The Role of Auditory Steady State Response (ASSR) in Audiology Today

James W. Hall III, Ph.D.

Clinical Professor and Chair
Department of Communicative Disorders
College of Health Professions
University of Florida
Gainesville, FL 32610
Jhall@hp.ufl.edu

Year 2000 JCIH Position Statement: Protocol for Confirmation of Hearing Loss In Infants and Toddlers (0 to 6 months)

- Child and family history
- Otoacoustic emissions
- ABR during initial evaluation to confirm type, degree & configuration of hearing loss (ASSR now also?)
- Acoustic immittance measures (including acoustic reflexes)
- Behavioral response audiometry *(if feasible)*
  - ✓Visual reinforcement audiometry *or*
  - ✓Conditioned play audiometry
  - ✓Speech detection and recognition
- Parental report of auditory & visual behaviors
- Screening of infant's communication milestones

AUDITORY STEADY STATE RESPONSE (ASSR) ASSESSMENT IN INFANCY: Strengths and Weaknesses

- ❑ Historical perspective
- ❑ General principles
- ❑ Anatomy and physiology
- ❑ Instrumentation
- ❑ Stimulus and analysis
- ❑ Literature review
- ❑ Clinical features
  - ✓ advantages
  - ✓ disadvantages

AUDITORY STEADY STATE RESPONSE (ASSR): Historical Perspective and Terminology

- Amplitude-modulation-following response (AMFR)
- Envelope -following response (EFR)
- Frequency-following response (FFR)
- Steady state evoked response (SSER)
- Steady state evoked potential (SSEP)
- 40 Hz response
- Auditory steady state response (ASSR)

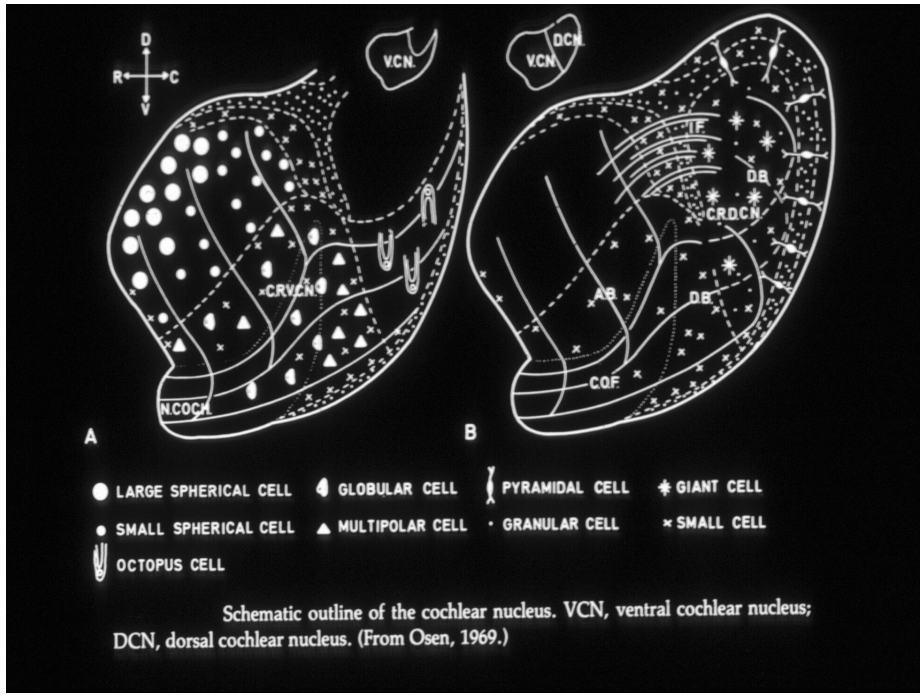
AUDITORY STEADY STATE RESPONSE (ASSR) ASSESSMENT IN INFANCY: Strengths and Weaknesses

- ❑ Historical perspective
- ❑ General principles
- ❑ Anatomy and physiology
- ❑ Instrumentation
- ❑ Stimulus and analysis
- ❑ Literature review
- ❑ Clinical features
  - ✓ advantages
  - ✓ disadvantages

AUDITORY STEADY STATE RESPONSE (ASSR) ASSESSMENT IN INFANCY: Strengths and Weaknesses

- ❑ Historical perspective
- ❑ General principles
- ❑ Anatomy and physiology
- ❑ Instrumentation
- ❑ Stimulus and analysis
- ❑ Literature review
- ❑ Clinical features
  - ✓ advantages
  - ✓ disadvantages

Anatomy & Physiology of ABR vs. ASSR: Neuronal Generator Types



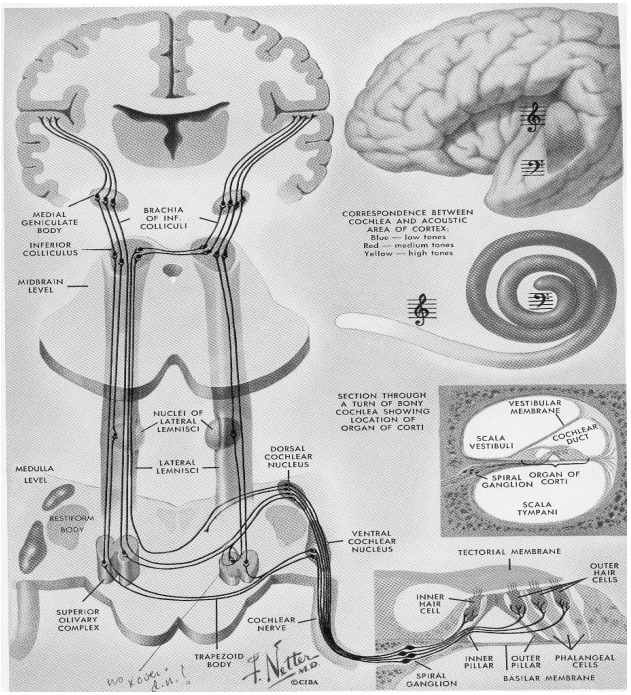
Schematic outline of the cochlear nucleus. VCN, ventral cochlear nucleus; DCN, dorsal cochlear nucleus. (From Osen, 1969.)

- ❑ onset (ABR)
- ❑ offset
- ❑ onset-offset
- ❑ pauser
- ❑ chopper
- ❑ inhibitory
- ❑ tonic (ASSR?)

Anatomy & Physiology of ASSR: Generators

Slower modulation rates (< 60 Hz) = Cortical regions

Faster modulation rates (> 60 Hz) = Brainstem



AUDITORY STEADY STATE RESPONSE (ASSR) ASSESSMENT IN INFANCY: Strengths and Weaknesses

- ❑ Historical perspective
- ❑ General principles
- ❑ Anatomy and physiology
- ❑ Instrumentation
- ❑ Stimulus and analysis
- ❑ Literature review
- ❑ Clinical features
  - ✓ advantages
  - ✓ disadvantages

Auditory Steady State Response (ASSR): Clinical Devices

- **GSI VIASYS**
  - **Audera**
  - **Descendant of Melbourne Australia system Field (Rickards, Gary Rance, Barbara Cone-Wesson, et al)**

- **Bio-Logic Systems Inc.**
  - **MASTER**
  - **Descendent of Canadian system (Terry Picton et al)**

