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Application of ABR in Objective Assessment of Infant Hearing

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- Introduction: Why early diagnosis of infant hearing loss is important
- Review of stimuli used to elicit the ABR in infants and young children
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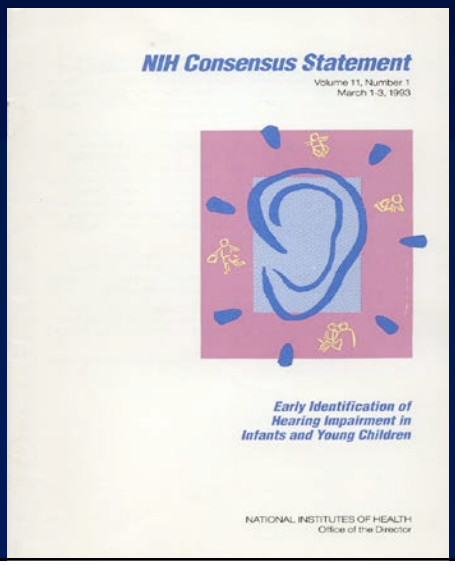
Universal Newborn Hearing Screening and Early Identification of Hearing Loss in Infants: Turning Point in the United States of America *(March 1993)*



- Evidence in support of benefits of early identification on speech and language development (for pediatricians)
- Recognition of economic consequences of hearing loss (by policy makers)
- Emergence of technology for automated auditory brainstem response (ABR) and otocoustic emissions (OAEs)
- Evidence of low failure rates (< 4%) and automated ABR and OAE techniques
- Relatively low cost of identifying infants with hearing loss versus expense of intervention with later identification
- *Identified research questions about benefits of early intervention*

UNHS Rationale: Effects of infant hearing loss

NIH Consensus Statement "Early Identification of Hearing Impairment in Infants and Young Children" (March 1-3, 1993)

"There is general agreement that hearing impairment should be recognized as early in life as possible, so the remediation process can take full advantage of the developing sensory systems and so that the child can enjoy normal social development."

Recommendation: Universal Newborn Hearing Screening

Christie Yoshingaga-Itano: Early Intervention (6 months after birth) is Important

Language of Early and Later Identified 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."

American Academy of Pediatrics
Newborn and Infant Hearing Loss: Detection and Intervention

- Pediatrics 103 (2): 527-529, 1999 (February)
- Screening
- Tracking & Followup
- Evaluation
- Abstract: *"This statement endorses the implementation of universal newborn hearing screening. In addition, the statement reviews the primary objectives, important components, and recommended screening parameters that characterize an effective universal newborn hearing screening program."*

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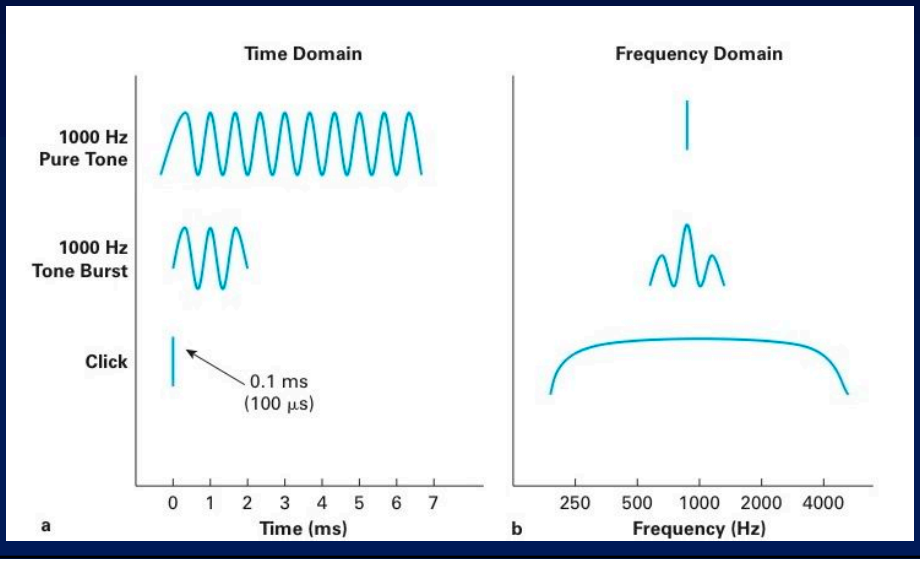
Year 2007 Joint Committee on Infant Hearing (JCIH): Protocol for Evaluation for Hearing Loss In Infants from Birth to 6 months

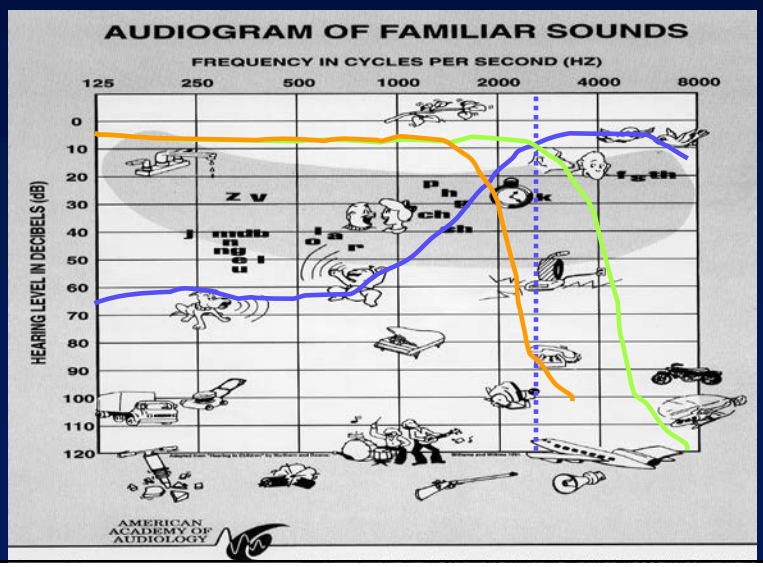
- Child and family history
- Evaluation of risk factors for congenital hearing loss
- Parental report of infant's responses to sound
- "Clinical observation of infant's auditory behavior. *Behavioral observation alone is not adequate for determining whether hearing loss is present in this age group, 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)

