N | 1443 | 1368 | 1396 | 1877 | 2051 | 1920 | 1794 | 1527 | 679 | 36 | 2727 | 16818 |
| % | 9 | 8 | 8 | 11 | 12 | 11 | 11 | 9 | 4 | 0 | 16 | 100 |

**Margolis RH & Saly GL (2008). Distribution of hearing loss characteristics in a clinical population. *Ear & Hearing, 29*, 524-532**

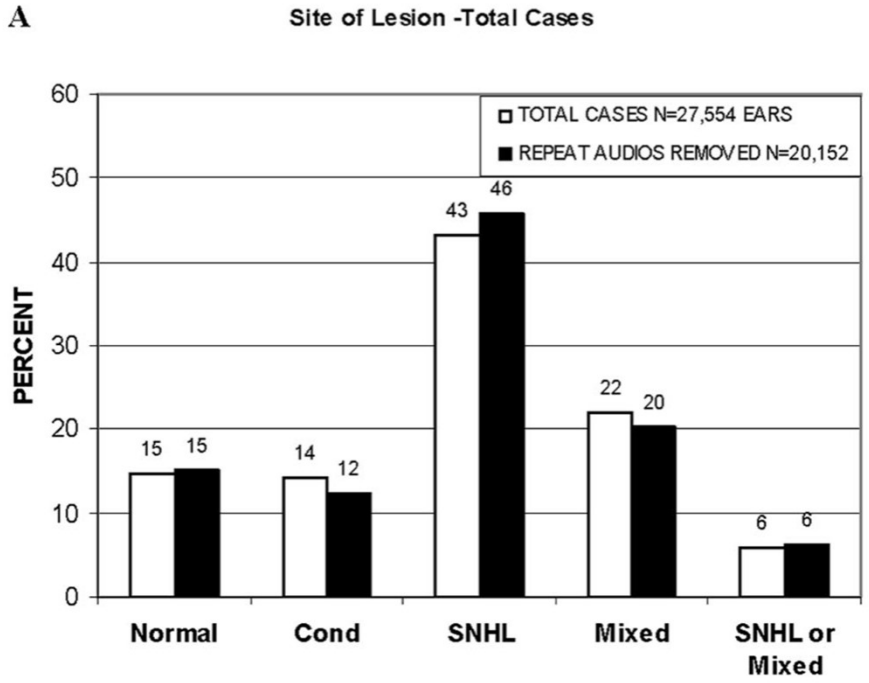
**For 53% of 16,818 patients, age was between 20 to 70 years.**

## The Concept of Value Added Tests:
## *Selective Use of Speech Reception Threshold*

- **Little or no value for**
  - **Adult patients age 20 to 65 years**
  - **Patients with normal hearing thresholds**
  - **Consistent findings available before pure tone audiometry**
    - ✓**Normal tympanograms bilaterally**
    - ✓**Acoustic reflex thresholds at expected normal levels**
    - ✓**Otoacoustic emission amplitudes within normal limits**
- **Speech reception threshold measurement in such patients will**
    - ✓**Waste valuable test time**
    - ✓**Not add value to the diagnosis**
    - ✓**Not add value to referral or management decisions**
    - ✓**Not lead to improved patient outcome**

# The Concept of Value Added Tests (VATs): A Critical Look at Three Traditional Procedures

## *Bone Conduction Pure Tone Audiometry*



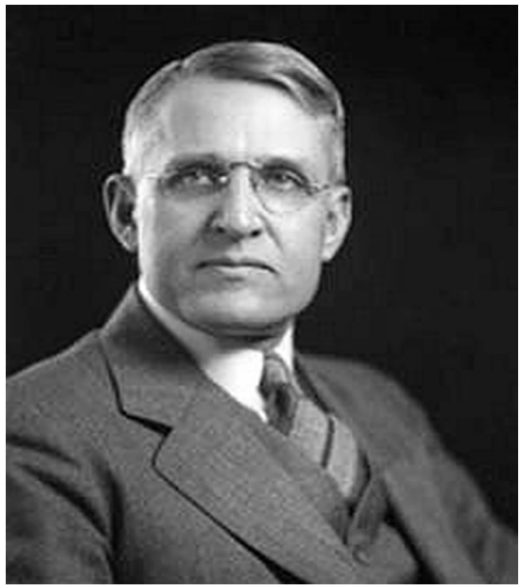

**Margolis RH & Saly GL (2008). Distribution of hearing loss characteristics in a clinical population. *Ear & Hearing, 29*, 524-532**

