Advantages of CE-Chirp Stimulation of the Auditory Brainstem Response (ABR)

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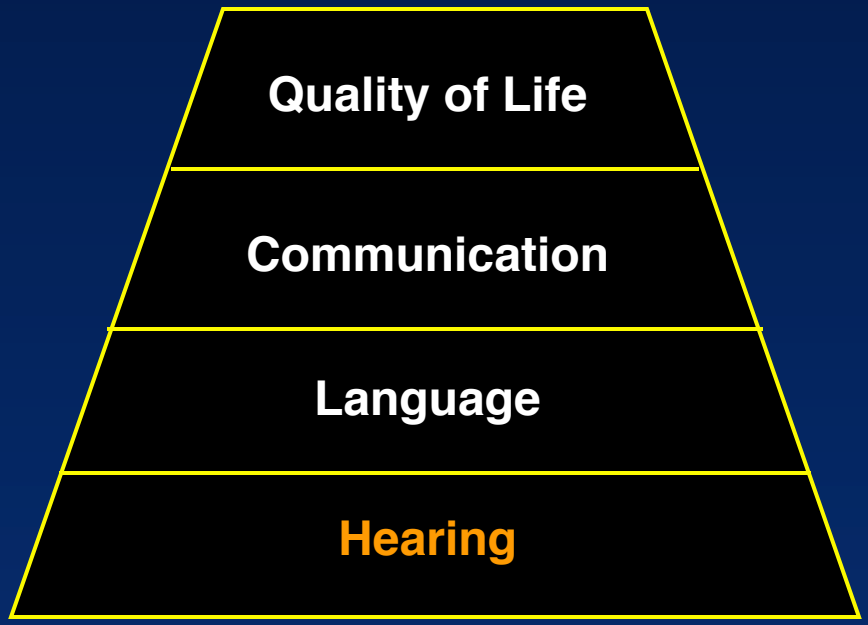
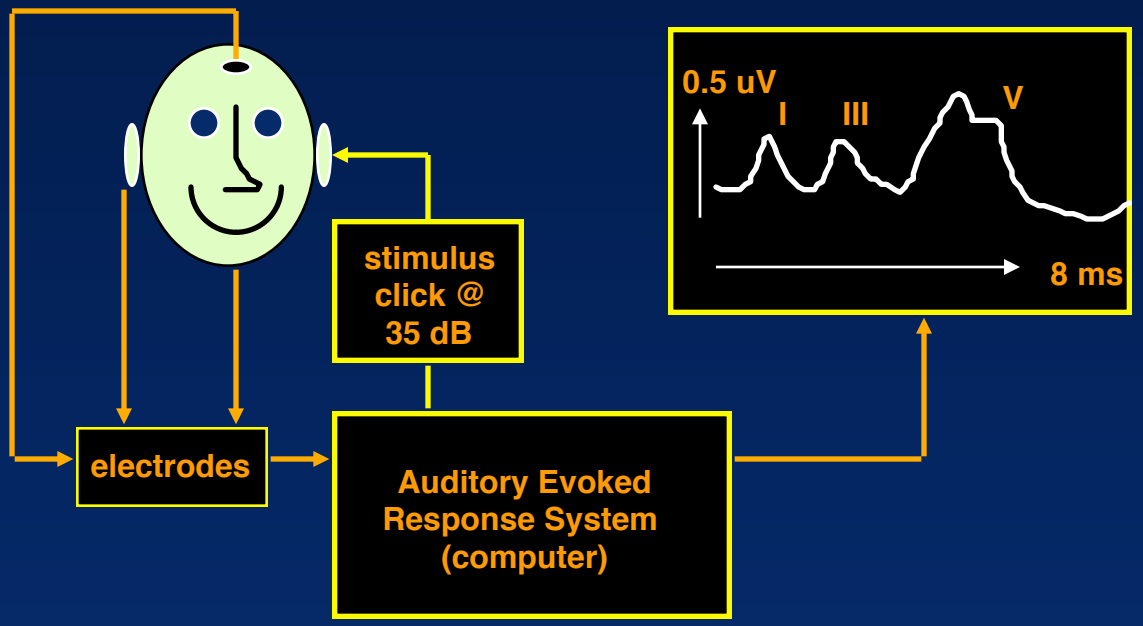
- Early identification, diagnosis, and intervention of infant hearing loss improves communication
- Accurate assessment of hearing in young children is standard of care
- Why it is important to record ABRs with click and also tone burst stimulation
- Protocol for tone burst (frequency specific) ABR
- Chirp stimuli in ABR measurement
- Summary of advantages of chirp-evoked ABR

Early Intervention for Hearing Loss in Children: A World-Wide Movement and Goal

Hearing: An Important Building Block in the Foundation for Communication and Quality of Life



Newborn Hearing Screening with Auditory brainstem response (ABR)



Beginning in 1974

Don Jewett and John Williston
"Discoverers of ABR"

Jewett D and Williston J.

Auditory evoked far fields averaged from the scalp of humans.

Brain 4: 681-696, 1971.

Famous Auditory Physiologist Who was Director of the Laboratory Where the ABR was Discovered: *Robert Galambos, PhD, MD*

Hecox C & Galambos R

Brain stem auditory evoked responses in human infants and adults.

Archives of Otolaryngology, 99: 30-33, 1974.

Benefits of Early Identification and Intervention of Children with Hearing Loss

- Yoshinago-Itano et al (Univ. of Colorado). Pediatrics 102 (5): 1161-1171, 1998.
  - N = 72 children with HL identified by 6 months and N = 78 children identified later
  - All children received intervention services with 2 months of identification
  - Conclusion: "Significantly better language development was associated with early ID of hearing loss and early intervention . . . the language advantage was found across all . . . degrees of hearing loss."

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The Cross-Check Principle in Pediatric Audiology

(Jerger J & Hayes D. Arch Otolaryngol 102: 1976)

The Cross-Check Principle Pediatric Audiology
(Jerger J & Hayes D. Arch Otolaryngol 102: 1976)

"We have found than simply observing the auditory behavior of children does not always yield an accurate description of hearing loss"…

"The basic operation of this principle is that no result be accepted until it is confirmed by an independent measure."

