Demystifying the CE-Chirp

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There is substantial evidence to support the use of the CE-Chirp for threshold estimation in lieu of click and tone burst stimuli.

Cutting edge technological advances generate a range of reactions within the professional community from reluctance, skepticism, and fear to enthusiasm, excitement, and anticipation. We've often witnessed the introduction of exciting and fascinating diagnostic technologies (ie, otoacoustic emissions, auditory brainstem response, acoustic reflexes, tympanograms, and more) which are reluctantly embraced over years and decades—until they become mandatory and irreplaceable!

Indeed, it often takes years (and sometimes decades) for many of these important technologies to become commonplace in clinics around the world. As would be expected, education and a pragmatic understanding of new technologies play a role in one's ability to accept change. It is our nature to view new technologies with some degree of skepticism—and rightfully so! Evidence-based research is critically important to support the introduction of new technologies. As such, this article will focus on a new family of acoustic stimuli, Level Specific CE-Chirps©, and the science them.

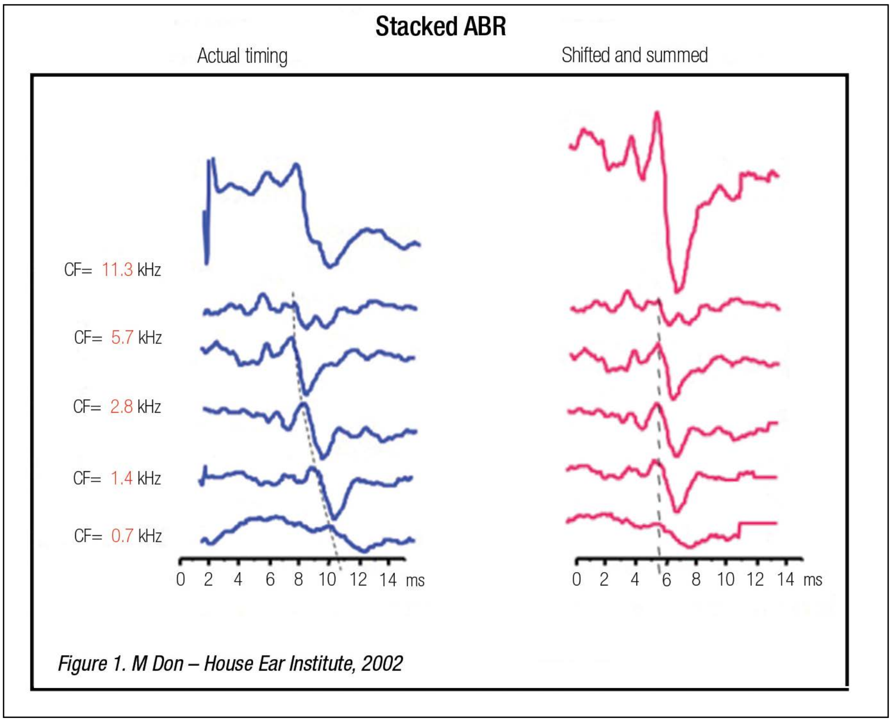

Figure 1. The stacked ABR as reported by Don et al.[2]

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Background

Clicks and Tone Bursts (TBs) used in tandem with (or for) auditory brainstem response (ABR) audiometry haven't changed much over the last four decades. Indeed, the auditory evoked response relies on the rapid "synchronous" firing of the auditory nerve to generate a tiny electrical signal which can be averaged and recorded.

Click and TB stimuli each stimulate a specific frequency range. When these stimuli are presented they produce a "less than ideal" response because hair cells of the cochlea are stimulated at different absolute times, creating a "smearing" effect which diminishes the amplitude of the ABR in general, and wave V in particular. These detrimental effects to the response are due to a mismatch between the timing of the different frequency components within the stimulus and the travel time for different frequencies within the cochlea. Smearing occurs as a natural byproduct from clicks, and smearing also occurs (although to a lesser degree) with TBs.

