

Michael O. Webb, M.S., CCC-A, FAAA /
Neuroaudiology & CAPD Specialist
EAR-Central, PLLC / Hereford, Arizona
mowebb.earc@gmail.com
www.EAR-Central.com

Auditory Evoked Potentials: **Application in CAPD and ANSD**

IGAPS 2017 Meeting
St. Luke's Medical Center
April 27-29, Kansas City



Session Assumptions:

- This session assumes a basic working knowledge of auditory electrophysiology measures and recording techniques.
- This is not a “how-to” presentation, but a discussion of AEP outcomes and 1) their place in differential diagnosis of CAPD and ANSD, as well as 2) possible uses in assessing post-therapeutic outcomes.

Session Confessions:

- I do not consider myself an “expert” in the diversities of electrophysiology, which are extensive. My use of AEPs has mostly been confined to CAPD assessment and treatment.
- ANSD is a complex area of diagnostic and rehabilitative sub-specialization in audiological practice. My actual practice experience with ANSD is limited.
- I am a fellow learner in these areas.

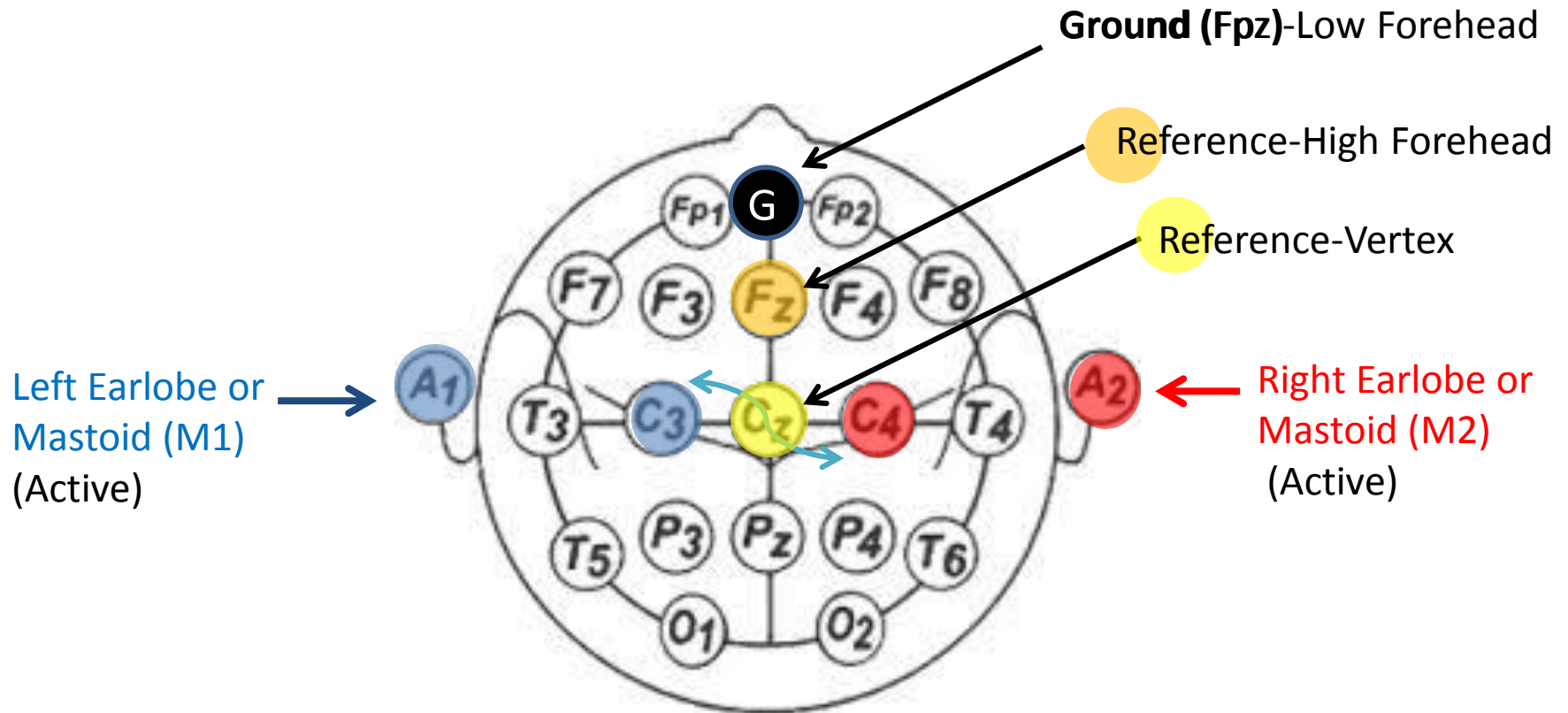
Auditory Evoked Potentials

- **Early (< 10 ms)**- (Cochlear/ 8th n./ Brainstem)- **ABR**
– **CM**, ECoG (AP/SP), **ABR** **Exogenous**
- **Middle (10-50 ms)**- Thalamo-cortical (**AMLR**)
Exogenous
- **Late (30-300 ms)** - Cortical (**ALR**): P1, **N1-P2**, N2
Exogenous
- **Late (30-600 ms)**-
Cortical Event-Related Potentials(CERPs)
P300: Endogenous: MMN: Exo/Endogenous

State-Dependent

Not isolated processes: Cumulative.
All affected by what went before.

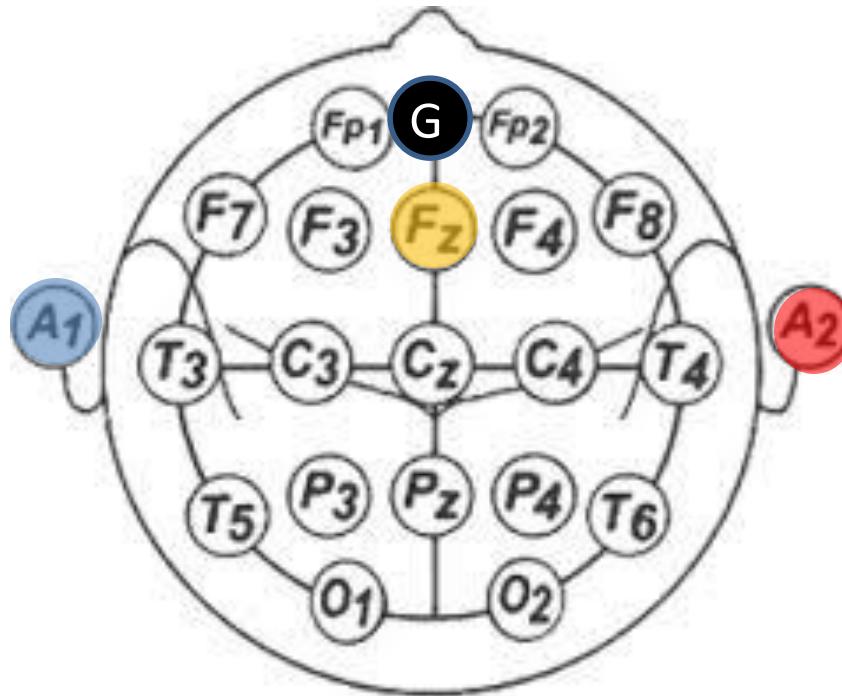
Typical Electrode Sites for AEP Montages



Electrode Montage

CM, ABR, AMLR, ALR (1)

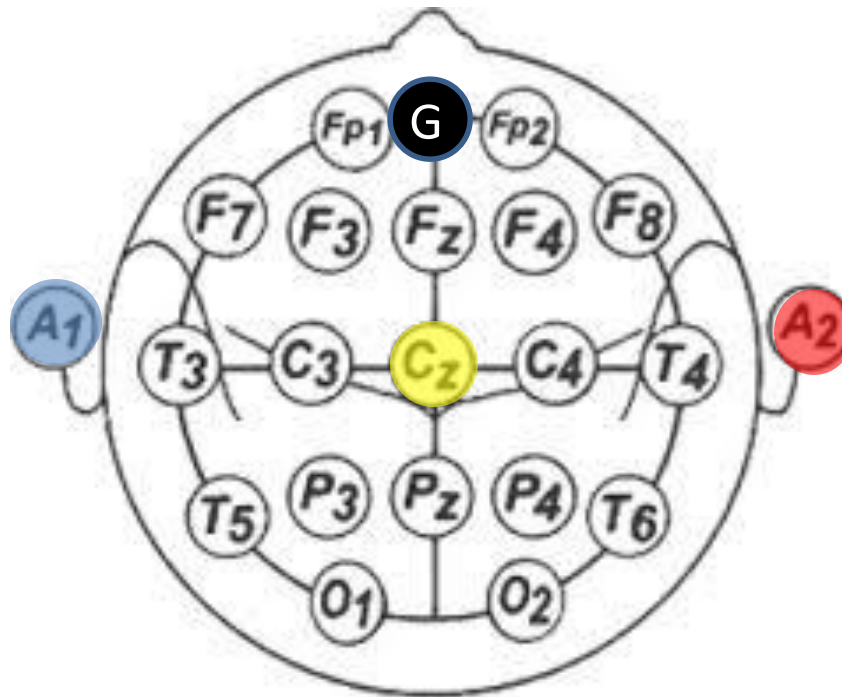
- >No laterality measure
- > ~15% average reduction in Wave V amplitude



Electrode Montage

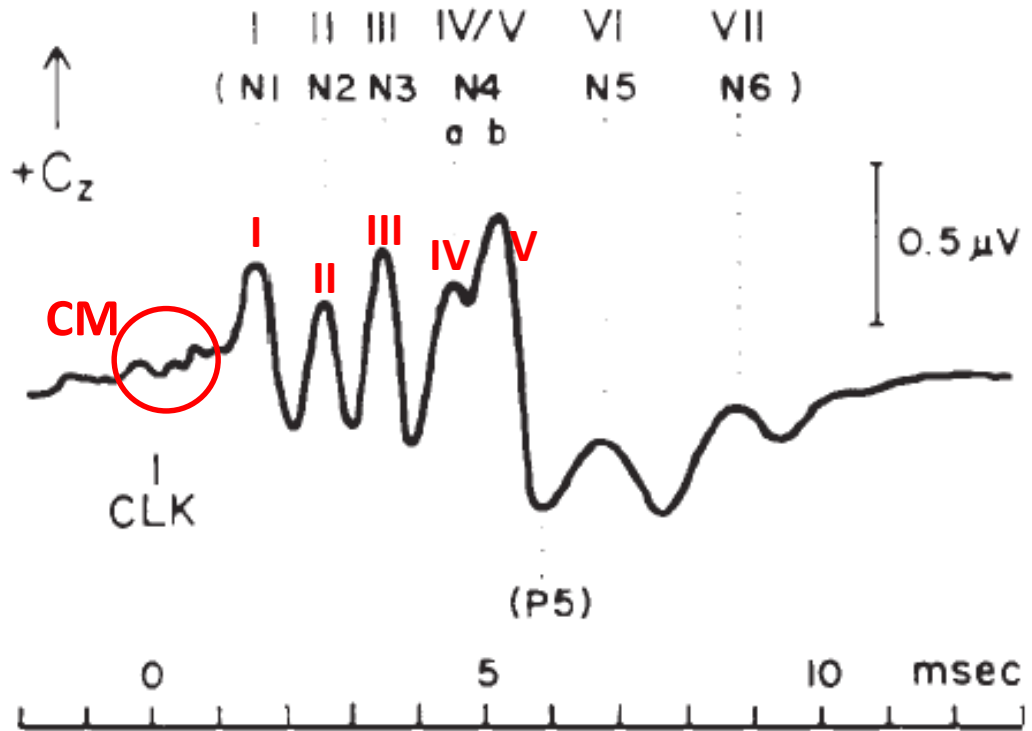
CM, ABR, AMLR, ALR (2) + CERPs

- >No laterality measure
- > ~15% more robust Wave V amplitude



Early AEPs (<10 ms): **ABR**

Classic Click ABR Waveforms



Click Stimulus is most sensitive to 2kHz-4kHz

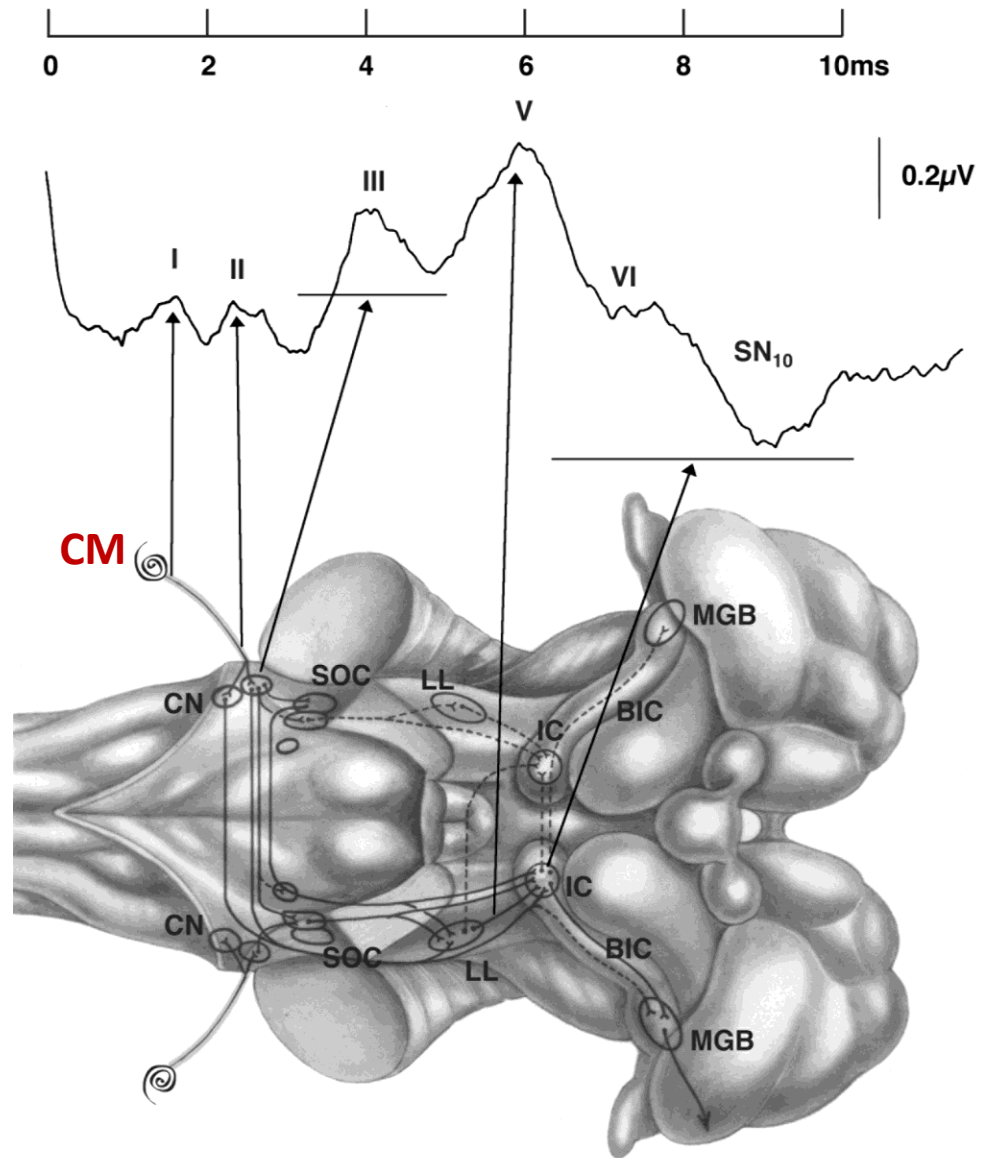
Peak I: distal
(cochlear)
auditory nerve

