“♪ CHIRP, CHIRP ♪”

A Little Birdie Told Me About Developments in ABR & ASSR Testing;

Using the CE Chirp Stimulus for Faster Test Times

Jill Craig, MA
2010 EHDI Meeting-Chicago
March 1, 2010
In a Perfect World
In the Real World
Challenges of Diagnosing Hearing Loss

• Can take multiple visits to finalize results
• Each appointment can take sometimes hours to complete
• Sedation or no sedation?
• Objective vs Subjective?
• “Peak Picking” Experience
The Auditory Brainstem Response (ABR)

• An evoked potential is an electrical response induced by sound; it arises from the structures within the ear, nerve, and brain at some distance from skin electrodes.
• It is measured in the time domain
• Relies on synchronous nerve firing
ABR....the good

- Historical, Gold Standard
- Normative Data/Research Supported
- Differential diagnosis ANSD
- Comfortable!
ABR.....the challenges

• Can Be Time Consuming
• Peak Picking Experience
• Intensity limitations
• Single Intensity and Frequency
The Auditory Steady State Response

- Similar to ABR, but EEG activity is analyzed in frequency domain
- Stimulus is modulated pure tone
- EEG activity modulating at same frequency as the stimulus is representative of a response
- The presence or absence of a response is determined by a statistical computer algorithm
ASSR History

• Late 1970’s and Early 1980’s-Initial Research
  – Galambos

• 1991-First clinically available system

• Today-Severa...
ASSR.....the good

• More Frequency Specific
• No peak picking—Objective Detection
• Multiple and Simultaneous Frequency Testing
• Can test at higher intensities than ABR
ASSR.....the challenges

• Limited normative/research data as compared to ABR
• Small amplitude response; maybe more sensitive to noise
• Exact Neural Generators not defined
• CHANGE!!
Testing Considerations

- Stimulus Methods
- Detection Methods
ABR Stimulus

• Click
  – Abrupt and rapid onset
  – Broad spectrum (theoretically stims the entire basilar membrane) **NOT FREQUENCY SPECIFIC!!!**
  – Test 2000-4000Hz frequency range!
  – The greater number of neurons that fire results in a larger response amplitude.
  – *Need Good Neural Synchrony*
ABR Stimulus

- **Tone Burst**
  - Provides more frequency specific information
  - High correlation between behavioral and TB responses
  - Can diagnosis low and high frequency HL
  - 500Hz can be difficult!
    - Repeatability is difficult because there is less synchronous activity at that region on the cochlea
    - Requires longer window
    - Response can be 4-8ms later than a click
New Stimulus for ABR & ASSR

Travel time in the cochlea is different for different frequencies.
Output compensation for traveling time

• If the narrow band activity is recorded, compensation for the traveling time can be obtained by time-shifting the narrow band activity
• After summation the so-called Stacked ABR is obtained
• The Stacked ABR is significantly larger than the normal ABR
• The procedure to obtain the Stacked ABR is complex and needs considerable recording time – and has therefore not become clinically popular.
Stacked ABR – effective but impractical

Actual timing

- CF = 11.3 kHz
- CF = 5.7 kHz
- CF = 2.8 kHz
- CF = 1.4 kHz
- CF = 0.7 kHz

Shifted and summed

M. Don – House Ear Institute, 2002
Input compensation for traveling time

• Another way to compensate for the traveling time is to time-shift the different frequency components of the stimulus.

• This is done by allowing the low-frequencies to appear before the high-frequencies.

• Such a click with re-shuffled frequency components is called a Chirp.

• A chirp stimulus is particularly effective at lower stimulation levels, where response amplitude almost doubles compared to an equal bandwidth click stimulus.*

Instead of Synchronizing the Response…. Synchronize the Stimulus!

Lower frequencies are sent a bit earlier into the cochlea than the higher frequencies.