***Only 36% of patients had conductive component to hearing loss***

## The Concept of Value Added Tests:
## *Selective Use of Bone Conduction Pure Tone Audiometry*

- **No value in many patients, e.g., older children and adults with**
  - **No history of middle ear disease**
  - **Pattern of findings available before pure tone audiometry**
    - ✓**Normal tympanograms bilaterally**
    - ✓**Acoustic reflex thresholds at expected normal levels**
    - ✓**Normal OAE amplitudes for low frequency stimuli**
  - **Air conduction pure tone audiometry showing sloping high frequency hearing loss plus any of the above**
- **Bone conduction pure tone audiometry in such patients will**
  - ✓**Waste valuable test time**
  - ✓**Not add value to the diagnosis**
  - ✓**Not add value to referral or management decisions**
  - ✓**Not lead to improved patient outcome**

## Assessment of Word Recognition with PB Words:
## *A Long Tradition Since the 1920s, 1930s &1940s*



**Harvey Fletcher**
***(1884-1981)***

**Ira Hirsh**
**(1922 - 2010)**

## The Concept of Value Added Tests (VATs): *Selective Use of Word Recognition in Quiet*

- Patient is an adult with the chief complaint of difficulty hearing in noisy settings
- Patient converses easily in the clinic without visual cues
- Pure tone audiometry findings are entirely normal
- Word recognition in quiet will …
  - Waste valuable test time
  - Not add value to the diagnosis
  - Not add value to management
  - Not lead to improved patient outcome
- Instead
  - Perform a test of speech perception in noise
  - Consider other tests of auditory processing

## Test Times for Administering Traditional Behavioral Tests: Cooperative Children > 6 – 14 Years Old

*(Time Date from Basar & Canbaz, J Int Adv Otol, 11, 42-47, 2015)*

- **Speech recognition threshold (SRT)**
  - **Mean both ears = 4.7 mins**
  - **Range = 1-10 mins**
- **Bone conduction pure tone audiometry**
  - **Mean both ears = 5.6 mins**
  - **Range = 1-10 mins**
- **Word recognition performance**
  - **Mean both ears = 5.3 mins**
  - **Range = 1-10 mins**

***NOTE: Total average time for SRT and BC = 10.3 mins. Plus routine use with no clinical value adds mIllions of dollars to health care costs annually in USA alone.***

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# Evidence Based Diagnostic Audiology: Enhancing Efficiency and Effectiveness with Value Added Tests

## *Value Added Objective Tests*

- ❑ **Aural immittance measures**
- ❑ **Otoacoustic emissions**


# Evidence Based Diagnostic Audiology: Enhancing Efficiency and Effectiveness with Value Added Tests

## *Aural Immittance Measurements*

- Ear canal volume
- Static compliance
- Tympanometry
  - 220 vs. 1000 Hz probe tones
  - Multiple admittance components
  - Eustachian tube tests
  - Fistula test
- Acoustic reflexes
  - Ipsi - and contralateral
  - Threshold
  - Decay
  - Latency

## The Diagnostically Valuable Yet Underutilized Acoustic Reflex: *Many Valuable Clinical Applications*

- Confirming or ruling out even subtle middle ear dysfunction
- Differentiating normal cochlear function versus sensory hearing loss
- Detection of neural dysfunction
  - 8th cranial nerve
  - 7th nerve
  - Auditory brainstem
- Diagnosis of auditory neuropathy spectrum disorder
- Identification of false or exaggerated hearing loss (confirmation of normal cochlear and neural auditory function)

