Infant ABR: Click versus CE-Chirp®

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Guest Speaker

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Professor at the Department of Communication Sciences and Disorders at East Carolina University (Greenville, North Carolina). Dr. Stuart joined ECU after completing his Ph.D. in Experimental Psychology at Dalhousie University, Halifax, Canada. Prior to beginning his doctoral studies he was employed as a clinical audiologist at the Children's Hospital of Eastern Ontario, Ottawa, Canada and then as a Research Audiologist at Dalhousie University.

His research interests include electrophysiology, pediatric audiology, psychoacoustics, and fluency enhancement in those who stutter via altered auditory feedback. Dr. Stuart has over 135 peer-reviewed articles and 200 national and international presentations in these areas.

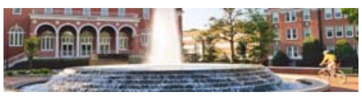
Course Objectives

- Understand differences between CE-Chirp and traditional click air and bone-conducted stimuli
- Describe similarities/differences in ABRs to CE-Chirp and Click air-conducted stimuli in newborn infants
- Describe similarities/differences in ABRs to CE-Chirp and Click bone-conducted stimuli in newborn infants

Webinar Overview

- Hearing Detection and Intervention
- The Role of ABR
- ABRs With Clicks
- CE-Chirp®
- East Carolina University & CE-Chirp®
- Conclusions/Observations

East Carolina University



Hearing Detection and Intervention

- "The goal of early hearing detection and intervention (EHDI) is to maximize linguistic competence and literacy development for children who are deaf or hard of hearing."
  - Joint Committee on Infant Hearing (JCIH; 2007)

Definition of Targeted Hearing Loss
(JCIH, 2007)

- Congenital permanent bilateral, unilateral sensory, or permanent conductive hearing loss.
- Neural hearing loss (e.g., "auditory neuropathy/dyssynchrony") in infants admitted to the Neonatal Intensive Care Unit (NICU).

JCIH (2007) 1-3-6 Plan

- All infants should be screened by *1 month* of age.
- Those who do not pass screening should have a comprehensive audiological evaluation by *3 months* of age.
- Infants with confirmed hearing loss should receive appropriate intervention by *6 months* of age.

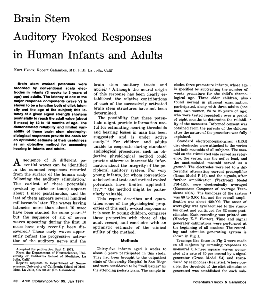
The Role of Auditory Brainstem Response (ABR)? (JCIH, 2007)

- Hearing-screening and rescreening protocols.
  - Well-infant nursery
    - ABR or Otoacosutic Emissions
  - Neonatal Intensive Care Unit (> 5 days)
    - ABR

- Diagnostic audiology evaluation
  - Click-evoked ABR for neural hearing loss.
  - Frequency-specific ABR testing is needed to determine the degree and configuration of hearing loss in each ear for fitting of amplification devices.

Infants ABRs to Clicks

- First report of infants ABR responses appeared in 1974:
  - Hecox & Galambos



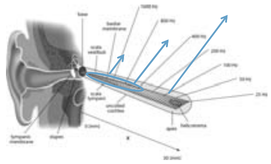
Brain Stem
Auditory Evoked Responses
in Human Infants and Adults

ABRs to Clicks

- The click is a transient stimulus with a broad acoustic spectrum.
- Consequently, the ABR to click stimuli is evoked from activity from the whole basilar membrane.

ABRs to Clicks

- The different neural units along the cochlear partition are not stimulated at the same time.
- Wave V is dominated by neural activity from high-frequency regions of the cochlea.



(Kernet et al., 2008)

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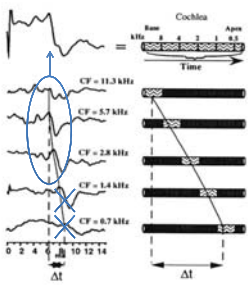
Derived Band ABRs

(Don et al., 1997)

- The frequency components along the basilar membrane are shown from base to apex.
- Each band contributes to the standard ABR.
- But – Wave V is dominated by neural activity from high-frequency regions of the cochlea as the low frequency components are phase canceled!