Test Battery in 1976:

- Behavioral audiometry
- Immittance (impedance) measurements
  - ✓ Tympanometry
  - ✓ Acoustic reflexes (contralateral only with SPAR)
- Auditory brainstem response (brainstem-evoked response audiometry or BSER)
  - ✓ Click stimulus air conduction
  - ✓ Click stimulus bone conduction

Year 2007 Joint Committee on Infant Hearing (JCIH): Protocol for Evaluation for Hearing Loss In Infants from Birth to 6 months

- Child and family history
- Evaluation of risk factors for congenital hearing loss
- Parental report of infant's responses to sound
- "Clinical observation of infant's auditory behavior. *Behavioral observation alone is not adequate for determining whether hearing loss is present in this age group, and is not adequate for the fitting of amplification devices."*
- Audiological assessment
  - Auditory brainstem response (ABR)
    - ✓ Click-evoked ABR with rarefaction and condensation single-polarity stimulation if there are risk factors for auditory neuropathy
    - ✓ Frequency-specific ABR with air-conduction tone bursts
    - ✓ Bone-conduction stimulation (as indicated)
  - Otoacoustic emissions (distortion product or transient OAEs)
  - Tympanometry with 1000 Hz probe tone
  - Supplemental procedures, e.g.,
    - ✓ Electrocochleography (ECochG)
    - ✓ Auditory steady state response (ASSR)
    - ✓ Acoustic reflex measurement (for 1000 Hz probe tone)

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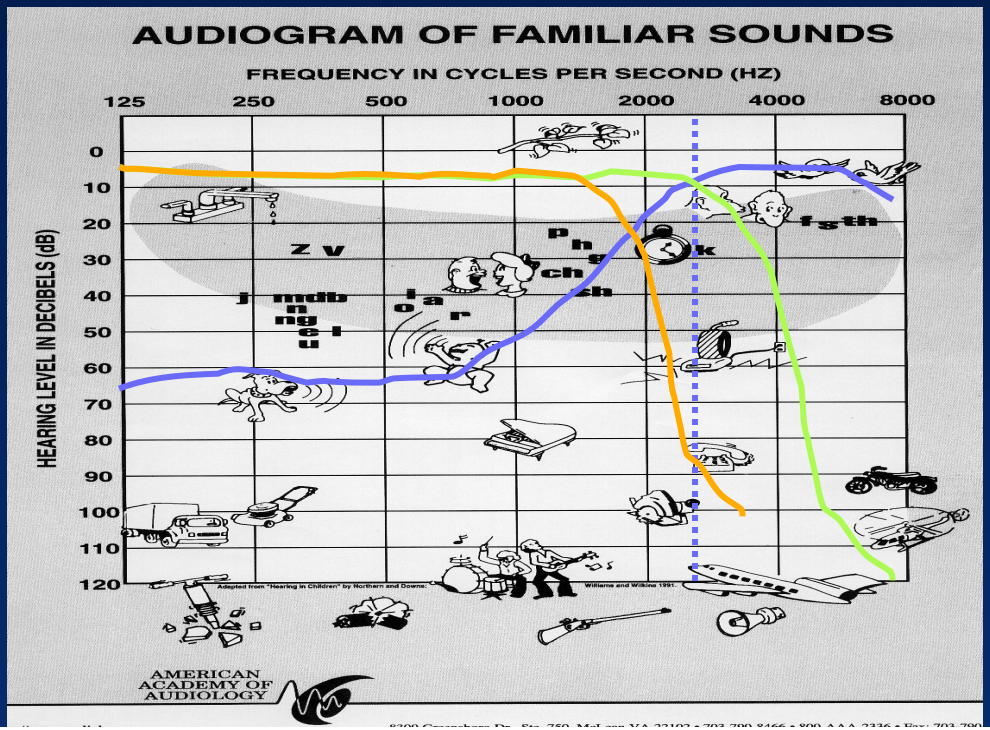
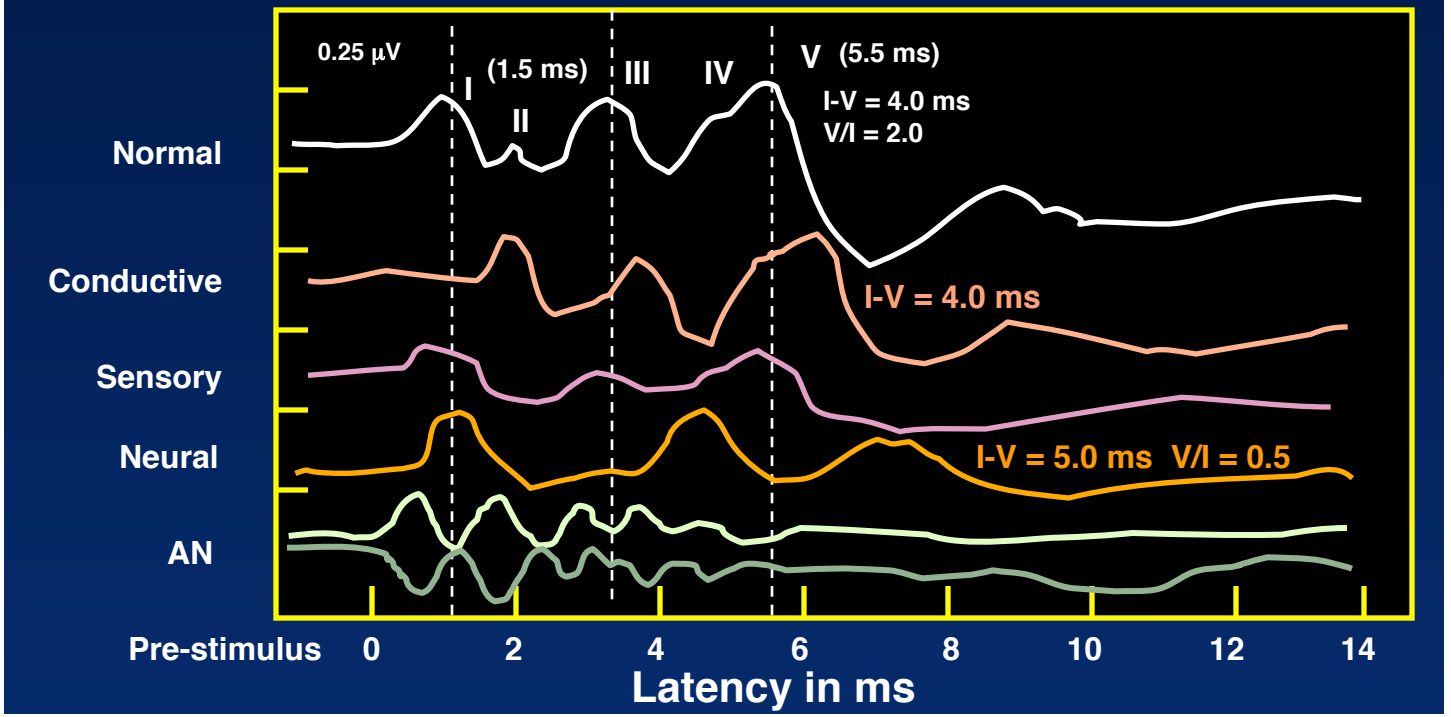
Limitation of Click-Evoked ABR: Lack of Frequency-Specificity