The Unavoidable Trade-Off Between Duration and Frequency-Specificity in ABR Stimulation

(Figure from Hall JW III. Introduction to Audiology Today, 2014)



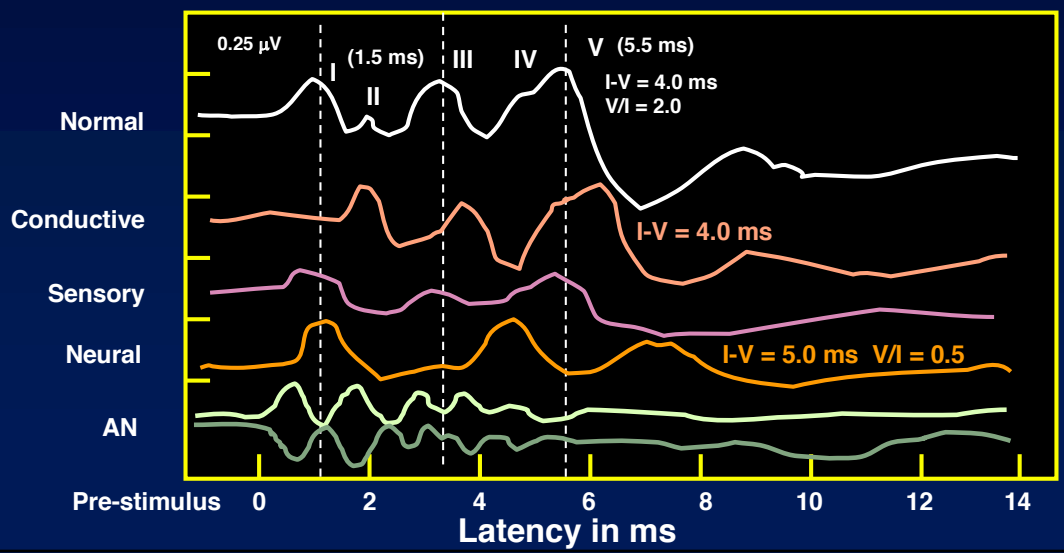
Click-Evoked ABR Lacks Frequency-Specificity: Should you stick with the click?



Normal click ABR

Abnormal or no click ABR

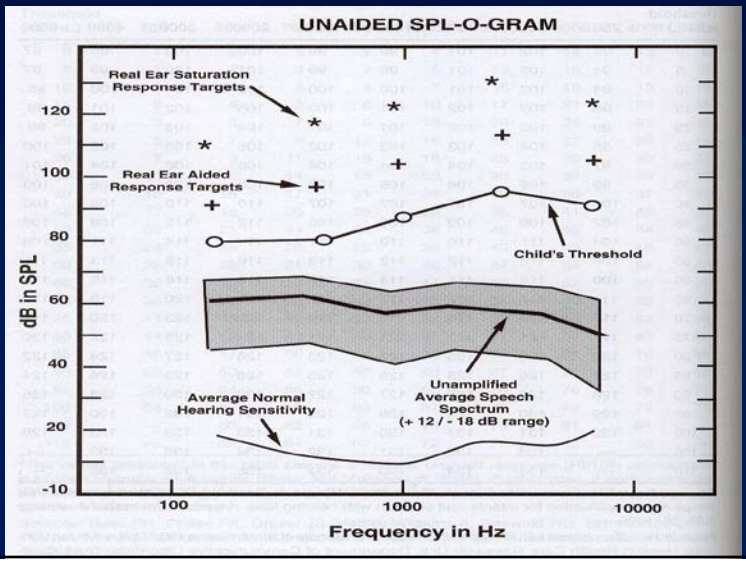
Diagnostic Value of the Click-Evoked ABR: Differentiation Among Types of Auditory Dysfunction



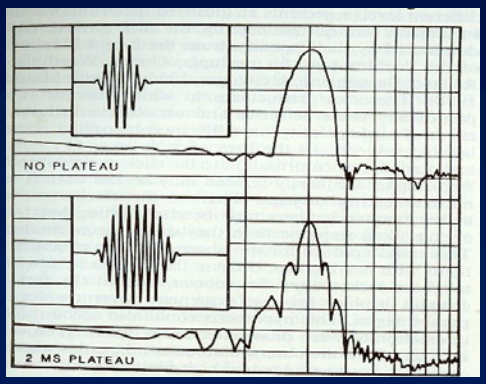
Electrophysiological Estimation of the Audiogram in Infants and Young Children with Clicks, Tone Bursts, and Chirps

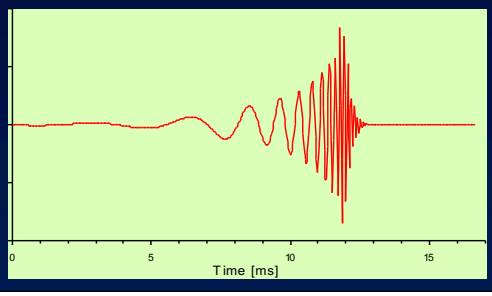
- Why it's a good strategy to begin the ABR assessment with click stimulation
  - Waveform analysis permits differentiation among types of hearing loss
  - Waveform analysis indicates test ear (presence of wave I)
  - Auditory neuropathy spectrum disorder (ANSD) can be ruled out or identified
  - Findings 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

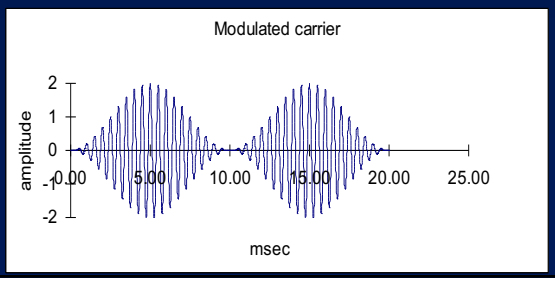
Estimation of Frequency-Specific Auditory Thresholds with Tone Burst ABRs: Initial Data Points for Hearing Aid Fitting



Frequency-Specific Stimuli Available for Eliciting ABR (and ASSR)







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Test Protocol for ABR in Children: Stimulus Parameters

Parameter	Selection	Rationale
Transducer	ER-3A inserts	Numerous infant advantages
Type	Click stimuli Tone bursts	Available on all systems Available on all systems Clinical trials of chirp stimuli
Frequencies	1, .5, 4, 2 K Hz	Sequence varies clinically
Duration		
Click	0.1 ms	
Tone Bursts	2-0-2 cycles	Equivalent intensity for each frequency 0 plateau < spectral splatter
TB Ramping (window)	Blackman	Less spectral splatter

Test Protocol for ABR in Children: Acquisition Parameters

Parameter	Selection	Rationale
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!"