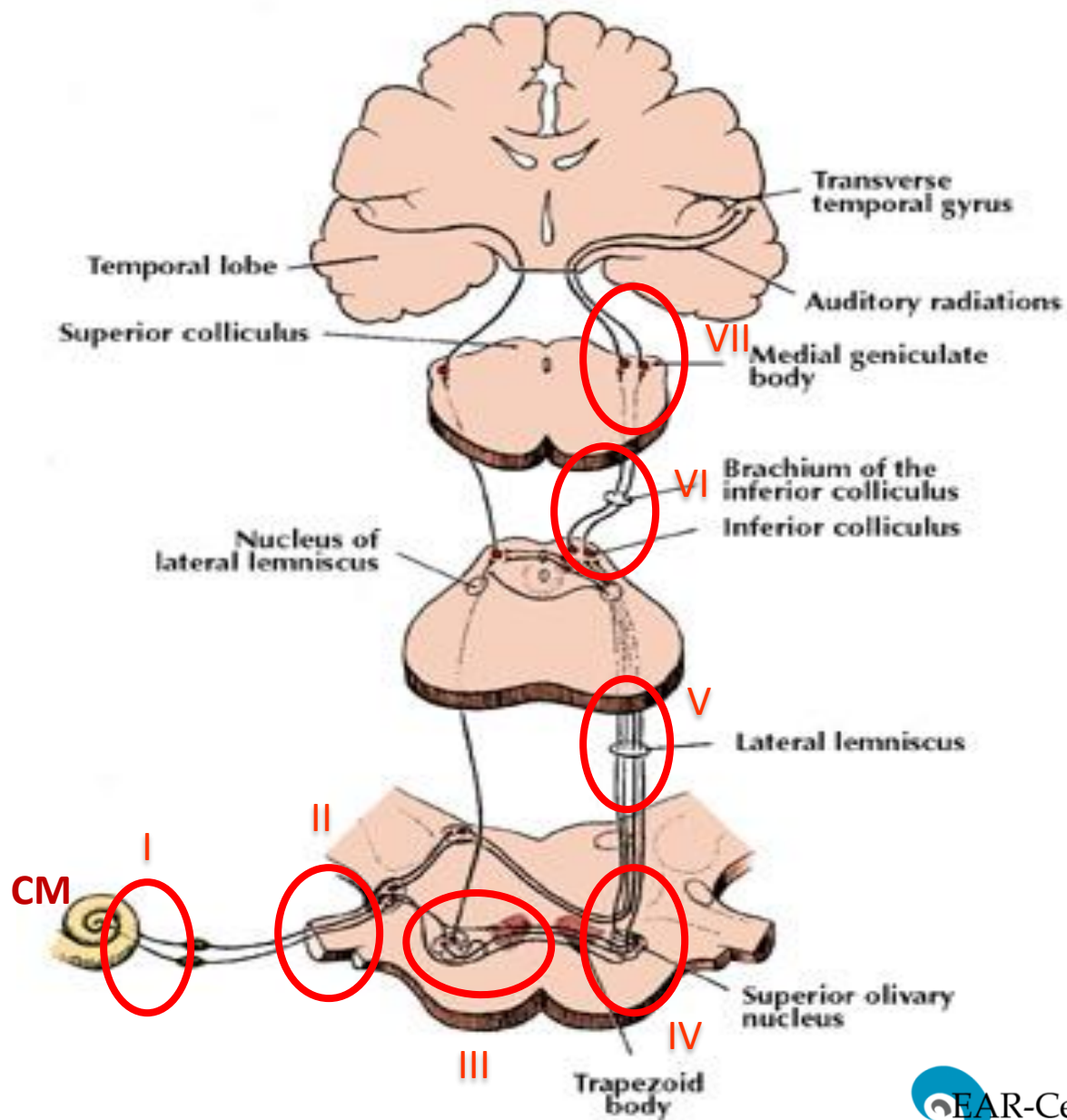
• **Peak II**: proximal
(CN) auditory nerve

• **Peak III**: mainly
cochlear nucleus/
SOC

• **Peak IV**: Likely SOC

• **Peak V**: termination
of the lateral
lemniscus
in the contralateral
inferior colliculus



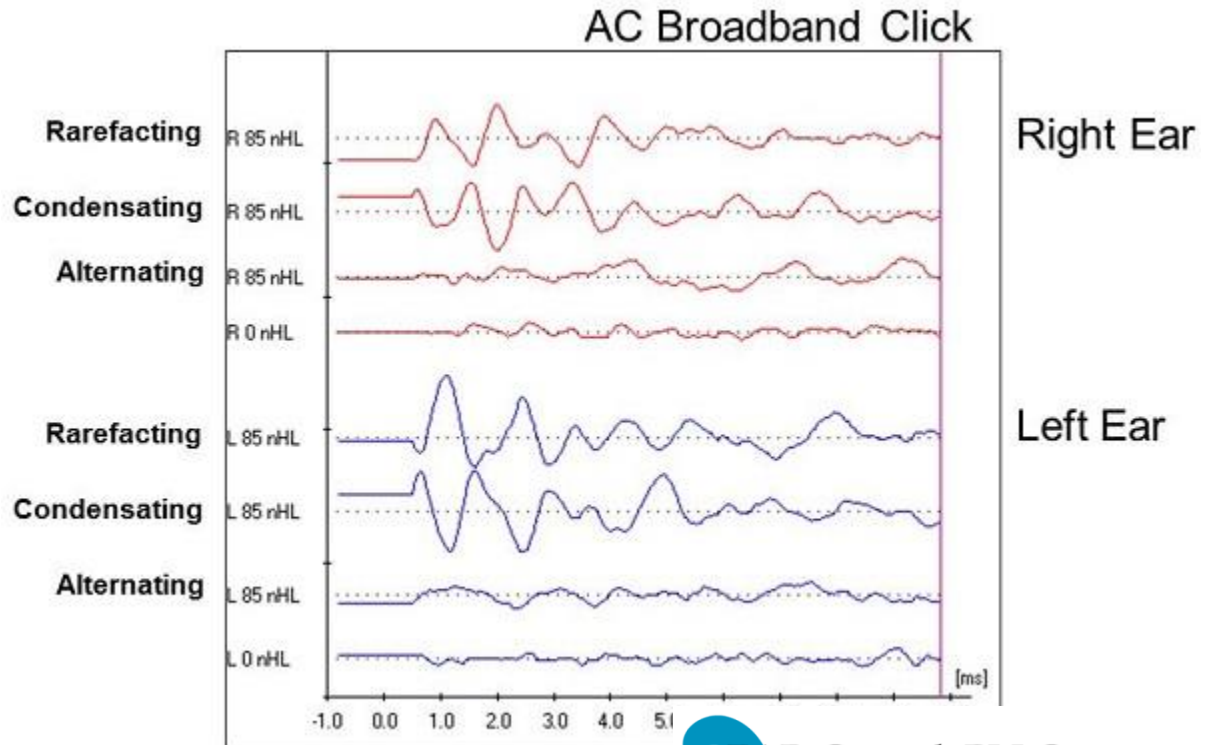


Compliments of Frank Musiek, Ph.D.

Early AEPs (<10 ms): **ABR**

- Earliest waves are cochlear: Cochlear Microphonic (CM)- Critical in diagnosis of Auditory Neuropathy Spectrum Disorder (ANSD)

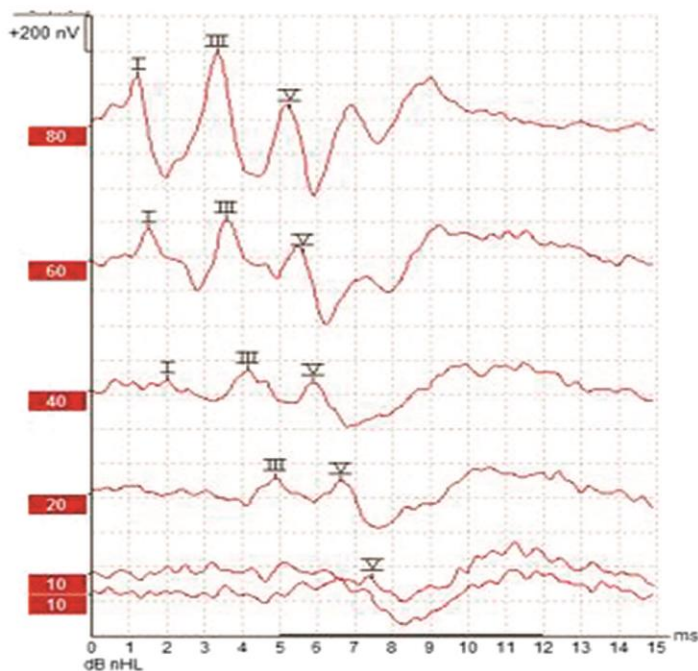
- Sensitive to **polarity** (Alternating cancels CM)
- Rar./Cond. Reverses CM
- Cochlear Amplifier (**OHC**)
- Mimics signal
- Rule out possible **artifact** (pinch tube).
- Starts ~ 0.4 ms+



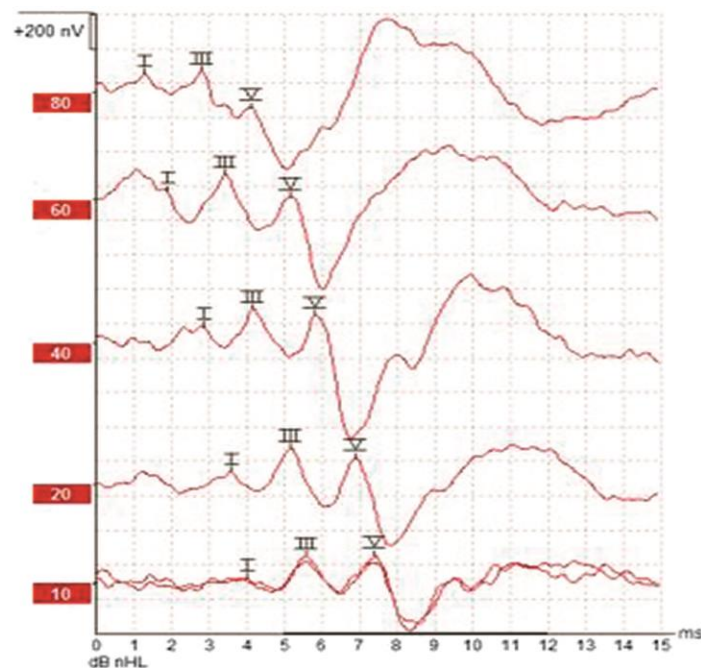
Early AEPs (<10 ms): **ABR**

- Used for hearing threshold estimation.
- Neuro-diagnosis (M.S., Tumors, ANSD)
- Click Stimulus vs. CE-Chirp[®] Stimulus