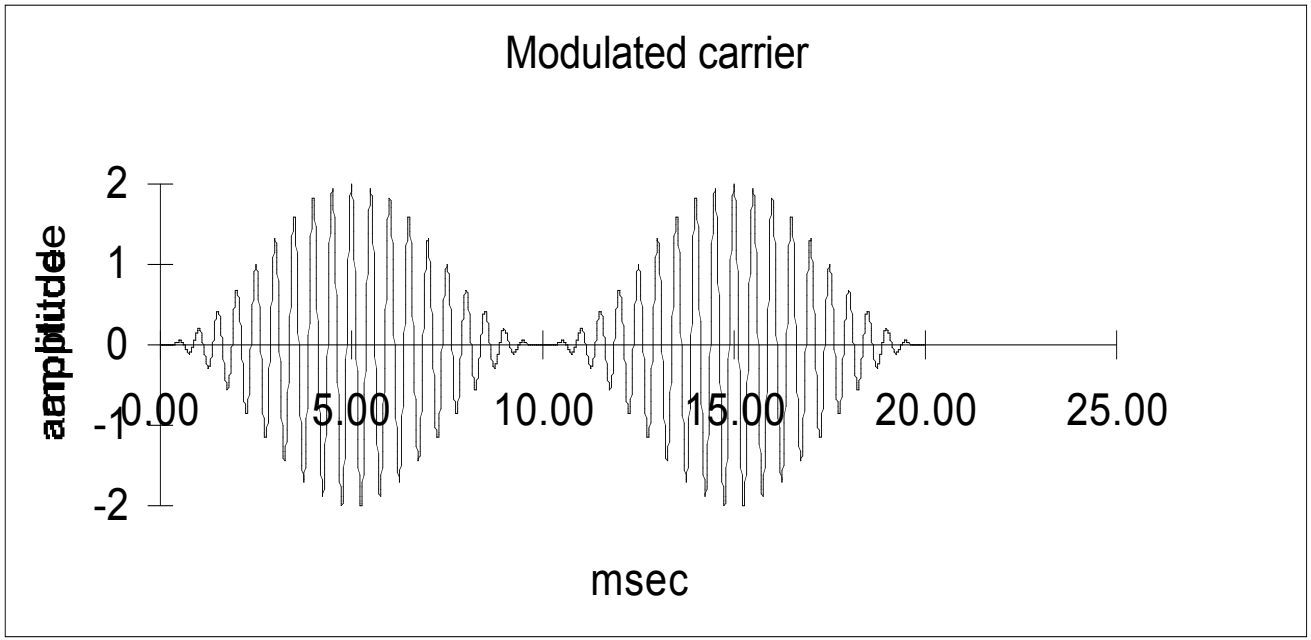
ASSR: General Principles

- An electrophysiologic response, similar to ABR.
- Instrumentation includes:
  - Insert earphones
  - Surface electrodes
  - Averaging computer
- Stimuli are pure tones (frequency specific, steady state signals) activating cochlea and CNS
- ASSR is generated by rapid modulation of “carrier” pure tone amplitude (AM) or frequency (FM).
- Signal intensity can be as high as 120 dB HL
- ASSR phase or frequency is detected automatically (vs. visual detection)

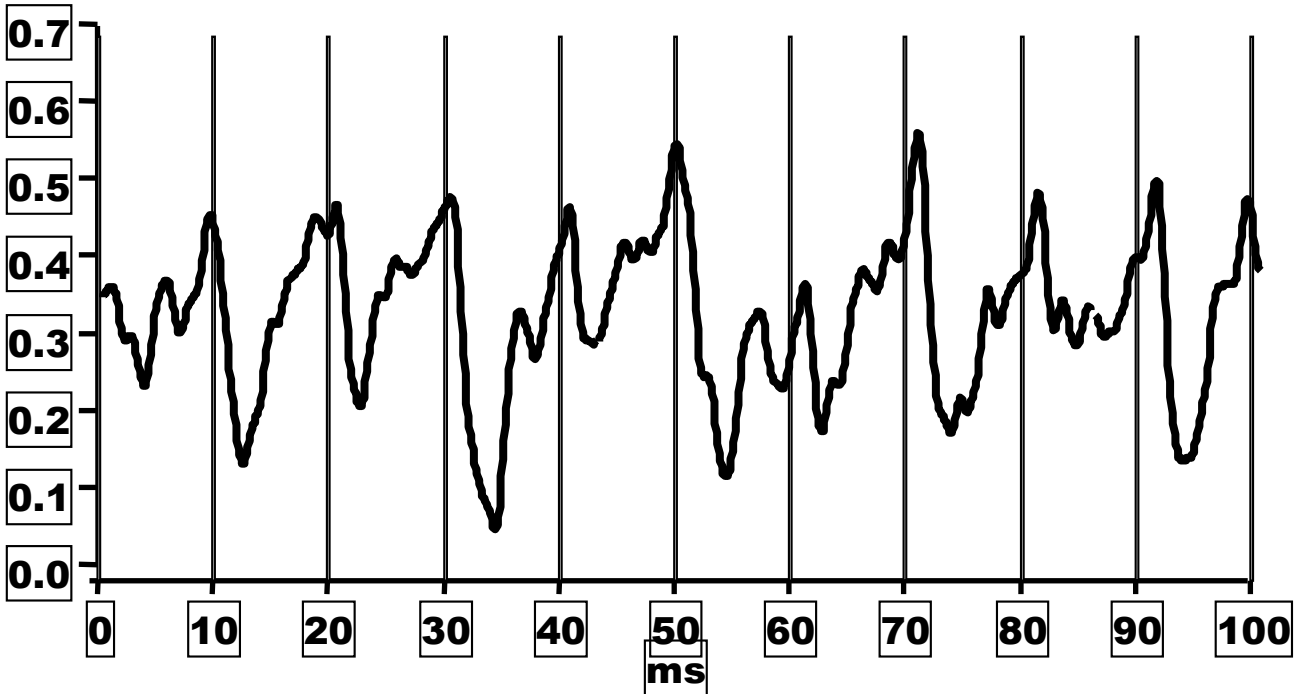
AUDITORY STEADY STATE RESPONSE (ASSR) ASSESSMENT IN INFANCY: Strengths and Weaknesses

- ❑ Historical perspective
- ❑ General principles
- ❑ Anatomy and physiology
- ❑ Instrumentation
- ❑ Stimulus and analysis
- ❑ Literature review
- ❑ Clinical features
  - ✓ advantages
  - ✓ disadvantages

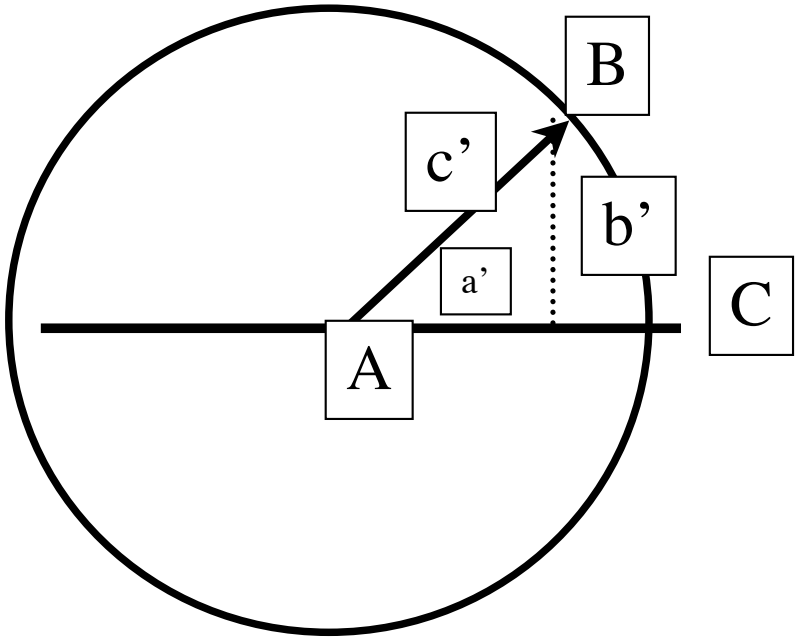
ASSR:
2000 Hz tone modulated at rate of 100 Hz