Normal click ABR

Abnormal or no click ABR

Diagnostic Value of the Click-Evoked ABR: Differentiation Among Types of Auditory Dysfunction



Electrophysiological Estimation of the Audiogram in Infants and Young Children with Clicks, Tone Bursts, and Chirps

- Why it's a good strategy to begin the ABR assessment with click stimulation
  - Waveform analysis permits differentiation among types of hearing loss
  - Waveform analysis indicates test ear (presence of wave I)
  - Auditory neuropathy spectrum disorder (ANSD) can be ruled out or identified
  - Findings help to determine next steps in the assessment, e.g.,
    - ✓ Bone conduction ABR or tympanometry?
    - ✓ ASSR?
  - Only requires a few minutes of test time
  - Recommended by the 2007 Joint Committee on Infant Hearing

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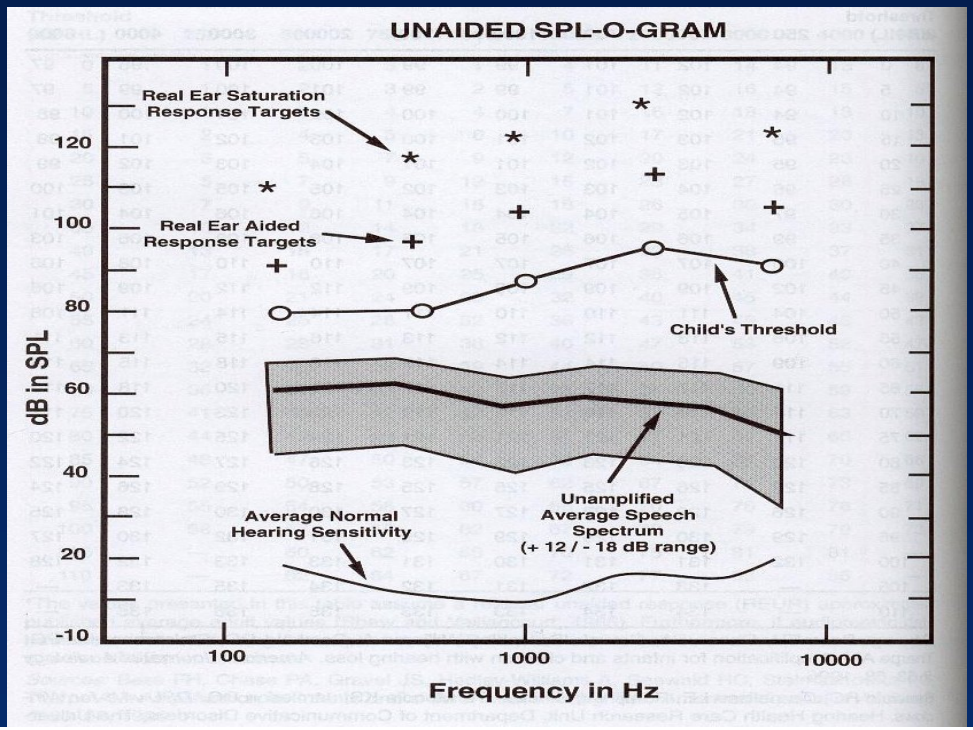
Estimation of Frequency-Specific Auditory Thresholds with Tone Burst ABRs: Initial Data Points for Hearing Aid Fitting



Frequency-Specific ABR Test Protocol: Stimulus Parameters and Research Needs

Parameter	Selection	Rationale/Research Needs
Transducer	ER-3A inserts	Numerous infant advantages Accurate in-ear SPL verification
Type	Tone bursts	Available on all systems Clinical trials of chirp stimuli
Ramping (window)	Blackman	Less spectral splatter
Frequencies	1, .5, 4, 2 K Hz	Sequence varies clinically High frequency option (> 4000Hz) Normative data for infants
Duration	2-0-2 cycles	Abrupt onset frequencies Equivalent intensity for each frequency 0 plateau < spectral splatter

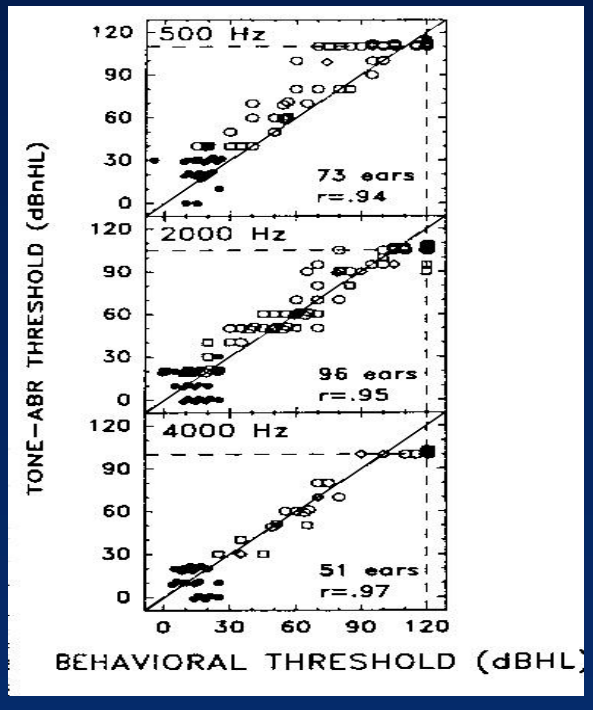
Frequency-Specific ABR Test Protocol: Acquisition Parameters and Research Needs

Parameter	Selection	Rationale/Research Needs
Artifact reject	On	Minimize muscle artifact Weighted averaging of all data
Analysis time	20 ms	Encompass delayed wave Vs and SN10 after wave V
Sweeps	1000 or 2000	Produce adequate SNR Automated detection of adequate response based on SNR
Reliability	2 or 3 runs	"If it doesn't replicate, you must investigate!"