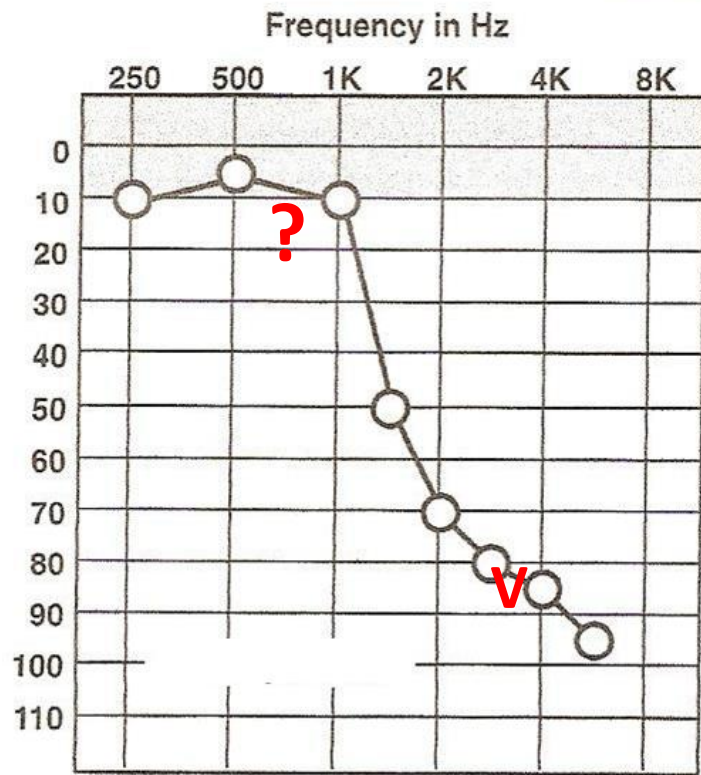
A. Click stimulus



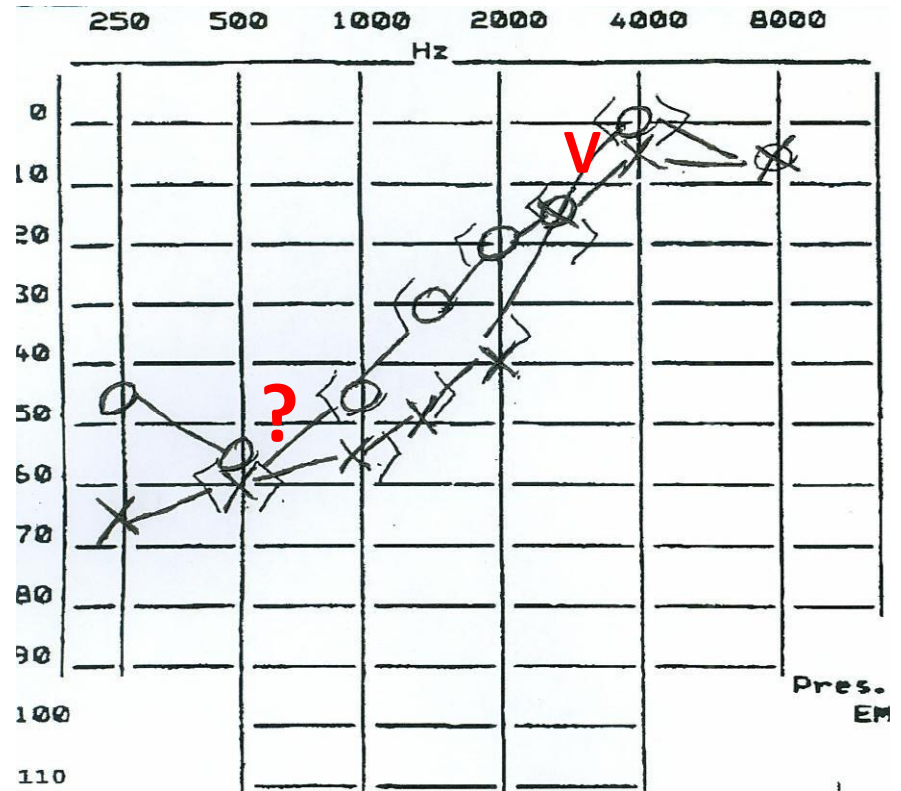
B. CE-Chirp stimulus



Early AEPs (<10 ms): **ABR**



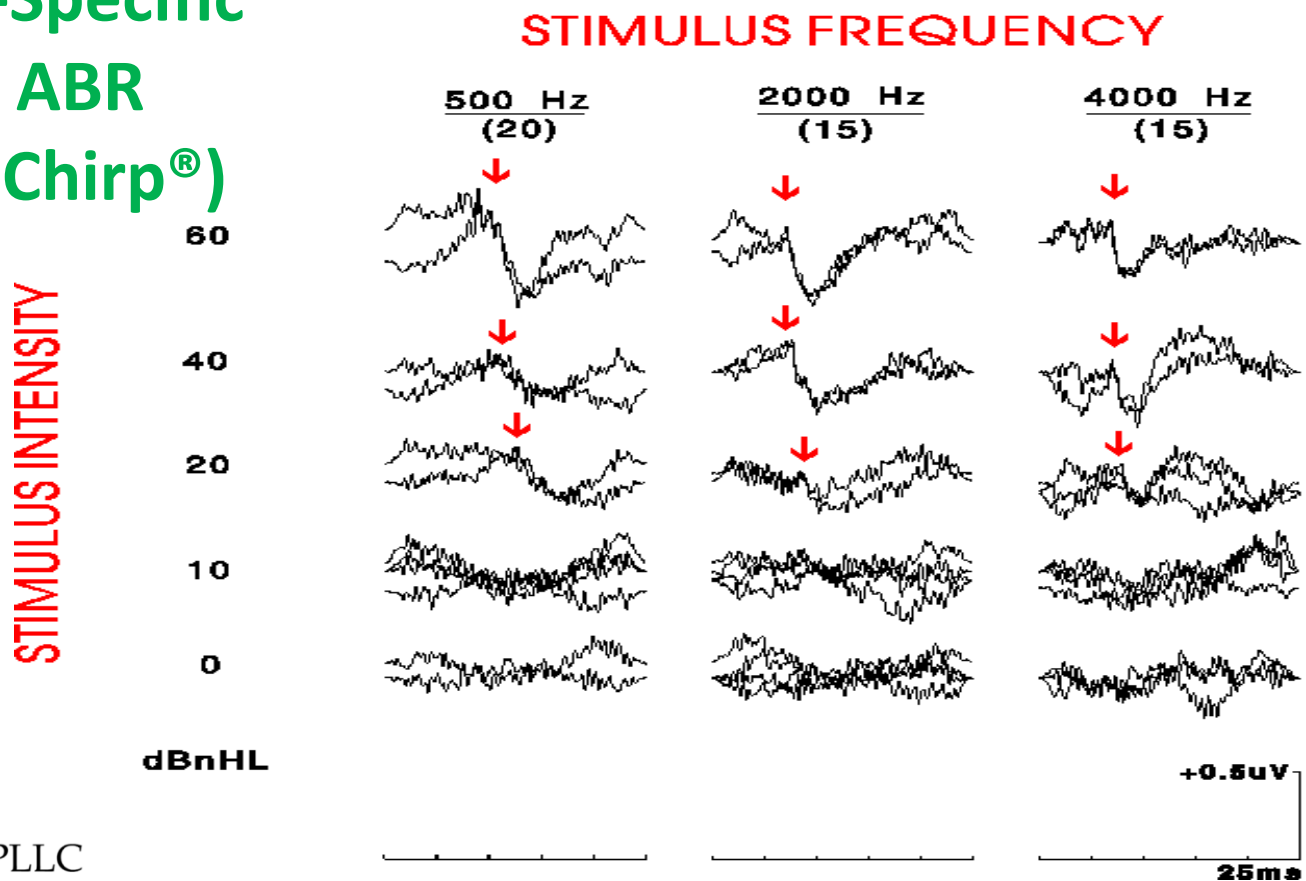
audiometric configuration, precipitous



Early AEPs (<25 ms): **ABR**

THRESHOLD ESTIMATION IN YOUNG
INFANT WITH NORMAL HEARING
(Air-conduction Tone-ABR)

Frequency-Specific
Tone-Burst ABR
(Or F.S. CE-Chirp®)

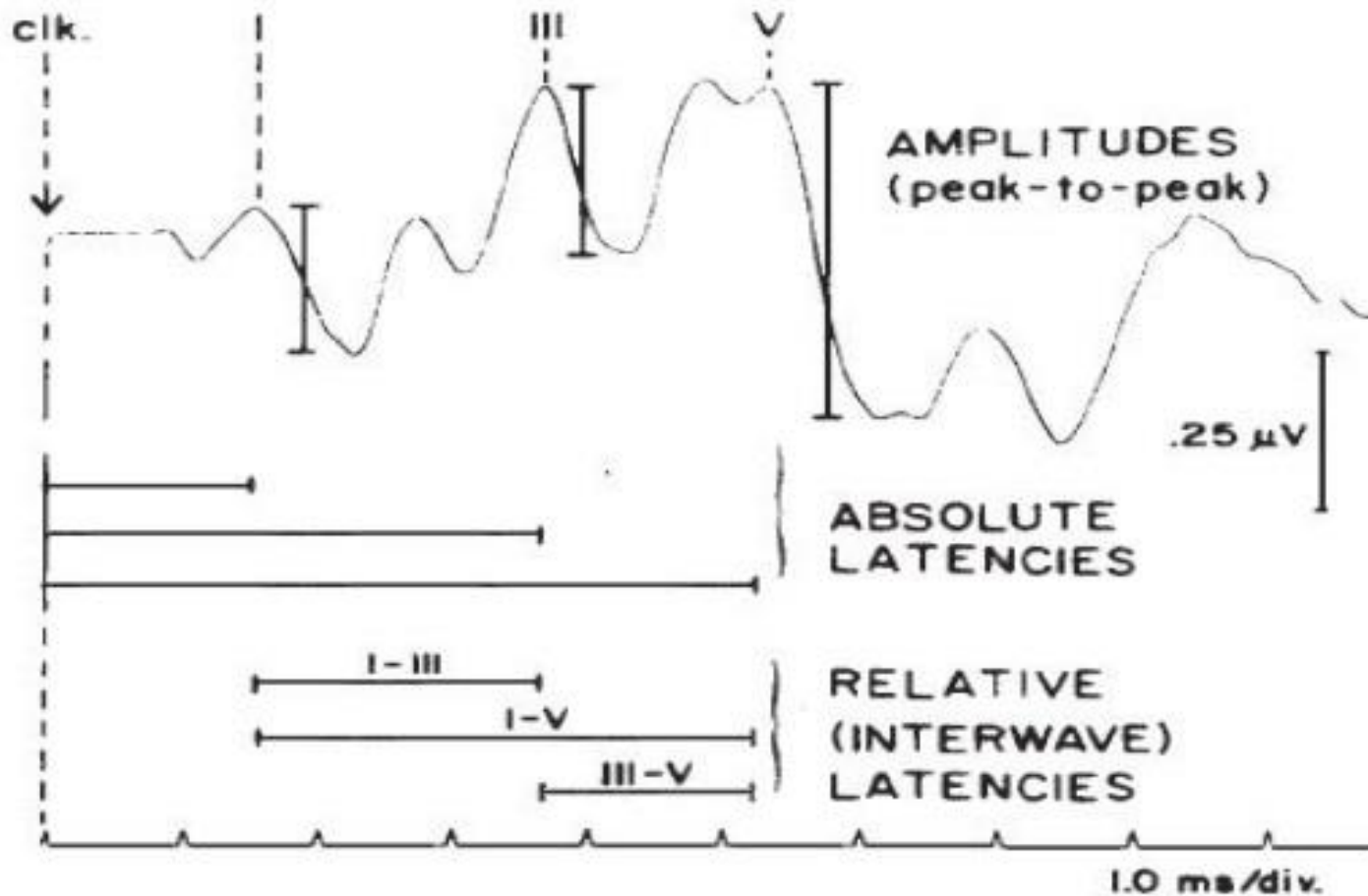


Early AEPs (<10 ms): **ABR**

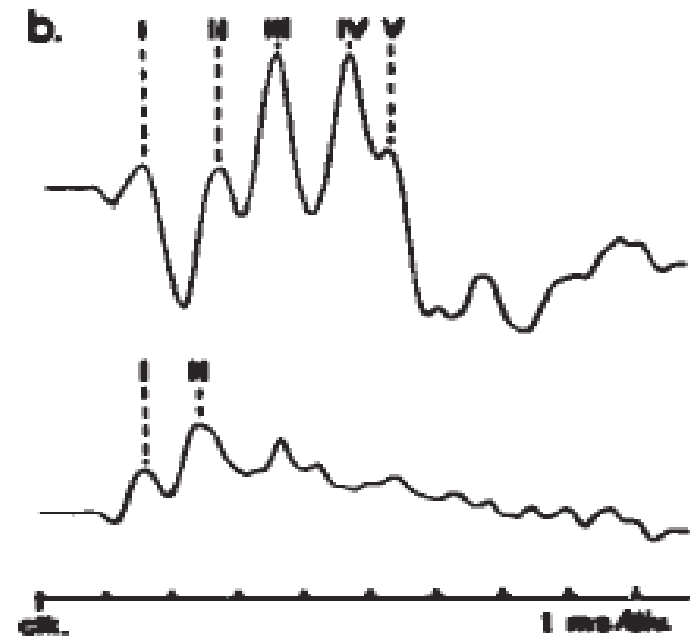
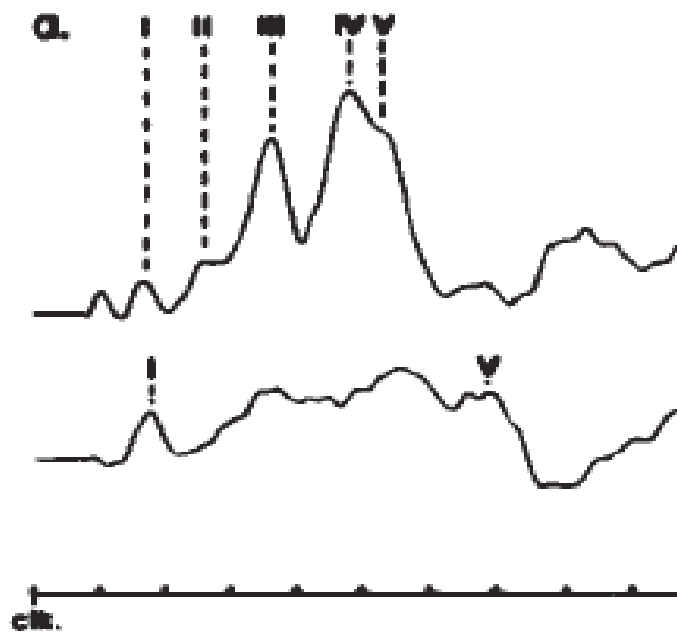
Interpretation:

- Presence/Absence of waves (esp. I-III-V)
- Morphology (Amplitude) of Waves
- Intra-aural Absolute Wave Latencies
- Inter-aural Absolute Latencies
- Inter-peak Latencies (I-V, I-III, III-V)
- Neuro-Rate Study
- Binaural Interaction Component (BIC)