Test Protocol for ABR in Children: Acquisition Parameters (2)

Parameter	Selection	Rationale
Electrode type	Disc & ear clip or disposable	Ease of application Infection prevention
Electrode location	Fz - Ai Fpz ground	Optimal infant response Good for BC stimulus Permits ipsi/contra recording
Filter settings	30 - 3000 Hz No notch filter	Encompass infant spectrum
Artifact reject	On	Minimize muscle artifact Weighted averaging is available on some devices

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Steps in Accurate Estimation of Auditory Thresholds

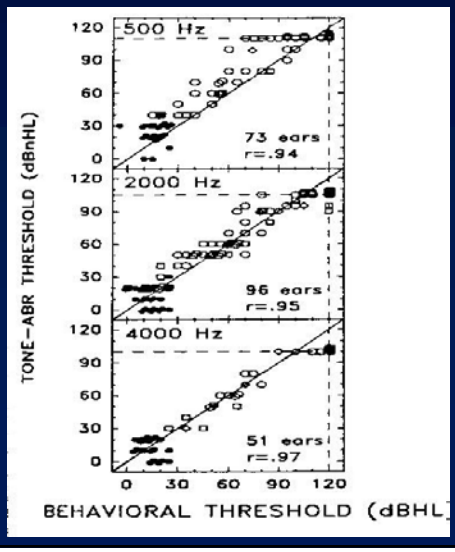
- With ABR system, obtain average normal behavioral thresholds (from 3 to 5 normal hearing adults) for click and each tone burst signal
  - Minimally click plus 500, 1000, 2000, and 4000 Hz
  - Calculate "dial" reading that is equivalent to 0 dB nHL
  - With ABR system
  - In typical test environment (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"

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

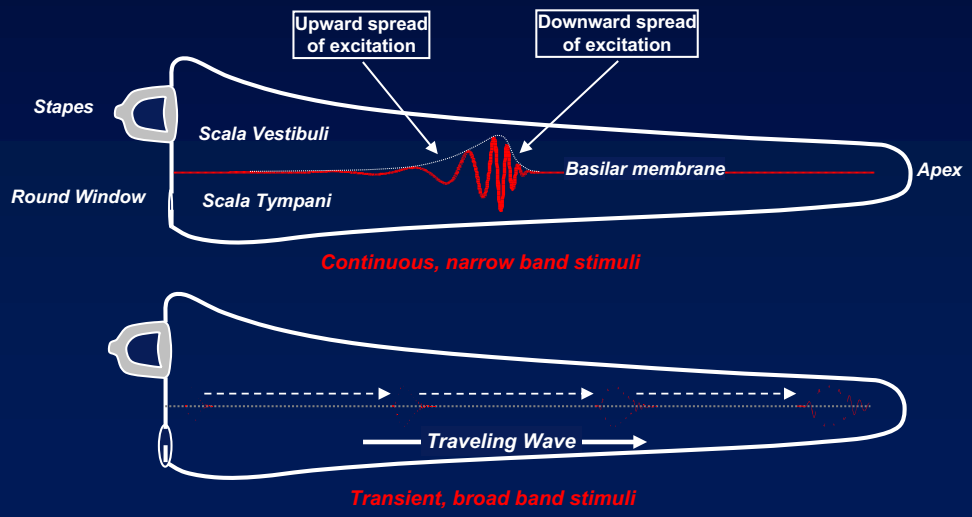
Source	500 Hz	1000 Hz	2000 Hz	4000 Hz
BCEHP	-15 dB	-10 dB	-5 dB	0 dB
Bagatto (2006)	-20 dB	-15 dB	-10 dB	-5 dB
Hall (2007)	-15 dB	-10 dB	-10 dB	-10 dB

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

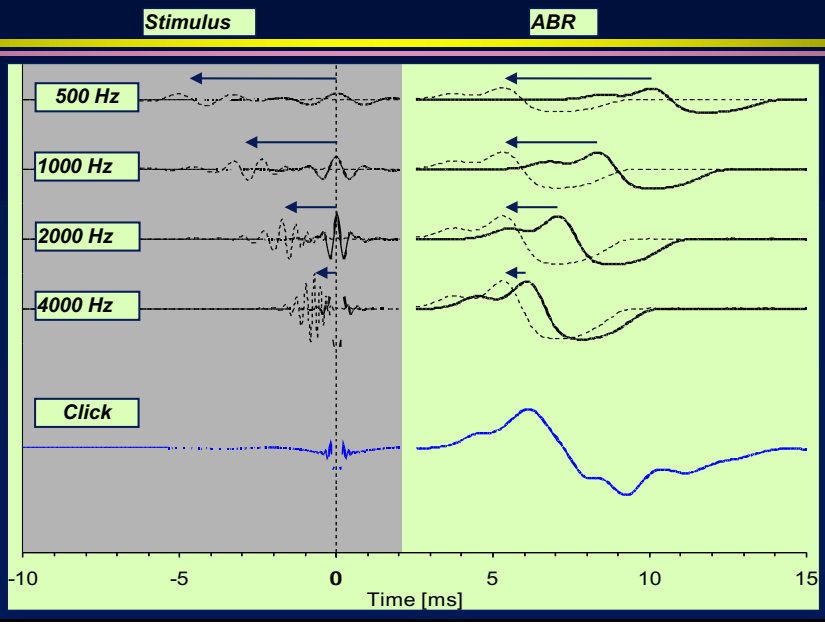
FREQUENCY-SPECIFIC AUDITORY BRAINSTEM RESPONSE (ABR): Relation to Audiogram (Oates & Stapells, 1998)



