Infant ABRs: Tone Burst Versus CE-Chirps® Octave Band

Andrew Stuart, Ph.D., CCC-A, Aud(C)
Department of Communication Sciences & Disorders
East Carolina University
Greenville, NC, USA

Guest Speaker

Andrew Stuart, Ph.D., CCC-A, Aud(C)

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.

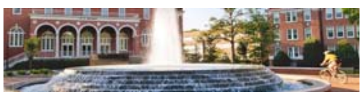
Course Objectives

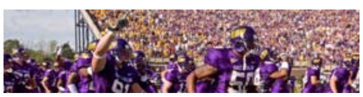
- Understand differences between air-conducted CE-Chirp® Octave Band and traditional tone burst stimuli.
- Describe similarities/differences in ABRs to air-conducted CE-Chirp® Octave Band and traditional tone burst stimuli in newborn infants.
- Describe similarities/differences in ABRs air-conducted CE-Chirp® Octave Band and traditional tone burst stimuli in newborn infants and adults.

Webinar Overview

- The Big Picture:
  - Hearing Detection and Intervention
  - Quantifying hearing loss following a failed newborn hearing screening
- East Carolina University & CE-Chirp®
- Promising New Research
- Conclusions/Observations
- Future Directions

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)

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.
- 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.*

So an infant has been referred following a newborn hearing screening... Now what do I do?

Model For Provision of Appropriate Amplification with Young Infants

(Seewald & Ross, 1998)

- Assessment
  - Quantify residual hearing.
- Selection
  - Define & provide electroacoustic dimensions.
- Verification
  - Evaluate adequacy & success of selection.
- Validation
  - Modify & monitor system as more data accumulates regarding child & performance.

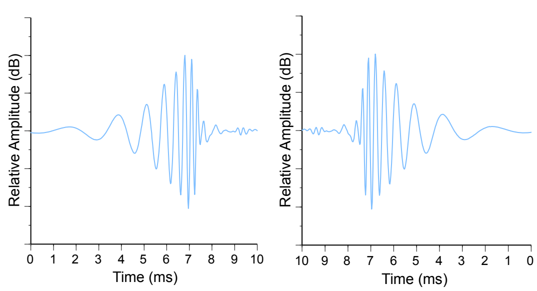
The CE-Chirp®

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

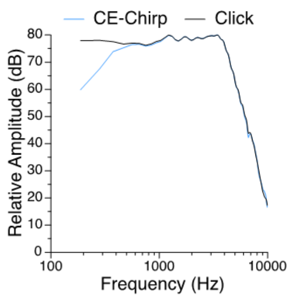
- Designed using a delay model based on derived-band ABR latencies.
- The electrical CE-Chirp® has a flat amplitude spectrum within five octave-bands ranging from 350 to 11,300 Hz.
- *Four octave-band filtered versions of the CE-Chirp® are also implemented with the center frequencies 500, 1000, 2000,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

CE-Chirp®:

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

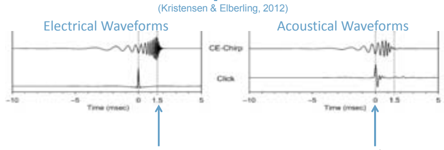


CE-Chirp® & Click



Some Temporal Issues

(Kristensen & Elberling, 2012)

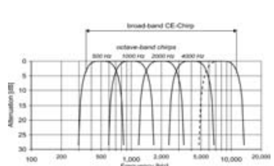


- The 10,000 Hz component of the CE-Chirp® is delayed by 1.5 ms to align ABR latencies to the chirps with the latencies to the click in normal-hearing subjects.
- The 0 ms point on the time axis for the acoustical waveforms indicates the start of the data collection and also the temporal reference for all latency measures.

