Auditory Evoked Potential Technology Update

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Auditory Evoked Potentials
- Frequency Specific ABR - CE Chirp Stimulus
- Auditory Steady State Response (ASSR)
- Electrocochleography
- cVEMP & oVEMP Testing

InterAcoustics Eclipse & Grason-Stadler Audera
Limitation of Click-Evoked ABR: Lack of Frequency-Specificity

Click versus Tone Burst ABRs

ABR Response to Tones

- ABR responses are onset sensitive.
- Click stimulus = instant onset
- Tone Burst rise time is frequency dependent.
- Tone Bursts must have at least 2 cycles of rise time to be frequency specific.
- 2-1-2 or 2-0-2 envelope
- Typical test frequencies are: .5K, 1k, 2k, 4k Hz
Time = 1/frequency (t=1/f) (f=1/t)

- T = 1/1000 = .001 = 1 millisecond
- F = 1/.001 = 1000 Hz
- 1000 Hz: T = 1 millisecond
- 2000 Hz: T = .5 millisecond
- 4000 Hz: T = .25 millisecond
- 500 Hz: T = 2 milliseconds
- 250 Hz: T = 4 milliseconds

Examples of ABR Elicited with Tone Burst Stimuli:
500 Hz stimulus
Examples of ABR Elicited with Tone Burst Stimuli:
1000 Hz stimulus

Typical Tone Burst eHL Corrections for nHL Calibrated Systems
- 250 Hz 25 dB
- 500 Hz 25 dB
- 1k Hz 20 dB
- 2k Hz 15 dB
- 4k Hz 10 dB
- Click 10 dB
FREQUENCY-SPECIFIC ABRs: Effect of Tone Burst Onset Window (Ramp)

Tone Burst Rise Times

- 250 Hz BB .5 cycles 2 mSec
- 500 Hz 1.5 cycles 3 mSec
- 1000 Hz 2 cycles 2 mSec
- 2000 Hz 2 cycles 1 mSec
- 4000 Hz 2 cycles .5 mSec
- Plateau = 0

15 Tone Burst Tips

- Shorter Rise Time
- Zero Plateau
- Fast Rep Rate
- 30 Hz High Pass Filter
- nHL Calibration
- Longer Averaging
- Gain
- Three Runs
- Focus on the wave 5 trough.
- Run a control run @ 0
- Electrode Impedance Match (CMR)
- Initial Sample Set Integrity
- 250 Hz Broad Band Tone Burst
- Digital Processing
- Pre-Amp Bandwidth
Synchronizing the Nerve Firings

In all Evoked Potentials, synchronization of individual nerve fiber firing is important for strongest response.

But the Cochlea has crucial timing issues!

500 Hz
1000 Hz
2000 Hz
4000 Hz
Click

ABRStimulus

Adjust Stimulus Timing

Instead of Synchronizing the Response we Synchronize the Stimulation

Lower frequencies are sent a bit earlier into the cochlea than the higher frequencies
Chirp versus Click

**Similarities** between click and chirp:
- Same broad band stimulation (same spectrum)
- Same intensity (same calibration)

**Differences** between click and chirp:
- Difference in timing of cochlear stimulation
- Chirp provides double response amplitudes
Frequency Specificity of Tone Bursts

1000 Hz Tone Burst with Blackman window

Acoustic Frequency spectrum

1000 Hz Tone Burst with Blackman window

Frequency Specific Narrow Band CE-Chirps

500 Hz NB Chirp
Example of Chirp-Evoked ABR in Normal Hearing 1-Month Infant (Courtesy of Todd Sauter)

2 kHz Tone-Burst 2 kHz Narrow-band Chirp

Amplitude CE-Chirp vs. Click

Amplitudes with CE-Chirp are larger than clicks, particularly at mid to high intensities.


CE-Chirp Octave Bands vs. Tone Bursts

ISO 389-6: 2-1-2 Tone Burst
peRETSPLs (blue = tone bursts)
3A Insert Earphones using 711 ear simulator
Range of 0.4 to 1.8 dB difference


GSI Confidential
Wave V amplitudes were significantly greater at 60, 40, 20 dB nHL.

Larger amplitudes are consistent with previously published research.


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**Adults: CE-Chirp Octave Bands**


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**Adults: CE-Chirp Octave Bands**

ABR Wave V thresholds for CE-Chirp OB stimuli were closer to behavioral pure-tone thresholds than tone bursts.