ASSR:
Response imbedded within EEG



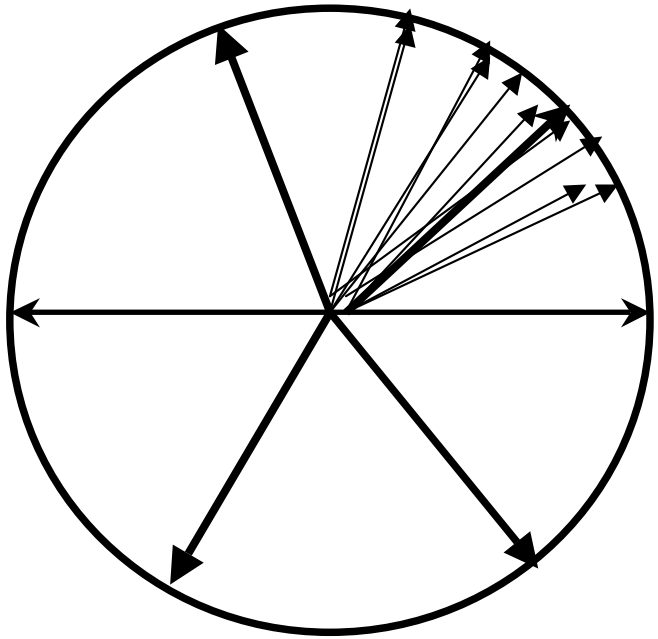
ASSR: Graphic display in vector plot of EEG samples at modulation frequency



Vector length (c') = magnitude of activity

Vector angle (a') = phase lag between stimulus MF and EEG at MF

ASSR: Vector plot confirming response at suprathreshold stimulus levels

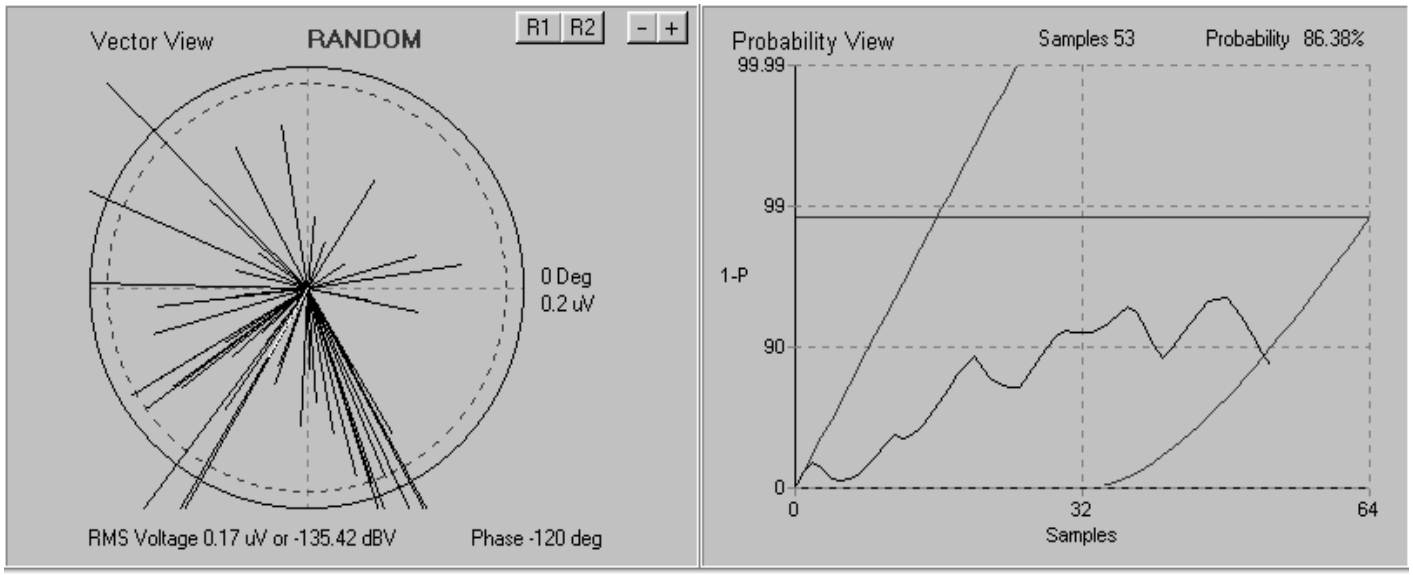


Phase of vectors of EEG samples at MF are clustered

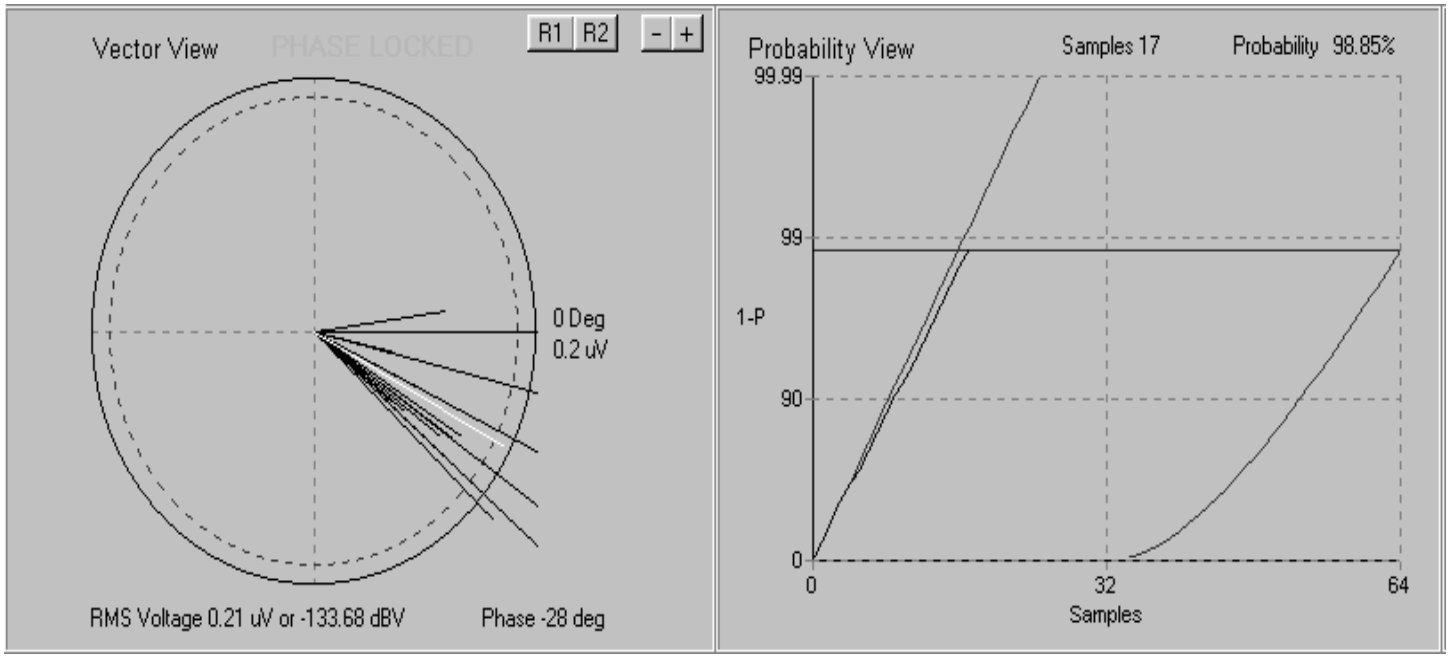
Brain EEG is “phase locked” or “coherent”