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How can one improve the ABR?

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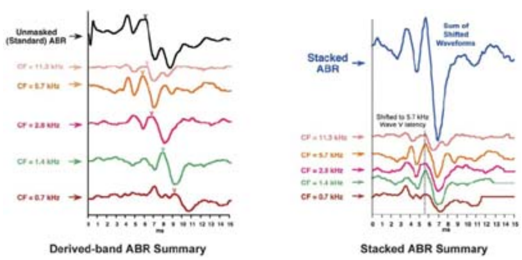
Temporal Alignment: Output
(Elberling et al., 2007)

- One way is to align the activity along the cochlear is to temporally align derived band ABRs.
  - i.e., output compensation
- The Stacked ABR is formed by first generating derived-band ABRs, temporally aligning wave V, and then summing stacked responses.
  - Aligning the derived-band ABRs eliminates phase cancellation of lower frequency activity.

Stacking Method
(Don et al., 2005)

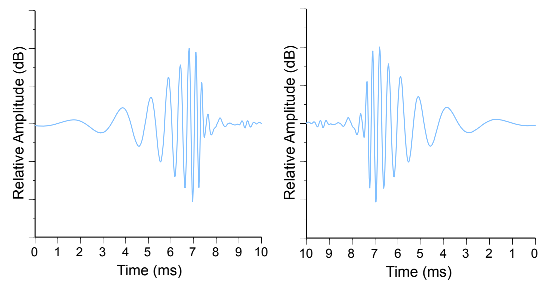


Temporal Alignment: Input
(Elberling et al., 2007)

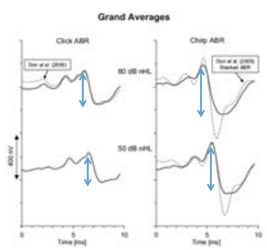
- Another way is to align the activity along the cochlear is to time-shifting the different frequency components of the click stimulus.
  - i.e., input compensation
- Ordering of the frequency components in the stimulus is based on a temporal model of the cochlear function.

The Chirp:

A "low-frequency leading" or rising frequency stimulus that compensates for the cochlear traveling wave delay!



- This compensation has been shown to *increase the amplitude of the ABR in adults* compared to the amplitude in response to a click.
  - Dau et al, 2000; Fobel and Dau, 2004; Elberling et al, 2007; Elberling and Don, 2008; Don et al, 2009; Elberling et al, 2010; Cebulla and Elberling, 2010; Elberling and Don, 2010; Petoe et al, 2010a, 2010b



(Elberling & Don, 2008)

The CE-Chirp®

(Elberling et al, 2007, 2010; Elberling & Don, 2008, 2010)

- Designed using a delay model based on derived-band ABR latencies.
- The electrical CE-Chirp® has a flat amplitude spectrum within five octave-bands ranging from 350 to 11,300 Hz.
- Four octave-band filtered versions of the CE-Chirp® are also implemented with the center frequencies 500, 1000, 2000, and 4000 Hz.
  - The octave-band chirps are obtained by decomposing the broad-band CE-Chirp®.

Chirps & Infants?

- ABRs to chirps have been advocated for both newborn neurodiagnostic and hearing screening applications.
- Normative ABR data, however, is presently not widespread.
  - van den Berg at al.(2010); Cebulla & Shehata-Dieler (2012); Ferm et al (2013); Mühler et al. (2013); & Rodrigues et al. (2013).

ECU & The CE-Chirp®

- Objectives:
  - Compare neonate ABRs to air- (AC) and bone-conducted (BC) CE-chirp® and click stimuli.
  - Compare neonate ABRs to AC and BC CE-chirp® octave band and toneburst stimuli.
  - Compare neonate and adult ABRs to AC and BC CE-chirp® and CE-chirp® octave band stimuli.