Frequency-Specific ABR Test Protocol: Acquisition Parameters and Research Needs

Parameter	Selection	Rationale/Research Needs
Electrode type	Disc & ear clip or disposable	Amplification of response at or near the electrode
Electrode location	Fz - Ai Fpz ground	Optimal infant response Good for BC stimulus Permits ipsi/contra meas't
Filter settings	30 - 3000 Hz No notch filter	Encompass infant spectrum
Artifact reject	On	Minimize muscle artifact Weighted averaging of all data

FREQUENCY-SPECIFIC AUDITORY BRAINSTEM RESPONSE (ABR): Relation to Audiogram (Oates & Stapells, 1998)



Correction Factors for Converting ABR Thresholds in dB nHL to Estimated Behavioral Thresholds in dB HL (or EHL)

Source	500 Hz	1000 Hz	2000 Hz	4000 Hz
BCEHP	-15 dB	-10 dB	-5 dB	0 dB
Bagatto (2006)	-20 dB	-15 dB	-10 dB	-5 dB
Hall (2007)	-15 dB	-10 dB	-10 dB	-10 dB

Note: According to Stapells (2000), ABR thresholds "overestimate" behavioral thresholds by 10 to 20 dB for normal hearers and 5 to 15 dB for patients with sensory hearing loss

Steps in Accurate Estimation of Auditory Thresholds

- With ABR system, obtain average normal behavioral thresholds (from 3 to 5 normal hearing adults) for click and each tone burst signal
  - Minimally click plus 500, 1000, 2000, and 4000 Hz
  - Calculate “dial” reading that is equivalent to 0 dB nHL
  - With ABR system
  - In typical test environment (s)
- ABR thresholds in dB nHL are not equal to pure tone hearing thresholds in dB HL
  - Subtract 10 dB from ABR threshold to estimate auditory threshold (edB HL)
- Plot estimated auditory thresholds on “tone burst ABR audiogram”

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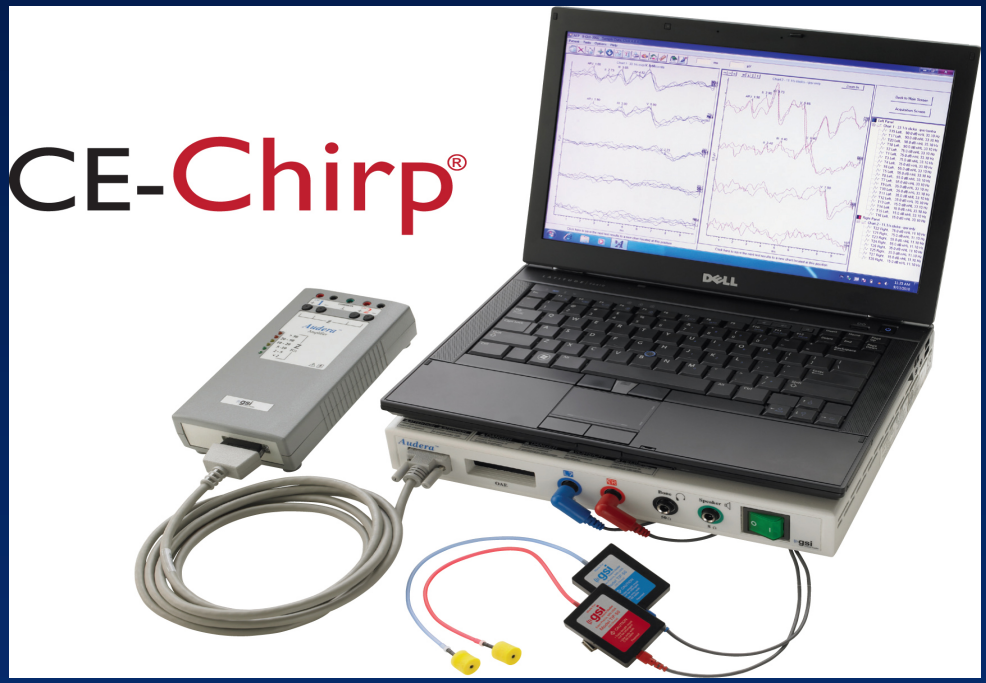
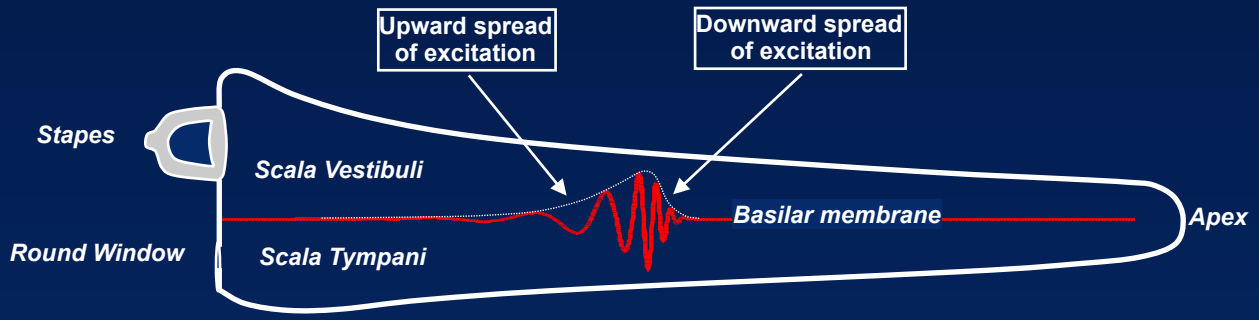
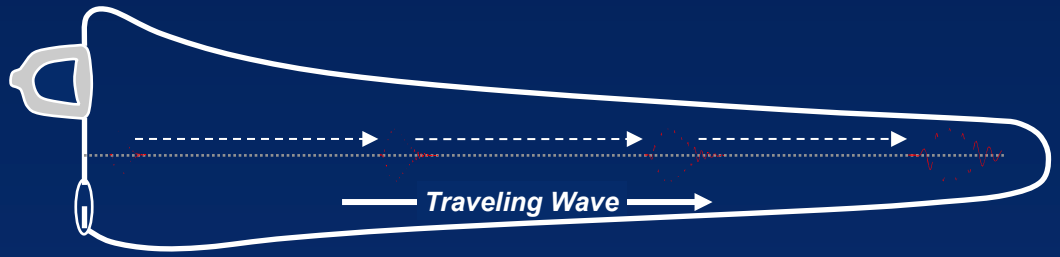
Chirp Stimuli in ABR Measurement: Promising So Far Yet Questions Remain