# Many Audiologists Do Not Record Acoustic Reflexes in Most Patients

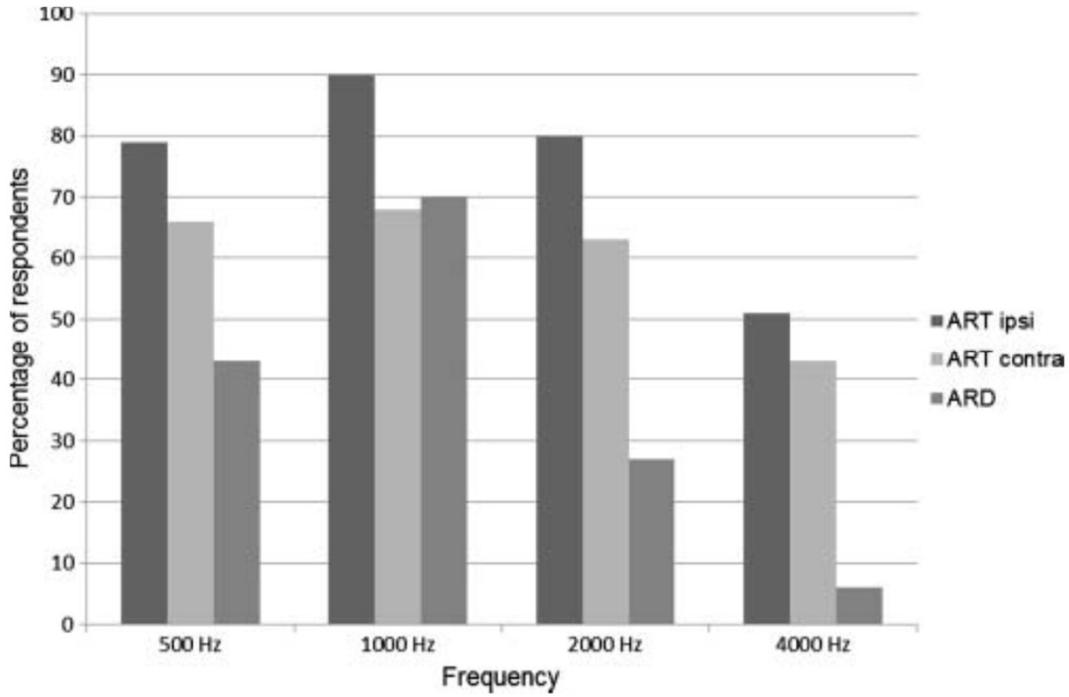
- Emanuel et al (2012). Survey of audiological immittance practices. *AJA, 21,* 60-85
  - Survey responses from 156 audiologists (2008 + 2009)
  - 61% always perform single component tympanometry
  - Less than 33% record multi-component tympanograms
  - Decrease in contralateral acoustic reflex testing over time from 81% to 60%
  - Patient discomfort reportedly common reason for not performing acoustic reflex measurement

# Many Audiologists Do Not Record Acoustic Reflexes in Most Patients

- Emanuel DC et al (2011). Survey of diagnosis and management of auditory processing disorder. AJA, 20, 48-60
  - Survey responses from 192 audiologists who perform APD assessments
  - >90% of audiologists evaluate APD in children
  - 97% perform tympanometry
  - 69% perform acoustic reflex threshold measurements

# Proportion of Audiologists Record Acoustic Reflexes Appears to Be Decreasing Over the Years

***Emanuel et al (2012)***



## The Concept of Value Added Tests (VATs): *Rationale for Inclusion of Aural Immittance Measures in Routine Diagnostic Test Battery (1)*

- ❑ **Contributes to understanding of patient's auditory status**
  - ✓**Yes … hundreds of published studies**
- ❑ **Provides information not available from other procedures**
  - ✓**Yes … only direct measure of middle ear function**
- ❑ **Information obtained quicker than another procedure**
  - ✓**Yes … test time of ~ 4 minute for both ears**
- ❑ **Poses less risk than an alternative procedure**
  - ✓**No risk**
- ❑ **Costs less than a comparable procedure**
  - ✓**Yes**
  - ✓**Can be administered by non-audiology personnel**

## The Concept of Value Added Tests (VATs): *Rationale for Inclusion of Aural Immittance Measures in Routine Diagnostic Test Battery (2)*

