Use of New Stimulus and Detection Technologies for Pediatric Electrophysiology

Sponsored By

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New Technologies

- CE-CHIRPS
- ABR $F_{mp}$ Noise and Signal Detection
- Bayesian Weighting
- Next Generation ASSR
Why Have Clicks Been Used for Eps?

- Click has a very short duration.
- This produces a **broad, flat spectrum**.
- Because of the broad spectrum, the entire basilar membrane and **all the corresponding neurons are activated** revealing a large response.
Traveling Wave Delays the Activation of Low Frequency Regions of the Cochlea
A CLICK WILL PROGRESSIVELY ACTIVATE THE ENTIRE LENGTH OF THE BASILAR MEMBRANE SEQUENTIALLY.

Transient, broad band stimuli

Traveling Wave
Stacked ABR

Derived-Bands (Actual timing)

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

Derived-Bands Aligned (Shifted and summed)

M. Don – House Ear Institute, 2002
Another way to compensate for the traveling time is to time-shift the different frequency components of the *click stimulus*. This is done by allowing the low-frequencies to appear before the high-frequencies. (Like starting the slow runners in a race first, staggering the runners by speed so they all cross the finish line together.)

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

A *chirp ABR* is significantly larger than a click ABR for the same reason that the stacked ABR is bigger.
The Amazing CE-Chirp®

- Stimulus that reorganizes timing of spectral components to synchronize cochlear response based on research of Claus Elberling (CE) and colleagues.
- CE-Chirps are of the same energy and frequency composition as traditional stimuli—clicks and tone bursts.
- Produces neural response (ABR, ASSR,...) with up to 2X amplitude of traditional stimuli.
- Greater amplitude enhances response detection.
- Reduces time to automated detection.
- Lowers threshold of response detection and reduces correction factors.
Frequency Component Delays are Based on Latency Information from Human Subjects.
Chirp ABR

Chirp stimulus

Dau et al. 2000
Using a chirp is no more work than using a click or a tone burst. Except for expected response latency, there is no other change in procedures.
What is a CE-Chirp

All chirps are not the same

Each is based on an estimate of cochlear travel time from different data sources.

The CE-Chirp was created using data from Manny Don and Claus Elberling using tone-burst ABR and derived band ABRs collected over many years of research.

Narrow band CE-Chirps for Clinical Audiology

500 Hz

1000 Hz

2000 Hz

4000 Hz
**NB CE-Chirps are staggered in time relative to the recording time, just as they are in the wide band CE-Chirp.**

Therefore:
- Response window can be consistent across stimuli for the NB CE-Chirps which is convenient for setting the response detection window.
- The NB CE-Chirp response is less likely than the tone burst to have interference from stimulus artifact.
Wave V Latency Norms

With the release of EP4.4 the wave V latency norms for Click, CE-Chirp® LS and NB CE-Chirp® LS have been aligned to make it easier to locate the wave V response. The figures below show how response latencies for all three types of stimuli are aligned for the different stimuli levels. Note that age, rates and filter settings can influence response latencies.

*LS= Level Specific*
Recent Study of Infants and Toddlers Using NB CE-Chirps:

Wave V latency for all frequencies at threshold are ~ 9 ms.

No more need for extended windows to view low frequency responses!
**British NBHS Compare NB CE-chirps and Tone Pips for Threshold Testing Following Screening Fails**

Comparison of ABR response amplitude, test time, and estimation of hearing threshold using frequency specific ce-chirp and tone pip stimuli in newborns


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 tone pip and chirp wave V to SN 10 ABR amplitudes and Fmp values were compared in this study.

• Infants with corrected ages under three months. Initially the NHSP discharge criterion for satisfactory hearing was satisfied (4-kHz tone tip ABR at 30 dBeHL ).
Ferm, Lightfoot & Stevens International Journal of Audiology 2013;
Responses to NB CE-Chirps were larger and generally showed lower thresholds than tone pips.
Lake Como Poster filled in .5 and 2k Hz Results

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 results support the use of NB CE-Chirps when testing newborns. In England, the NHSP protocols\(^{(5,6)}\) now allow the use of chirp stimuli as an alternative to tone pips for post-screening ABR diagnostic assessments. 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.
The NB CE chirps evoked a larger response than the tone pips in 93% of 2 kHz comparisons and 71% of 500 Hz comparisons. 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.
New (?)Technologies

• ABR Noise and Signal Detection
Average ABR = Neural Potential + Noise.

It is not possible to accurately determine how much of each is present, merely by looking.

Noise can obscure a response so it is important to know how much noise is present.
Noise can be measured as the change in amplitude of fixed points from sweep to sweep. The bigger the amplitude variation, the more noise is entering the recording. Fsp uses one point per sweep, Fmp (multiple point) uses 5 per sweep.