Cochlear Excitation Patterns for Click versus Narrow Band Stimulation

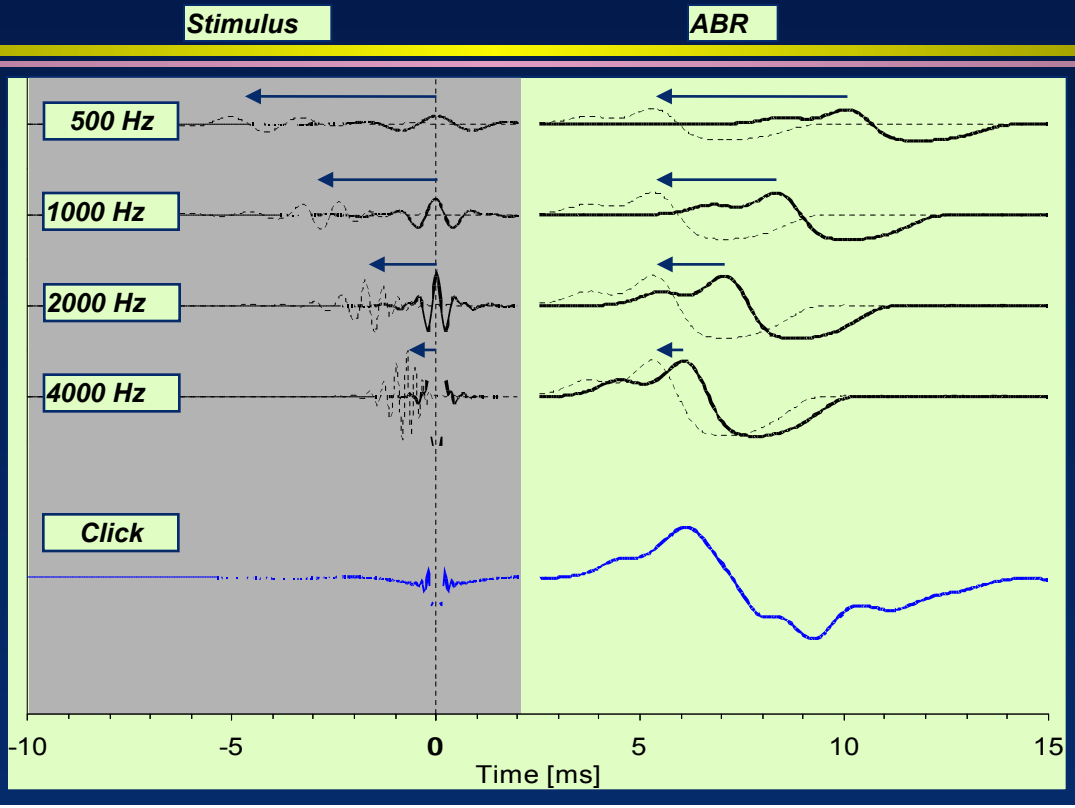


Continuous, narrow band stimuli

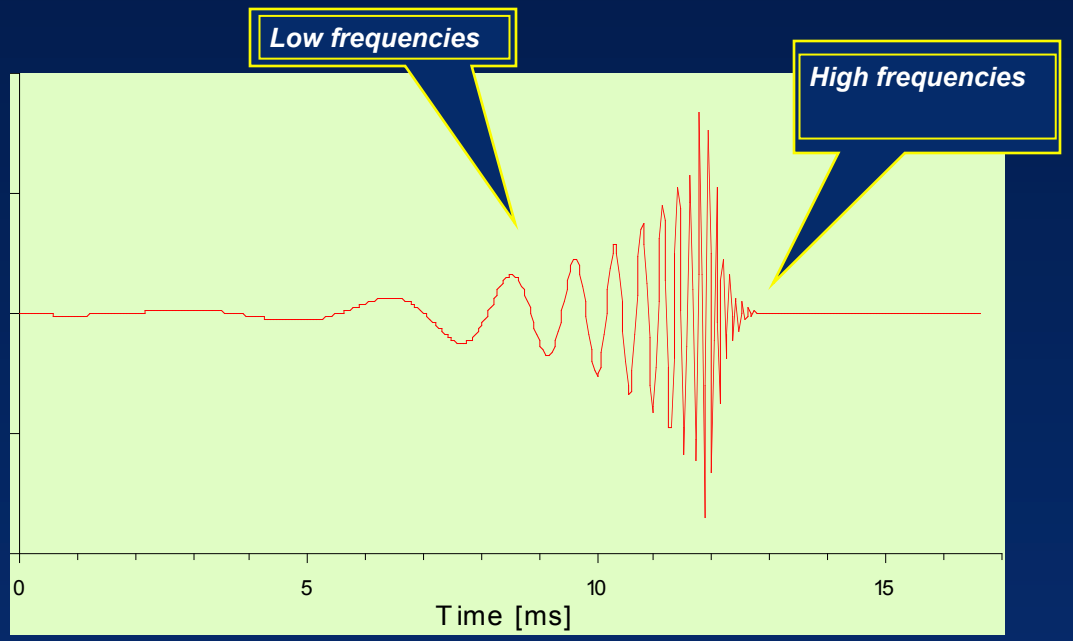


Transient, broad band stimuli

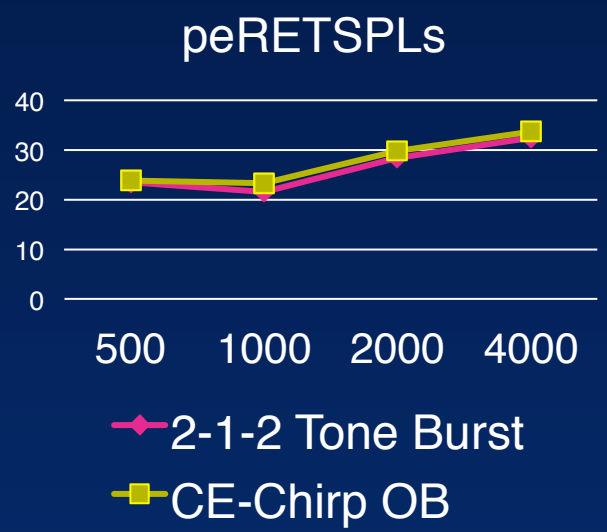
Temporal Compensation via Input Compensation (Courtesy of Claus Elberling)