- ❑ **Findings are more reliable or valid than an alternative test**
  - ✓**Reliable and valid in patients of all ages**
  - ✓**Not influenced by listener variables**
- ❑ **Highly sensitive to auditory dysfunction**
  - ✓**Most sensitive measure of middle ear function**
- ❑ **Provides site-specific information on auditory dysfunction**
  - ✓**Information on structures from middle ear to brainstem**
- ❑ **Contributes to more accurate diagnosis**
  - ✓**Findings permit diagnosis of type of hearing loss**
- ❑ **Provides information useful in managing the patient and/or**
  - ✓**Findings directly impact medical and audiologic management**
- ❑ **Information leads to better outcome for the patient**
  - ✓**Yes**

# Evidence Based Diagnostic Audiology: Enhancing Efficiency and Effectiveness with Value Added Tests
## *Otoacoustic Emissions*

- Distortion product OAEs
- Transient evoked OAEs
- Protocols
  - Automated (CPT 92558)
  - Limited (CPT 92587)
  - Diagnostic (CPT 92588)

## The Concept of Value Added Tests (VATs): *Rationale for Inclusion of OAEs in Routine Diagnostic Test Battery (1)*

- ❑ **Contributes to understanding of patient's auditory status**
  - ✓**Yes … hundreds of published studies**
- ❑ **Provides information not available from other procedures**
  - ✓**Yes … only direct measure of outer hair cell function**
- ❑ **Information obtained quicker than another procedure**
  - ✓**Yes … test time of ~ 30 secs - 3 minutes per ear**
- ❑ **Poses less risk than an alternative procedure**
  - ✓**No risk**
- ❑ **Costs less than a comparable procedure**
  - ✓**No comparable procedure but reasonable cost**
  - ✓**Can be administered by non-audiology personnel**

## The Concept of Value Added Tests (VATs): *Rationale for Inclusion of OAEs in Routine Diagnostic Test Battery (2)*

- ❑ **Findings are more reliable or valid than an alternative test**
  - ✓**Reliable and valid in patients of all ages**
  - ✓**Not influenced by listener variables**
- ❑ **Highly sensitive to auditory dysfunction**
  - ✓***Most* sensitive measure of cochlear (outer hair cell) status**
- ❑ **Provides site-specific information on auditory dysfunction**
  - ✓**Highly site specific to outer hair cells**
- ❑ **Contributes to more accurate diagnosis**
  - ✓**Yes … Findings permit very specific diagnosis (e.g., ANSD)**
- ❑ **Provides information useful in managing the patient and/or**
  - ✓**Findings directly impact medical and audiologic management**
- ❑ **Information leads to better outcome for the patient**
  - ✓**Yes**

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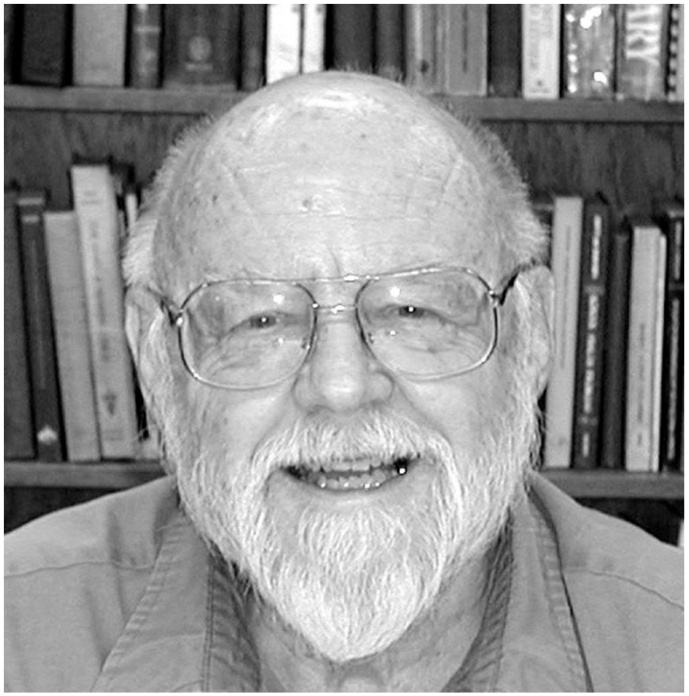
# The Cross-Check Principle in for Diagnosis of Hearing Loss in Children

