UPDATE ON ELECTROPHYSIOLOGIC MEASURES OF HEARING SENSITIVITY IN INFANTS

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Why do we need frequency-specific stimuli?

- Most (>80%) SNHL does NOT have flat configuration
- Children have a wider variety of configurations than adults
AUDITORY STEADY-STATE RESPONSES (ASSRs)

- The technique
- Current status/New data
- What’s needed
Multiple-ASSR: Multiple Simultaneous Stimuli May Be Used

INDIVIDUAL STIMULI
each with own \( f_{\text{mod}} \)

STIMULI ADDED TOGETHER
each with own \( f_{\text{mod}} \)

stimuli are processed by the cochlea

EEG analysis – computer automatically determines if significant energy at modulation rates for each carrier frequency

Lins & Picton, 1995
DO ASSR AMPLITUDES DECREASE WITH MULTIPLE STIMULI?

Not for 60 dBHL stimuli (or lower) -- no “interactions” multiple thus faster!

Lori Wood thesis, 2009
DO ASSR AMPLITUDES DECREASE WITH MULTIPLE STIMULI?

FOR 80 dBHL STIMULI: YES! \(\rightarrow\) SIGNIFICANT “INTERACTIONS”

MULTIPLE MAY NOT BE FASTER!  

Lori Wood thesis, 2009
EFFICIENCY OF MULTIPLE-ASSR AUDIOMETRY: IS MULTIPLE FASTER THAN SINGLE?

AT LEAST IN NORMAL ADULTS, EVEN WITH INTERACTIONS, MULTIPLE 80-Hz ASSR REMAINS MORE EFFICIENT (FASTER) THAN SINGLE ASSR, AT LEAST FOR LOW-MODERATE INTENSITIES

SURPRISINGLY, THIS QUESTION NOT FORMALLY TESTED IN (i) INFANTS OR (ii) INDIVIDUALS WITH SNHL

YET MANY MANUFACTURERS ARE MARKETING MULTIPLE-ASSR SYSTEMS AND MANY CLINICIANS ARE JUMPING TO MULTIPLE ASSR
INTERACTIONS: WHAT ABOUT INFANTS?

Hatton & Stapells (in press)

• In contrast with adults, infants show significant interactions at 60dBSPL (i.e., smaller amplitudes for multiple stimuli)

• However, even with smaller amplitudes, the multiple-ASSR method remains significantly more efficient (faster) than single stimulus ASSR

• Also, no significant difference in threshold single vs multiple ASSR

• However, we do not whether multiple is better for infants/adults with SNHL
80-Hz ASSR ESTIMATION OF AC THRESHOLD
Many studies in adults indicating good accuracy estimating pure-tone behavioural threshold

Multiple-ASSR & SNHL (ADULTS)

Dimitrijevic et al., 2002
Very similar to tone-ABR results
Results are promising (esp. 1000-4000 Hz)

89% of thresholds accurately classified as “normal” or “elevated” (92% 1k-4k)

Bone-Conduction ASSR: Adults with SNHL?

VERY FEW DATA!
What about me?
Multiple ASSR (AC) vs tone-ABR in infants with hearing loss

Van Maanen & Stapells, JAAA, 2010

CORRELATIONS

ALL: $r = .97-.98$

EXCLUDE "NR":
$r = .75 (1k) to .87$
ASSR IN INFANTS/YOUNG CHILDREN:

WHAT’S MISSING?

Too few multiple-ASSR data for infants with documented HL

- Only 3 studies! Hot off the press! 4th study just published (Alaerts et al., 2010)
- Several other studies with only AC click-ABR
- Many studies with older children and adults, but few with infants/young children

No AC-ASSR results (single or multiple) in infants with documented conductive/mixed HL

- Only 1 study in children (BUT: no bone conduction; only AC click-ABR)

No BC-ASSR results (single or multiple) in infants with documented SNHL or conductive loss

- Only 1 study in children (BUT: no bone conduction; only AC click-ABR)
BUT: WE DO KNOW WHAT IS NORMAL FOR INFANT ASSR THRESHOLDS (AIR-CONDUCTION STIMULI)

Based on at least 8 studies, we now have a good idea about what a "normal" AC ASSR threshold is in an infant

“Normal AC Levels” → Maximum intensity to be considered normal (i.e., must be present at):

<table>
<thead>
<tr>
<th>FREQ</th>
<th>dBHL</th>
</tr>
</thead>
<tbody>
<tr>
<td>500 Hz:</td>
<td>50</td>
</tr>
<tr>
<td>1000 Hz:</td>
<td>45</td>
</tr>
<tr>
<td>2000 Hz:</td>
<td>40</td>
</tr>
<tr>
<td>4000 Hz:</td>
<td>40</td>
</tr>
</tbody>
</table>

Van Maanen & Stapells, 2009

CLINICAL IMPLICATION: AC multiple-ASSR could be used to quickly establish whether "normal“ or “elevated” simultaneously for both ears & four frequencies
Multiple-ASSR (4 frequencies to each ear) can quickly determine if “normal” or “elevated”

**RECORDING TIME FOR "NORMAL" BOTH EARS (40-50 dBHL)**

- **Median:** 3.6 min
- **80% < 5 minutes**

*Van Maanen & Stapells, 2009*
Do these AC-ASSR “normal” levels miss hearing loss?