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Duke University Medical Center, Raleigh, NC

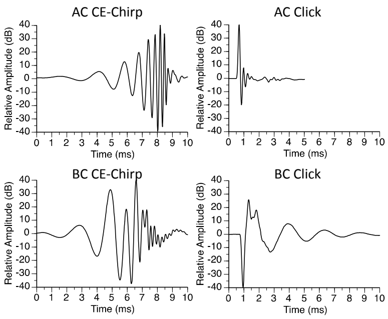
Participants

- Participants were 169 healthy neonates recruited from the well-baby nursery Vidant Medical Center, Greenville, NC.
- The neonates were:
  - 37-42 weeks gestational age
  - APGAR scores ≥ 7 at 1 and 5 minutes
  - Birth weight ≥ 2500 g
  - Physically and neurologically normal, with no risk of hearing loss
  - Passed a newborn hearing screening

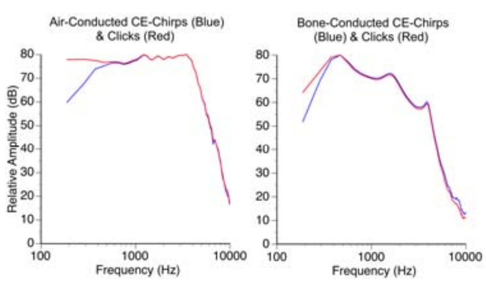
Apparatus

- A GSI Audera (V2.7) evoked potential system was utilized.
- ABRs were obtained with 100µs AC and BC clicks and CE-Chirps®.
- Stimuli were presented through a GSI TIP-50 insert earphone or a Radioear B-71 bone vibrator.

AC & BC CE-Chirp® Amplitude-Time Waveform



AC & BC CE-Chirp® Spectra



Procedure

- Neonates were tested in natural sleep.
- Monaural AC and BC stimuli.
- Controlled stimulus delivery with bone vibrator:
  - Infants:
    - Supero-posterior auricular position during stimulus delivery.
    - An elastic band with Velcro was used to hold the bone vibrator in place.
    - Vibrator-to-head coupling force was 425 ± 25 g.

Recording Parameters

- Ipsilateral montage.
- Inter-electrode impedances < 5000 Ω.
- EEG was amplified 10^5 and bandpass filtered (30 - 3000 Hz).
- Artifact rejection ± 20 µV.
- Analysis time of 13 or 25 ms post-stimulus.
- Sampling at 25,000 Hz.
- A total of 1026, 2044, 2030, and 2028 samples were averaged and replicated for 8.7, 27.7, 57.7, and 77.7/s, respectively.

Stimulus Parameters: CE-Chirp® vs. Click

- AC & BC Intensity
- AC Rate
- AC Polarity
- AC Sweeps
- AC & BC Reliability

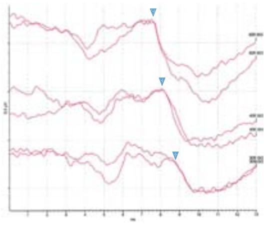
- Due to the number of stimulus conditions, not all participants underwent every test.
  – Minimum of 20 infants per test condition.
- Responses were analyzed for ABR Wave V latencies and amplitudes.

AC & BC Intensity: CE-Chirp® vs. Click

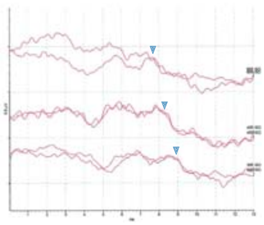
Effect of Stimulus Intensity			
Air Conducted Chirp vs. Click Stimuli			
Intensity (dB nHL)	Rate (/s)	Phase	Sweeps
60, 45, 30	57.7	Alternating	2030
Bone Conducted Chirp vs. Click Stimuli			
45, 30, 15	57.7	Alternating	2030