***(Jerger J & Hayes D. Arch Otolaryngol 102: 1976)***



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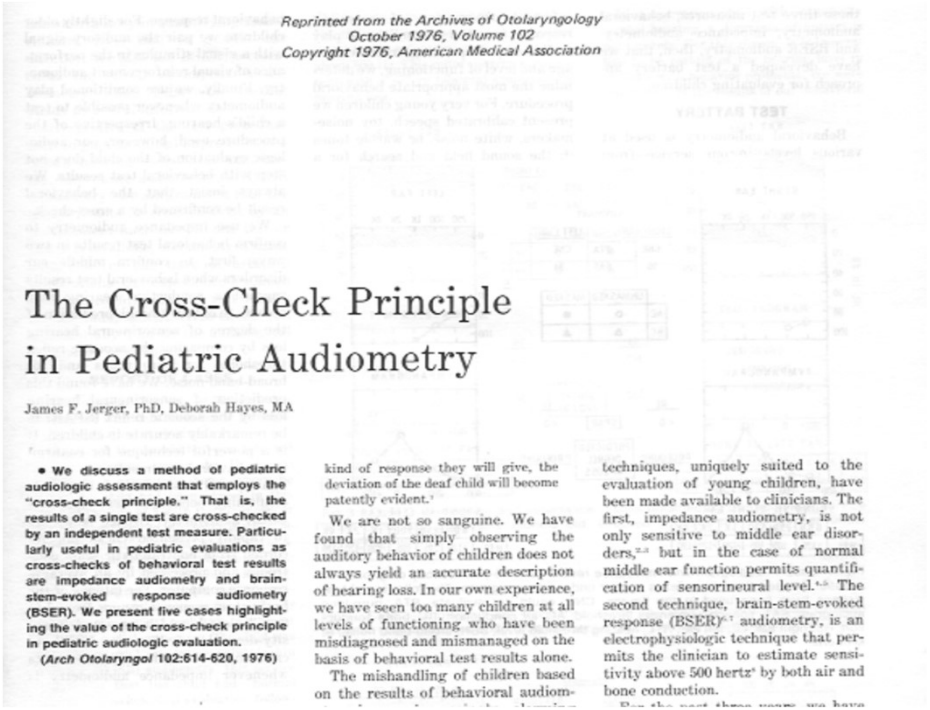

*Reprinted from the Archives of Otolaryngology*
*October 1976, Volume 102*


## The Cross-Check Principle in Pediatric Audiometry

James F. Jerger, PhD, Deborah Hayes, MA

• **We discuss a method of pediatric audiologic assessment that employs the "cross-check principle." That is, the results of a single test are cross-checked by an independent test measure. Particularly useful in pediatric evaluations as cross-checks of behavioral test results are impedance audiometry and brain-stem-evoked response audiometry (BSER). We present five cases highlighting the value of the cross-check principle in pediatric audiologic evaluation.**

(*Arch Otolaryngol* 102:614-620, 1976)

kind of response they will give, the deviation of the deaf child will become patently evident.[1]

We are not so sanguine. We have found that simply observing the auditory behavior of children does not always yield an accurate description of hearing loss. In our own experience, we have seen too many children at all levels of functioning who have been misdiagnosed and mismanaged on the basis of behavioral test results alone.

The mishandling of children based on the results of behavioral audiom-

techniques, uniquely suited to the evaluation of young children, have been made available to clinicians. The first, impedance audiometry, is not only sensitive to middle ear disorders,[2,3] but in the case of normal middle ear function permits quantification of sensorineural level.[4-6] The second technique, brain-stem-evoked response (BSER)[6,7] audiometry, is an electrophysiologic technique that permits the clinician to estimate sensitivity above 500 hertz[8] by both air and bone conduction.