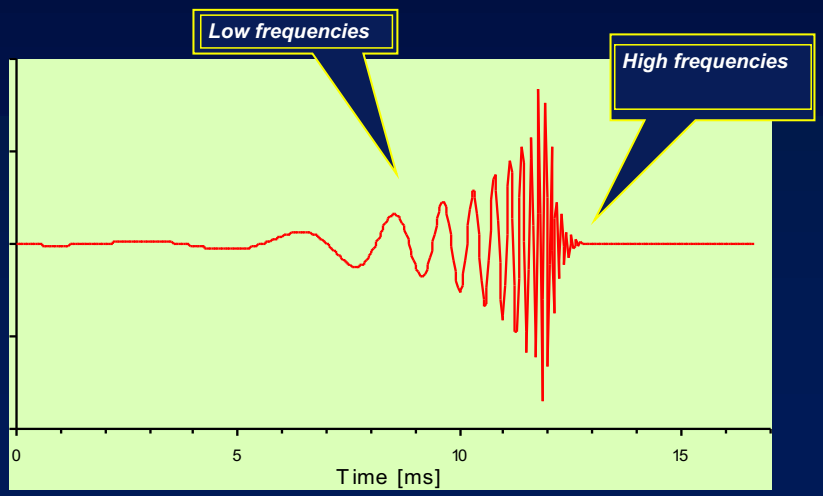
Cochlear Excitation Patterns for Click versus Narrow Band Stimulation



Temporal Compensation via Input Compensation (Courtesy of Claus Elberling)