Phase coherence values are statistically difference from noise

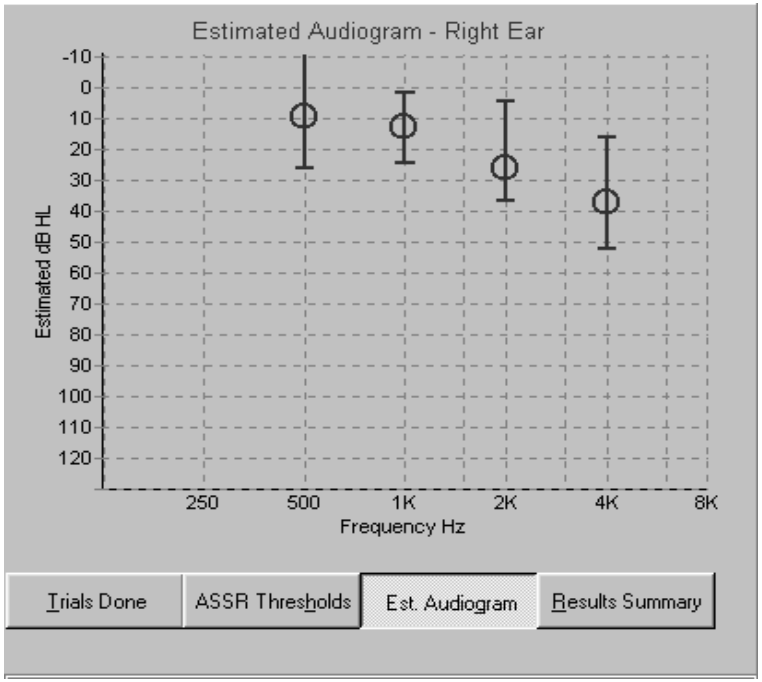
ASSR (Audera):
No Response Condition

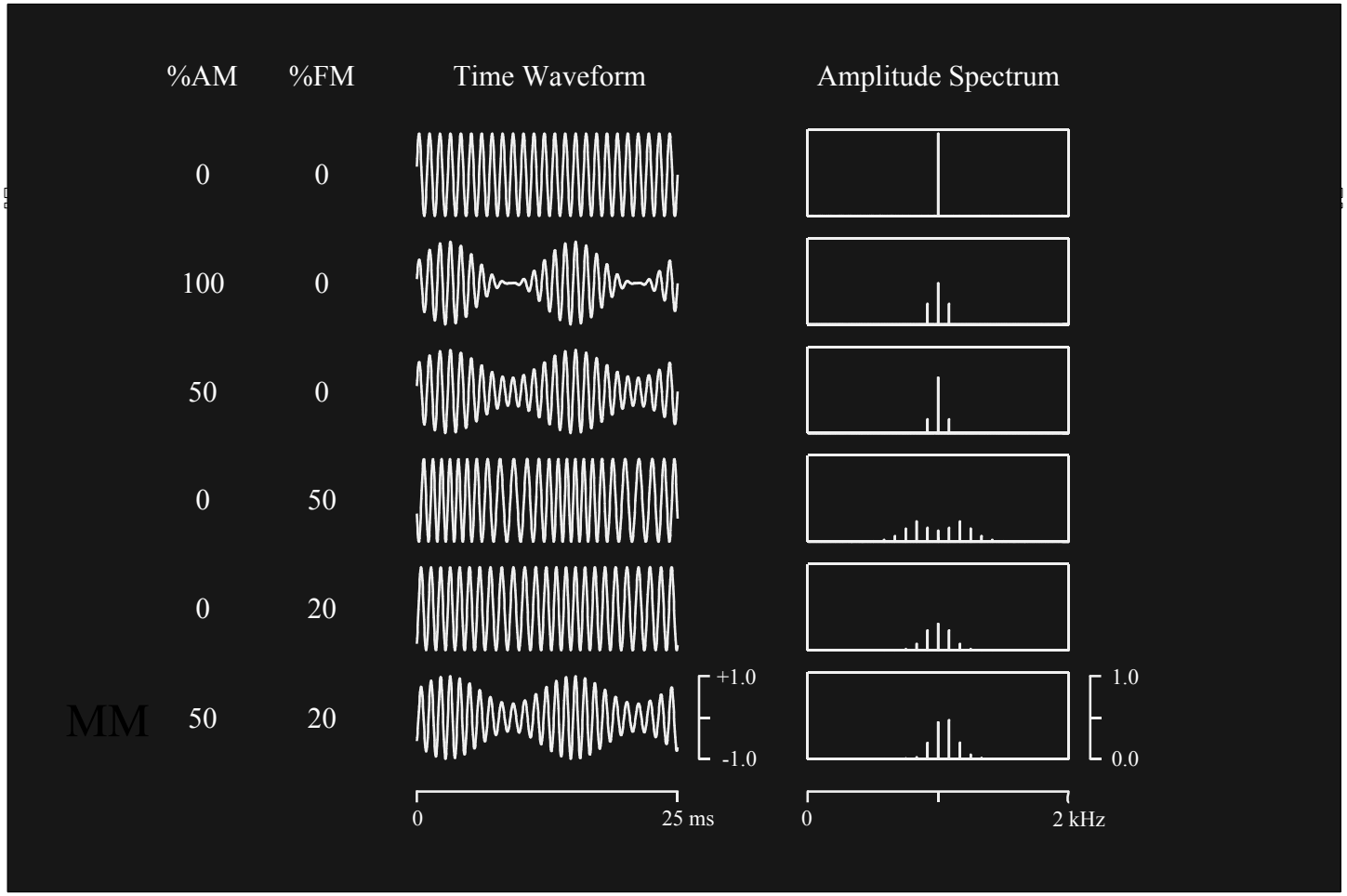


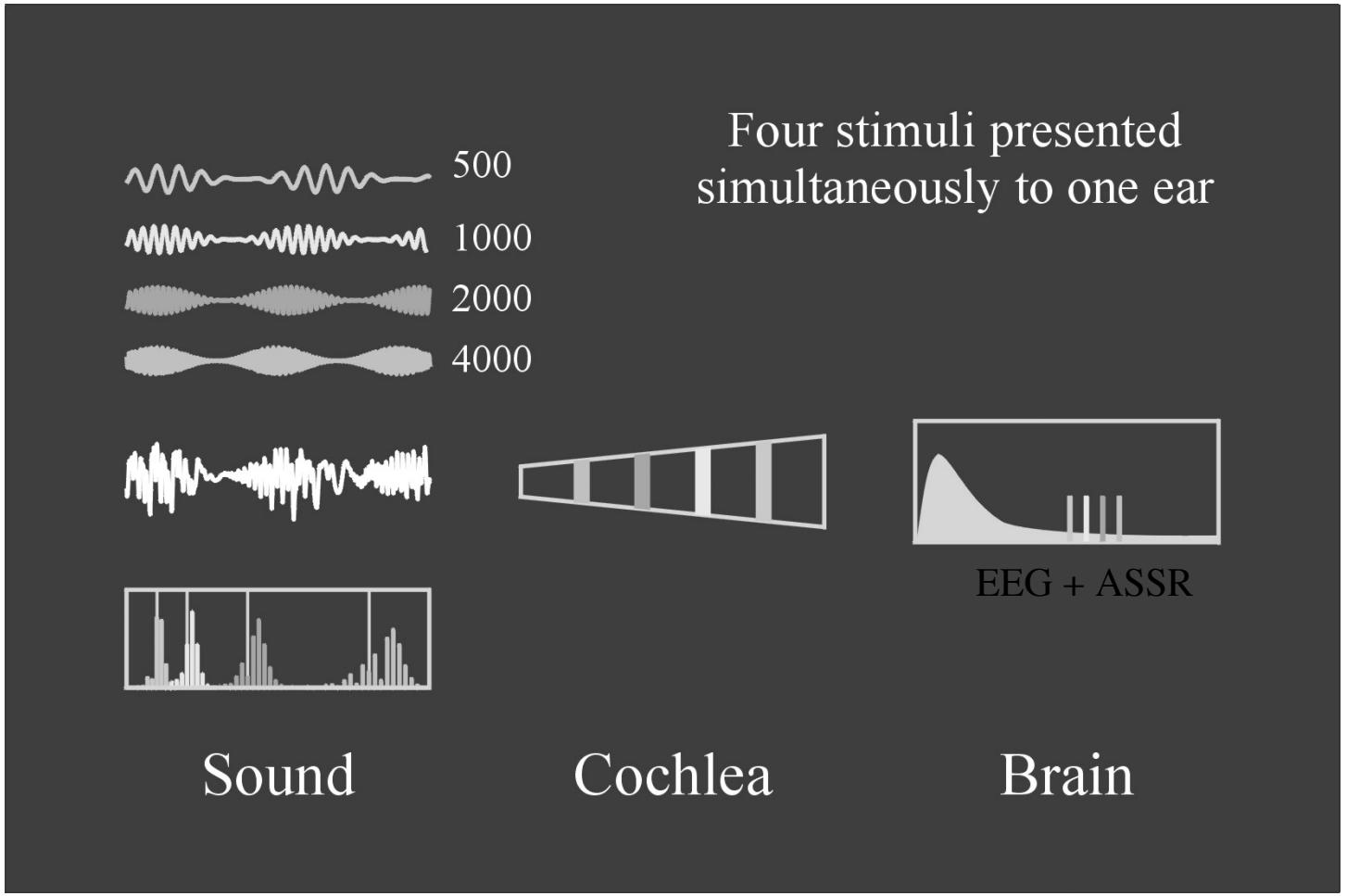
ASSR (Audera):
Significant phase coherence