# The Cross-Check Principle Pediatric Audiology

***(Jerger J & Hayes D. Arch Otolaryngol 102: 1976)***

***What's missing from the test battery?***

**"We have found than simply observing the auditory behavior of children does not always yield an accurate description of hearing loss"…**

**"The basic operation of this principle is that no result be accepted until it is confirmed by an independent measure."**

**Test Battery:**

- **Behavioral audiometry**
- **Immittance (impedance) measurements**
  - ✓ **Tympanometry**
  - ✓ **Acoustic reflexes (contralateral only with SPAR)**
- **Auditory brainstem response (brainstem-evoked response audiometry or BSER)**
  - ✓ **Click stimulus air conduction**
  - ✓ **Click stimulus bone conduction**

## The Cross-Check Principle Revisited: *Test Battery Today*

- Pure tone audiometry
- Speech audiometry
  - Word recognition tests
  - Diagnostic speech audiometry
- Aural immittance measurements
  - Tympanometry (multi-frequency and multi-component)
  - Acoustic reflexes (ipsilateral and contralateral)
- Otoacoustic emissions
- Auditory evoked responses
  - ECochG
  - ABR
  - ASSR
  - Cortical auditory evoked responses

# The Cross-Check Principle Revisited 40 Years Later

*(jwhall3phd@gmail.com)*

**REVIEW**
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## Crosscheck Principle in Pediatric Audiology Today: A 40-Year Perspective

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# Rethinking Your Diagnostic Audiology Battery:
# Part 1. Using Value Added Tests
## *Comparative Times for Different Tests*

**“Remember that time is money”**

**Benjamin Franklin**

***Advice to a Young Tradesman***
***1748***

## Times for Administering Behavioral and Objective Tests: Cooperative Children > 6 Years Old

*(Basar & Canbaz, J Int Adv Otol, 11, 42-47, 2015)*

- **Behavioral Tests = > 25 minutes**
  - **Speech recognition threshold (SRT) = ~ 5 mins**
  - **Pure tone audiometry: AC = ~7.5 minutes**
  - **Pure tone audiometry: BC = ~ 6 mins**
  - **Word recognition = ~ 5 – 6 mins**
- **Objective Tests = < 11.5 minutes**
  - **Tympanometry and acoustic reflexes = ~ 4.5 mins**
  - **DPOAEs = < 7 minutes**

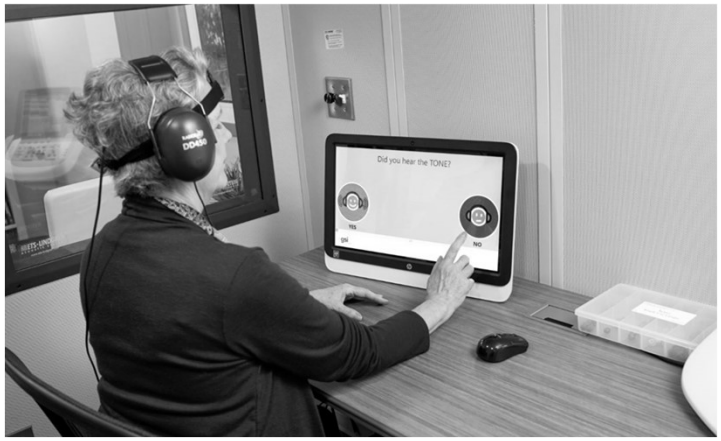
## A Modern Diagnostic Audiologic Test Battery
## In the Order of Testing for New Patients
***Total Test Time = < 30 - 45 minutes.***