Early AEPs (<10 ms): **ABR**



8th Nerve Tumor

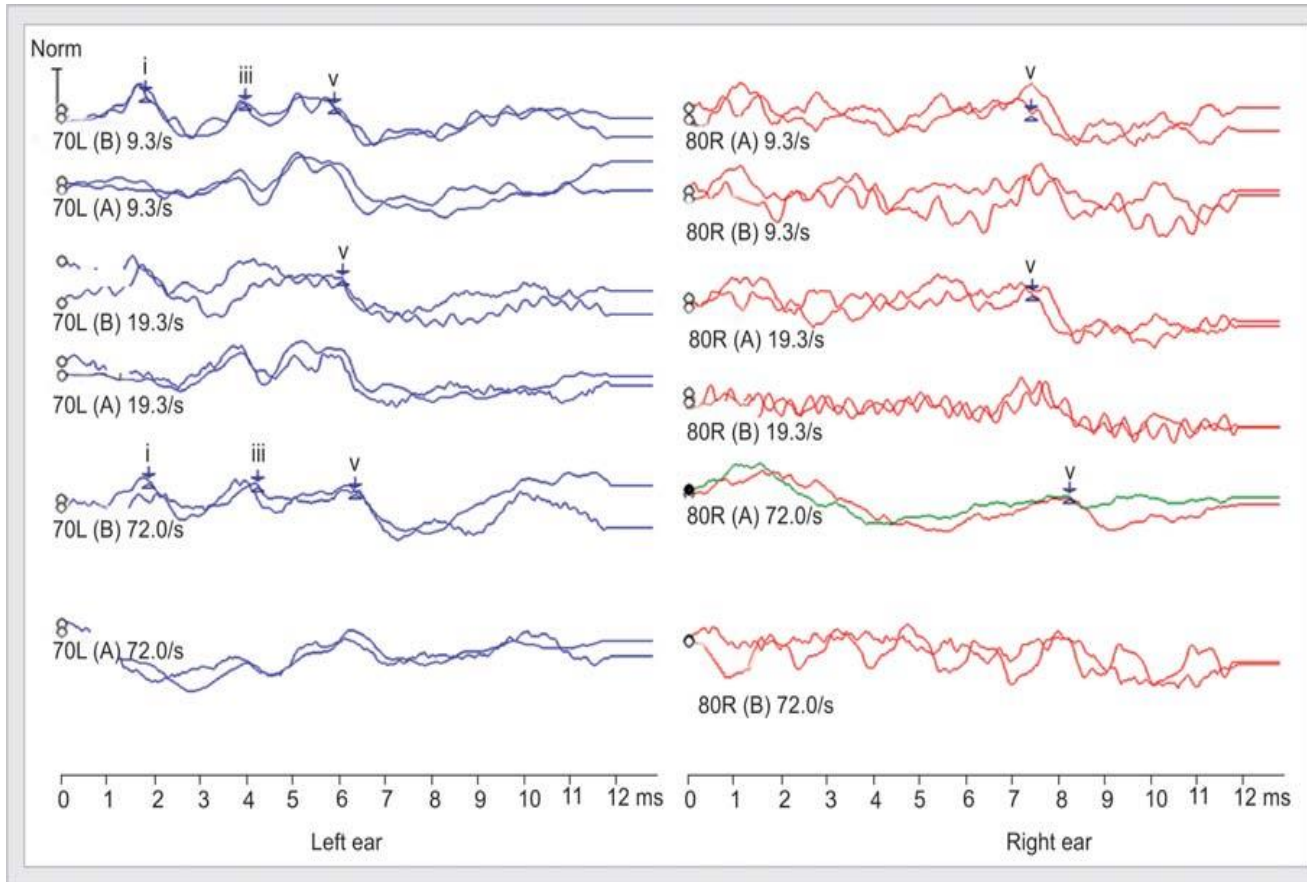


8th Nerve Tumor

NEURO-RATE STUDY

Normal

Tumor



**9.3
Clicks/sec**

**19.3
Clicks/Sec.**

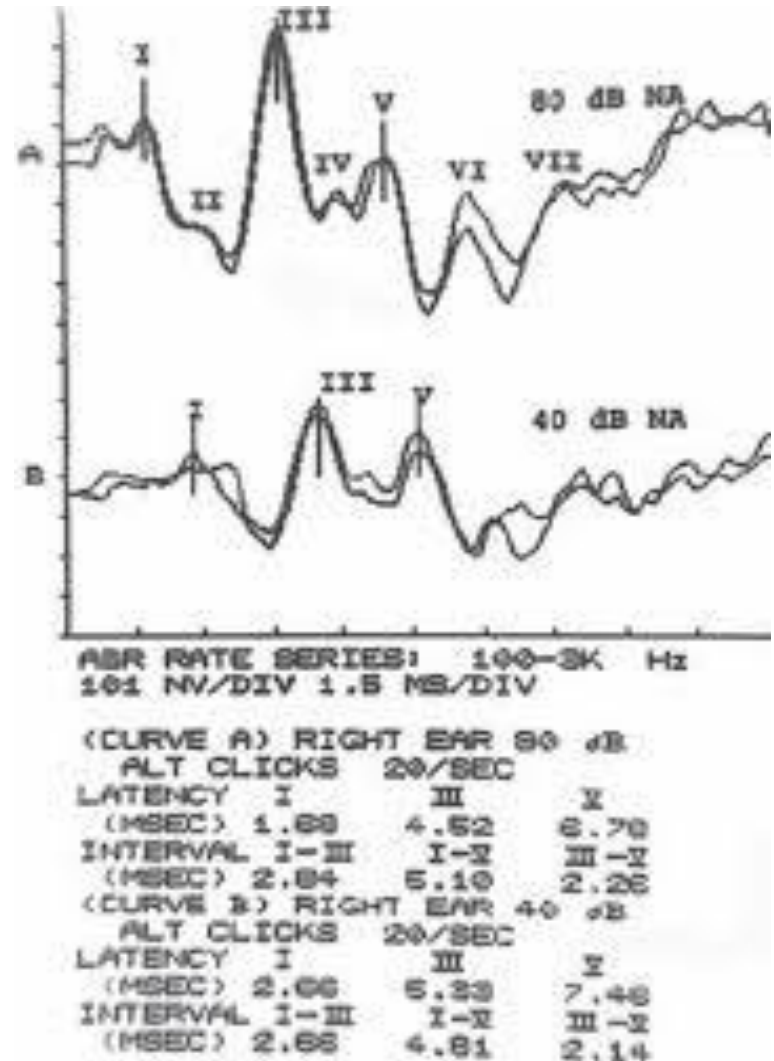
**72.0
Clicks/Sec.**

Hyperbilirubinemia/Kernicterus

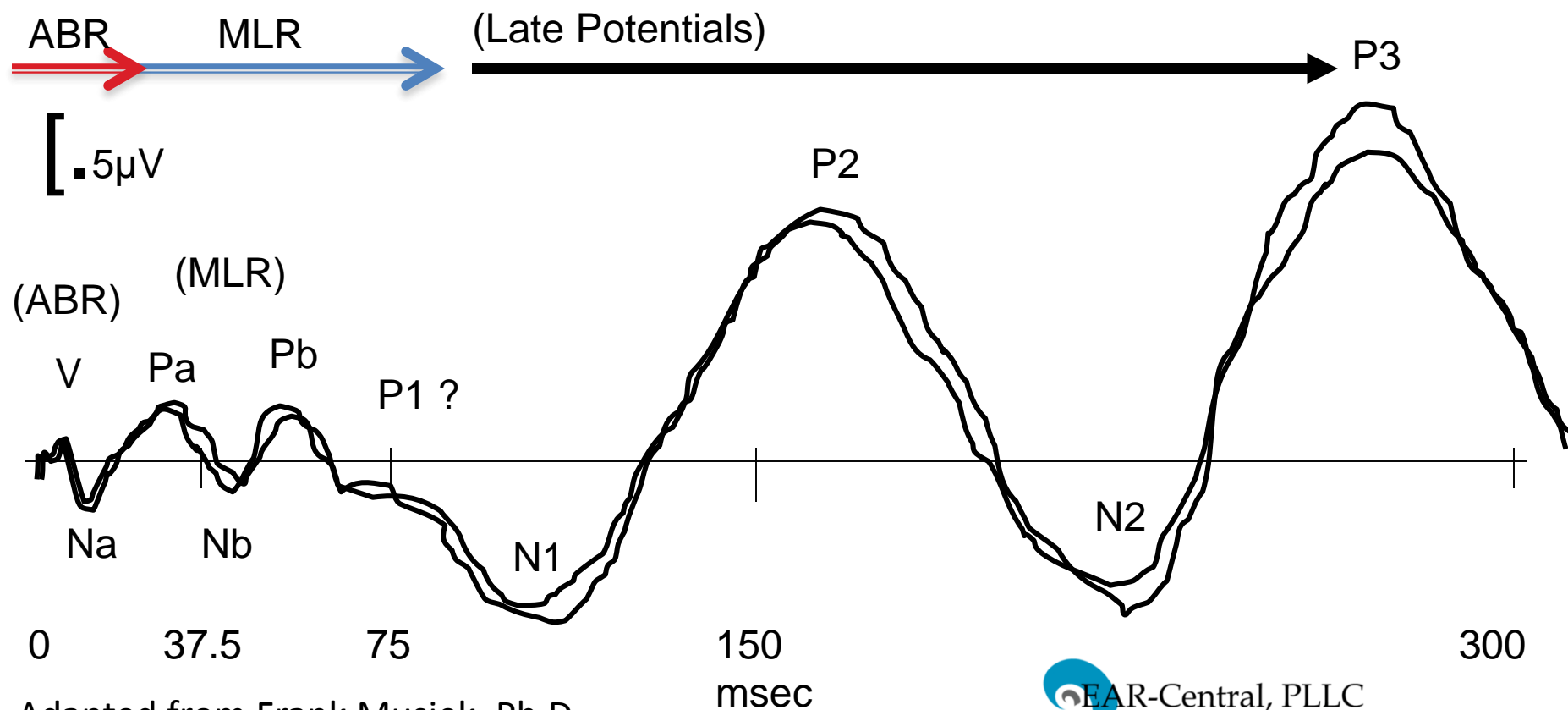
- Hyperbilirubinemia (H) occurs in ~84% of term and late pre-term births during the first week of life.
- Elevated Total serum/plasma Bilirubin (TB) levels are usually **transitory** without permanent sequelae
- Bilirubin-induced Neurologic Dysfunction (BIND) is a **spectrum disorder**, including Kernicterus (K), produced by acute/prolonged CNS exposure to TB. (> 15-20 mg/dL TB levels)
- Auditory system is particularly sensitive to H, even at lower levels previously thought to be harmless, without signs of K.
- May **range** from subtle abnormalities in speech and hearing processing (like CAPD?) to total deafness.
- **Musiek reports that the primary site of lesion is the Cochlear Nucleus (CN), so BIND is technically not included in ANSD.**

ABR in Hyperbilirubinemia

- Decreased/missing III, IV-V w. involving CN.
- Decreased amplitude of BIC (abnormal input to the SOC)
- Reduced amplitudes / prolonged latencies in ABR
- Higher TB levels may see the absence of ABR wave I
- Increased brain conduction time (seen in I-V inter-wave latencies)
- ABR may improve with treatment. (Transfusion/Photo)



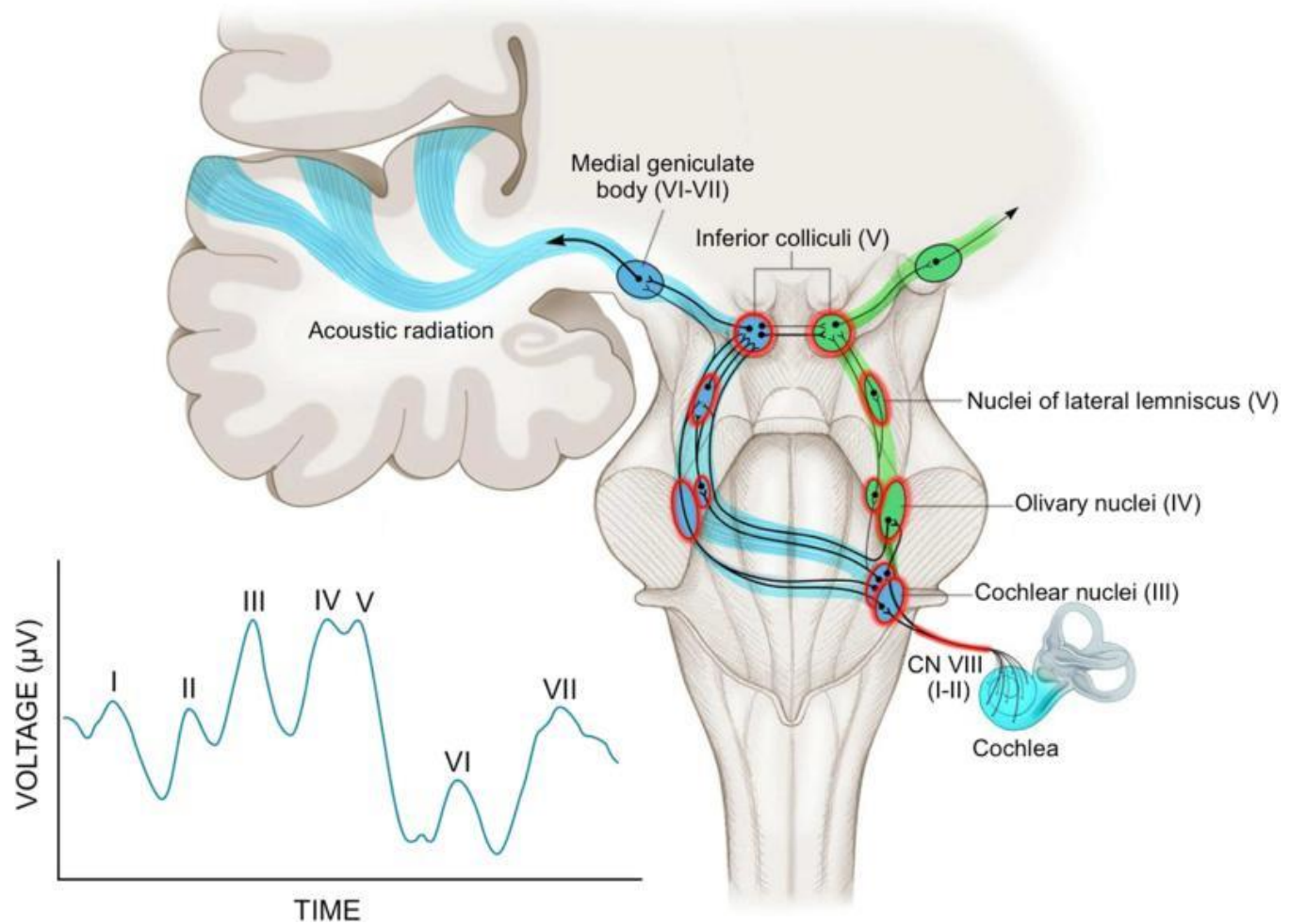
Middle-Late, Late, Event-Related AEPs (~10-600 ms): **AMLR, ALR, CERPs**



Adapted from Frank Musiek, Ph.D.