ASSR (Audera):
Estimated Audiogram




%AM
%FM
Time Waveform
Amplitude Spectrum
0
0
100
0
50
0
0
50
0
20
MM
50
20
+1.0
-1.0
1.0
0.0
0
25 ms
0
2 kHz


Four stimuli presented
simultaneously to one ear
500
1000
2000
4000
EEG + ASSR
Sound
Cochlea
Brain

ASSR with MASTER:
Detecting the signal using F test

- Takes into account the variance of the noise along with the variance of the response

- F-ratio of Significance must have a p<.05 or better

- Response color plot
  - Red = >.101
  - Yellow = .051 - .101
  - Green = <.050

AUDITORY STEADY STATE RESPONSE (ASSR) ASSESSMENT IN INFANCY: Strengths and Weaknesses

- ❑ Historical perspective
- ❑ General principles
- ❑ Anatomy and physiology
- ❑ Instrumentation
- ❑ Stimulus and analysis
- ❑ Literature review
- ❑ Clinical features
  - ✓ advantages
  - ✓ disadvantages

Auditory Steady State Responses (ASSRs): Selected Literature from the Australian Group

- Rickards & Clark. Steady-state evoked potentials to amplitude modulated tones. In Evoked Potentials II. Boston: Butterworth, 1984.
- Rickards et al. Auditory steady-state evoked responses in newborns. British Journal of Audiology 28: 1994.
- Rance, Rickards et al. The automated prediction of hearing thresholds in sleeping subjects using steady state evoked potentials. Ear & Hearing 16: 1995.
- Rance, Dowell, Rickards et al. Steady-state evoked potential and behavioral hearing thresholds in a group of children with absent click-evoked ABRs. Ear & Hearing 19: 1998.
- Rance, Beer, Cone-Wesson et al. Clinical findings for a group of infants and young children with auditory neuropathy. Ear & Hearing 20: 1999.
- Rance & Briggs. Assessment of hearing in infants with moderate to profound impairment: The Melbourne experience with auditory steady-state evoked potential testing. Ann Otol Rhinol Laryngol 111: 2002

Auditory Steady State Responses (ASSRs): Selected Literature from the Canadian Group

- Linden, Campbell, Hamel, Picton: Human auditory steady state evoked potentials during sleep. Ear & Hearing 6: 1985.
- Stapells, Makeig, Galambos. Auditory steady-state response threshold prediction using phase coherence. EEG & Clin Neurophysiol 67: 1987.
- Valdes, Perez-Abalo et al. Comparison of statistical indicators for the automatic detection of 80 Hz auditory steady state responses. Ear & Hearing 18: 1997.
- Picton et al. Objective evaluation of aided thresholds using auditory steady-state responses. JAAA 9: 1998.
- John & Picton. Human auditory steady-state responses to amplitude-modulated tones: phase and latency measurements. Hearing Research 141: 2000.
- John & Picton. MASTER: A Windows program for recording multiple auditory steady-state reponses. Computer Methods and Programs in Biomedicine 61: 2000.
- Dimitrijevic, John, van Roon, Picton. Human auditory steady-state responses to tones independently modulated in both frequency and amplitude. Ear & Hearing 22: 2001.

The Auditory Steady State Response: Part I.
J Amer Acad Audiol 13 (4) special issue, April 2002.

- **Cone-Wesson B, Dowell RC, Tomlin D, Rance G, Ming WJ. The auditory steady-state response: Comparisons with the auditory brainstem response. [U. of Arizona and Melbourne, Australia]**

- **Kuwada et al. Sources of scalp-recorded amplitude-modulated following response. [U. of Connecticut]**

- **Dimitrijevic, Picton, et al. Estimating the audiogram using multiple auditory steady-state responses. [Toronto]**

The Auditory Steady State Response: Part I.
J Amer Acad Audiol 13 (5) special issue, May 2002.

- Cone-Wesson, Rickards, et al. The auditory steady-state response: Clinical observations and applications in infants and children. [U. of Arizona and Melbourne, Australia]
- Cone-Wesson, Parker, Swiderski, Rickards. The auditory steady state evoked response: full-term and premature neonates [U. of Arizona]
- Rance & Richards. Prediction of hearing thresholds in infants using auditory steady state evoked potentials [Melbourne]
- Vander Werff, Brown, Gienapp, Schmidt. Comparison of auditory steady state response and auditory brainstem response thresholds in children. [U. of Iowa]
- John, Purcell, Dimitrijevic, Picton. Advantages and caveats when recording steady state responses to multiple simultaneous stimuli [U. of Toronto]

AUDITORY STEADY STATE RESPONSE (ASSR) ASSESSMENT IN INFANCY: Strengths and Weaknesses

- ❑ Historical perspective
- ❑ General principles
- ❑ Anatomy and physiology
- ❑ Instrumentation
- ❑ Stimulus and analysis
- ❑ Literature review
- ❑ Clinical features
  - ✓ advantages
  - ✓ disadvantages

ASSR, ABR, and Pure Tone Audiometry: Asking the clinically relevant question

Not:

Which frequency-specific electrophysiologic technique is best … tone burst ABR or ASSR?

But:

How does the ASSR technique complement click and tone burst ABR techniques in the infant test battery?