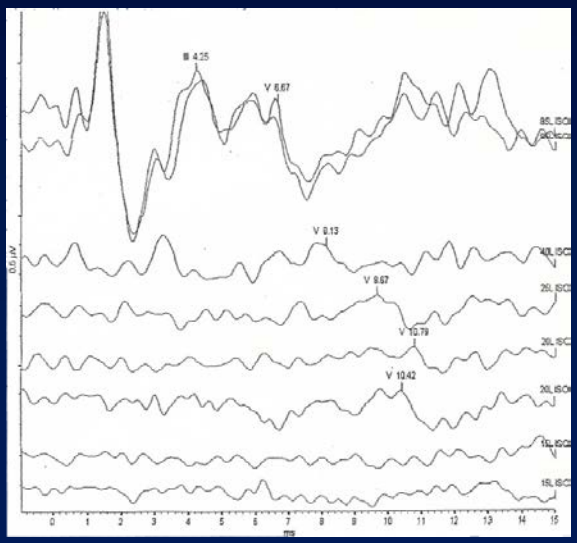


Chirp Temporal Waveform



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

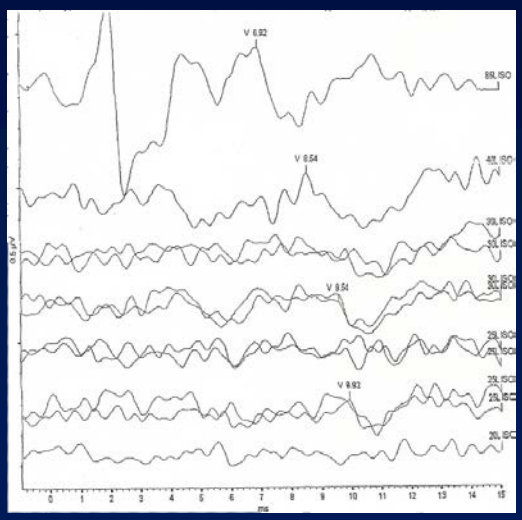
20 dB nHL Click

20 dB nHL CE Chirp

15 dB nHL Click

15 dB nHL CE Chirp

4000 Hz Conventional versus Chirp Evoked ABR



Left Ear
85 dB nHL
Tone Burst

40 dB nHL
Tone Burst

30 dB nHL
Tone Burst

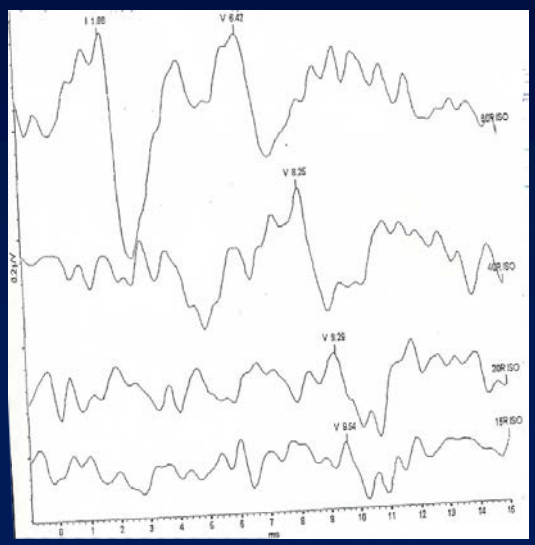
30 dB nHL, Chirp Tone Burst

25 dB nHL, Tone Burst

25 dB nHL, Chirp Tone Burst

15 dB nHL, Chirp Tone Burst

4000 Hz Chirp Evoked ABR
Stimulus rate = 37.7/sec
Total sweeps = 2622; Total test time = 69.5 seconds



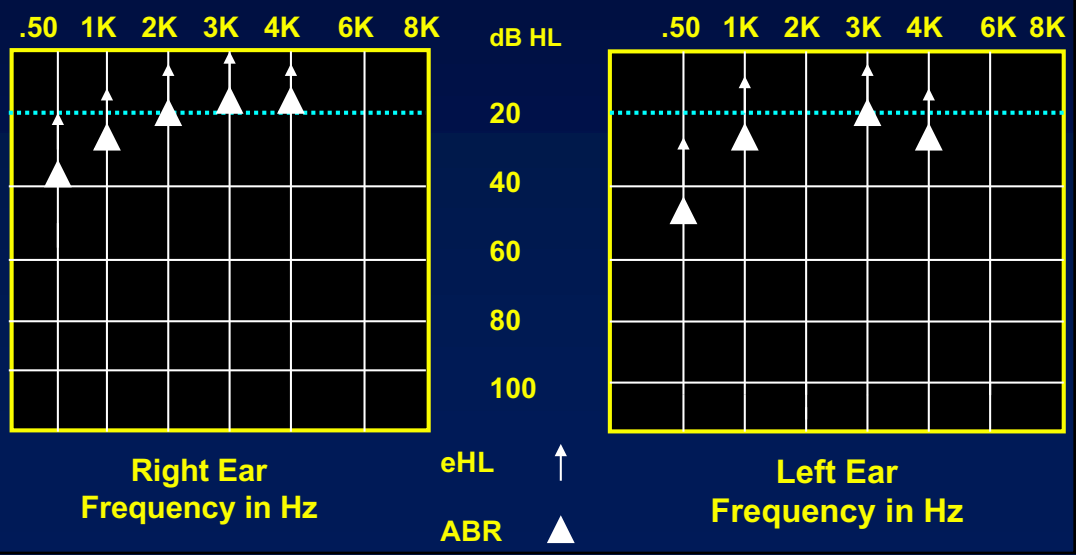
Right Ear
80 dB nHL
684 sweeps

40 dB nHL
456 sweeps

20 dB nHL
570 sweeps

15 dB nHL
912 sweeps

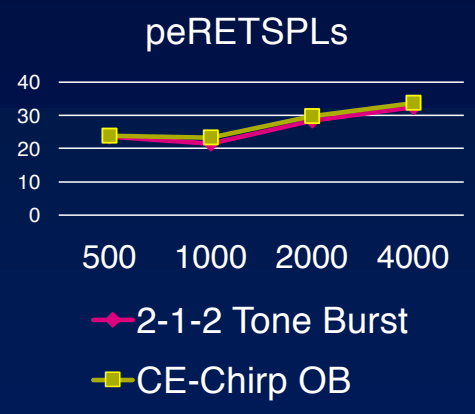
Electrophysiologic Estimation of the Audiogram: One year 4 month boy



Right Ear
Frequency in Hz

Left Ear
Frequency in Hz

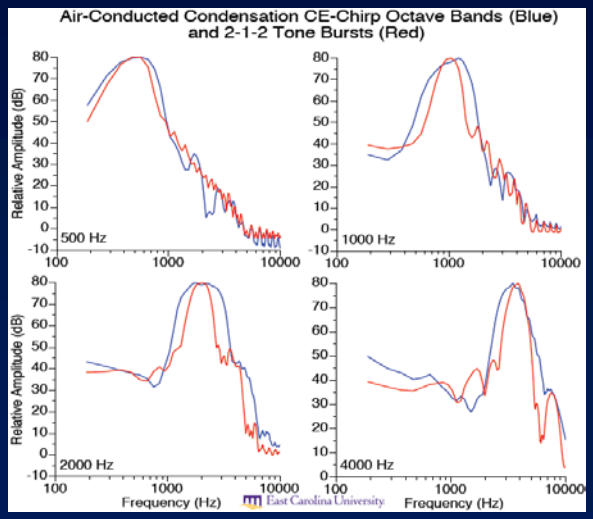
peRETSPLs: CE-Chirp Octave Bands vs. Tone Bursts



- 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

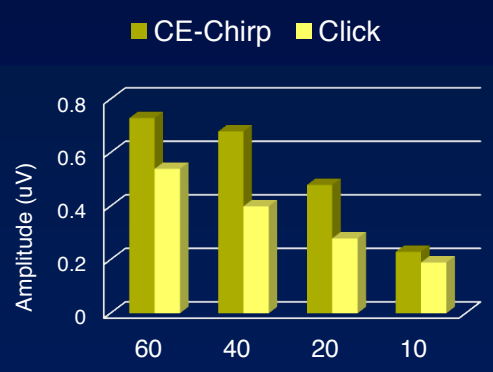
Acoustic Spectrum: CE-Chirp Octave Bands vs. Tone Bursts



Courtesy of East Carolina University

Adults:
CE-Chirp Amplitudes

Amplitude Comparison

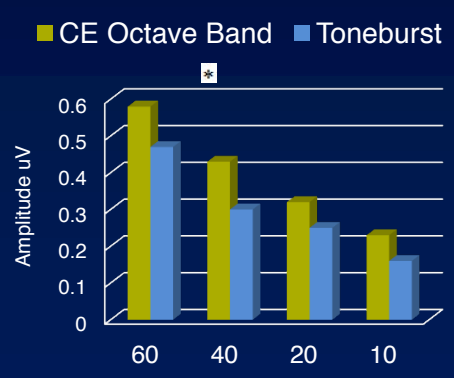


- **Wave V amplitudes were significantly greater at 60, 40, 20 dB nHL**
- **Greater amplitudes are consistent with previously published research**

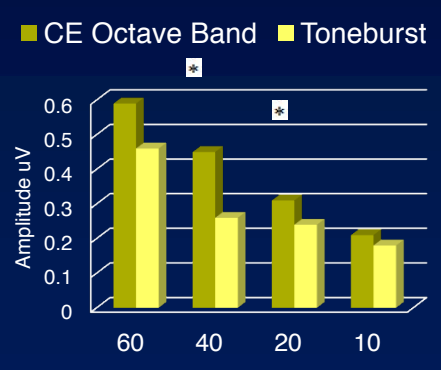
Stangl S, Rentmeester L, Hood LJ. (2013). Auditory brainstem responses to clicks, chirps, tonebursts, and octave-band chirps. Poster presented at the 2013 Meeting of the American Auditory Society, Scottsdale, Arizona.