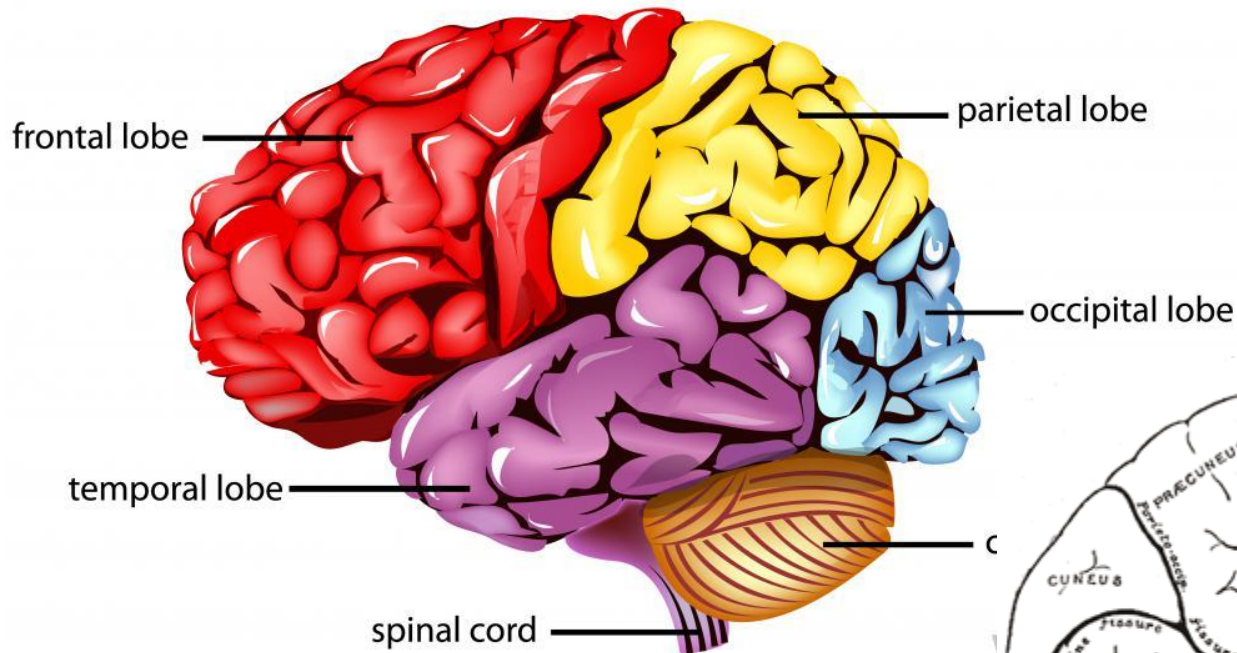
Generators of the Mid/Late Potentials

- **AMLR** : Auditory Cortex, Thalamo–cortical pathways, and reticular nuclei of thalamus.
- **P1,N1**
 - Primary auditory cortex
 - Auditory association areas of the superior temporal plane
- **P2**
 - Auditory cortex along the Sylvian fissure
- **P3**
 - Auditory cortex?
 - Temporal–parietal junction
 - Hippocampus
- **MMN**– Aud. Cortex (Frontal Rad?)

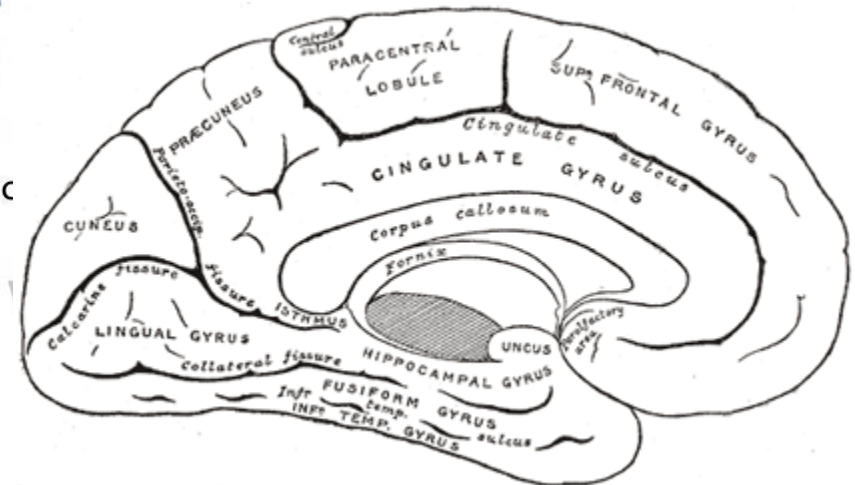


Generators of the Mid/Late Potentials

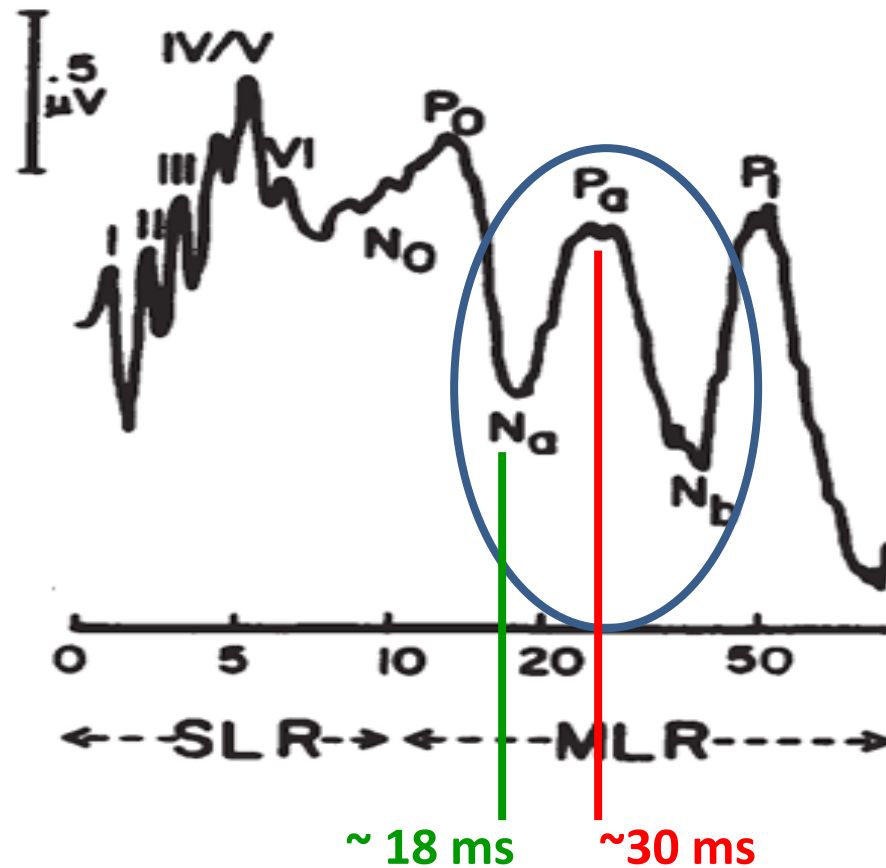
Parts of the Human Brain



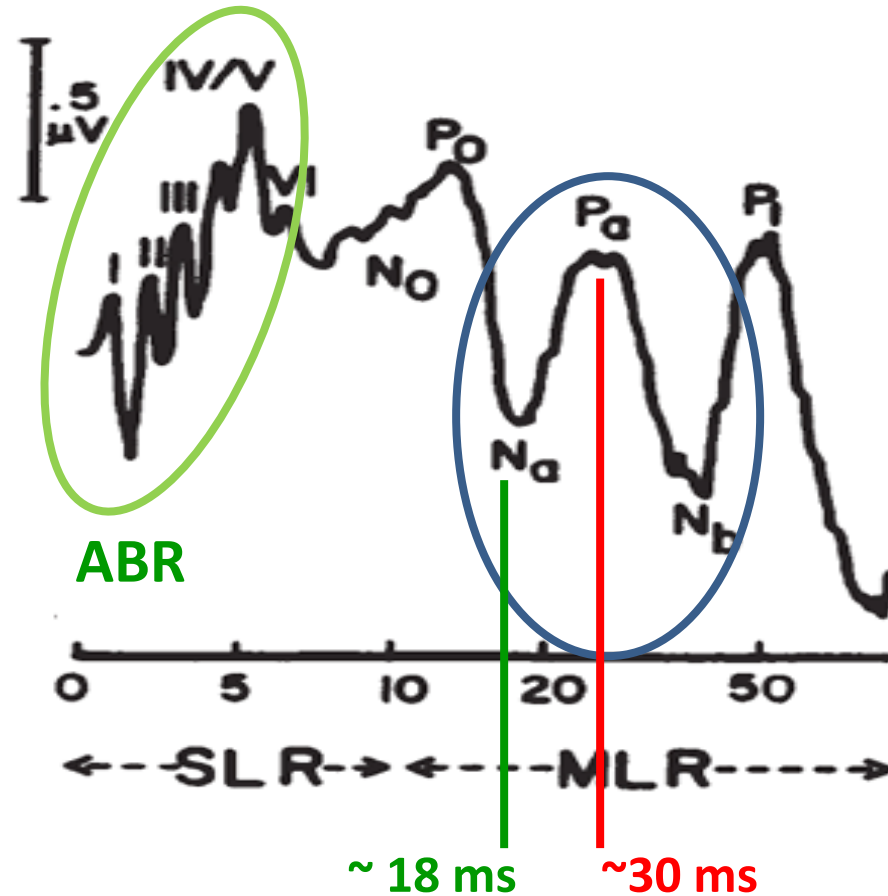
Medial Surface Brain (Forebrain)



Middle-Late AEPs (<50 ms): **AMLR**



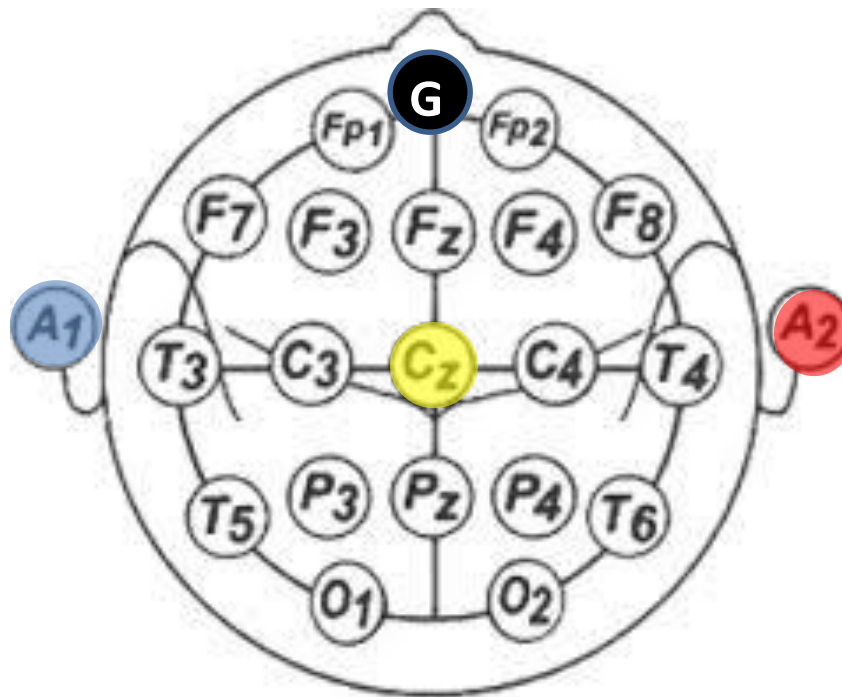
Middle-Late AEPs (<50 ms): **AMLR**



Electrode Montage 1

AMLR, ALR, CERP

(Can see Ear Effects, but not Electrode [laterality] Effects)



Ear Effect, Montage 1

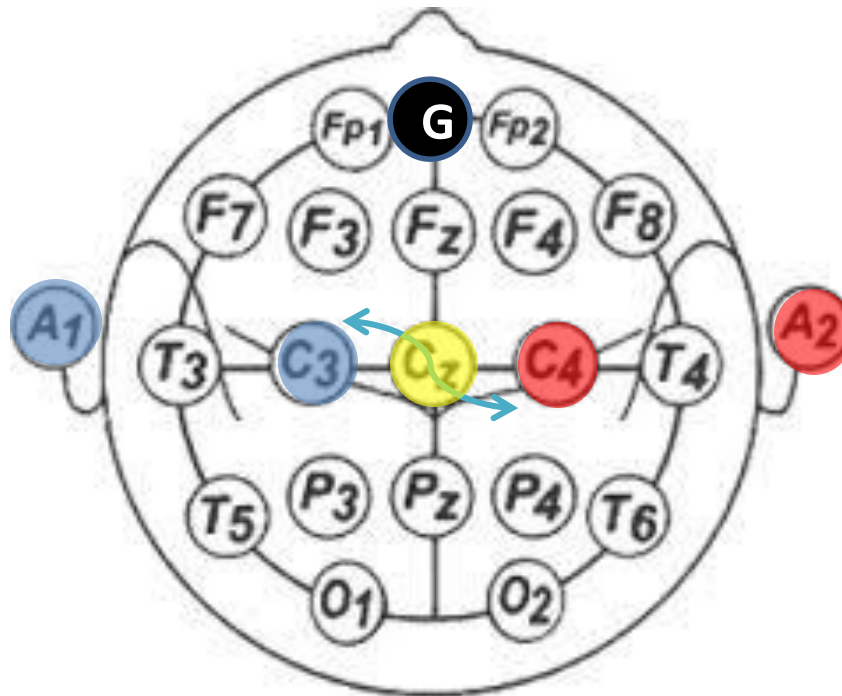
(Possibly Contra to Site of Lesion)