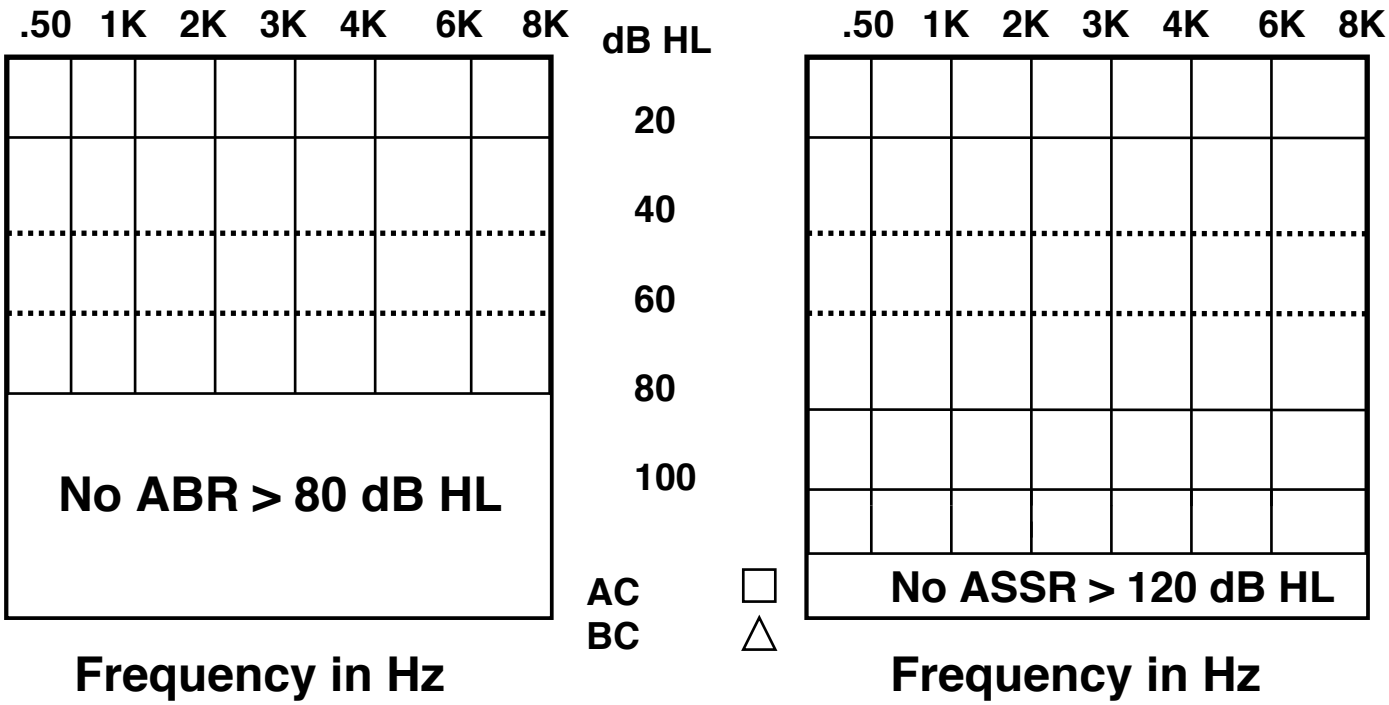
Tone Burst ABR versus Auditory Steady State Response (ASSR): Advantages and Disadvantages

Auditory dysfunction	ABR	ASSR
Normal hearing	♦ accurate estimation	♦ may over-estimate thresholds if patient is not sedated
Conductive HL	♦ ear-specific findings bone conduction without masking (wave I presence)	♦ bone conduction tone-burst measures but masking required
Sensory HL	♦ accurate only to moderate HL degree	♦ accurate from moderate to profound HL
Neural / Auditory Neuropathy	♦ identified with wave I or CM	♦ cannot distinguish profound sensory versus neural HL

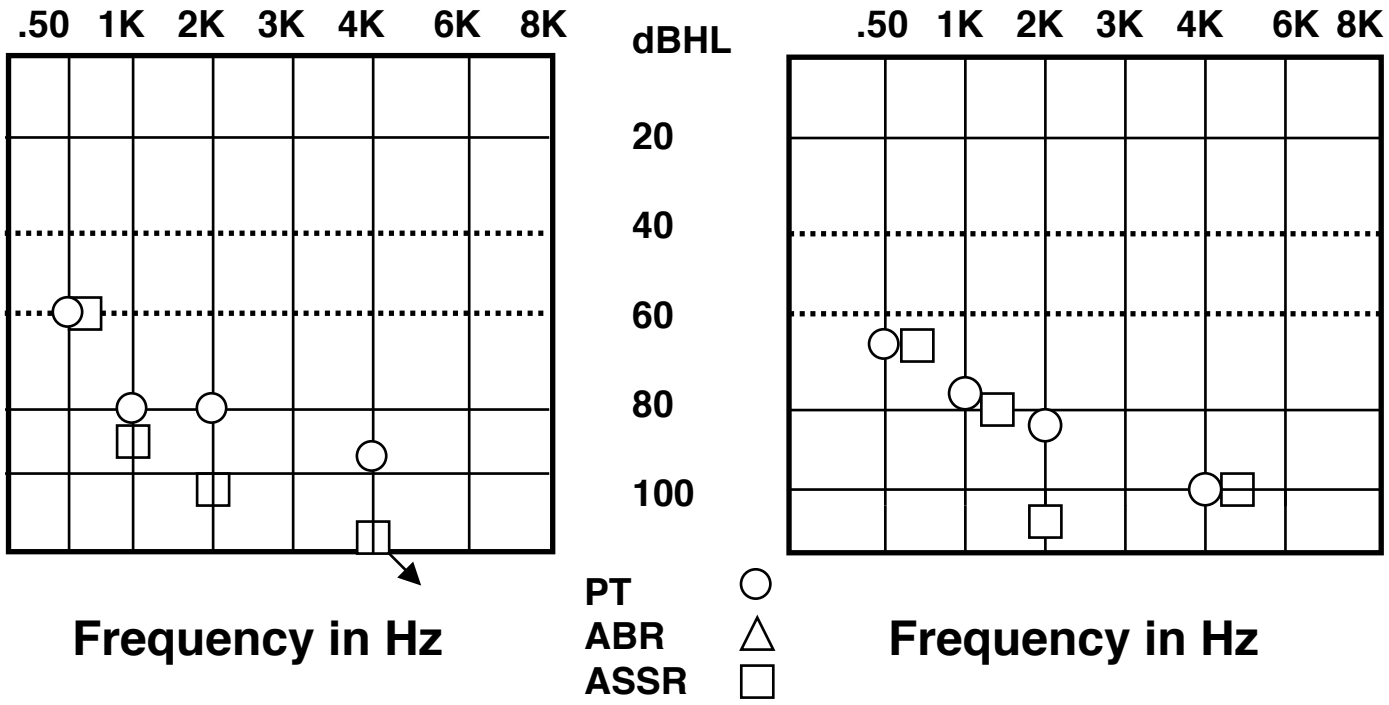
Hearing Status in Infants Undergoing Sedated Frequency Specific ABR *(Nicolet Spirit)* and ASSR *(GSI Audera)*
N = 74

Normal hearing sensitivity	**54% (40)**
Hearing loss	**46% (34)**
Conductive	**26% (9)**
Sensory	**44% (15)**
◆ **mild**	**6/15**
◆ **moderate**	**2/15**
◆ **severe**	**5/15**
◆ **profound**	**2/15**
Mixed	**9% (3)**
Neural	**6% (1)**
Auditory neuropathy	**18% (6)**