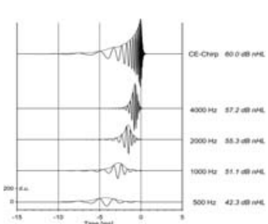
Decomposing The CE-Chirp®

(Elberling et al., 2010)

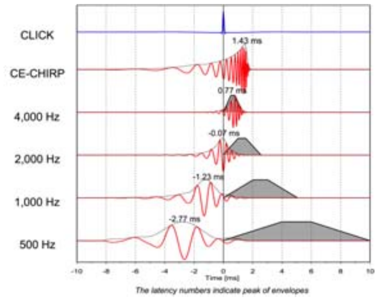
Amplitude Frequency



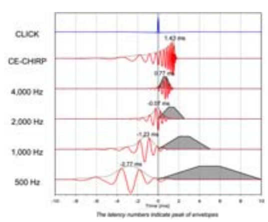
Waveform and Envelope



CE-Chirp® Octave Band: Temporal Characteristics (GSI, 2013)

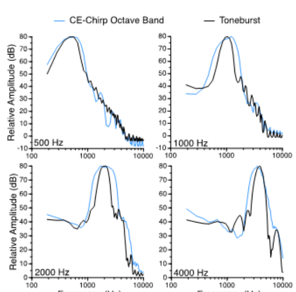


Temporal Alignment



- The timing of each CE-Chirp® Octave Band stimulus is derived from the timing of the same component in the CE-Chirp®.
- *Notice that the tone burst presentation starts at 0 ms, while the CE-Chirp® Octave Band stimulus presentation precedes 0 ms.*

CE-Chirp® Octave Band & Tone Burst Spectra



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 CE-Chirp® octave band and tone burst stimuli.
  - Compare neonate and adult ABRs to AC CE-Chirp® octave band stimuli.

Kensi M. Cobb, PhD, AuD
Duke University Medical Center, Raleigh, NC

Participants: Infants

- Healthy neonates (N = 169) 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.

Participants: Adults

- Adult participants (*N* = 20)
  - 10 females and 10 males.
  - 20 to 31 years old (*M* = 25.7 years, *SD* = 3.1).
  - Normal hearing
    - Air-conduction thresholds ≤ 25 dB HL (Goodman, 1965).
  - Normal middle ear function.
  - No significant history of hearing loss, neurological, otological disorders, and/or communication impairments.

Apparatus/Stimuli

- A GSI Audera (V2.7) evoked potential system was utilized.
- ABRs were obtained with 500, 1000, 2000, and 4000 Hz CE-Chirps® Octave Bands and 2-1-2 tone burst stimuli.
- Stimuli were presented through a GSI TIP-50 insert earphone.

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 25 ms post-stimulus.
- Sampling at 25,000 Hz.
- A total of 2052 samples were averaged and replicated with a rate of 37.7/s.

Procedure

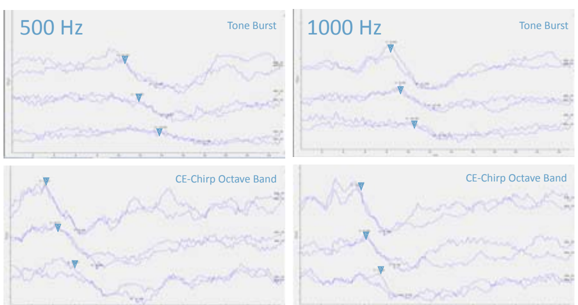
- Neonates were tested in natural sleep.
- Adults rested quietly.
- Monaural stimuli presentation.
- Test ear counterbalanced.

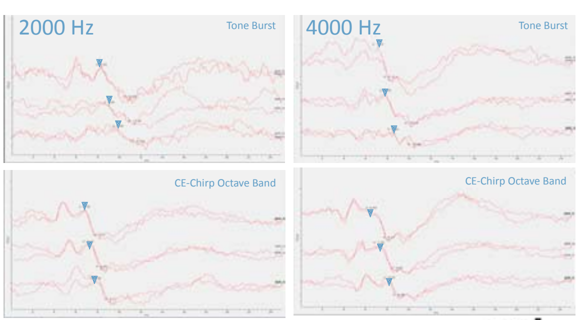
- Due to the number of stimulus conditions, not all participants underwent every test.
  - Minimum of 20 infants per test condition.
- Responses were analyzed for ABR Wave V latencies and amplitudes.