Electrode Montage 2

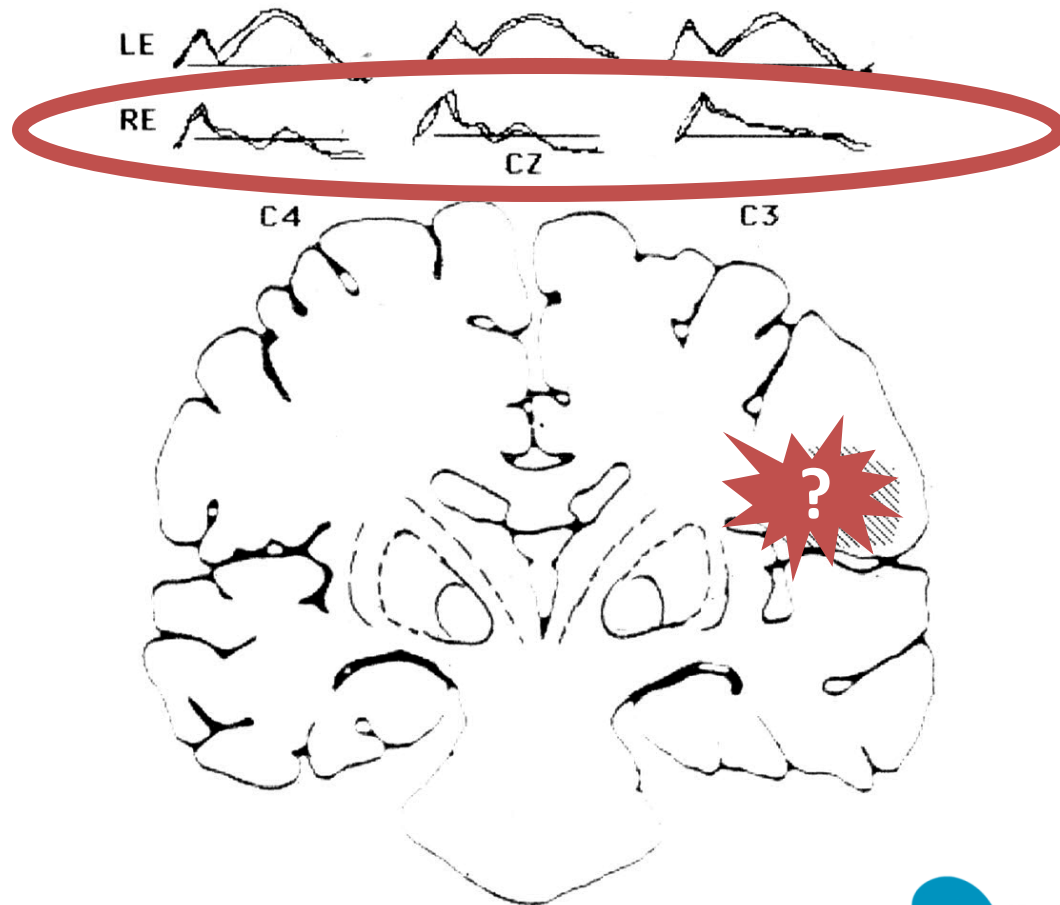
AMLR, CERP

(Laterality: Electrode Effects)



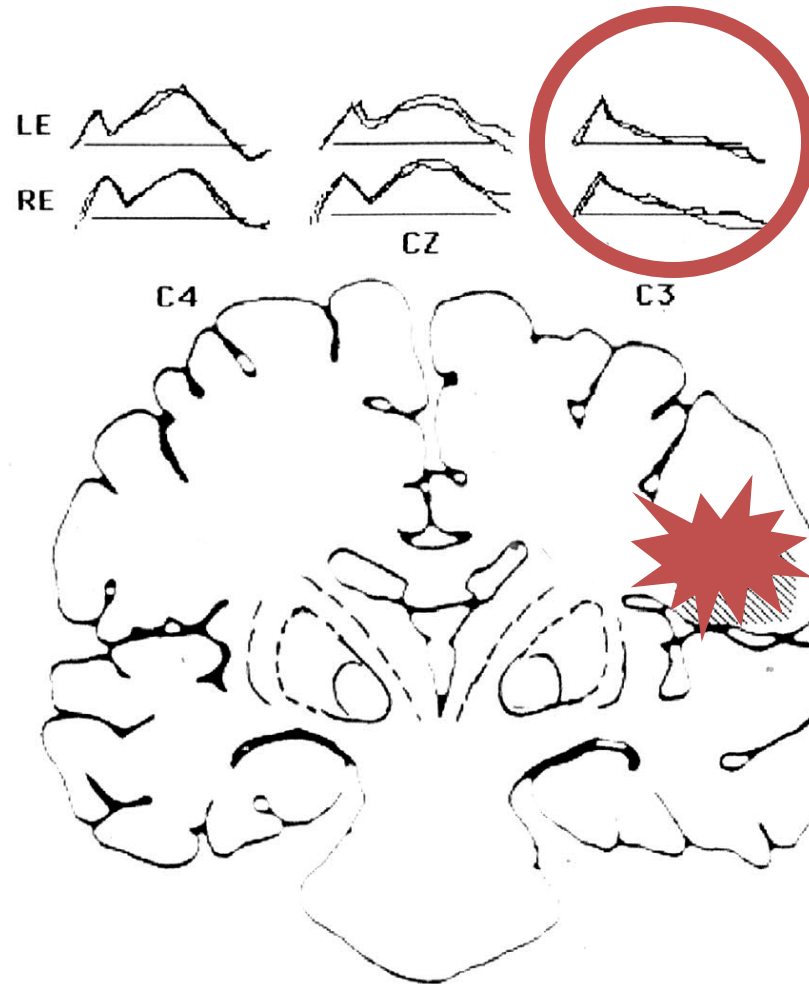
Ear Effect, Montage 2

(Possibly Contra to Site of Lesion)



Electrode Effect (Montage 2)

(Closest to site of lesion)



Middle-Late AEPs (<50 ms): **AMLR**

Advantages & Disadvantages

► **Advantages**

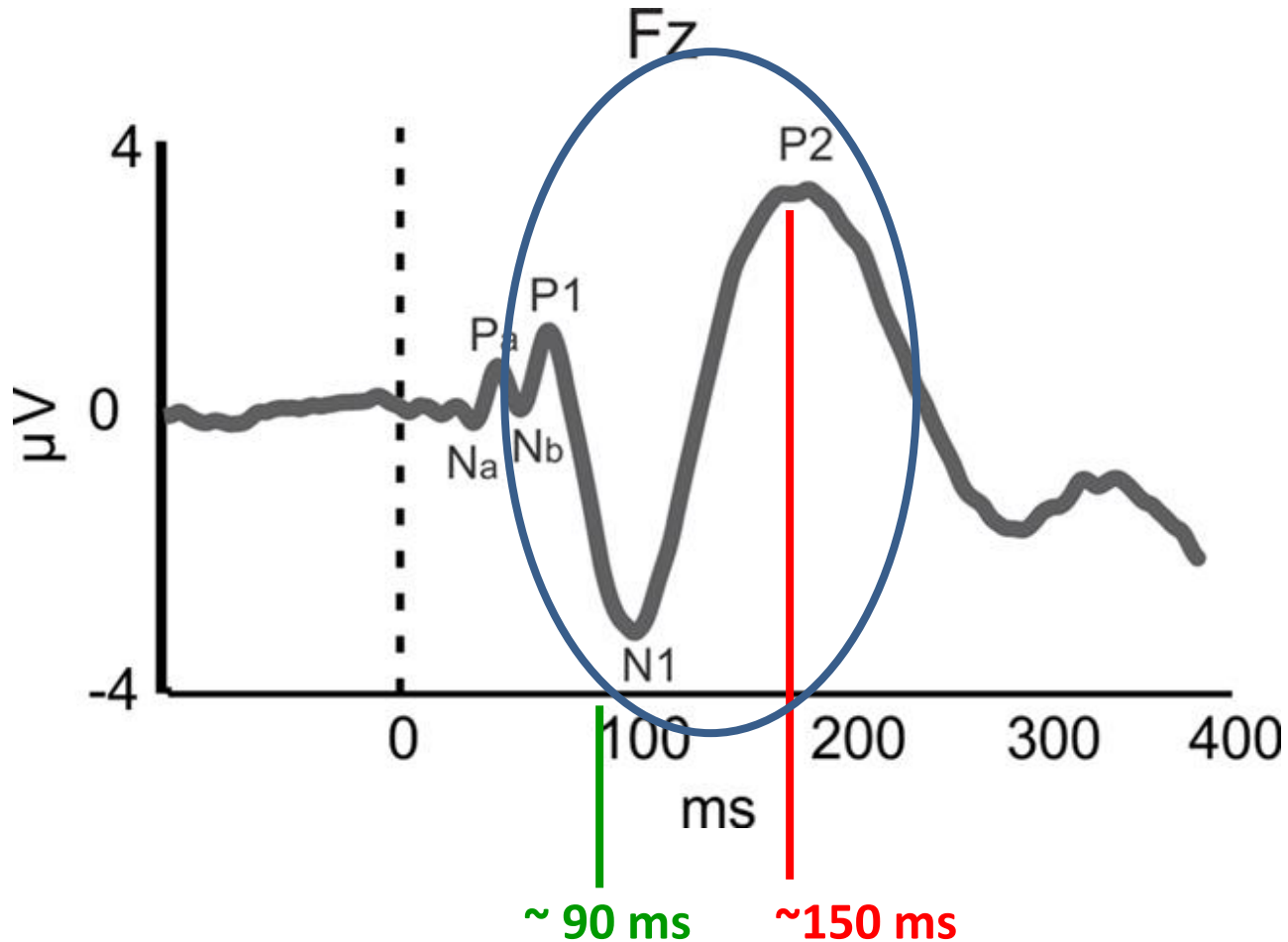
- Accepted test protocols
- Information re: the **thalamocortical pathway & auditory cortex**
- Measurable pre-adolescent (~ 10 years +): **N_a before P_a***
- Non-linguistic
- Can also be used to assess hearing sensitivity
- Usually includes the ABR (esp. Wave V) at beginning of the tracing.

► **Disadvantages**

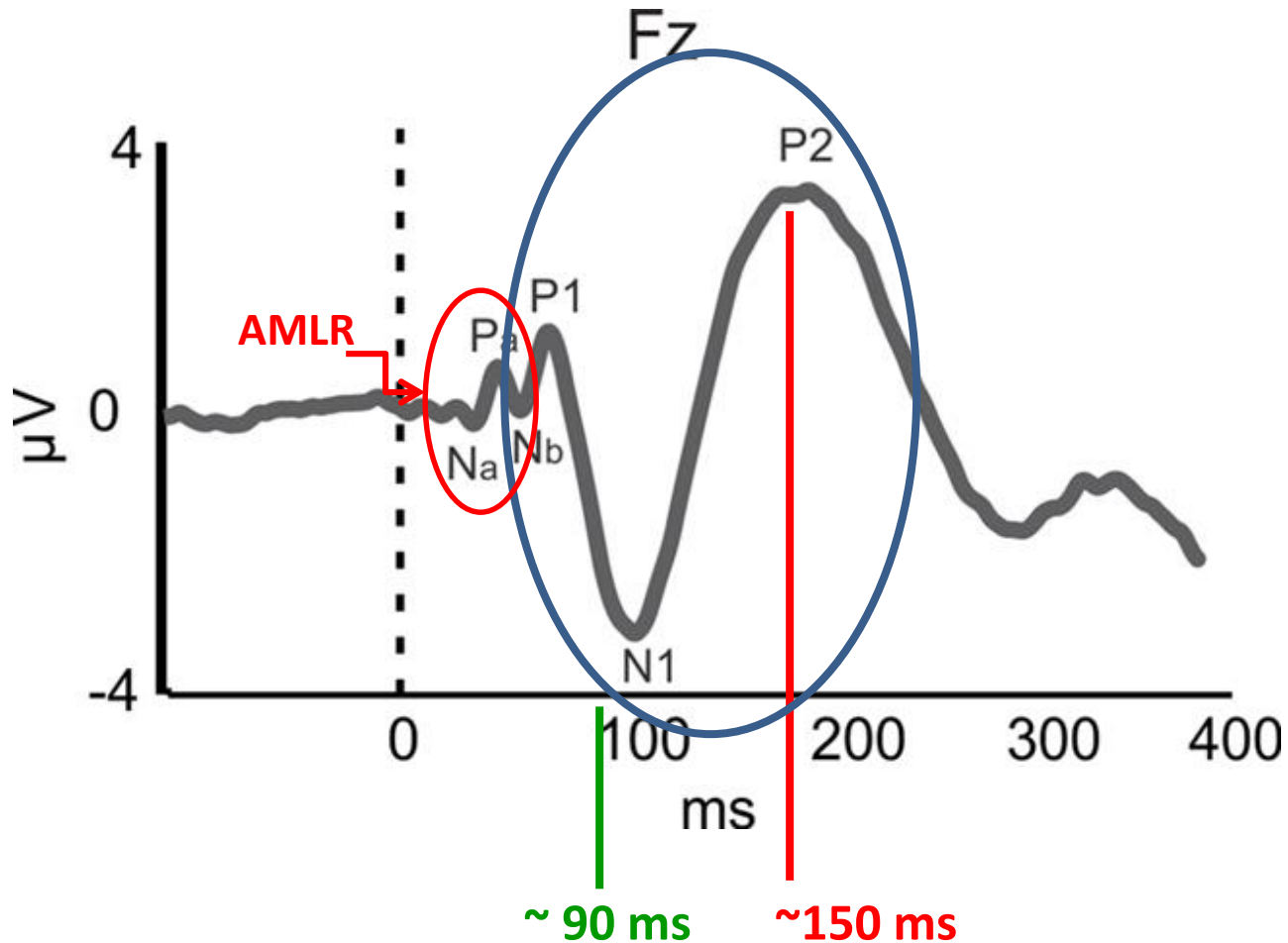
- Cannot always obtain reliable responses in young [<10 yrs.] children *
- Requires multiple electrode placements (for Electrode Ef.)
- State dependent
- Little data on relationship to behavioral APD measures
- Fair/good sensitivity (better if combined with other EPs)
- Noisy (PAM artifact)
- Experience needed