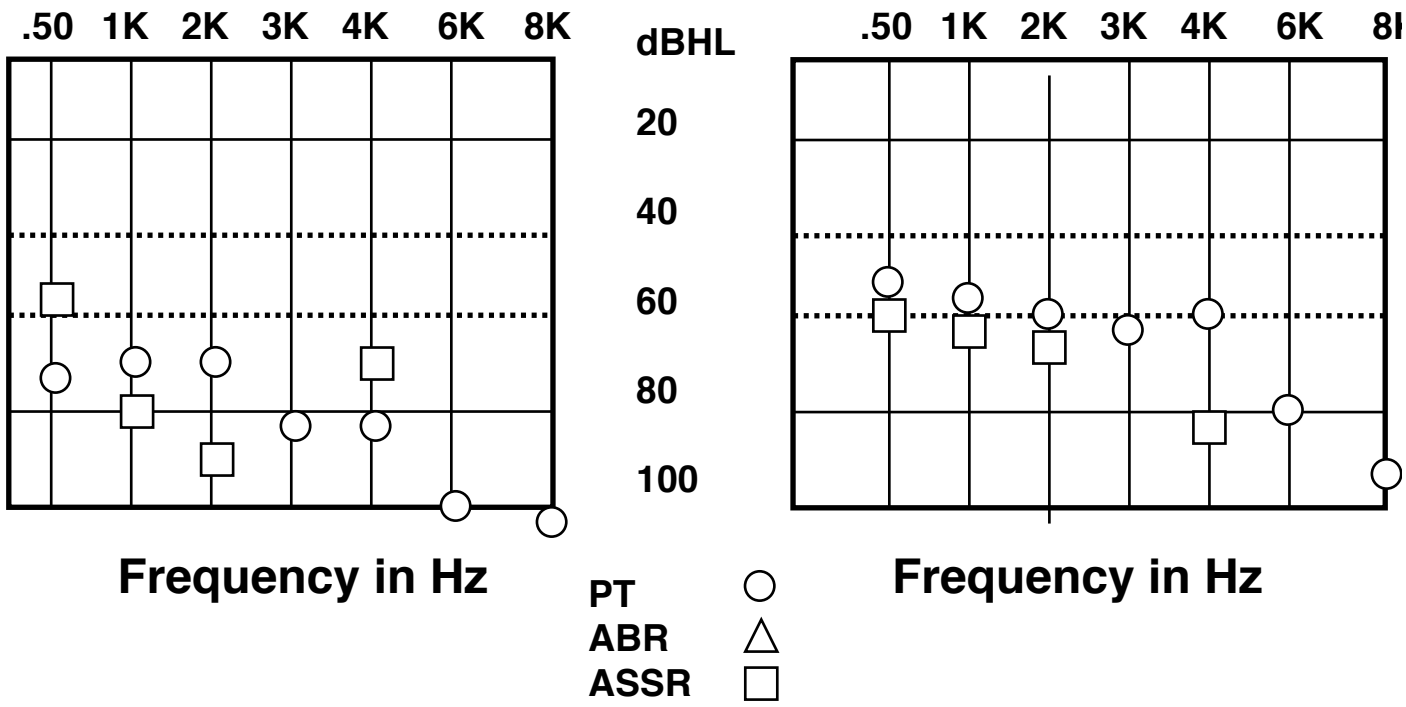
Limitation of Tone Burst ABR in Severe-to-Profound Hearing Loss



ABR vs. ASSR:
Case (severe hearing loss in an adult)



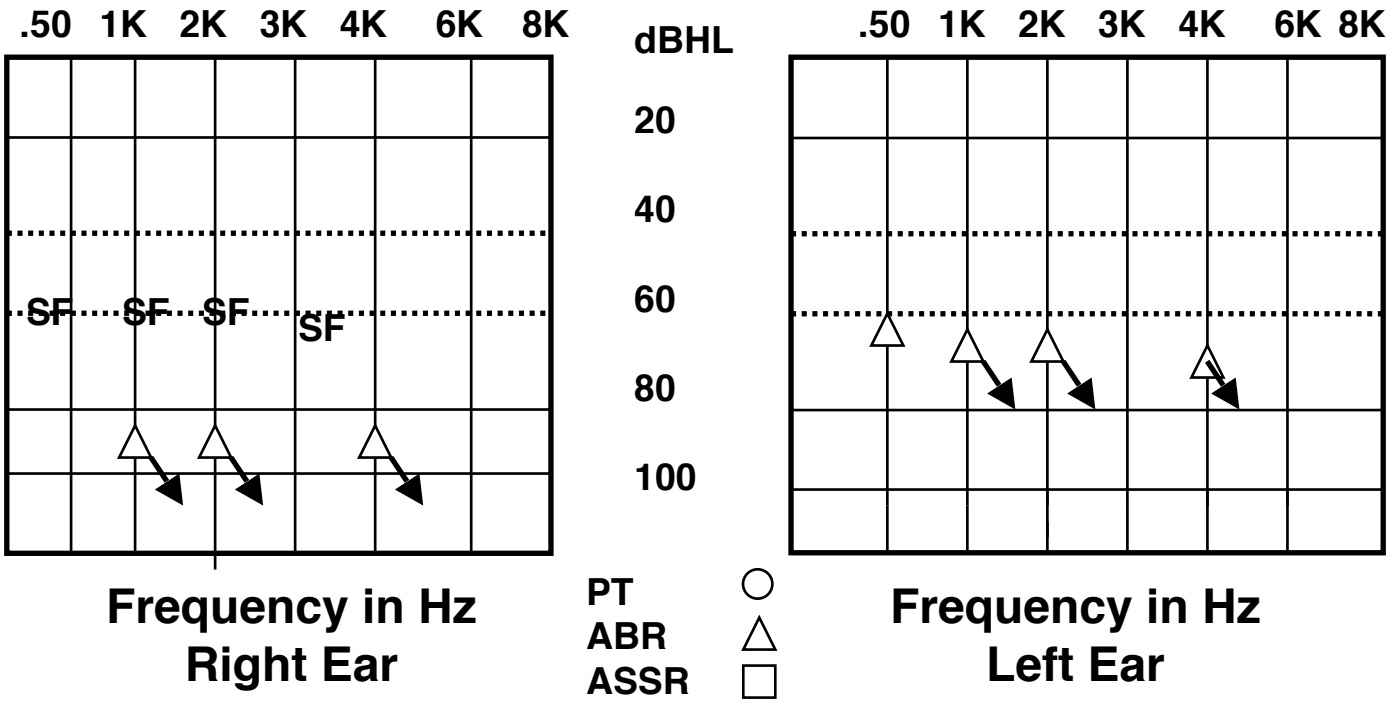
Pure Tones vs. ASSR:
Case (severe hearing loss in a child)



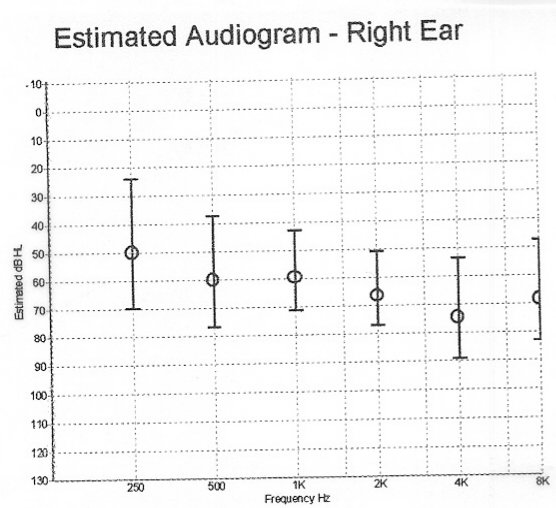
ASSR:
Case Report (limits of tone burst ABRs)

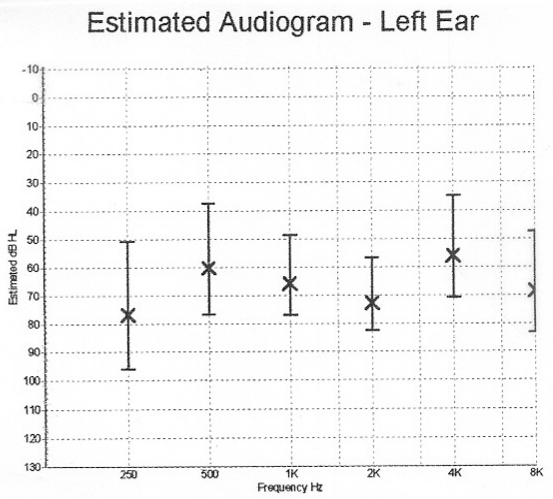
- 2 year old girl
- Previous audiologic assessment
  - sound field behavioral audiometry indicated moderate hearing loss (apparently since birth)
  - ABR threshold only for 500 Hz tone burst in left ear
  - no ear specific hearing thresholds
  - Inadequate hearing aid aid fitting (language delay)
- Referred to University of Florida for ASSR under light anesthesia

