Technology Advances to Meet the Needs of Pediatric Electrophysiologic Assessments: The Use of CE-Chirp Stimuli for Pediatric Electrophysiology

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Introduction

Manny Don      Claus Elberling    Curtis Ponton    Jos Eggermont
The Miracle CE-Chirp

• Stimulus that reorganizes timing of spectral stimulation to synchronize cochlear response.
• Produces response (ABR, ASSR,...) with up to 2X amplitude of traditional stimuli of same level
• Enhances response detection
• Reduces time to automated detection (Huge need)
• Lowers threshold of response detection
Basilar Membrane
View from above.

- Sound (vibration) enters the cochlea through the oval window at the base.
- The energy must travel through the fluids from base to apex until the region registering the sound frequency is reached.
- This is the traveling wave and it slows the activation of the lower frequency regions.

http://www.youtube.com/watch?v=dynenMluFaUw
TONAL STIMULI WILL ACTIVATE THE BASILAR MEMBRANE AT THEIR POINT OF RESONANCE.
A CLICK WILL PROGRESSIVELY ACTIVATE THE ENTIRE LENGTH OF THE BASILAR MEMBRANE

Transient, broad band stimuli
Curtis Ponton estimates delay to 500 Hz as 4 ms
Stacked ABR:
Removing the Wave V delay from Frequency change- produces a much bigger component response!

M. Don – House Ear Institute, 2002
Chirps are stimuli created using “input” compensation for traveling wave delay.

Instead of compensating at the response level a chirp compensates at the stimulus.

The click is broken into component frequencies. The low-frequencies are presented before the high-frequencies in a progressive manner. (Like starting the slow runners in a race first, staggering the runners by speed so they all cross the finish line together.)

A *chirp-evoked ABR* is significantly larger than a click ABR (even though they have the same spectral energy) for the same reason that the stacked ABR is bigger.
Chirp vs Click-Evoked ABR

Chirp stimulus

Low frequencies  High frequencies
Many models of cochlear travel time have been used to develop different Chirps.
CE-Chirp delay functions derived from narrow-band ABR latencies based on data from M. Don

CE=Claus Elberling
Why Use the *CE*-Chirp?

- Studied most extensively
- Narrow Band CE-Chirps
- Developed Level-Specific Chirps
- Onset timing adjusted to maximize clinical use
Narrow band CE-Chirps for Clinical Audiology

500 Hz

1000 Hz

2000 Hz

4000 Hz
Inga Ferm* and Guy Lightfoot Amplitudes, test time and estimation of hearing threshold using frequency specific chirp and tone pip stimuli in newborns. HEAL 2014, Lake Como, Italy
The mean NB CE-chirp response amplitude was approximately 50% larger than that of a pip at 2 kHz and approximately 30% larger at 500 Hz. Fmp values were typically double for NB CE-chirps.”

“4 kHz difference equates to an average chirp threshold advantage of 5.2 dB, whilst at 1 kHz the chirp advantage is 6.2 dB”
Level Specific CE-Chirps Maintain Amplitude Advantage at High Levels
After EP4.4 Latency Norms for WB and NB
CE-Chirps are as expected for Clicks
CE-Chirps also enhance ASSR amplitude!

50 dBnHL

**Chirp**

820 nVpp

**Click**

340 nVpp
F. Venail et al. Narrow band CE-Chirps evoked ASSR in Children
International Journal of Audiology 2014; Early Online: 1–8

2000 Hz

4000 Hz
$y = 0.9927x + 4.502$
$R^2 = 0.8664$

$y = 0.9669x + 0.5818$
$R^2 = 0.9057$

**500 Hz**

**1000 Hz**
Comparison of threshold estimation in infants with hearing loss or normal hearing using Auditory Steady-State Response evoked by narrow band CE-chirp and ABR evoked by tone pips: results for 2000 Hz

Franck Michel, Audiology Clinic, Department of Otorhinolaryngology, Aarhus University Hospital, Denmark

Statistics for HL group:
\[ r = 0.9458 \]
\[ y = 0.998x - 3.88 \]
In Addition to use of CE-NB Chirps- New ASSR uses Enhanced Detection Algorithm
Amplitude Advantage = Test Time Reduction

When response amplitude is doubled, it will take ¼ of the averaging time to achieve the same signal to noise ratio!