Chirp Temporal Waveform



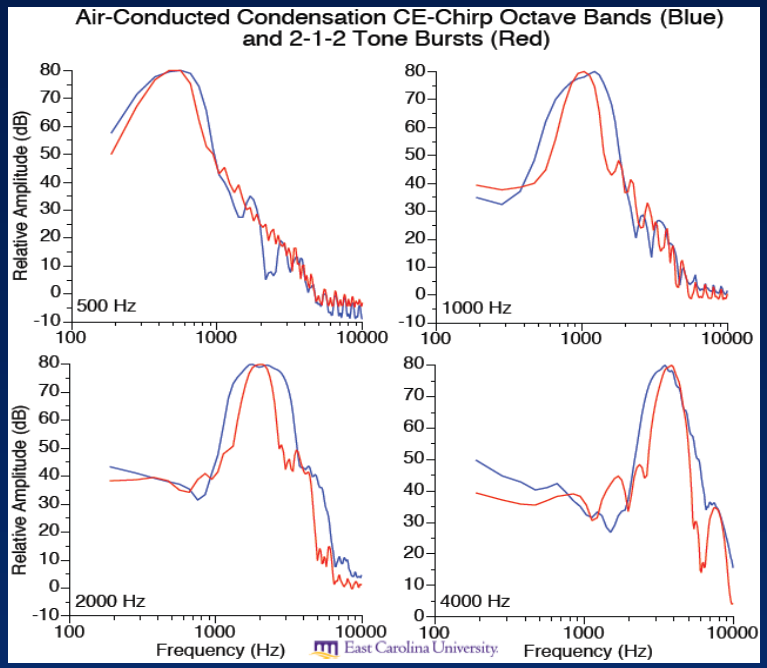
peRETSPLs:
CE-Chirp Octave Bands vs. Tone Bursts



- ISO 389-6: 2-1-2 Tone Burst peRETSPLs (blue = tone bursts)
- 3A Insert Earphones using 711 ear simulator
- Range of 0.4 to 1.8 dB difference

Reference: Gotsche-Rasmussen, Poulsen, Elberling, Reference Hearing Threshold Levels for Chirp Signals Delivered by an ER-3A Earphone, International Journal of Audiology, 2012, Early Online: 1-6

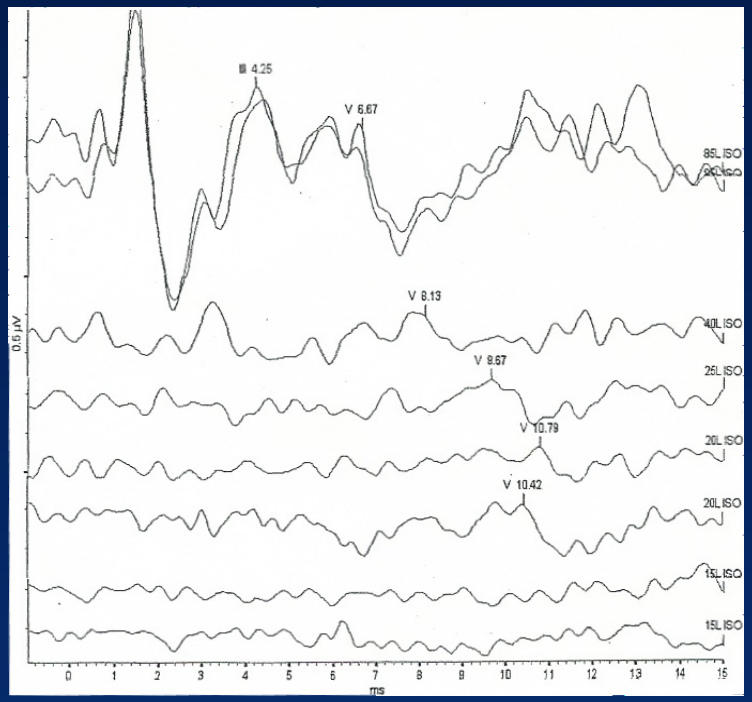
Acoustic Spectrum:
CE-Chirp Octave Bands vs. Tone Bursts



Courtesy of East Carolina University

Conventional Click versus CE Chirp Evoked ABR

(1 year 4 month old boy with speech & language delay who failed hearing screening in nursery. Parents do not speak English)