Auditory Late Response

(~50-200 ms): **ALR**



Auditory Late Response (~50-200 ms): **ALR**



Late Response AEPs (~50-200 ms): **ALR**

Advantages & Disadvantages

► **Advantages**

- Accepted test protocol
- Uses Tone Burst (2Khz)
- Information re: the **auditory cortex**
- Measurable pre-adolescent (~ 10 years +): **N₁ before P₂***
- Non-linguistic
- Can also be used to assess hearing sensitivity
- May include the AMLR at beginning of the tracing.
- Stable, clear response

► **Disadvantages**

- Cannot always obtain reliable responses in young [<10 yrs.] children *
- Requires multiple electrode placements (for Electrode Ef.)
- State dependent
- Little data on relationship to behavioral APD measures
- Fair/good sensitivity (better if combined with other EPs)
- Experience needed

(C)ERPS: P300, MMN

(Cochlear) Event-Related Potentials

- (C)ERPs, not to be confused with CE-Chirps!
- State-Dependent
- Endogenous: Cognitive response to external signal task. (MMN: Bridge exo-endo. -“Pre-attentive”
- P300 highly sensitive to attention
- May be affected by eyeblinks.
- Requires oddball paradigm stimulus
- Used in psychiatric applications: Schizophrenia

(C)ERPS

THE ODD-BALL PARADIGM

Stimulus Train

1k

1k

1k

1k

2k

1k

1k

2k

1k

da

da

da

ba

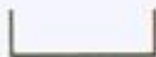
da

da

ba

da

da



1 sec

(C)ERPS

THE ODD-BALL PARADIGM

Stimulus Train

1k 1k 1k 1k ● 1k 1k ● 1k

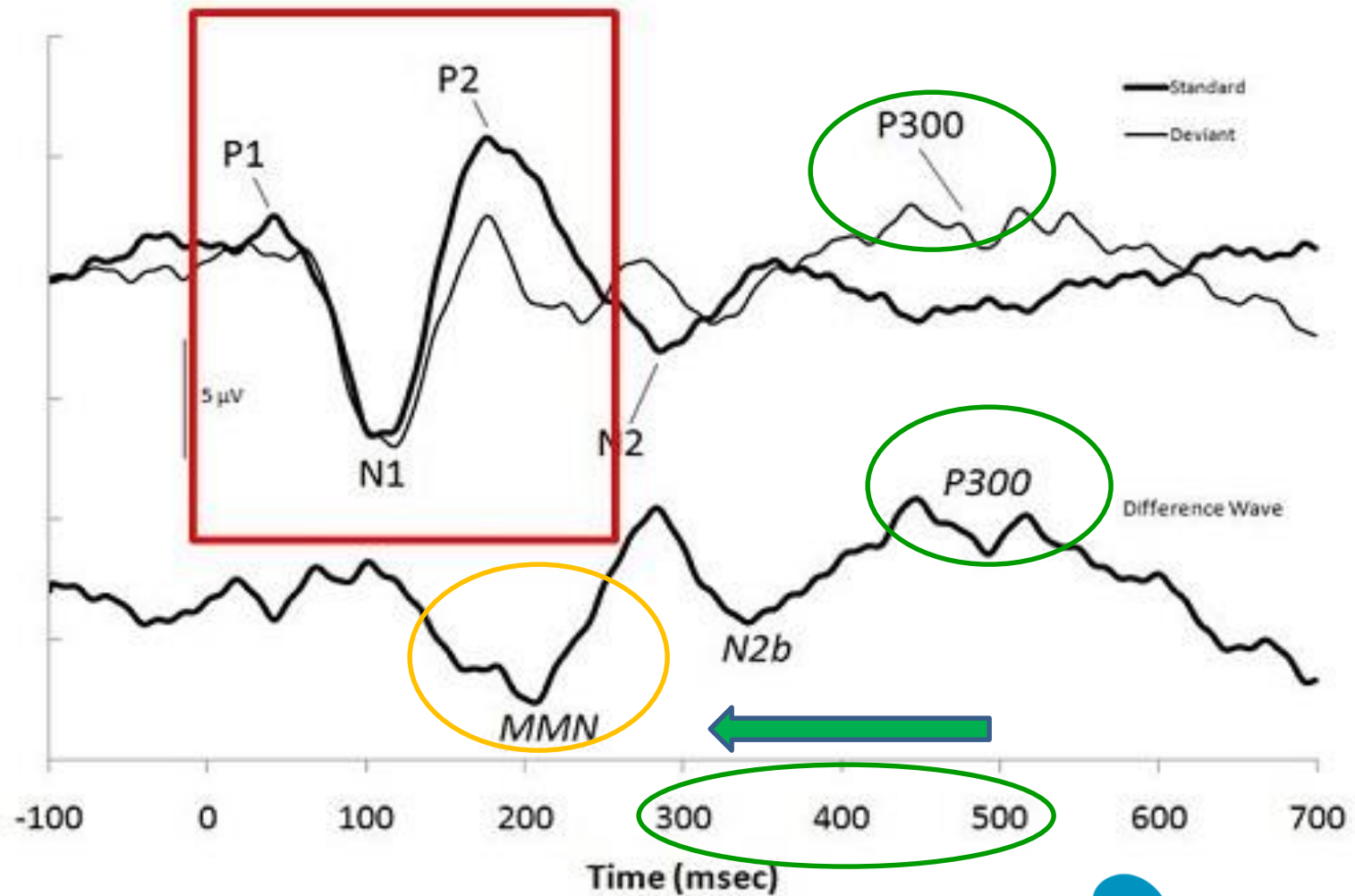
ODDBALL STIMULUS CAN BE A NULL—“ABSENCE”