Elberling, Don, and their colleagues[1,2] recognized the pitfalls of clicks and TBs, and investigated possible alternatives. Don[2] addressed this problem using a technique known as the "Stacked ABR" (Figure 1) which was aimed at improving small tumor detection. Stacked ABR protocols time-shifted the response waveforms (collected using filtered clicks) and lined up the Wave V at the same point in time, adding them together. Although it produced Wave V responses twice as large as, and more easily identifiable than, standard click protocols, the Stacked ABR protocol (also known as "output compensation") proved to be time consuming and soon lost favor among clinicians.

As digital technology and software evolved, Elberling and colleagues[3] addressed this issue, asking "What if we could alter the stimulus to compensate for cochlear travel times?" Consequently, they engineered an acoustic broad spectrum stimulus with inherent timing functions (Figure 2) to simultaneously stimulate the majority of cochlear hair cells. Their new "chirp" maximized the synchronous neural firing of the auditory nerve and produced Wave V amplitudes twice as large as standard clicks, as evidenced via Stacked ABR. Of note, not only were amplitudes increased while using the chirp, but the chirp also substantially reduced test times when conducting clinical threshold assessment.

These re-engineered acoustic stimuli (ie, chirps) have become known as CE-Chirps. An entire family of stimuli called "Level Specific CE-Chirps" have been developed to produce the most robust Wave V responses regardless of stimulation level. (The Interacoustics Eclipse has Level Specific CE-Chirps from 0-100 dB in 5 dB steps).

Evidence Based Benefits

Stürzebecher, Cebulla, and Elberling[4] conducted studies with the CE-Chirp utilizing an ASSR-like application to evaluate its effectiveness as applied to hearing screenings. When compared to a click at a screening level of 30 dB, the CE-Chirp demonstrated a 50% reduction in test times (on normal-hearing individuals) with a median test time of 30 seconds per ear and the generated responses with twice the amplitude of a traditional click.

Multiple studies have documented the superiority of the CE-Chirps as compared to traditional stimuli. For example, Ferm and Lightfoot[5] used data gathered from the United Kingdom's universal newborn screening program and demonstrated Narrow Band (NB) CE-Chirp responses were 31% larger (on average) than tone pip responses at 0.5 kHz, and were 52% larger at 2 kHz (Figure 3). On average, NB CE-Chirp responses were 1.6 times larger than standard TB counterparts, and the ability to achieve responses closer to threshold was improved significantly with the added benefit of reduced test times. As a result, the official UK NHSP recommendations for threshold estimation were modified to reflect the documented improvements from NB CE- Chirps.

Venail et al[6] evaluated the Interacoustics Eclipse ASSR using NB CE-Chirp stimuli. Comparisons were made between traditional TB ABRs, NB CE-Chirp ASSR, and behavioral thresholds. The authors' reported ASSRs were highly and significantly correlated to the behavioral thresholds for normal-hearing and hearing-impaired children at 0.5, 1, 2, and 4kHz. The also reported, while using multiple narrow-band CE-Chirps, the ASSR total test time was 22 minutes, similar to what others have previously reported (Rodriguez et al[7] reported 21 minutes; Mühler et al[8] reported 19 minutes; Seidel et al[9] reported 33 minutes). Venail et al[6] concluded "Narrow-band CE-Chirps© allow a fast and reliable assessment of auditory thresholds in children, especially in the low-frequency range, by comparison with other stimuli [such as 500 Hz]."