- **Chirp**
  - Lower frequencies
  - Higher frequencies

- **Click**
  - All frequencies

[Image: Diagram showing the timing of lower and higher frequencies in a chirp and a click sound.]
Frequency Specific Narrow Band CE-Chirps

Lower frequencies

500 Hz
360 - 720

1,000 Hz
720 – 1,440

2,000 Hz
1,440 – 2,880

4,000 Hz
2,880 – 5,760

Higher frequencies
Understanding the CE Chirp

Animation of the CE Chirp
Supporting literature

Study #1 on adults

• Testing:
  – **Delay Comp. Click** VS. **Click** (= full frequency range)
  – 49 normal-hearing younger adults
Supporting literature

Grand Average ASSR temporal waveforms

**30 dBnHL**

- **Delay Comp. Click**: 560 $nV_{pp}$
- **Click**: 280 $nV_{pp}$

**50 dBnHL**

- **Delay Comp. Click**: 820 $nV_{pp}$
- **Click**: 340 $nV_{pp}$

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## Supporting literature

### Conclusion study #1

30 dBnHL

<table>
<thead>
<tr>
<th></th>
<th>Detection Rate</th>
<th>Detection Time</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Click</strong></td>
<td>83.3 %</td>
<td>72 s</td>
</tr>
<tr>
<td><strong>Delay Comp. Click</strong></td>
<td>97.7 %</td>
<td>30 s</td>
</tr>
</tbody>
</table>
Supporting literature

Study #2 on newborns

• **Screening:**
  - **Click** (40 dBnHL) and **Chirp** (35 dBnHL)
  - Several studies – incl two groups of newborns (each of about N = 1,800)
Supporting literature

- **Click - 40 dBnHL**
  - maximum test time: 120 s
  - detection criterion: 0.1 %
  - number of ears: 1744
  - detection rate: 95.4 %
  - detection time: **42 s** (median) 47 s (mean)
• Chirp - 35 dBnHL
  – maximum test time: 180 s
  – detection criterion: 0.1 %
  – number of ears: 1833
  – detection rate: 96.3 %
  – detection time: 28 s (median)
  38 s (mean)
## Supporting literature

### Conclusion study #2

<table>
<thead>
<tr>
<th></th>
<th>Detection Rate</th>
<th>Detection Time</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Click 40dBnHL</strong></td>
<td>95.4 %</td>
<td>42 s</td>
</tr>
<tr>
<td><strong>Delay Comp. Click 35dBnHL</strong></td>
<td>96.3 %</td>
<td>28 s</td>
</tr>
</tbody>
</table>
Documenting Efficiency of CE-Chirp® family

The efficiency of these new stimuli are documented in a series of publications:


Implementation of ASSR into the Clinic

ASSR is an additional tool in the “Cross Check Principle”

“In summary, we believe that the unique limitations of conventional behavioral audiometry dictate the need for a ‘test battery’ approach. The key concept governing our assessment strategy is the cross-check principle. The basic operation of this principle is that no result be accepted until it is confirmed by an independent measure. . . . We believe that the application of the cross-check principle to our clinical population has had an appreciable effect on the accuracy with which we can identify and quantify hearing loss during the critical years for language-learning.” (Jerger and Hayes, 1976, p. 65)
An EP Process to Consider

**MS ASSR**
- 4 frequencies per ear to assess normal infant hearing levels (between 40 to 50 dB HL)

**PRESENT**
- Normal hearing

**Click ABR**
- Assess neurological integrity and CM (70–80 dB)

**ELEVATED**
- Threshold (≥70 dB)

**BC ABR**
- Frequency-specific thresholds (500–4000 Hz)

**ELEVATED Threshold (≥70 dB)**

**SS ASSR**
- Thresholds in mod-sev-to-prof range (500–4000 Hz)

**ABSENT**
- Threshold, neurological integrity and CM at high intensity

**Click ABR**
- Threshold, neurological integrity and CM at high intensity

**ABSENT/ABNORMAL**
- CM present

**Auditory neuropathy**

**SS ASSR**
- High intensities for threshold (500–4000 Hz)

**ABSENT**
- Max intensity without CM

*Hall, Swanepoel, Objective Assessment of Hearing, Plural Publishing 2009, page 132, figure 6-8*
Data Samples
The ASSR Screen

To optimize session strategy decisions as test progresses, the response confidence is tracked over time for each test frequency.
Implementation in the clinic

Stimulus intensity and response development during test:

- Green = Response
- Red = No Response

<table>
<thead>
<tr>
<th>Frequency</th>
<th>500Hz</th>
<th>1kHz</th>
<th>2kHz</th>
<th>4kHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 dB</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>40%</td>
</tr>
<tr>
<td>40 dB</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Session Status:
Time elapsed: 0:08:22

Start
Pause
They can’t all be good!