85 dB nHL Click, rarefaction, 21.1/sec
I = 1.46 ms
V = 6.67 ms
I-V = 5.21 ms

45 dB nHL Click

25 dB nHL Click

20 dB nHL Click

20 dB nHL CE Chirp

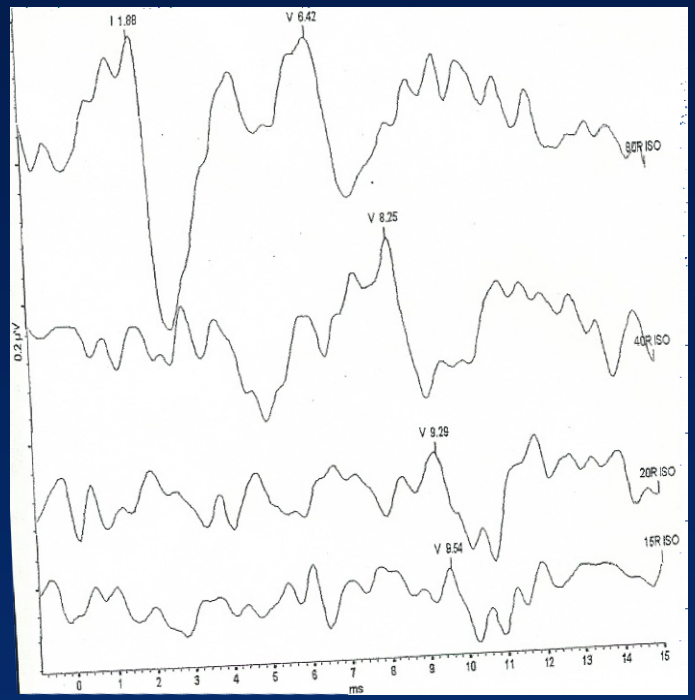
15 dB nHL Click

15 dB nHL CE Chirp

4000 Hz Chirp Evoked ABR

Stimulus rate = 37.7/sec

Total sweeps = 2622; Total test time = 69.5 seconds



Right Ear
80 dB nHL
684 sweeps

40 dB nHL
456 sweeps

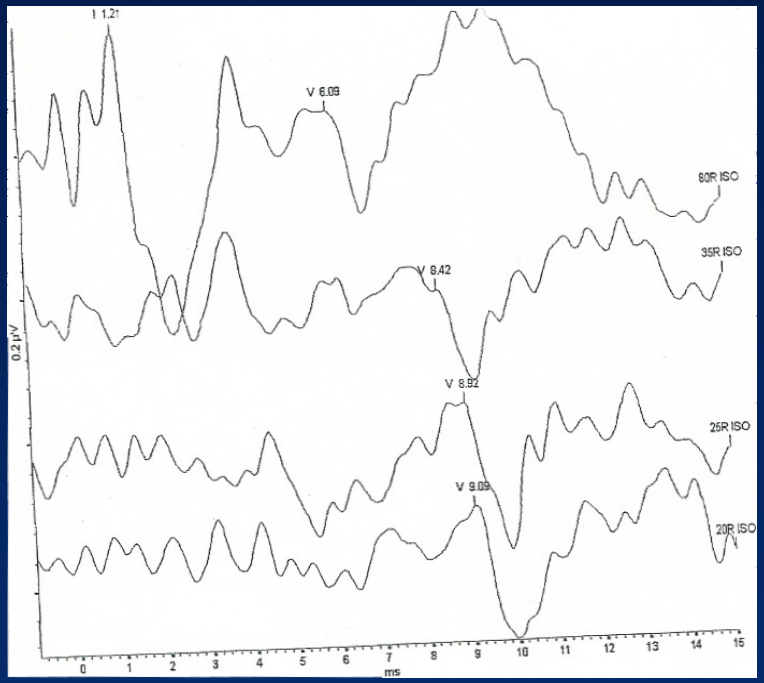
20 dB nHL
570 sweeps

15 dB nHL
912 sweeps

2000 Hz Chirp Evoked ABR

Stimulus rate = 37.7/sec

Total sweeps = 2318 ; Total test time = 61 seconds



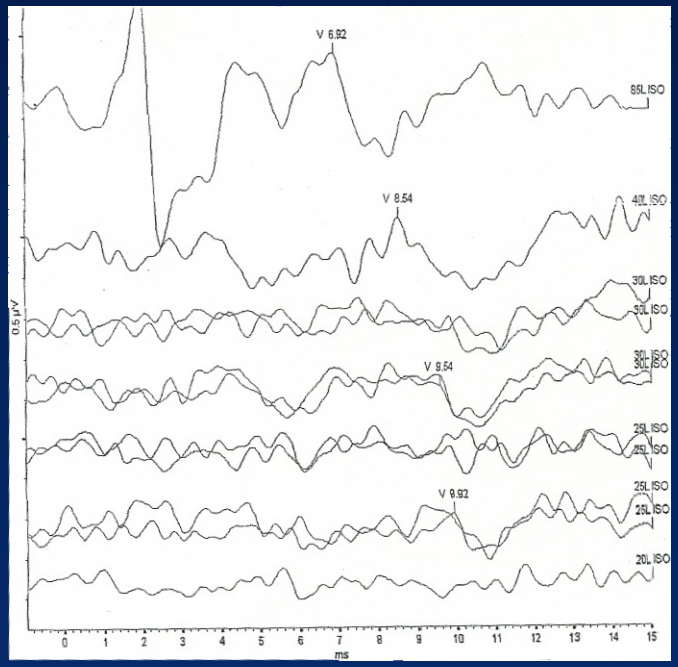
80 dB nHL
722 sweeps

35 dB nHL
570 sweeps

25 dB nHL
456 sweeps

20 dB nHL
570 sweeps

4000 Hz Conventional versus Chirp Evoked ABR



Left Ear
85 dB nHL
Tone Burst

40 dB nHL
Tone Burst

30 dB nHL
Tone Burst

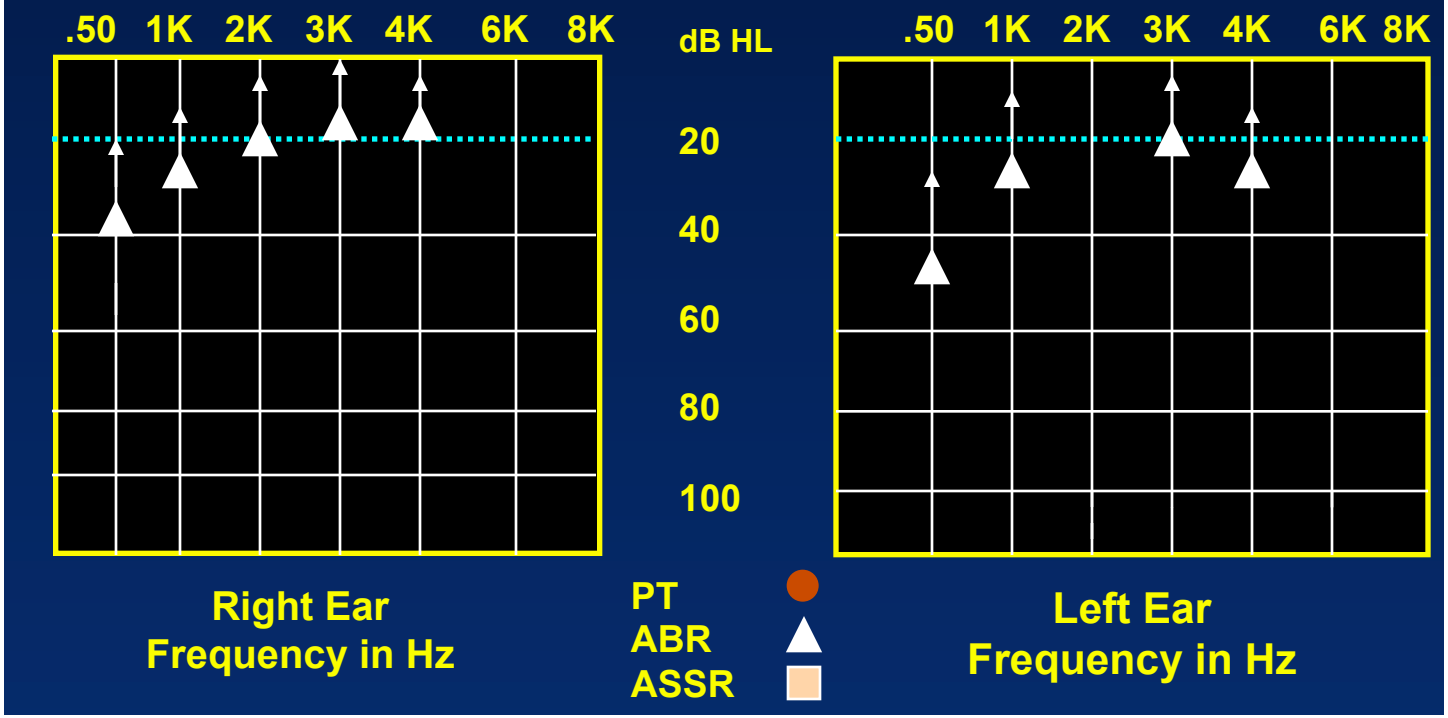
30 dB nHL, Chirp Tone Burst

25 dB nHL, Tone Burst

25 dB nHL, Chirp Tone Burst

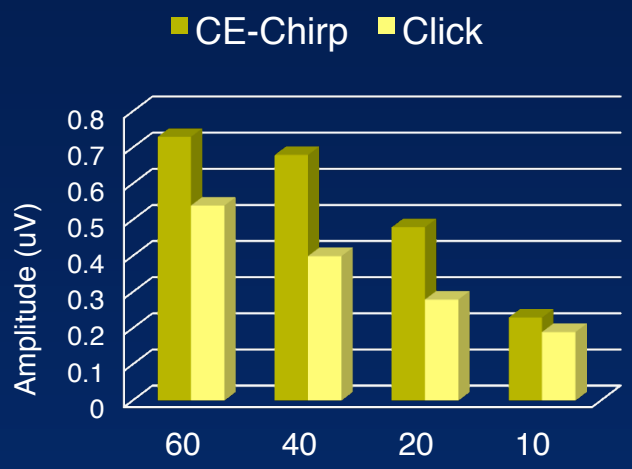
15 dB nHL, Chirp Tone Burst

Electrophysiologic Estimation of the Audiogram: One year 4 month boy



Adults:
CE-Chirp Amplitudes

Amplitude Comparison

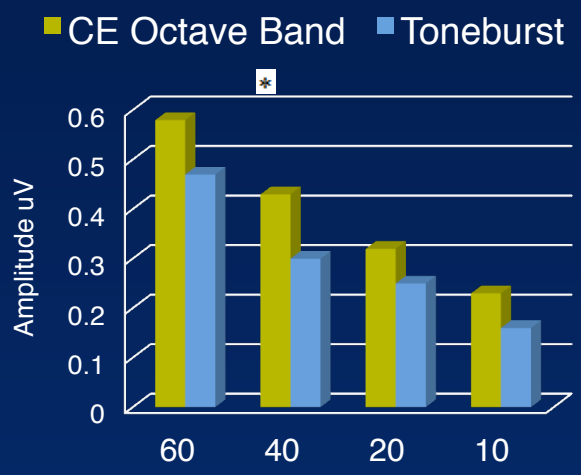