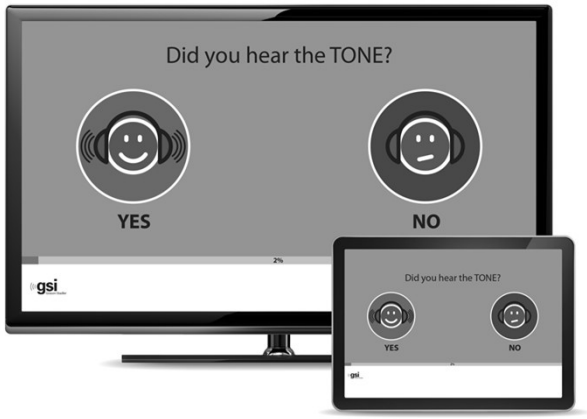
- ❑ **Otoscopy**
- ❑ **Distortion product otoacoustic emissions (DPOAEs)**
  - ● **500 to 8000 Hz**
  - ● **5 frequencies/octave**
  - ● **L1= 65 dB; L2 = 55 dB**
  - ● **Three possible outcomes**
    - ✓ **Normal (DP – NF > 6 dB and amplitudes WNL)**
    - ✓ **Present but abnormal (DP – NF > 6 dB)**
    - ✓ **Absent (DP – NF = < 6 dB)**
- ❑ **Aural immittance measures**
  - ● **Tympanometry**
  - ● **Acoustic reflexes**
    - ✓ ***Ipsilateral***
    - ✓ ***Contralateral***

## A Modern Diagnostic Audiologic Test Battery
## In the Order of Testing for New Patients.
***Total Test Time = < 30 - 45 minutes.***

- **Behavioral measures**
  - **Pure tone audiometry *(automated technique as appropriate)***
    - ✓**Inter-octave frequencies (always 3000 and 6000 Hz)**
    - ✓**High frequency (> 8000 Hz) audiometry *as indicated***
    - ✓**Bone conduction measurement *only as indicated***
  - **Speech audiometry**
    - ✓**SRT *only as indicated***
    - ✓**Word recognition (recorded material) with 10 most difficult words first**
    - ✓**Speech-in-noise test**
    - ✓**Screen auditory processing as indicated**

# A Modern Diagnostic Audiological Test Battery:
## *Automated Pure Tone and Speech Audiometry*
## *(GSI AMTAS)*




## GSI AMTAS
## (Automated Method for Testing Auditory Sensitivity)

# A Modern Diagnostic Audiological Test Battery:
## *Automated Pure Tone Audiometry*
## *(GSI AMTAS Software Options)*


**GSI AudioStar Pro**


**GSI Pello**

## Automated Pure Tone and Speech Audiometry
### *Selected References on AMTAS Method*


- Margolis RH, Glasberg, BR, Creeke S, Moore BC (2010). AMTAS: Automated method for testing auditory sensitivity: Validation studies. Int J Audiol, 49, 185-194
- Margolis RH, Frisina R, Walton JP (2011). AMTAS: Automated method for testing auditory sensitivity: II. Air conduction audiograms in children and adults. Int J Audiol, 50, 434-439
- Margolis RH & Moore BC (2011). AMTAS: Automated method for testing auditory sensitivity: III. Sensorineural hearing loss and air-bone gaps. Int J Audiol, 50, 440-447
- Eikelboom RH, Swanepoel D, Motakef S. Upson GS (2013). Clinical validation of the AMTAS automated audiometer. Int J Audiol, 52, 342-349

# A Modern Diagnostic Audiological Test Battery:
## *Using Saved Time to Perform Value Added Speech AudiometryTests*


- SII calculation
- Word lists (digital with scoring capability)
- Speech in noise tests, e.g.,
  - QuickSin
  - BKBSin
- Other APD speech tests available on TympStar Pro upon request

# A Modern Diagnostic Audiologic Test Battery: Speech Audiometry with Modern Audiometers

## *SRT*

# A Modern Diagnostic Audiologic Test Battery: Speech Audiometry with Modern Audiometers

## *Efficient Word Recognition Testing*

# A Modern Diagnostic Audiologic Test Battery: Speech Audiometry with Modern Audiometers

## *Speech Perception in Noise*

# Evidence Based Diagnostic Audiology: Enhancing Efficiency and Effectiveness with Value Added Tests

- Summary
  - The diagnostic audiolology test battery used by most audiologists is outdated and inefficient
  - Efficiency and effectiveness should also be considered in the diagnostic audiology test battery … the most clinical information in the least test time
  - The test battery should consist of value added tests … always ask: "Will the test findings contribute to diagnosis or management of the patient?"
  - Objective measures meet criteria for value added tests
  - Automated audiometry contributes to clinical efficiency
- Questions and Answers