Responses to 500 Hz CE-Chirp Octave Bands were present for more subjects at lower intensity levels than toneburst stimuli.

- 20dB: Toneburst N=6, Chirp OB N = 11
- 10dB: Toneburst N=0, Chirp OB N = 8

CE-Chirp thresholds were lower than clicks, but differences were not significant.


Newborns

Air Conduction Amplitude

Mean Wave V Amplitude as a function of intensity:
- CE-Chirp Wave V amplitudes were significantly (p < .05) greater than clicks at all intensity levels.

N=45, Rate = 57.7, Polarity = Alternating, Statistics = two-factor ANOVA


Newborns

Bone Conduction Amplitude

Mean Wave V Amplitude as a function of intensity:
- CE-Chirp Wave V amplitudes were significantly (p < .05) greater than clicks at all intensity levels.

N=49, Rate = 57.7, Polarity = Alternating, Statistics = two-factor ANOVA

CE-Chirp Benefits

- Larger amplitude with fewer averages
- Increased clinical confidence
- Shorter test time
- Frequency-specific testing
- More responses at lower frequencies and intensities
- Potentially better correlation to behavioral thresholds

Residual Noise

The practical implementation:

Example of Fmp Implementation
Traditional Averaging - Not Perfect

Without Bayesian weighting:
- Size EEG signal (noise content)
- Weight of response when averaging
- Rejection level
- Individual sweep

Problem 1: Where should I put the rejection level?
Problem 2: All accepted sweeps are treated equal, but they are not equal:
- Low noise sweeps are burdened by noisy sweeps in the averaging.
- Residual noise may even start growing during continued averaging!
Problem 3: Rejected sweeps do not contribute at all.

Weighted Averaging Solves the Problems

With Bayesian weighting:
- Size EEG signal (noise content)
- Weight of response when averaging
- Rejection level (e.g. ≤ 40µV)
- Individual sweep

Solution 1: Rejection level is no longer important for averaging quality (set higher).
Solution 2: All accepted sweeps are now NOT treated equal, because they are not equal:
- All sweeps are now weighted according to their quality (noise content).
Solution 3: All sweeps now contribute according to their quality – nothing is wasted.

To conclude on Bayesian

By having the averager assign low importance to sweeps with much noise, and very high importance to sweeps with low noise, it is possible to obtain cleaner recordings in typical test situations. Incidents with higher noise level from the patient will not ruin a good test. It may even be possible to get reasonable data in situations otherwise not suitable for ABR recording.

Claiming that this puts an end to sedation would be naive. But Bayesian will take you as far in that direction as any available technology.
InterAcoustics Titan 2 Tymp, OAE, ABR Screening

Advances in AABR Screening Techniques
- CE Chip
- Bayesian Weighting
- Super Fast Sampling Rate
- Digital Noise Filtering
- AABR Detection Algorithm
- Test Time – 24 seconds average per ear
Chirp – 35 dBnHL
- number of cases: 1833
- detection rate: 96.3%
- detection time: 28 s (median)
38 s (mean)

ASSR definition
*A periodic electrical response from the brain evoked by a periodically varying continuous acoustic signal, typically a sinusoidally modulated tone*
Ridder, 2003
A method of objectively measuring hearing sensitivity with the goal of creating an estimated audiogram

What is ASSR then?
An evoked response to a continuous sound... but one that we pulse the volume up and down
In the time domain, we record a sine wave at the frequency of the modulation, delayed by some latency from the stimulus modulation
Response analysis
The nerves we stimulate will now pulse at the modulation frequency.
In the frequency domain, we see a spike of energy at the modulation frequency [e.g. 40 Hz].

The Traditional ASSR Stimulus

Carrier at 1 kHz
100% AM
81 Hz modulation frequency

Activation at 1 kHz
region of basilar membrane

Steady-State response
at the modulation frequency

Modulated stimuli produce steady-state responses at the modulation frequency.