AC Intensity: CE-Chirp® vs. Click

CE-Chirp®: 60, 45, & 30 dB nHL @ 57.7/s

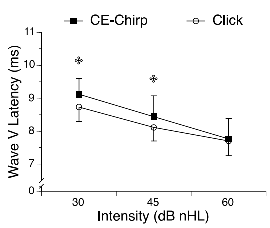


Click: 60, 45, & 30 dB nHL @ 57.7/s

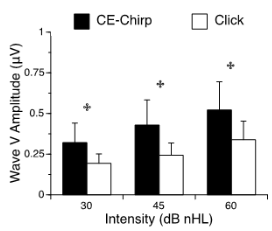


AC Intensity: CE-Chirp® vs. Click

Latency

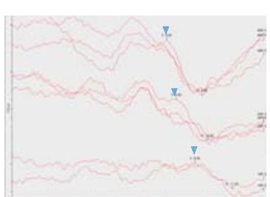


Amplitude



BC Intensity: CE-Chirp® vs. Click

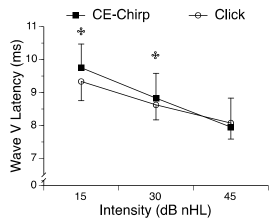
CE-Chirp®: 45, 30, & 15 dB nHL @ 57.7/s



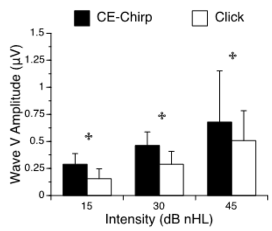
Click: 45, 30, & 15 dB nHL @ 57.7/s

BC Intensity: CE-Chirp® vs. Click

Latency



Amplitude

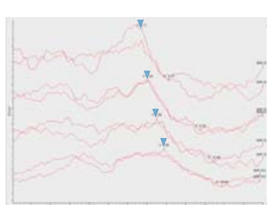


AC Rate: CE-Chirp® vs. Click Rate

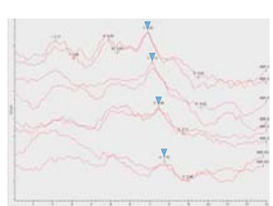
Effect of Stimulus Rate			
Air Conducted Chirp vs. Click Stimuli			
Intensity (dB nHL)	Rate (/s)	Phase	Sweeps
60	8.7, 27.7, 57.7, 77.7	Alternating	1026, 2044, 2030, 2028

AC Rate: CE-Chirp® vs. Click

CE-Chirp®: 60 dB nHL @ 8.7, 27.7, 57.7, & 77.7/s

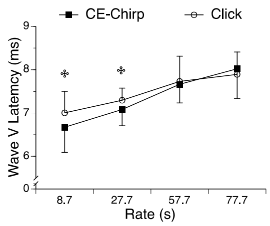


Click: 60 dB nHL @ 8.7, 27.7, 57.7, & 77.7/s

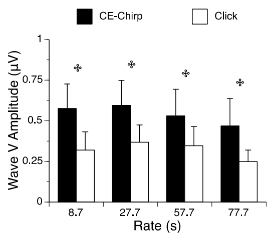


AC Rate: CE-Chirp® vs. Click

Latency



Amplitude

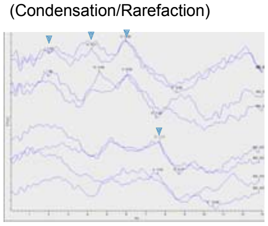


AC Polarity: CE-Chirp® vs. Click

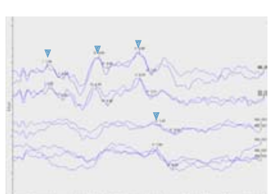
Effect of Stimulus Polarity			
Air Conducted Chirp vs. Click Stimuli			
Intensity (dB nHL)	Rate (/s)	Phase	Sweeps
60	8.7, 77.7	Rarefaction, Condensation	1026, 2028

AC Polarity: CE-Chirp® vs. Click

CE-Chirp®: 60 dB nHL @ 8.7, & 77.7/s (Condensation/Rarefaction)

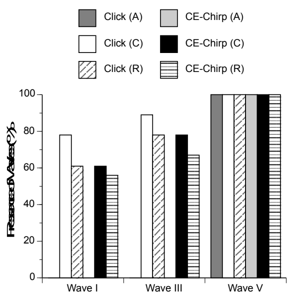


Click: 60 dB nHL @ 8.7, & 77.7/s (Condensation/Rarefaction)



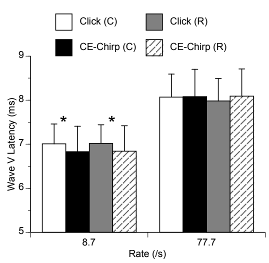
% presence of waves I, III, & V

(60 dB nHL @8.7/s)