Table 3. Accuracy of “normal” multiple-ASSR levels for classification of “normal” versus “elevated” threshold

<table>
<thead>
<tr>
<th></th>
<th>ASSR Threshold</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Normal</td>
</tr>
<tr>
<td>ALL</td>
<td>136 (20%)</td>
</tr>
<tr>
<td>Tone-ABR</td>
<td></td>
</tr>
<tr>
<td>THRESHOLD</td>
<td>Elevated</td>
</tr>
<tr>
<td>Normal</td>
<td></td>
</tr>
<tr>
<td>(N=34 normal; N=98 hearing loss)</td>
<td></td>
</tr>
</tbody>
</table>

**ANSWER: No.**

Even the few (3%) that were “missed” were not really “lost” because other frequencies were elevated.
FREQUENCY-SPECIFIC THRESHOLDS IN YOUNG INFANTS:

TONE-EVOKED AUDITORY BRAINSTEM RESPONSE

• The current “gold standard”
• Air- and Bone-Conduction tone-ABR
• Protocols
A REMINDER: ISSUES WITH CLICKS (Click-ABR)

TONE-ABR REQUIRED!

Stapells, 1984
Infant Tone-ABR @ “normal” intensities*

* Infant hearing considered “normal” if responses present at these intensities (BCEHP)
Great!

But what about thresholds if I have a hearing loss?
MANY STUDIES AND CLINICAL EXPERIENCE HAVE SHOWN TONE-ABR PROVIDES GOOD ESTIMATION OF PURE-TONE BEHAVIOURAL THRESHOLD IN INFANTS AND YOUNG CHILDREN.

Stapells, Gravel & Martin, 1995
Infant ABR threshold assessment

AIR-CONDUCTION, 2000 Hz (Infant #23A1)

Flat tympanogram
Absent OAE

H owever: Too commonly, clinicians have stopped here...

Nature of threshold elevation? Management? Info for parents?
CONCLUSION: BC THRESHOLD = 50dBnHL → SENSORINEURAL LOSS

- AC 2k ABR = 60dBnHL
- Flat tymps
- Absent OAEs
- BC 2k ABR = 50dBnHL

BONE CONDUCTION ABR REQUIRED FOR ALL INFANTS WITH ELEVATED AC ABR!
(similar to older children and adults)
SUMMARY: TONE-EVOKED ABRs

• Tone-ABR provides good estimate of audiogram in infants & young children

• Results for young children are different from adults (smaller difference scores) – must use infant corrections

• ABR to air- and bone-conducted stimuli allow differentiation of conductive and sensorineural hearing loss

• Tone-ABR requires clinician experience and skill with ABR waveforms and use of fast, efficient protocols. Not all clinicians may be capable of this....
Problem

Misinterpretation of ABR waveforms
(When is it a “response”, “no response” or “could not evaluate”?)

• Requires both **experience and innate skill**

• **Online measures** of signal-to-noise and, especially, waveform “residual noise” must be used *(required for all new equipment to be purchased!)*

\[ \text{SNR} \text{ usually } \geq 1 \text{ BUT not always: Visual replicability overrides} \]

\[ \text{RN must be } \leq 0.08 \mu V \text{ (} \leq 0.08 \mu V \text{ not always quiet enough for NR); SNR almost always } < 1. \]

\[ \text{RN > 0.08} \mu V, \text{ no visually replicable wave seen; SNR almost always } < 1 \]

\[ \text{RESPONSE PRESENT} \]

\[ \text{SNR=1.26} \text{ RN=0.07} \mu V \]

\[ \text{NO RESPONSE} \]

\[ \text{SNR=0.64} \text{ RN=0.04} \mu V \]

\[ \text{COULD NOT INTERPRET} \]

\[ \text{SNR=0.16} \text{ RN=0.15} \mu V \]

* SNR & RN measures using IHS SmartEP
In general, testing for most infants seen for ABR assessment aims to answer the following three questions, in order of priority:

1. Is an ear’s AC threshold normal or elevated? Is the other ear’s AC threshold normal or elevated? Start at low (“normal”) intensity; Switch ears

2. If elevated, is the elevation conductive in nature or is there a sensorineural component? Go to bone conduction early in testing

3. If elevated, what are the specific thresholds (AC and/or BC)? Determine actual thresholds after the above
Conclusions: ASSR vs Tone-evoked ABR?

• **November 2010:** *Only* the tone-evoked ABR has the necessary clinical database to be recommended for general clinical implementation as a "stand alone" AEP procedure

• However, the multiple ASSR to AC stimuli may currently be used at beginning of diagnostic test to quickly check if “normal” or “elevated” (i.e., both ears, 4 frequencies simultaneously). *If ASSR absent at normal level, elevation must then be assessed using AC & BC tone-ABR*

• When thresholds elevated, only the tone-evoked ABR can be recorded to both air- and bone-conduction stimuli

• AC-ASSR good as a “cross check” *after* AC & BC tone-ABR results completed

• REMINDER: If auditory neuropathy spectrum disorder (or other neurophysiologic problem) suspected/present, *ABR recordings to high-intensity clicks required*
THANK YOU FOR LISTENING!

GOOGLE:
“BCEHP DIAGNOSTIC AUDIOLOGY PROTOCOLS”

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