Sound
Cochlea
Brain
Four stimuli presented simultaneously to one ear

Four stimuli to the Right ear
Four stimuli to the Left ear

Detection of higher harmonics
To optimize session strategy decisions as test progresses, the response confidence is tracked over time for each test frequency.
Eclipse ASSR
- Automated ASSR to Estimated Audiogram
- Correction factors applied automatically during the test

Normal ASSR
Resulting Estimated Audiogram

Binaural Loss - 4 Frequencies

Estimated Audiogram
Documenting Efficiency of CE-Chirp family

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


Original Description of Electrocochleography (ECochG)


Why order an ECochG?

- As an objective confirmation of Meniere’s Disease (Endolymphatic Hydrops)
Meniere’s Disease

- Inner ear disorder that effects both balance & hearing
- Meniere’s disease occurs when a part of the semicircular canal called the endolymphatic sac becomes swollen. This sac regulates the fluid pressure in the canals, so excess pressure results.
- Head Injury, Middle-ear Infection, Syphilis, Allergies, Alcohol use, Stress, Smoking, Aspirin

ECochG Electrode Montage

- 1 channel test
- Tip Trodes are most common
- Best Montage is horizontal
- For positive going AP the test ear is Ref, Input 2 or Neg (-)
- The other ear is Act, Input 1, Pos (+)
- Ground is on the forehead

ECochG Measurement Principle:
The closer to the cochlea, the better.
ELECTROCOCHLEOGRAPHY (ECochG): AP (ABR wave I) amplitude as a function of electrode site.

<table>
<thead>
<tr>
<th>Electrode Site</th>
<th>Amplitude in μvolts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mastoid</td>
<td>3.5</td>
</tr>
<tr>
<td>Earlobe</td>
<td>3.0</td>
</tr>
<tr>
<td>Earcanal</td>
<td>2.5</td>
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<td></td>
<td>1.0</td>
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<tr>
<td></td>
<td>0.5</td>
</tr>
</tbody>
</table>

TipTrode: Part transducer and part electrode.

TipTrodes and TipTrode Leads.
**Far Field ECochG**

- TipTrodes

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**ECochG TEST PROTOCOL (1)**

**Stimulus Parameters:**
- **Type:** clicks
- **Duration:** 0.1 mSec
- **Rate:** 7.1/sec or slower as necessary
- **Polarity:** alternating (for AP) (Rarefraction for CM)
- **Intensity:** maximum or lower (95 dB nHL)
- **Transducer:** Insert
- **Masking:** never needed (response is ipsilateral)

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**ECochG TEST PROTOCOL (2)**

**Aquisition Parameters:**
- **Amplification:** 75,000 or less
- **Analysis time:** 5 or 10 mSec
- **Sweeps:** 500 or less
- **Filters:** 10 to 1500 Hz
- **Notch filter:** never
- **Electrodes:**
  - option 1: TipTrode
  - option 2: TM (Tympanic Membrane) Electrode
  - option 3: Trans-tympanic Needle Electrode
Normal ECochG

AP = 0.6 µV

ECochG and Hearing Loss
ECochG and Hearing Loss

ECochG Tips/Rules of Thumb

- **AP**: 1.5 mSec (Find it first.)
- **SP**: AP - .6 mSec
- **Baseline SP**: -.6 mSec (or pre-stimulus BL)
- **SP/AP Ratio**: Normal is <.53 or 53%
- **Positive Predictive Value**: 63%
- Use alcohol and NuPrep in the ear canal.
- Use the small TipTrodes with deep canal placement.
- Insist upon the “2k 25 rule” / “2k 35 rule”
- “If it doesn’t replicate you must investigate.”
Amplitude Ratio

Amplitude ratio is simply marked with the baseline, the summing potential and the action potential. A ratio between the SOLCP and SOLAP is calculated automatically by the system.

Area Ratio

Area ratio is marked with the baseline, the summing potential, the action potential, the summing baseline, the action potential, the SOLCP and SOLAP.
AP/SP Area Ratio

ECochG Area Measurements

- Normal Sp/Sp Area Ratio Measurement is 1.02 to 1.75
- SD = .30
- Normal is < 1.76
- Sensitivity - positive predictive value = 83%

Meniere's disease
13 Interference Tips

- Shorter Test Leads
- 60 Hz Notch
- High Pass Filter
- Electrode Impedance Match (CMR)
- Lower Gain
- Electrode Lead Breading
- Single Channel Test
- Lead Dress
- Power Line Filter
- In-line R.F. Filters
- R.F. Chokes (ferrite)
- Pre-Amp Bandwidth
- Digital Processing