Hall[10] recently reported "Chirps represent an excellent advance in auditory science and clinical audiology." Similarly, Bargen[11] reported "when presented at 60 dBnHL or lower, broadband chirp (ie, CE-Chirp) gener-

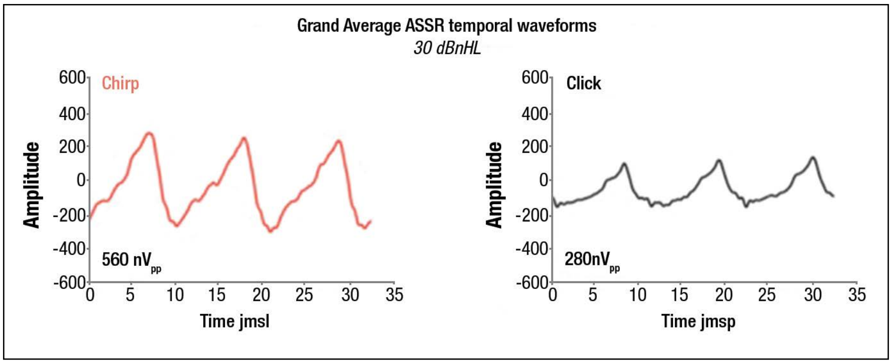

Figure 2. The "CE-Chirps" produce Wave V amplitudes twice as large as the standard clicks.

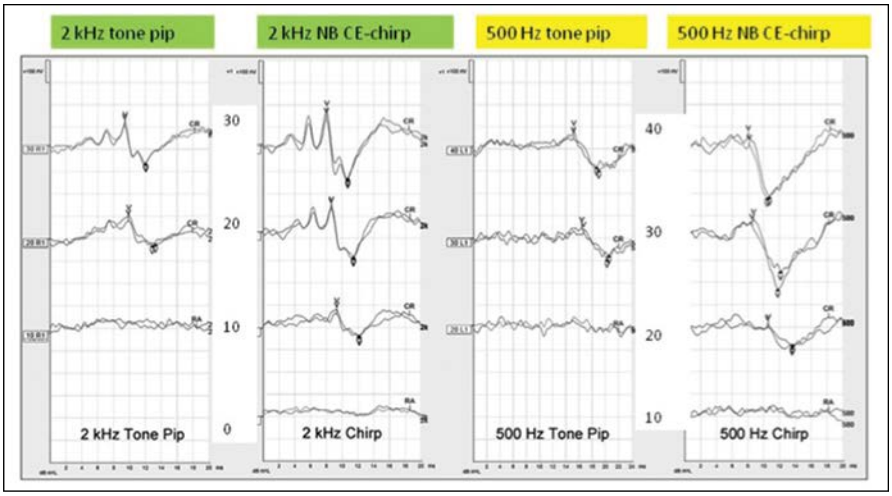

Figure 3. Ferm and Lightfoot[15] reported Narrow Band (NB) CE-Chirp responses that were 1.6 times larger than standard tone bursts.

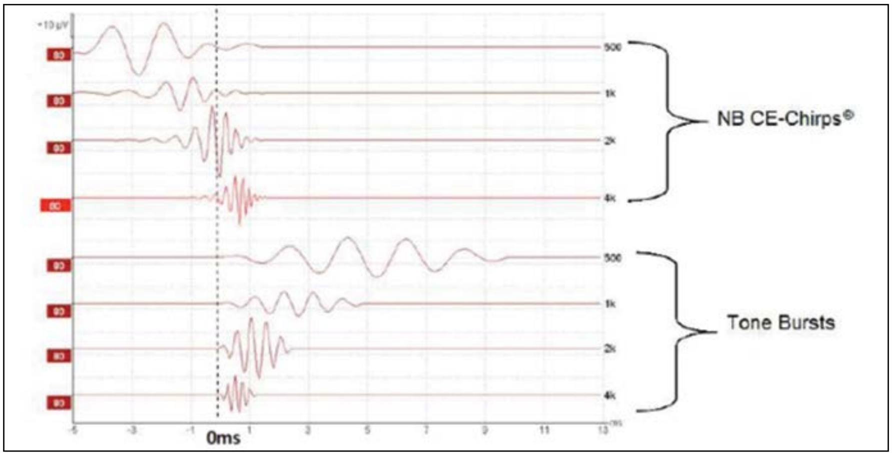

Figure 4. Stimulus timing onset.

ated ABRs have larger amplitiudes than click generated ABRs in children with normal hearing…" She also reported "test-retest" reliability, sensitivity, and specificity were good while using chirp-evoked ABRs in newborn screenings.