- Failed UNHS (OAE and AABR)
- Full Term
- No Family History
- 5 months old at time of testing
- Normal Tymps/Absent Reflexes
### OAE Results

#### Right Ear

<table>
<thead>
<tr>
<th>f2</th>
<th>DP</th>
<th>L1</th>
<th>L2</th>
<th>DP level</th>
<th>Noise level</th>
<th>S/N level</th>
</tr>
</thead>
<tbody>
<tr>
<td>500 Hz</td>
<td>318 Hz</td>
<td>65 dB</td>
<td>65 dB</td>
<td>16.5 dB</td>
<td>13.0 dB</td>
<td>3.5 dB</td>
</tr>
<tr>
<td>1000 Hz</td>
<td>638 Hz</td>
<td>65 dB</td>
<td>55 dB</td>
<td>9.9 dB</td>
<td>7.2 dB</td>
<td>2.7 dB</td>
</tr>
<tr>
<td>2000 Hz</td>
<td>1278 Hz</td>
<td>65 dB</td>
<td>55 dB</td>
<td>9.1 dB</td>
<td>2.5 dB</td>
<td>6.5 dB</td>
</tr>
<tr>
<td>4000 Hz</td>
<td>2556 Hz</td>
<td>65 dB</td>
<td>55 dB</td>
<td>-3.2 dB</td>
<td>-9.4 dB</td>
<td>6.2 dB</td>
</tr>
<tr>
<td>6000 Hz</td>
<td>3836 Hz</td>
<td>65 dB</td>
<td>55 dB</td>
<td>-3.2 dB</td>
<td>-12.4 dB</td>
<td>9.2 dB</td>
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<tr>
<td>8000 Hz</td>
<td>5114 Hz</td>
<td>65 dB</td>
<td>55 dB</td>
<td>-12.0 dB</td>
<td>-9.5 dB</td>
<td>-2.5 dB</td>
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<tr>
<th>S/N stop criteria</th>
<th>Rejection level</th>
<th>Stimulus tolerance</th>
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<td>7 dB</td>
<td>20 dB</td>
<td>± 3 dB</td>
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#### Left Ear

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<td>500 Hz</td>
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<td>65 dB</td>
<td>19.5 dB</td>
<td>14.6 dB</td>
<td>4.8 dB</td>
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<tr>
<td>1000 Hz</td>
<td>638 Hz</td>
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<td>55 dB</td>
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Generates an Audiogram

Estimated Audiogram

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ASSR AC Thresholds

• Many studies published and in process
  – Recently, Van Maanen & Stapells, 2009 found:

<table>
<thead>
<tr>
<th></th>
<th>250Hz</th>
<th>500Hz</th>
<th>1000Hz</th>
<th>2000Hz</th>
<th>4000Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infants and Children</td>
<td>50</td>
<td>45</td>
<td>40</td>
<td>40</td>
<td></td>
</tr>
</tbody>
</table>

Must find this level or better to be called normal!!

MORE RESEARCH IS NEEDED!!
There is NOT sufficient evidence to support the use of ASSR only!
# ASSR BC Thresholds

- Few studies published

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<th>4000Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preterm Infants &lt;br&gt; (0-11 months)</td>
<td>≤30</td>
<td>≤30</td>
<td>≤50</td>
<td>≤50</td>
</tr>
<tr>
<td>Post-term infants &lt;br&gt; (0-11 months)</td>
<td>≤30</td>
<td>≤20</td>
<td>≤40</td>
<td>≤30</td>
</tr>
<tr>
<td>Infants &lt;br&gt; (12-24 months)</td>
<td>≤40</td>
<td>≤20</td>
<td>≤40</td>
<td>≤30</td>
</tr>
<tr>
<td>Adults</td>
<td>≤50</td>
<td>≤40</td>
<td>≤30</td>
<td>≤30</td>
</tr>
</tbody>
</table>

Correction Factors Are Not All The Same!
Other Considerations for ASSR

- Future Research
  - Hearing Aid Fittings
  - Hearing Screening
  - Assessing Suprathreshold Hearing
  - ANSD
One Step Further......

• If we can generate larger response amplitudes for ASSR......

.........how about for ABR???
Take Home Messages

• Use of the CE Chirp is well documented in the literature
• Use of the CE Chirp can increase response amplitudes resulting in a shorter test time
• ASSR can be a part of the cross check principle
THE END!

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