Measuring the amplitude variance across the average response gives an estimate of the strength of the neural potential + background noise.

\[ F_{sp} \text{ or } F_{mp} = \text{Signal} + \frac{\text{Noise}}{\text{Noise}} \]
Averaging Reduces Stationary Noise by the Square Root of Sweeps

Noise starts high

Noise starts low

Don & Elberling
JASA 96:5, 1994
Response Detection as Amplitude Changes (Noise is unchanged)

As signal (response amplitude) increases, $F_{mp}$ grows faster and response is achieved earlier!
**Response slope is related to signal strength**

When stimulus is below threshold (no signal): Response does not grow!
Same Signal (ABR) With Different Background Noise
High Noise Prevents Detection

![Graph showing signal and noise levels over time with response criteria](image-url)
Average can be set to stop when 1) Fmp is large enough to judged a good response OR 2) when the noise is low enough to be sure of a no response or 3) some maximum # of sweeps.
Cross Correlation for Detection
An Alternative “Objective” Detection Scheme

Fmp=2.45
1100 sweeps

Fmp=0.82
4000 sweeps

Correlation 54%

Correlation 5%

Correlation 31%

Correlation 0%

95 R

95 R1

98 R

98 R1
How does Fmp compare to Cross Correlation detection and noise measurements??

**Fmp**
1) Fixed time window length
2) Statistically based response criteria
3) Noise is considered in the detection criteria
4) Constant updated readout
5) Clear published guidelines

**Cross-Correlation**
1) Arbitrary Time window length
2) No clear response criteria – How much is good?
3) Noise can be estimated but how much is too much?
4) Many systems require stopping and calculating
5) No set guidelines
New Technologies

- Bayesian Weighting
Bayesian Weighting
What is it and why would I use it?

First proposed by Elberling & Wahlgren in 1985 as a method of noise reduction during averaging.

Rather than rejecting all sweeps with high amplitude (traditional noise rejection) Bayesian weighting assigns a “weight” to each block (50) of sweeps based on estimated noise in the block.

When a block is quiet, it is given greater “weight” in the average than when a block is noisy. Almost nothing is discarded.
Bayesian Weighting with Sudden Noise Burst

Don & Elberling
JASA 96:5, 1994
New Technologies

• Next Generation ASSR Detection
Skepticism Regarding ASSR

“ASSR testing (as carried out in this study) cannot reliably differentiate between normal ears and those with mildly elevated hearing levels. The accuracy of the technique does, however, improve dramatically in ears with sensorineural hearing loss” (Rance et al., 2005, p. 298).

Early ASSR technology could detect supra-threshold responses but missed low-levels near threshold in normally-hearing subjects.
Comparison of Thresholds from Normally-Hearing Infants by ASSR and ABR Using GSI Audera

Rance et al. 2006 Ear & Hearing.

Open Circles ABR, closed are ASSR. Blue Star is ABR threshold from Sininger et al on Normally Hearing Newborns at 0-1 week.

ASSR Thresholds were determined by Phase Coherence only at the modulation frequency

Thresholds determined using ASSR by Audera in 2006 were unacceptably high demonstrating that the technique could not meet the then standard of TB ABR!!
Unacceptable Behavioral Prediction from ASSR

Attias et al., 2014
Adult Data
Used Amplitude of Mod Frequency (80-90 Hz) F test.
How are ASSR and ABR Alike, Different?

ABR and ASSR both look at the same brainstem neural activity.

ASSR modulates the stimulus at a known frequency.

Response detection then searches for evidence of that frequency in the ongoing EEG.

If the neurons are activated by the stimulus, there will be a spike in the frequency response of the EEG at the modulation frequency and the phase of the EEG will be synchronized with the stimulus onset.

ASSR technique is solid but “Response Detection” had been under-developed.
Traditional ASSR Detection Searches for Significant Amplitude and/or Phase Coherence of the Modulation Frequency
How is the “Next Generation” ASSR Different than the First Generation??

Next Generation uses BOTH amplitude and phase information for detection.

Next Generation uses the fundamental and 20+ harmonics for response detection.

Next Generation ASSR uses Narrow Band CE-Chirps.
Next Gen ASSR uses Response Detection (Phase and Amplitude) at Fundamental and 12 Harmonics Compared to Fundamental Alone

Frequency [Hz]

Amplitude [dB]

Response components + Noise

Noise
Next Gen ASSR uses Narrow Band CE-Chirps as Stimuli
Known to produce Larger Amplitude Responses
And Lower Thresholds

30 dBnHL

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

500 Hz

1000 Hz

2000 Hz

4000 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:
\[ r = 0.9458 \]
\[ y = 0.998x - 3.88 \]
Strength of the Next Generation Detection is Demonstrated by Lowest Threshold for Normally Hearing Children

- Rodriguez & Lewis, 2014
- Rance et al., 2005*
- Lins et al 1996 *
- Savio et al., 2001 (0-1 month)*
- Swanepoel & Steyn, 2005*
- Van Mannen & Stapells, 2009*
- Michel & Jorgensen, 2017
- Savio et al., 2010 7-12 mo*
- Rickards et al., 1994*
- Rance & Rickards 2002*
- Cone-Wesson & Rickards, 2002*
- Levi et al., 1995*
- Casey & Small, 2014*
Subject 3513  9 Months

ASSR

33 Minutes, 23 seconds

Right Ear

500Hz

1000Hz

2000Hz

4000Hz

Left Ear

500Hz

1000Hz

2000Hz

4000Hz

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Questions?