Adults:
CE-Chirp Octave Bands

4000 Hz

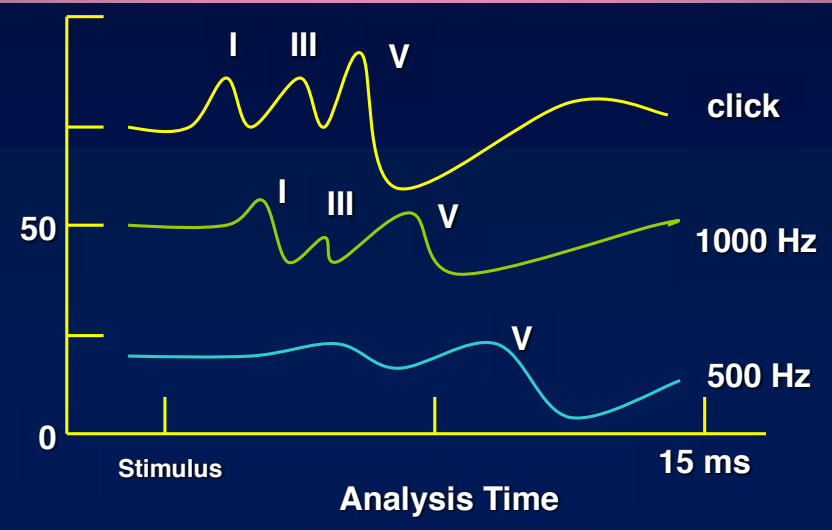


2000 Hz



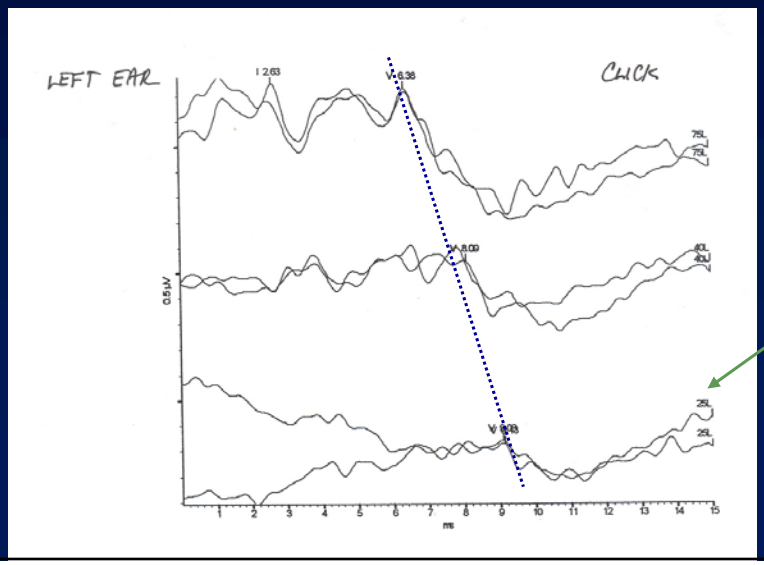
Stangl S, Rentmeester L, Hood LJ. (2013). Auditory brainstem responses to clicks, chirps, tonebursts, and octave-band chirps. Poster presented at the 2013 Meeting of the American Auditory Society, Scottsdale, Arizona.

Click versus Tone Burst ABRs: Differences in Morphology and Latency



Examples of ABR Elicited with Tone Burst Stimuli: Click ABR

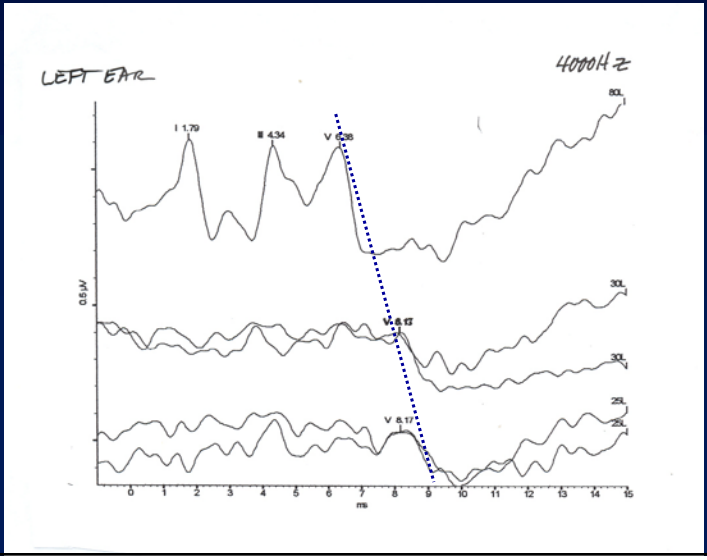
(1.5 year child with language delay; parents from Thailand)



75 dB nHL to 40 dB HL
(Why waste time with other intensity levels?)

25 dB nHL = 15 dB HL
(Why go lower?)

Examples of ABR Elicited with Tone Burst Stimuli: 4000 Hz stimulus



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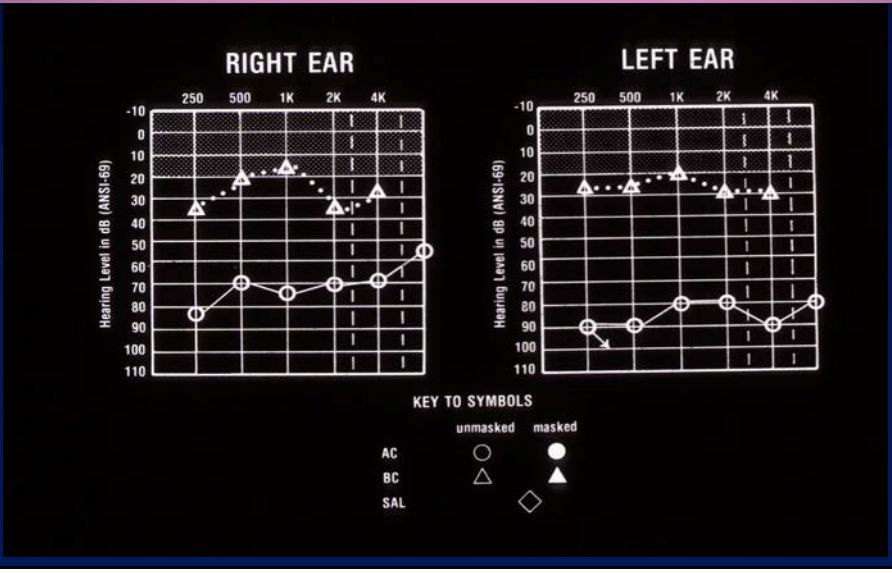
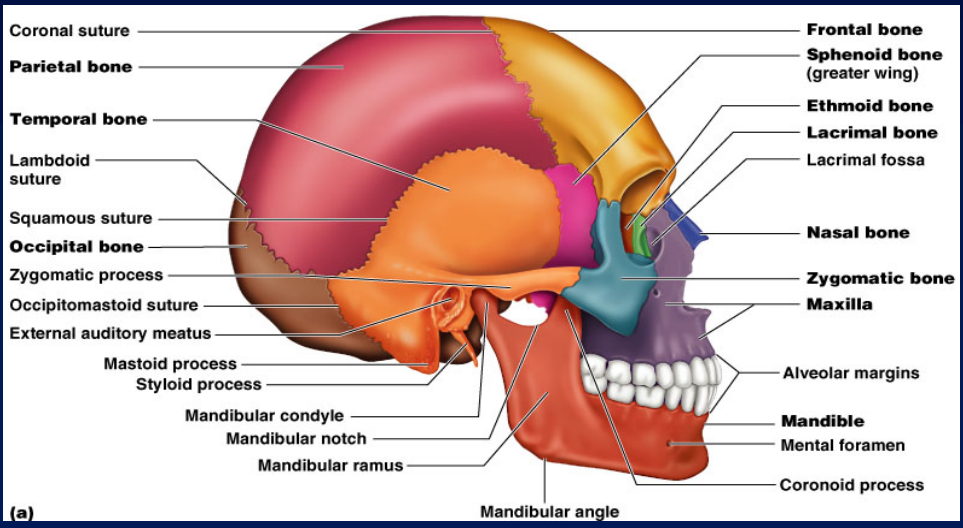
Bone Conduction Auditory Brainstem Response

