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

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

- 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
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- 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)
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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 different from noise
ASSR (Audera):
No Response Condition
ASSR (Audera):
Significant phase coherence
ASSR (Audera):
Estimated Audiogram
<table>
<thead>
<tr>
<th>%AM</th>
<th>%FM</th>
<th>Time Waveform</th>
<th>Amplitude Spectrum</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MM</td>
<td>50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>20</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Four stimuli presented simultaneously to one ear

Sound

Cochlea

Brain

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

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

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]

The Auditory Steady State Response: Part I.

- Cone-Wesson, Parker, Swiderski, Rickards. The auditory steady state evoked response: full-term and premature neonates [U. of Arizona]
- John, Purcell, Dimitrijevic, Picton. Advantages and caveats when recording steady state responses to multiple simultaneous stimuli [U. of Toronto]
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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

<table>
<thead>
<tr>
<th>Auditory dysfunction</th>
<th>ABR</th>
<th>ASSR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal hearing</td>
<td>♦ accurate estimation</td>
<td>♦ may over-estimate thresholds if patient is not sedated</td>
</tr>
<tr>
<td>Conductive HL</td>
<td>♦ ear-specific findings</td>
<td>♦ bone conduction tone-burst measures but masking required</td>
</tr>
<tr>
<td></td>
<td>bone conduction</td>
<td></td>
</tr>
<tr>
<td></td>
<td>without masking</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(wave I presence)</td>
<td></td>
</tr>
<tr>
<td>Sensory HL</td>
<td>♦ accurate only to moderate HL degree</td>
<td>♦ accurate from moderate to profound HL</td>
</tr>
<tr>
<td>Neural / Auditory Neuropathy</td>
<td>♦ identified with wave I or CM</td>
<td>♦ cannot distinguish profound sensory versus neural HL</td>
</tr>
</tbody>
</table>
Hearing Status in Infants Undergoing Sedated Frequency Specific ABR (*Nicolet Spirit*) and ASSR (*GSI Audera*)

N = 74

<table>
<thead>
<tr>
<th>Category</th>
<th>Percentage</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal hearing sensitivity</td>
<td>54%</td>
<td>40</td>
</tr>
<tr>
<td>Hearing loss</td>
<td>46%</td>
<td>34</td>
</tr>
<tr>
<td>Conductive</td>
<td>26%</td>
<td>9</td>
</tr>
<tr>
<td>Sensory</td>
<td>44%</td>
<td>15</td>
</tr>
<tr>
<td>- mild</td>
<td>6/15</td>
<td></td>
</tr>
<tr>
<td>- moderate</td>
<td>2/15</td>
<td></td>
</tr>
<tr>
<td>- severe</td>
<td>5/15</td>
<td></td>
</tr>
<tr>
<td>- profound</td>
<td>2/15</td>
<td></td>
</tr>
<tr>
<td>Mixed</td>
<td>9%</td>
<td>3</td>
</tr>
<tr>
<td>Neural</td>
<td>6%</td>
<td>1</td>
</tr>
<tr>
<td>Auditory neuropathy</td>
<td>18%</td>
<td>6</td>
</tr>
</tbody>
</table>
Limitation of Tone Burst ABR in Severe-to-Profound Hearing Loss

No ABR > 80 dB HL

No ASSR > 120 dB HL
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

OAE/ABR Screening
Refer Outcome

Normal?
Wave I
Wave I-V
20 dB nHL

Tone Burst
ABR or OAEs

Click ABR

Delayed
Wave I?

Bone Conduction
ABR

Abnormal ABR
or No Response

Wave I only?
CM only?

ASSR

Auditory
Neuropathy
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)