- **Wave V amplitudes were significantly greater at 60, 40, 20 dB nHL**
- **Greater amplitudes are consistent with previously published research**

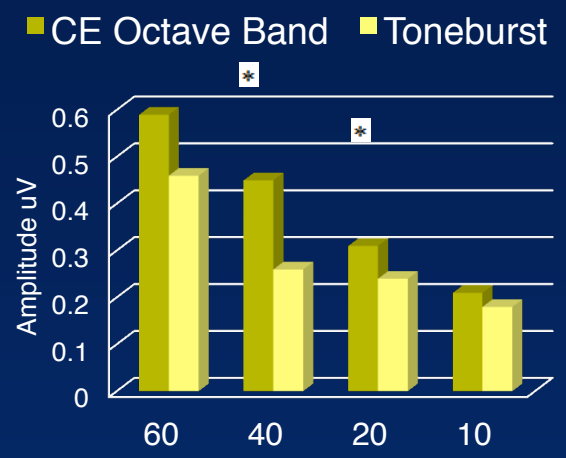
Stangl S, Rentmeester L, Hood LJ. (2013). Auditory brainstem responses to clicks, chirps, tonebursts, and octave-band chirps. Poster presented at the 2013 Meeting of the American Auditory Society, Scottsdale, Arizona.

Adults:
CE-Chirp Octave Bands

4000 Hz



2000 Hz



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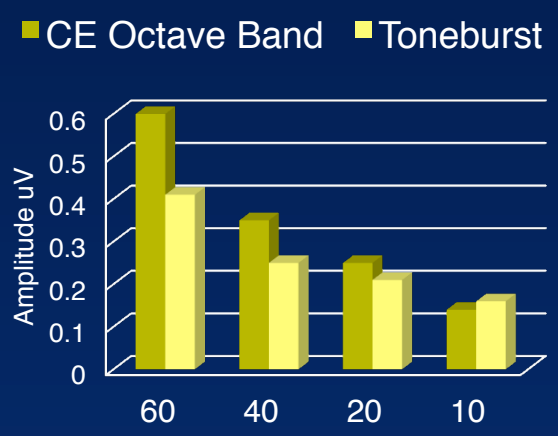
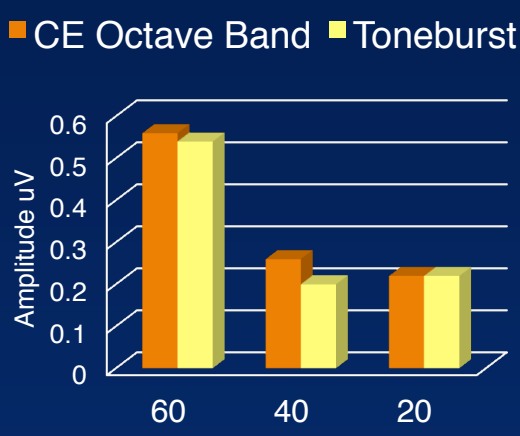
Adults: CE-Chirp Octave Bands

1000 Hz



500 Hz



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Advantages of CE-Chirp Stimulation of the Auditory Brainstem Response (ABR): Advantages of Chirp Stimulation

- ABR amplitude is larger for chirp stimulation
- Larger amplitude contributes to:
  - More confident identification of wave V
  - Shorter test time is needed to identify wave V
  - Reduced test time for each stimulus frequency permits more complete estimation of auditory threshold in speech frequency region
  - More accurate thresholds are sometimes possible with chirp stimulation

Thank You!
Questions?