(Case: 6 year old girl with Treacher Collins syndrome and bilateral aural atresia. Previous diagnosis: Probable left "dead ear")

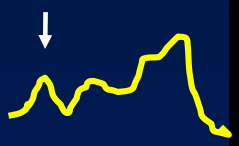


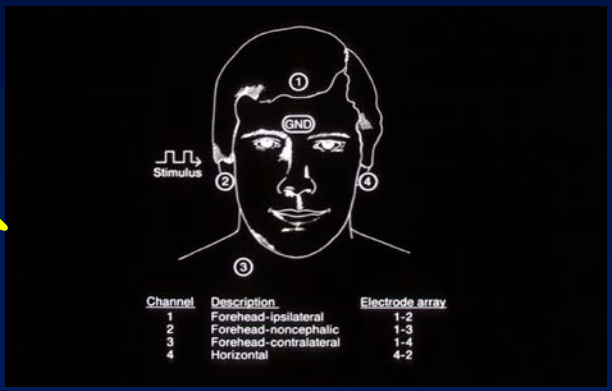
Anatomy of the Skull in Infants:
An Advantage in Ear Specific Bone Conduction ABR



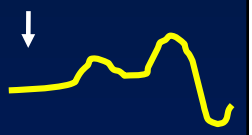
Two-Channel Bone Conduction ABR Recording: Applying ECochG Principles to Verify the Test Ear