Tone Burst vs. CE-Chirps® Octave Band

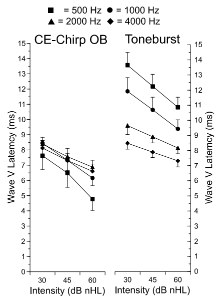
Effect of Stimulus Type				
Air Conducted CE-Chirps® Octave Bands vs. Tone Bursts				
Stimulus	Intensity (dB nHL)	Rate (/s)	Phase	Sweeps
500, 1000, 2000, 4000 Hz	60, 45, & 30	37.7	Alternating	2052

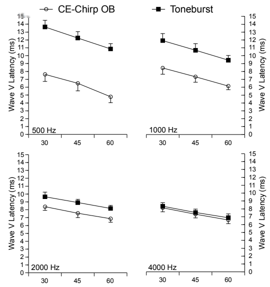
ABR Waveforms: Tonal Stimuli





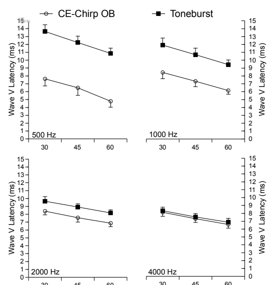
ABR Wave V Latency



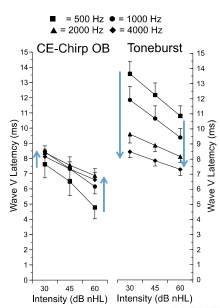


Conclusions: Wave V Latency

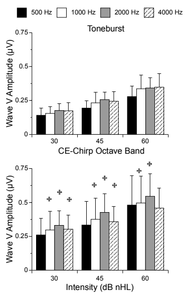
- Latency
  - Wave V latencies significantly earlier to CE-Chirps® Octave Bands versus tone bursts.
    - Related to input delay for “rising frequency” chirp.
      - (Cebulla et al., 2014; Kristensen & Elberling, 2012)

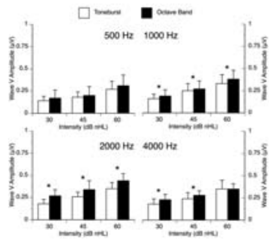


- Latency Reversal!
  - Wave V latencies *increase with increasing frequency* of CE-Chirps® Octave Band.
  - Wave V latencies *decrease with increasing frequency* with tone burst.
    - Rodrigues et al. (2013)