When using a SNR-based stopping rule for determining response presence/absence, such as Fmp for ABR or automated detection in ASSR, one can see dramatic decreases in test time when using CE NB Chirps.
Test Time Using Chirps: *Time to Achieve 8 Thresholds*

<table>
<thead>
<tr>
<th></th>
<th>Mean Minutes</th>
<th>Median Minutes</th>
<th>10th Percentile</th>
<th>90th Percentile</th>
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<tbody>
<tr>
<td>ABR</td>
<td>24.76</td>
<td>25.00</td>
<td>13.00</td>
<td>41.00</td>
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<tr>
<td>ASSR</td>
<td>18.20</td>
<td>14.80</td>
<td>8.25</td>
<td>32.79</td>
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</tbody>
</table>

P=0.002

Preliminary Data from 29 Cases of Infants & Toddlers, mostly natural sleep; many with normal hearing. Air conduction 500, 1k, 2k & 4k Hz in both ears.
Case Example: 3-month old Natural Sleep, Normal Hearing
ABR 17 minutes

500 Hz

dB nHL
1000 Hz
### Table

<table>
<thead>
<tr>
<th>Recorded</th>
<th>Masking</th>
<th>Wave reprod</th>
<th>LP</th>
<th>HP</th>
<th>Ratio</th>
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</thead>
<tbody>
<tr>
<td>1000</td>
<td>Off</td>
<td>20 %</td>
<td>1.5 Hz</td>
<td>3.3 Hz 6/oct</td>
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</tr>
<tr>
<td>Rejected</td>
<td>0%</td>
<td>Residual noise</td>
<td>20 nV</td>
<td>Fmp</td>
<td>2.57</td>
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<tr>
<td>Reaction</td>
<td>20 µV</td>
<td>Insert phone</td>
<td>Polarity</td>
<td>Alter.</td>
<td>A=Rane, B=Cond</td>
</tr>
</tbody>
</table>

### Diagram

- **2000 Hz**
- **Gain Settings**:
  - 20 R: +200 nV
  - 10 R: 10 R
  - 20 L: 20 L
  - 10 L: 10 L

- **Current Setup**:
  - Volume: NB Chip L5 24.37.1
  - All

- **Display Filter Settings**:
  - Low pass: 1000 Hz
  - High pass: None
### Table

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>Masking</td>
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<tr>
<td>Wave repro.</td>
<td>28%</td>
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<tr>
<td>LP</td>
<td>1.9 kHz</td>
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<tr>
<td>HP</td>
<td>33 kHz 6/dct</td>
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<tr>
<td>Residual noise</td>
<td>32 nV</td>
</tr>
<tr>
<td>Frmr</td>
<td>3.21</td>
</tr>
<tr>
<td>Ratio</td>
<td>170.48/31.78V=5.4</td>
</tr>
<tr>
<td>Alter. A=Rare, B=Cord</td>
<td></td>
</tr>
<tr>
<td>Stim.</td>
<td>NB CE-Chrpb LS, 4k</td>
</tr>
</tbody>
</table>

### Graph

- **4000 Hz**
- **Frequency Range**: 0 to 20 ms
- **dB nHL**: 0 to 20
- **Lines**: 20 R, 10 R, 20 L, 10 L
- **Markers**: Y

The graph shows measurements for different frequencies and thresholds, indicating responses at 4000 Hz.
ASSR 7.34 min
ABR 17 minutes
CE- Chirps

Try em- You will like em!
We’ve Come a Long Way in Hearing Evaluation
Amplitude Adv ABR FS
Amplitude/Accuracy using ASSR
Amplitude -> Time Advantage
CE-NB Chirps Achieve Lower Thresholds than Traditional Tone Bursts.

Using linear extrapolation the 4 kHz difference equates to an average chirp threshold advantage of 5.2 dB, whilst at 1 kHz the chirp advantage is 6.2 dB.