Ipsi Channel
Wave I





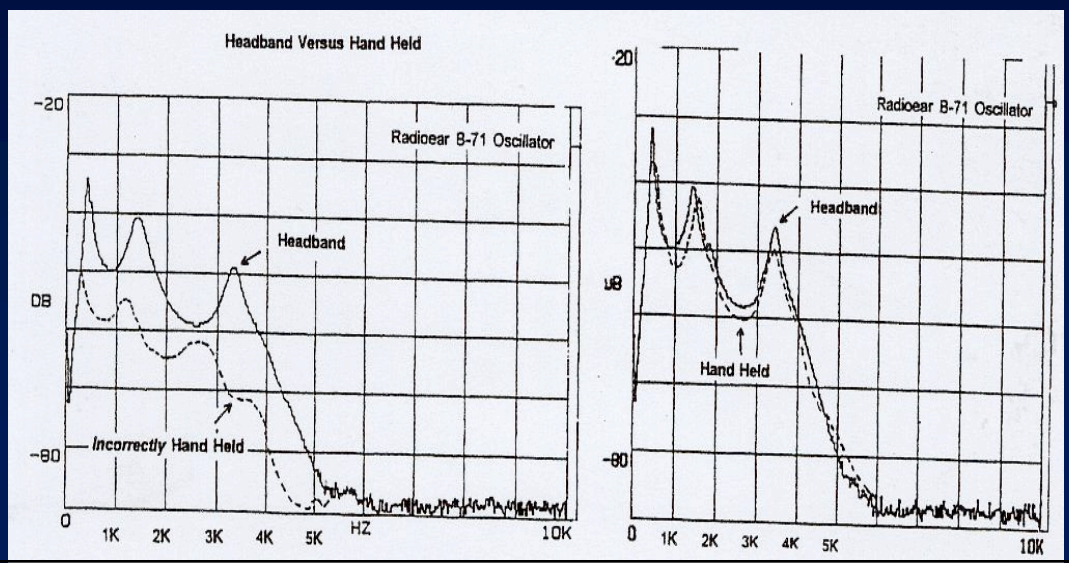
Contra
Channel
No Wave I



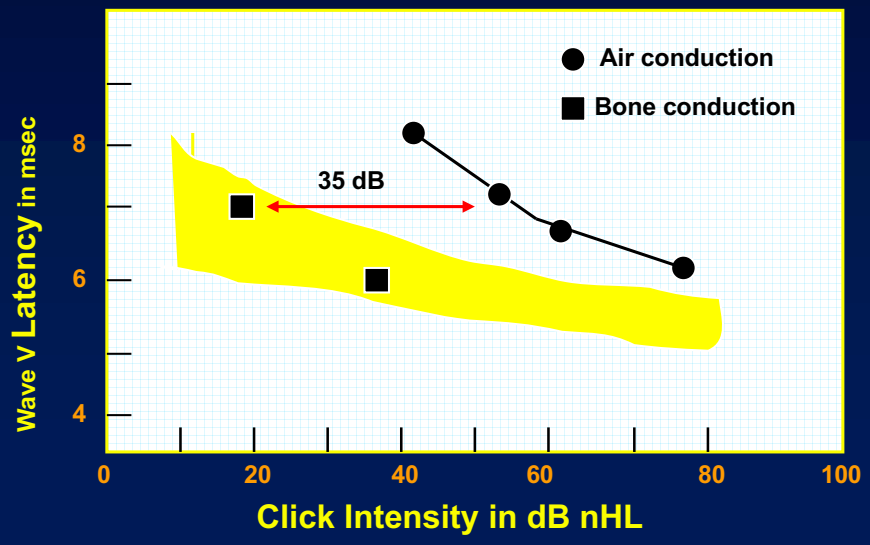
ABR: Protocol for Bone Conduction

- B-70 or B-71 bone vibrator
- Mastoid placement
  - 10 dB increase in intensity
  - Less electrical interference with recording electrodes
- Leave insert earphones in ear canals after air conduction ABR
- Increased distance between inverting electrode and transducer
- Alternating click stimuli to minimize stimulus artifact
- Slower rate (e.g., 11.1/sec) as needed to enhance wave I
- 30 to 3000 Hz (low frequencies enhance response amplitude)
- Begin near maximum intensity level (about 50 dB nHL)
- Identify wave I in ipsilateral array to verify test ear
- Plot latency/intensity function for wave V for BC vs. AC

Bone Conduction: Effect of Transducer Factors



Example of Estimation of Air-Bone Gap with ABR



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Un-Sedated ABR Measurement: Techniques

- Non-medical techniques
  - Sleep deprivation
  - Record ABR immediately after feeding
  - Bean bag "bed" to minimize movement
  - Benedryl (with pediatrician approval)
  - Melatonin
    - ✓ Schmidt et al. Melatonin is a useful alternative to sedation in children undergoing brainstem audiometry with an age dependent success rate: A field report of 250 investigations. *Neuropediatrics 38: 2-4, 2007*.

Un-Sedated ABR Measurement: Melatonin

- Selected publications on use of melatonin to induce sleep in medicine
  - Brzezinski A. (1997) Melatonin in humans. *N Engl J Med, 336*, 186-195.
  - Dodge NN & Wilson GA. (2001). Melatonin for treatment of sleep disorders in children with developmental disabilities. *J Child Neurol, 16*, 581-584.
  - Johnson et al. (2002). The use of melatonin as an alternative to sedation in uncooperative children undergoing an MRI examination. *Clin Radiol, 57*, 502-506.
  - Milstein V et al. (1998). Melatonin for sleep EEG. *Clin Electroencephal, 29*, 49-53.
  - Seabra et al. (2000). Randomized, double-blind clinical trial, controlled with placebo, of the toxicology of chronic melatonin treatment. *J Pineal Res, 29*, 193-200.
  - Wassmer E et al. (2001). Melatonin is useful for recording sleep EEGs: a prospective audit of outcome. *Dev Med Child Neurol, 43,* 735-738.

ABR in the Clinic with Conscious Sedation (e.g., chloral hydrate): No Longer an Option in the USA

ABR in Ambulatory Surgical Center with Light Anesthesia (e.g., Propofol)

Breaking News from CNN
Concerns about Anesthesia in Children
August 20, 2012

Breaking News from CNN
August 20, 2012

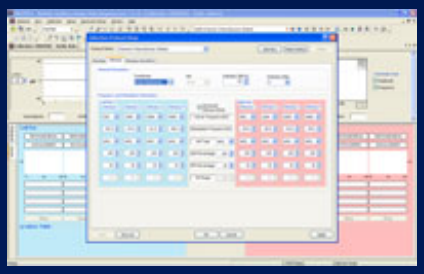
Anesthesia in young kids may carry developmental risks. While surgery carries risks for anyone, "going under" can have some particular risks for the very young.A study coming out in the September issue of Pediatrics finds that children who have anesthesia before the age of 3, are at a higher risk for developmental delay issues later in life.The study looked at more than 2,600 children in Australia who were tracked as part of the Raine Study. Authors found that by the age of 10, children who'd been exposed to anesthesia at a young age were more than twice as likely to have developmental issues with listening and speaking comprehension.

Vivosonic Integrity System
(Clinic day at Kalaphong Hospital in Pretoria South Africa)

Auditory Steady State Response (ASSR) for Objective Frequency-Specific Estimation of Severe-to-Profound Hearing Loss: A Variety of Clinical Devices



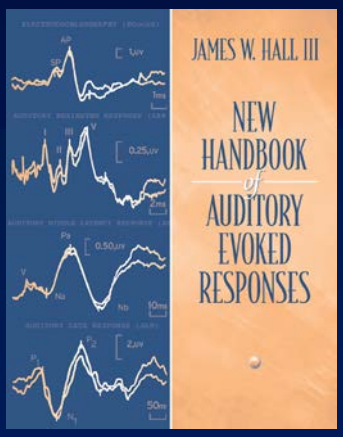


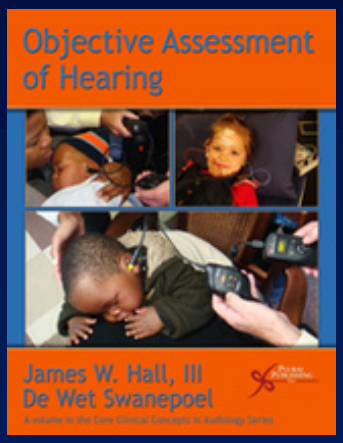


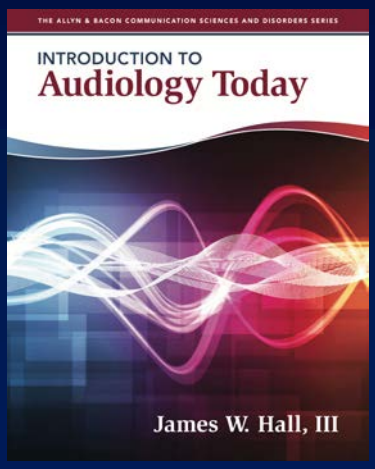
Application of ABR in Objective Assessment of Infant Hearing

- Introduction: Why early diagnosis of infant hearing loss is important
- Review of stimuli used to elicit the ABR in infants and young children
- Test protocol for ABR recording in children
- Measurement and analysis of tone burst and bone conduction ABRs
- Bone conduction ABRs
- Techniques for un-sedated ABRs and sedation options
- Discussion, questions, & answers

Thank You!
Questions?







Pearson
July 2013