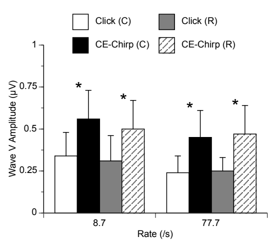


AC Polarity: CE-Chirp® vs. Click

Latency



Amplitude

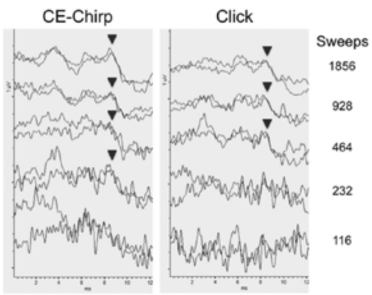


AC Sweeps: CE-Chirp® vs. Click

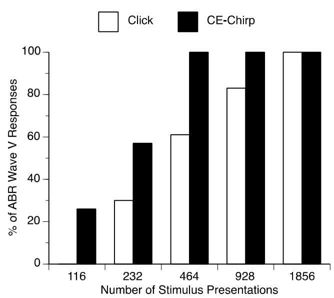
Effect of Number of Sweeps			
Air Conducted Chirp vs. Click Stimuli			
Intensity (dB nHL)	Rate (/s)	Phase	Sweeps
30	57.7	Alternating	116, 232, 464, 928, 1856

Stuart, A., & Cobb, K.M. (2014). Effect of stimulus and number of sweeps on the neonate auditory brainstem response. *Ear and Hearing, 35,* 585-588.

AC Sweeps: CE-Chirp® vs. Click



AC Sweeps: CE-Chirp® vs. Click

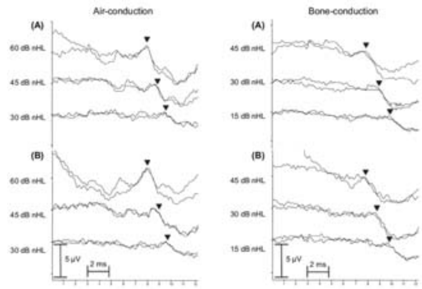


AC & BC Test-Retest Reliability: CE-Chirp®

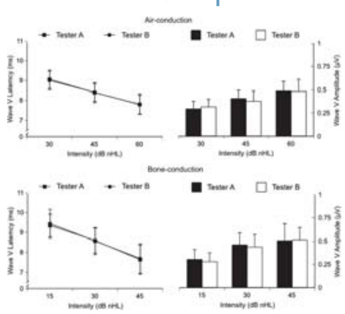
Test-Retest Reliability			
Air Conducted Chirp Stimuli			
Intensity (dB nHL)	**Rate (/s)**	**Phase**	**Sweeps**
60, 45, 30	57.7	Alternating	2030
Bone Conducted Chirp Stimuli			
45, 30, 15	57.7	Alternating	2030

Cobb, K.M., & Stuart, A. (2014). Test-retest reliability of auditory brainstem responses to chirp stimuli in newborns. International Journal of Audiology, 53, 829-835.

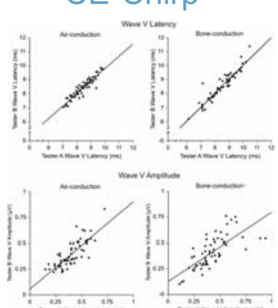
AC & BC Test-Retest Reliability: CE-Chirp®



AC & BC Test-Retest Reliability: CE-Chirp®



AC & BC Test-Retest Reliability: CE-Chirp®



Conclusions/Observations

- Wave V amplitudes to AC and BC CE-Chirp® are significantly larger than those evoked to standard click.
- Wave V latency differences exist between the AC and BC CE-Chirp®.

- AC and BC ABRs can be reliably evoked with low intensity 30 dB nHL CE-Chirp® and a fast rate of 57.7/s, similar to the current parameters of newborn hearing screenings.
- With the CE-Chirp®, wave V can be detected with 1/4 the amount of stimulus presentations required for the click.

- ABRs to AC and BC CE-Chirps® may be valuable in the assessment of newborn infants.
- The prognostic value of AC and BC CE-Chirps® need to be validated with newborn infants.

Acknowledgements

- Vidant Medical Center Audiology and Hearing Aid Center (Greenville, NC):
  - Rhonda Joyner, Mel Fratzke, Bethany Britt, & Ashley Fuller.
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  - Joey Bair

Questions

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