We propose that the ABR nHL threshold to eHL correction for NB CE-Chirps should be approximately 5 dB less than the corrections for tone pips at 2 kHz and 500 Hz, in line with NHSP guidance at 4 & 1 kHz.
Simultaneous multi-frequency ASSR-testing
Band-limited Chirps

500 Hz - one octave
1,000 Hz - one octave
2,000 Hz - one octave
4,000 Hz - one octave
Amplitude spectrum of the ASSR

Response components + Noise

Noise
Amplitude Comparisons
WB Chirps and Clicks

[Graph showing data for different age groups: Adult Chirps, Toddler Chirps, Infant Chirps (Muhler), Newborn Clicks, with dB HL on the x-axis and Wave V amplitude (nV) on the y-axis, including data from 19-48 months, 1-18 months, Elberling et al. (2012), and Sininger et al. (2000).]
• The NB CE-Chirp response is less likely to have interference from stimulus artifact.
• Important to use alternating TB stimuli to avoid artifact and CM.
• Response window will be consistent across stimuli for the NB CE-Chirps which is convenient for setting the response detection window.

Adjustment of start of recording time relative to stimulus onset is implemented.
Calibration Standards for CE-Chirps are Published

Specifications
The EPx5 version 4.3 by Interacoustics contains a novel series of brief stimuli:
- Click (wave-click)
- CE-Chirp® (also referred to as broadband CE-Chirp®)
- Narrow Band CE-Chirp® (also referred to as NB CE-Chirp®)

Calibration nHL
- Click stimuli are presented in nHL following the ISO standard 389-6 for peRETSPL to nHL².
- NB & CE-Chirp® family stimuli are not specified in the current international standard and are calibrated to nHL on the basis of two studies, PTB in Germany 2008 and DTU (Gøtscbe-Rasmussen et al., 2012).³

Please refer to section Calibration in the Eclipse ABR operational manual for more details.
Free Lunch

Using a chirp is no more work than using a click or a tone burst. There is no change in procedures otherwise.
Amplitudes from Chirps are significantly larger at low stimulus levels (did not use LS)!

Gabriela Ribeiro Ivo Rodrigues *, Nata´ lia Ramos, Doris Ruthi Lewis
Comparing auditory brainstem responses (ABRs) to toneburst and narrow band CE-chirp1 in young infants International Journal of Pediatric Otorhinolaryngology 77 (2013) 1555–1560
“4 kHz difference equates to an average chirp threshold advantage of 5.2 dB, whilst at 1 kHz the chirp advantage is 6.2 dB “.
The mean NB CE-chirp response amplitude was approximately 50% larger than that of a pip at 2 kHz and approximately 30% larger at 500 Hz. Fmp values were typically double for NB CE-chirps.
• Screening:
  - Click (40 dBnHL) and Chirp (35 dBnHL)
  - two groups of newborns (each of about N = 1,800)

• 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)

• 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)

**Normal Infants**
Auditory Brainstem Response
Stimulus: Click, 25/s, Insert Earphones
Right Ear

Age at Test: 2 years, 9 months

<table>
<thead>
<tr>
<th>dB nHL</th>
<th>Fsp</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>60</td>
<td>3.0</td>
<td>7.9</td>
</tr>
<tr>
<td>40</td>
<td>3.2</td>
<td>8.9</td>
</tr>
<tr>
<td>30</td>
<td>2.7</td>
<td>9.0</td>
</tr>
<tr>
<td>20</td>
<td>1.5</td>
<td>9.7</td>
</tr>
</tbody>
</table>

200 nV
Auditory Brainstem Response
Stimulus: 500 Hz Tone Burst, Insert Earphones  Age at Test: 2 years, 9 months

Right Ear
60 dBiHL
V = 12.7

30 dBiHL

Left Ear
60 dBiHL
V = 11.9

30 dBiHL
V = 13.1

Age at Test: 2 years, 9 months
Patient: ES
Age at Test: 2 years, 9 months

Auditory Brainstem Response
Stimulus: 4000 Hz Tone Burst, Insert Earphones

Right Ear
- 100 dBnHL: No Response
- 90 dBnHL: No Response
- 80 dBnHL: No Response

200 nV

0 5 10 15 20 25 ms