Simplifying the Process

As CE-Chirp technology has evolved, so have the efforts of programmers to simplify the operator interface—especially as it relates to editing ABR waveforms and converting ASSR data to estimated thresholds. As expected, these new stimuli also affect the latency at which Wave V would be determined. The most dramatic difference was observed with the 500 Hz NB CE-Chirp. Of note, a typical 500 Hz TB (at 60 dB) generates a Wave V latency at approximately 9 msec in normal ears. In contrast, the 500 Hz NB CE-Chirp (also at 60 dB) generates a Wave V latency more comparable to clicks, primarily due to the earlier "start" time of the stimulus.

Figure 4 shows the principle behind the response latencies' dependence upon stimulus positioning: The LS NB CE-Chirps are positioned earlier on the timeline than Tone Bursts, and therefore provide shorter response latencies. Of note, the broad-band CE-Chirp Wave V latency corresponded quite closely to the traditional click.

One might think of these earlier "stimuli start times" as analogous (although opposite!) to the 0.9 msec acoustic timing delay (and compensation) all manufactures use to accommodate the tubing length of insert earphones. Likewise, on the Eclipse EP25 stimulus start times have been "normalized" for the newest Level Specific NB CE-Chirps to produce Wave V latencies which are identical to each other and also similar to the Broad Band LS CE-Chirp Wave V latency which approximates the traditional click (Table 1).

For NB CE-Chirps, correction factors for electrophysiologic ABR thresholds to estimated audiogram can be "decreased" by 5 dB (Table 2). For example, if a 20 dB correction factor for 500 Hz TB was previously used, clinicians using the new software would modify this to 15 dB. The same applies to bone-conducted thresholds. A complete list of age- and transducer-dependent correction factors can be found on the UK NHSP website.

dBnHL	Click	CE-Chirp LS Broad-band	CE-Chirp LS NB 4kHz	CE-Chirp LS NB 2kHz	CE-Chirp LS NB 1kHz	CE-Chirp LS NB .5kHz
90dB	5.23	5.33	4.95	4.95	4.95	4.95
80dB	5.36	5.35	5.27	5.27	5.27	5.27
70dB	5.57	5.51	5.60	5.60	5.60	5.60
60dB	5.84	5.80	5.96	5.96	5.96	5.96
50dB	6.20	6.20	6.36	6.36	6.36	6.36
40dB	6.64	6.71	6.82	6.82	6.82	6.82
30dB	7.13	7.32	7.35	7.35	7.35	7.35
20dB	7.70	8.02	7.97	7.97	7.97	7.97
10dB	8.35	8.80	8.70	8.70	8.70	8.70

Table 1. Adult Wave V Latency Tables for the Interacoustics Eclipse EP25.

AC - Inserts	Tone pip/click ABR					Chirp			
Corrected age	0.5k	1k	2k	4k	Click	0.5k	1k	2k	4k
< 12 weeks (<84 days)	-15	-10	-5	0	5	-10	-5	0	5
13 to 24 weeks (85-168 days)	-20	-15	-10	-5	0	-15	-10	-5	0
> 24 wk (>168 days)	-20	-15	-10	-10	-5	-15	-10	-5	-5

Figure 4. This table shows the official nHL to estimated audiogram correction factors for level specific NB CE-Chirps© as used by the UK NHSP program.

Summary

There is substantial evidence to support the use of LS CE-Chirps for threshold estimation in lieu of click and tone burst stimuli. However, at this time, we can't discount the continued use of the click for other neurological applications, as well as its contribution in evaluating auditory neuropathy. Interacoustics provides educational materials and tutorials on the CE-Chirp at www.interacoustics-us.com (click on "Academy").

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