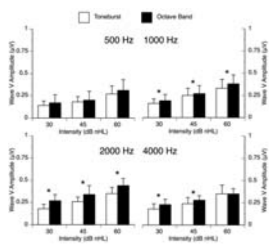
ABR Wave V Amplitudes



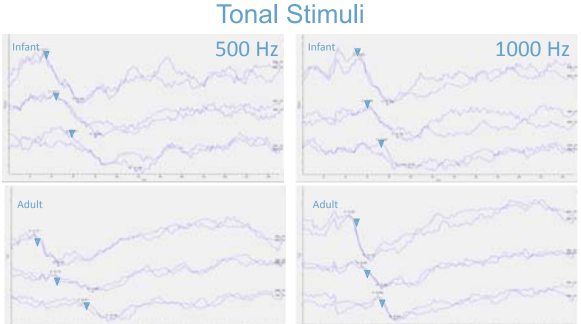


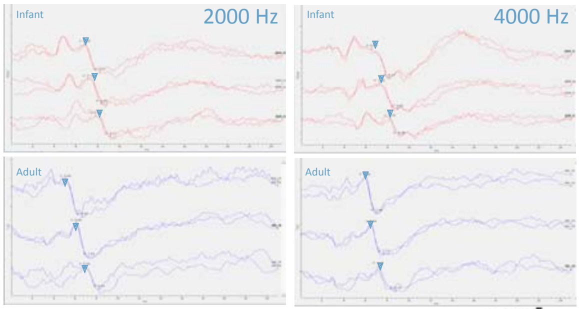
Conclusions: Wave V Amplitudes

- Amplitude
  - Wave V amplitude was significantly larger at all intensities for CE-Chirps® Octave Bands at 1000 and 2000 Hz and 4000 Hz at 45 and 30 dB nHL.
    - Related to wider spectral widths?
      - (Bell et al., 2002)

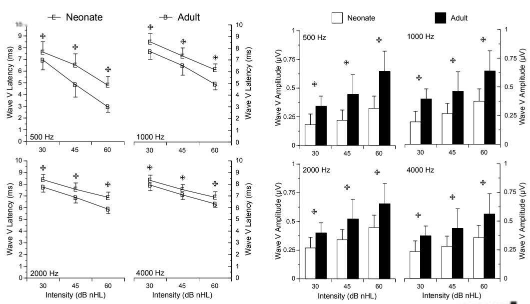


Infants *vs.* Adult ABR Waveforms: Tonal Stimuli



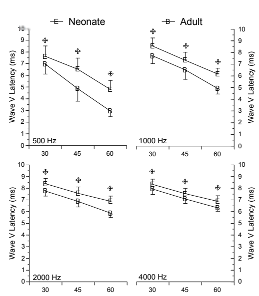


ABR Wave V Latency & Amplitude: Neonate *vs.* Adult



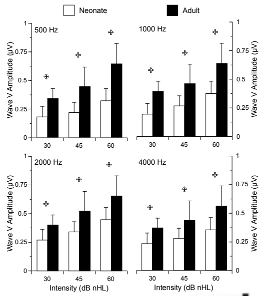
Conclusions: Wave V Latency

- Latency
  - Wave V latencies earlier for adults than neonates for CE-Chirps®.
    - Maturation of the central auditory system.
    - To a lesser extent, presence of vernix, debris, and/or fluid in the external auditory canal and/or middle ear space following birth.

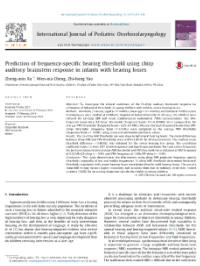


Conclusions: Wave V Amplitudes

- Amplitude
  - Wave V amplitudes to CE-Chirps® Octave Band stimuli were significantly larger in adults for all conditions tested.
    - Values in agreement with those seen in previous adult and infant studies.
      - (Cebulla et al., 2014; Elberling et al., 2012b; Kristensen &Elberling, 2012; Mühler et al., 2013; Petoe et al., 2010a, b)



Where do we go from here?


International Journal of Pediatric Otorhinolaryngology

Prediction of frequency-specific hearing threshold using chirp auditory brainstem response in infants with hearing losses

- Can we predict frequency-specific behavioural thresholds from ABRs to chirp octave band stimuli in young infants?
  - Xu, Cheng, & Yao (2014)

Prediction of frequency-specific hearing threshold using chirp ABR in infants (Xu et al., 2014)

- They investigate the relationship between frequency-specific ABR thresholds to LS-chirps and VRA behavioral thresholds in infants with varying degrees of sensorineural hearing loss.
- Infants (*N* = 68) aged from 6-12 months (*M* = 9.2 months).
  - They were referred following a newborn ABR screening to click stimulus.

Procedure/Stimuli

- VRA measurements were established for each ear.
  - 250, 500, 1000, 2000, & 4000 Hz.
- ABRs were obtained to low- and high-frequency band LS-Chirps.
  - LF-chirp = 100-850 Hz.
  - HF-chirp = 1000-10000 Hz.