ASSR Case Report: Estimating Auditory Thresholds (previous inconclusive behavioral and ABR findings)

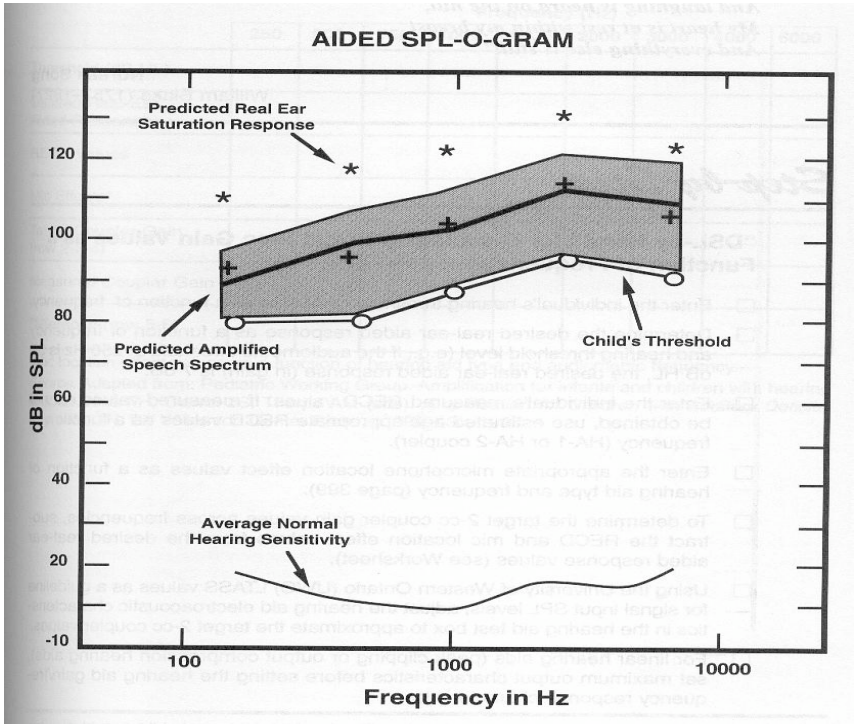


ASSR Case Report: Estimating Auditory Thresholds (GSI Audera)

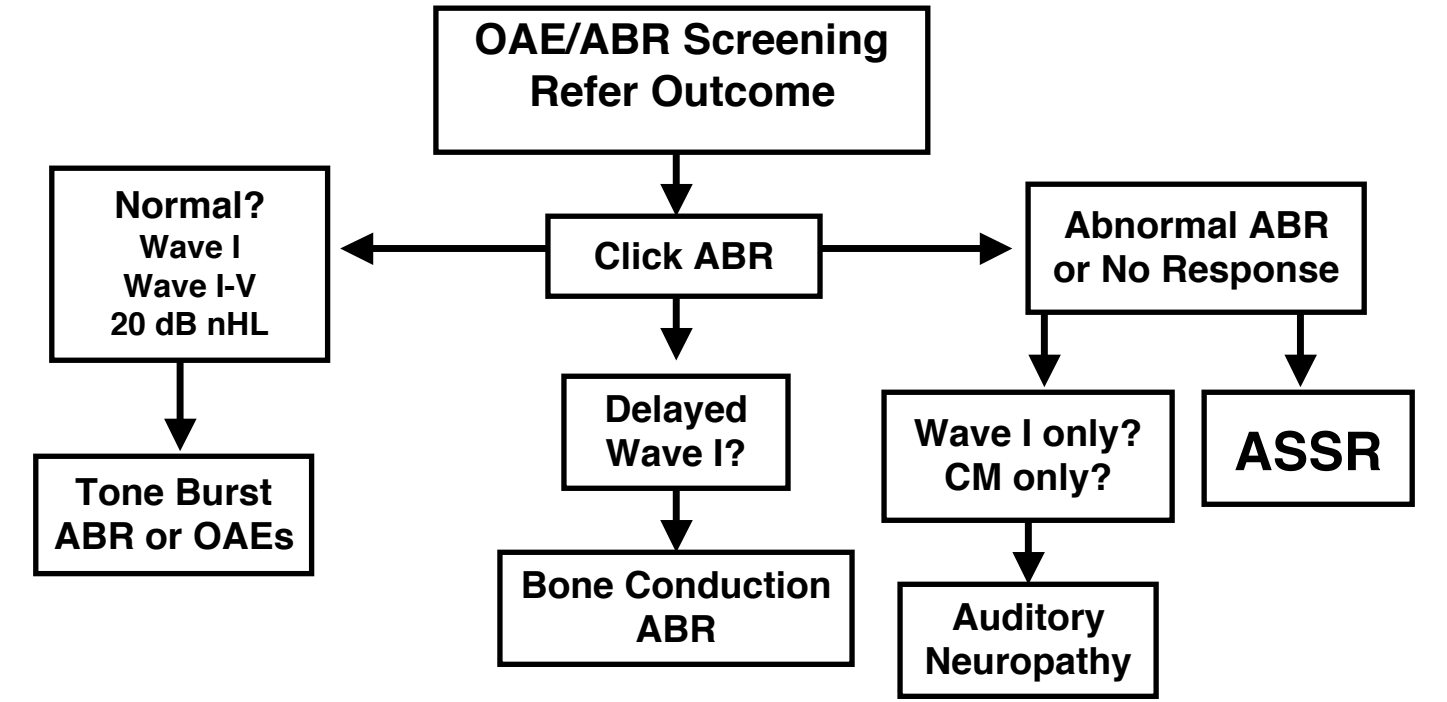




Estimation of Frequency-Specific Auditory Thresholds with Auditory Electrophysiology: DSL Hearing Aid Fitting



Role of ASSR in Frequency-Specific Estimation of Hearing Sensitivity in Infancy



ASSR:
Some clinical questions

- **Are there maturational effects on ASSR from premature infants through childhood?**
- **What are the effects of anesthesia on ASSR (low and high frequency modulation rates)?**
- **Is ASSR as reliable as tone burst ABR in estimating hearing thresholds in infants and young children?**
- **Can ASSR be accurately recorded from non-sedated patients?**
- **Can ASSR be used in estimation of *bone conduction* auditory thresholds?**

ASSR:
Some clinical applications

- Estimating hearing thresholds in infants and young children.
- Objective estimation of hearing aid gain (e.g., unaided versus aided signal presentation via loud-speakers)?
- Objective estimation of cochlear implant integrity and function?
- Frequency specific newborn hearing screening?
- Neuro-diagnostic detection of auditory neural timing deficits, e.g., auditory processing disorders?

Advances in Diagnostic Audiology
Procedures by the Decade

- 1940's: Pure tone audiometry
- 1950's: Speech audiometry
- 1960's: Site-of-lesion diagnostic procedures
- 1970's: Impedance measurements
- 1980's: Auditory brainstem response (ABR)
- 1990's: Otoacoustic emissions (OAEs)
- Now: Auditory steady state response (ASSR)

Auditory Processing Disorders (APD) in Children : Diagnosis & Management

Dr. Hall's lectures can be downloaded
and printed
from the following website:

www.phhp.ufl.edu/cd
(faculty presentations … James Hall)