- The ABR thresholds to LF-Chirps were compared to the average low-frequency (250-500 Hz) VRA thresholds.
- The ABR thresholds to HF-Chirps were compared to the average high-frequency (1000-4000 Hz) VRA thresholds.
- Infants were divided into two categories based on ABR threshold-level.
  - Category 1 (*M* = 45-65 dB HL).
  - Category 2 (*M* = 70-90 dB HL).

Results

- The mean differences between chirp-ABR and VRA thresholds were within 5 dB HL for all measurements.
- The correlation coefficient values (*r*) were 0.97 at low-frequency and high-frequency bands.

Threshold Differences as a Function of Frequency Band & Hearing Loss

Table 1
Mean VRA thresholds and LS-chirp ABR estimates for category 1 (45–65 dB HL) and category 2 (70–90 dB HL) groups (no. = 136 ears).

Category	Low frequency band (0.25–0.5 kHz vs 0.1–0.85 kHz)		High frequency band (1–4 kHz vs 1–10 kHz)	
	Mean threshold dB ± SD	No.	Mean threshold dB ± SD	No.
Category 1				
VRA	50.5 ± 5.5	58	50.3 ± 5.4	58
Chirp-ABR	55.1 ± 6.3	58	55.1 ± 6.3	58
Difference	4.6	58	4.8	58
Category 2				
VRA	78.3 ± 6.1	88	78.1 ± 6.4	88
Chirp-ABR	80.5 ± 6.5	88	80.5 ± 6.5	88
Difference	2.2	88	2.4	88

Correlations Between Thresholds as a Function of Frequency Band & Hearing Loss

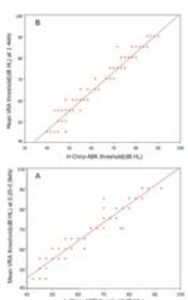


Table 2
The frequency distribution of the obtained behavioral and LS-chirp-ABR thresholds for correlation coefficient values in categories 1 and 2.

	Frequency (kHz)				
	L-chirp-freq. (0.1–0.85)		H-chirp-freq. (1–10)		
VRA freq.	0.25	0.5	1	2	4
Category 1					
Pearson r	0.87	0.71	0.88	0.72	0.66
Category 2					
Pearson r	0.91	0.88	0.91	0.88	0.90

Conclusions/Observations

- ABRs to CE-Chirps® and CE-Chirps® Octave Band stimuli may be valuable in the assessment of newborn infants.
- The prognostic value of CE-Chirps® and CE-Chirps® Octave Band stimuli is beginning to be validated with newborn infants.
  - CE-Chirps®
    - Cebulla & Shehata-Dieler, 2012; Cebulla et al., 2014, van den Berg, 2010
  - LS-Chirps® Octave Band
    - Xu et al., 2014

- An understanding of the temporal properties of CE-Chirps® Octave Band stimuli is necessary for successful clinical application.
  - Wave V latencies *increase with increasing frequency* of CE-Chirps® Octave Band.
  - The recording window can be shortened relative to the traditional window for tone burst.

Acknowledgements

- Vidant Medical Center Audiology and Hearing Aid Center (Greenville, NC):
  - Rhonda Joyner, Mel Fratzke, Bethany Britt, & Ashley Fuller.
- GSI:
  - Sherrie Weller and GSI team
- Carolina Sales & Service:
  - Joey Bair

Questions

Thank You!

Visit the Grason-Stadler Website for additional CEU opportunities
www.grason-stadler.com/e-learning

Sign-up for E-Learning Alerts
http://www.grason-stadler.com/e-learning/e-learning-alerts

Contact Information

Andrew Stuart, Ph.D.
STUARTA@ecu.edu

GSI Audiology
audiology@grason-stadler.com

GSI Marketing
marketing@grason-stadler.com