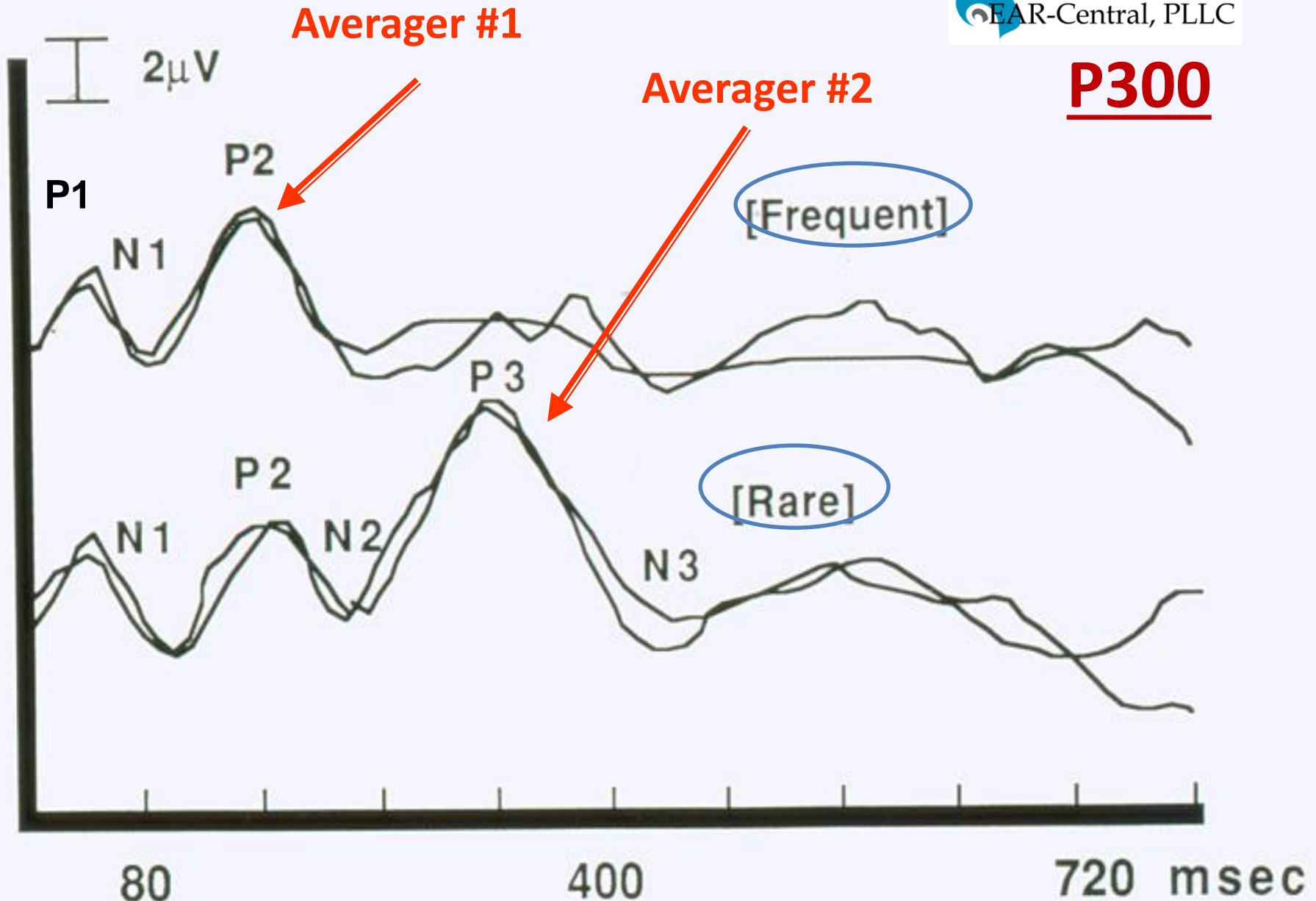
da da da ● da da ● da da

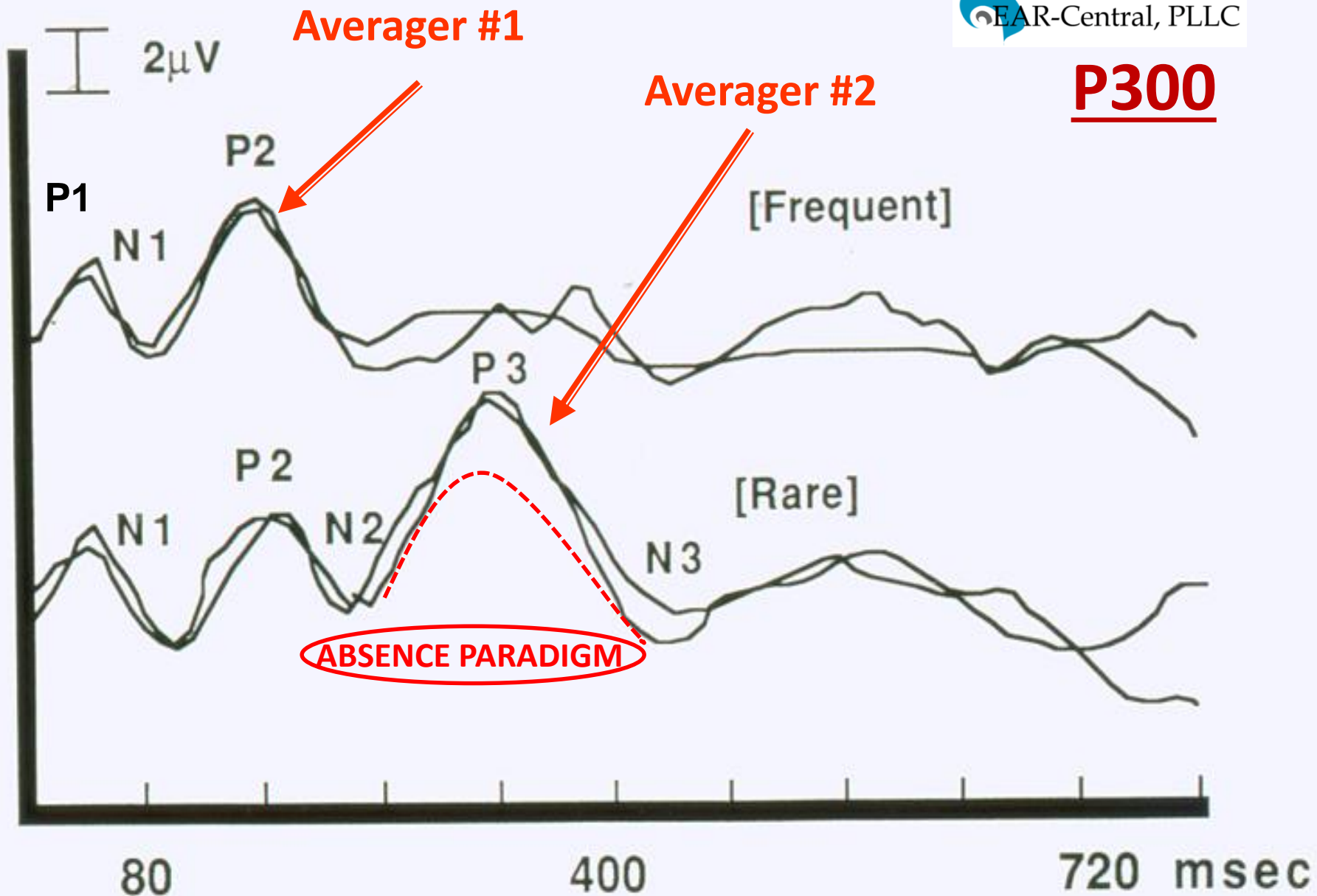


1 sec

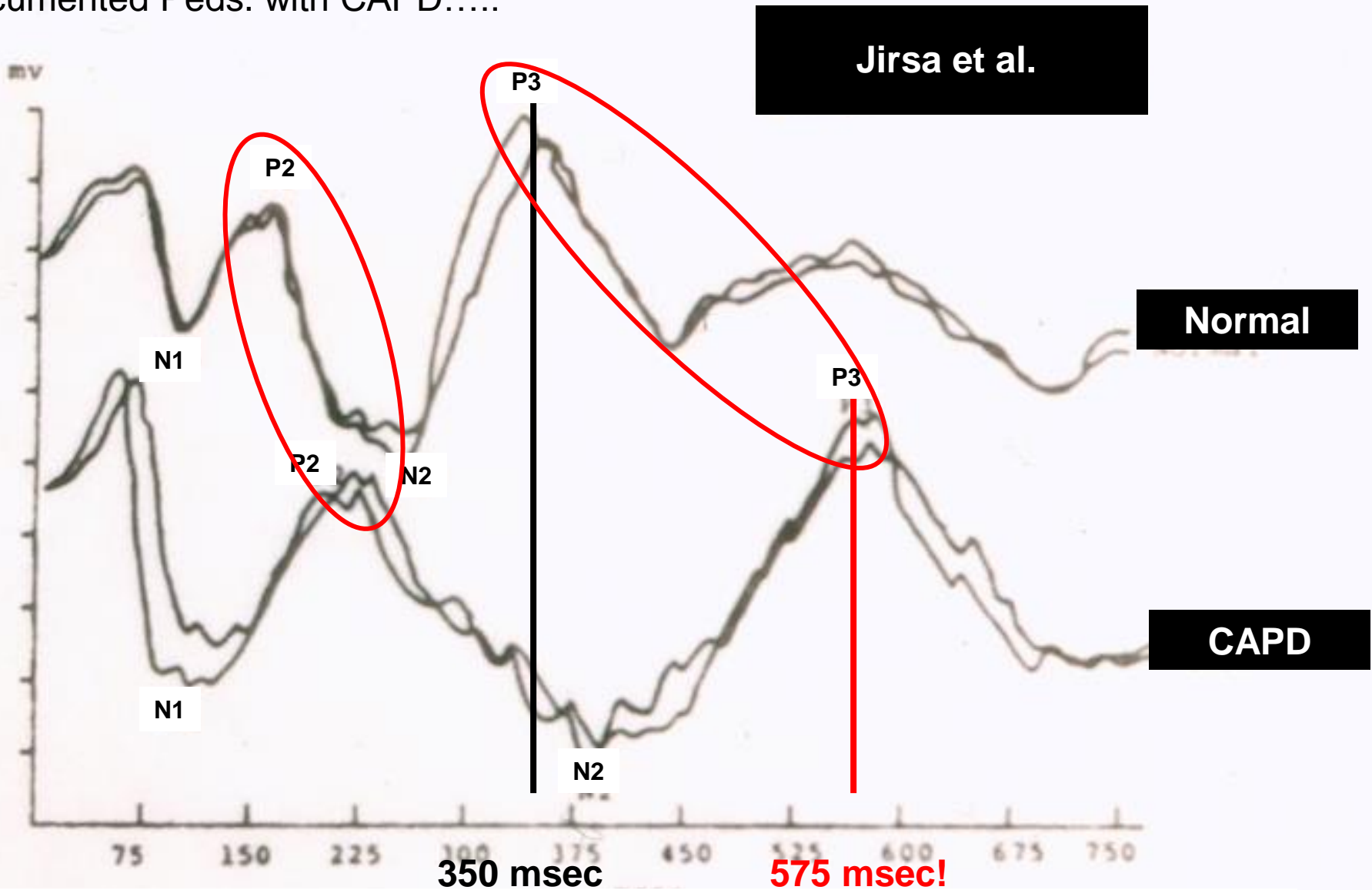
N1-P2, P300, MMN







Documented Peds. with CAPD.....

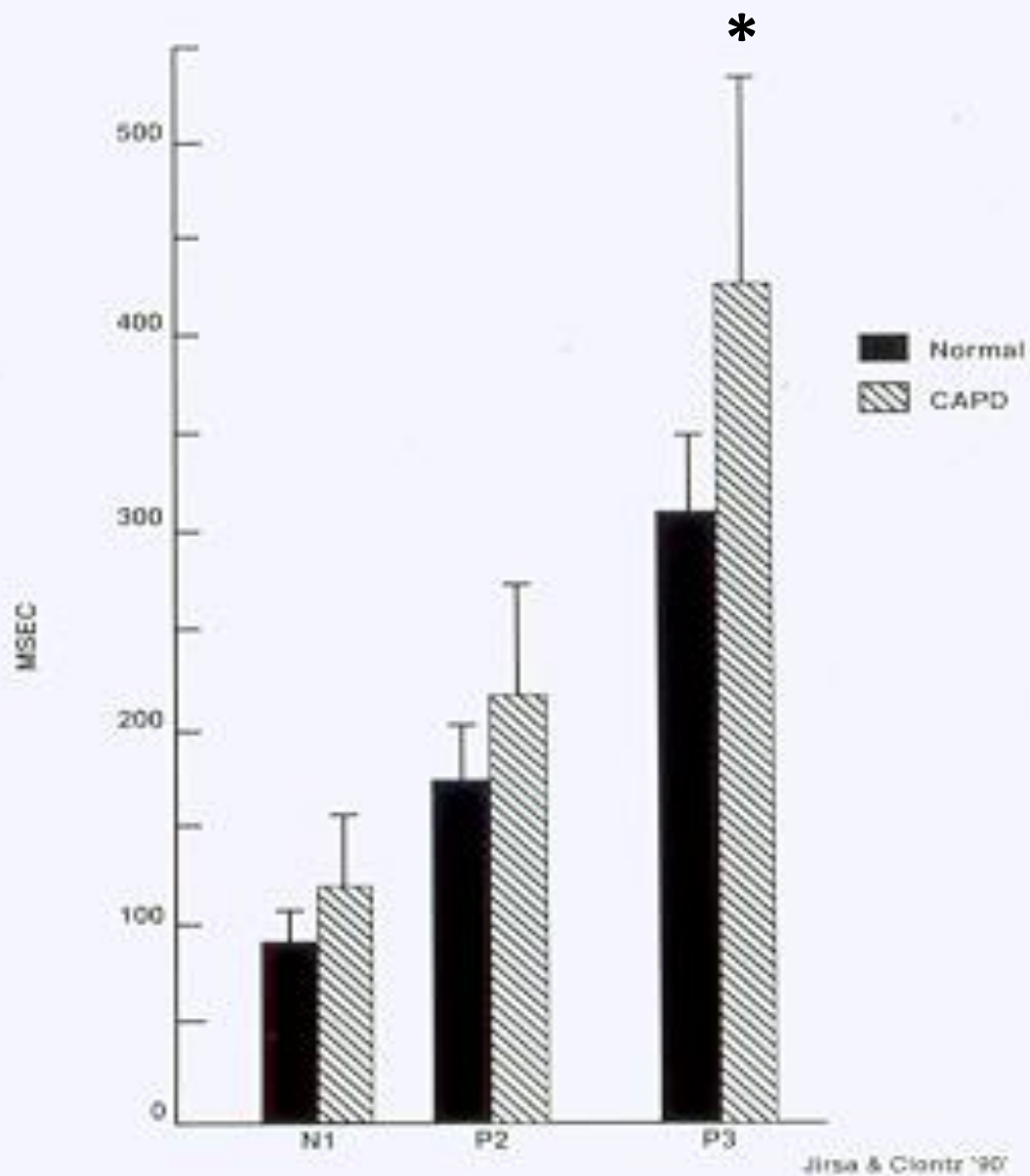


Case illus.



Compliments of Frank Musiek, Ph.D.

LATENCY CAPD VERSUS NORMALS



Compliments of Frank Musiek, Ph.D.

(Mid) Lates Interpretation Review

- AMLR, ALR (N1–P2)

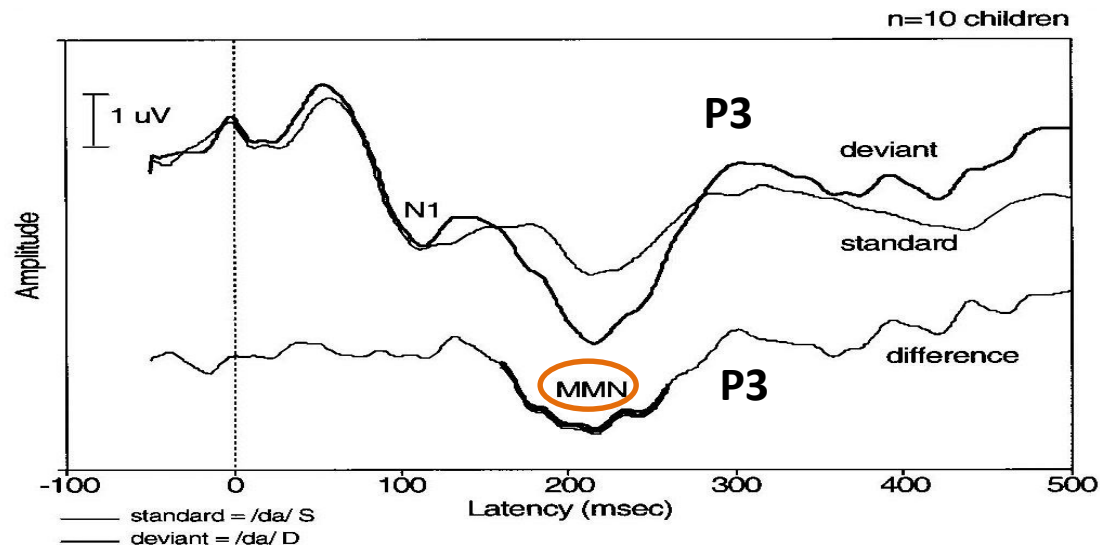
- Presence of a response
- Ear effects
- Electrode effects
- Extended Latencies
- Reduced amplitude

- CERPs: P300 (MMN)

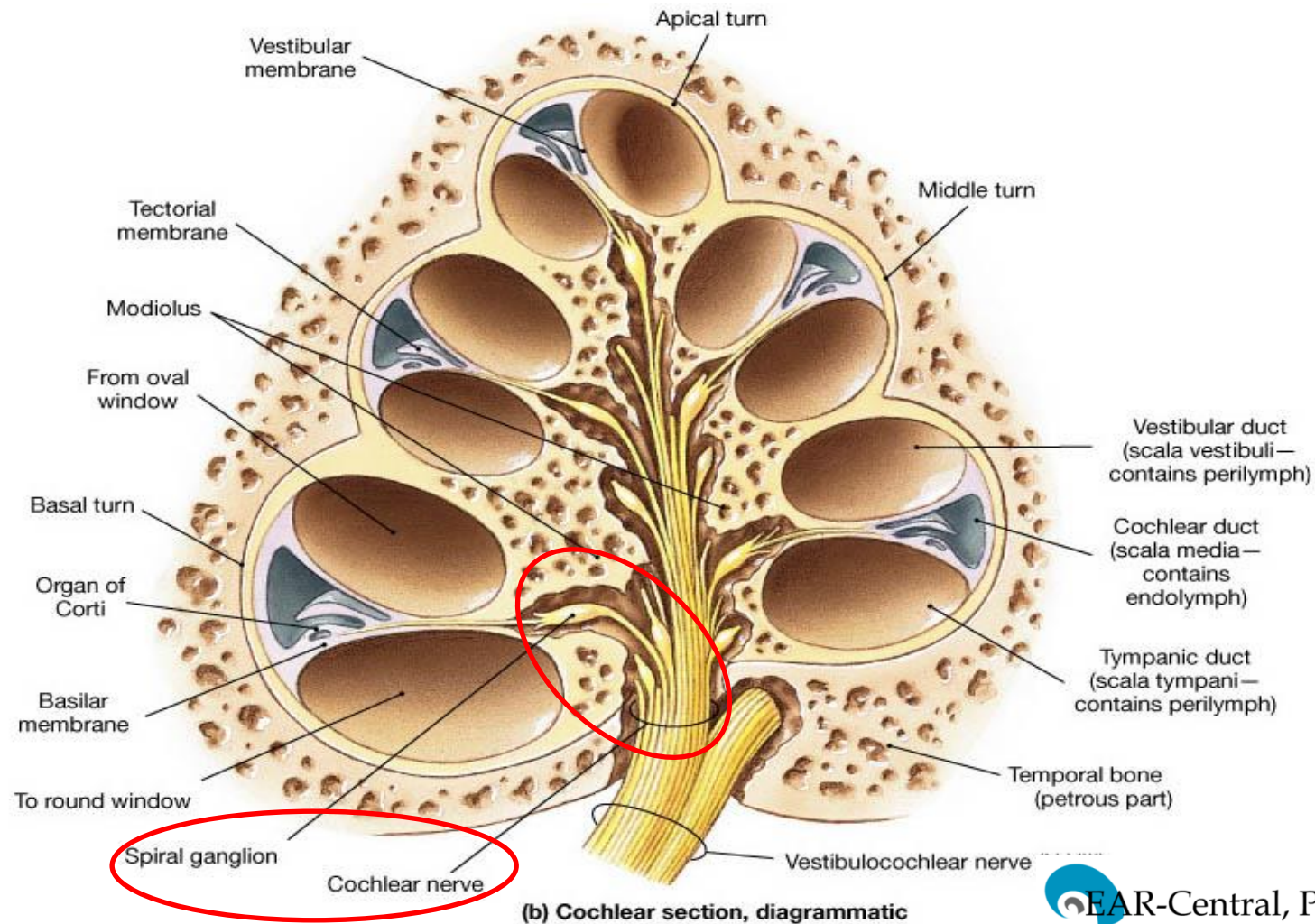
- Presence of a response
- Electrode effect
- Increased latency
- Amplitude measure highly variable (due to focus/attention)

Mismatch Negativity (MMN)

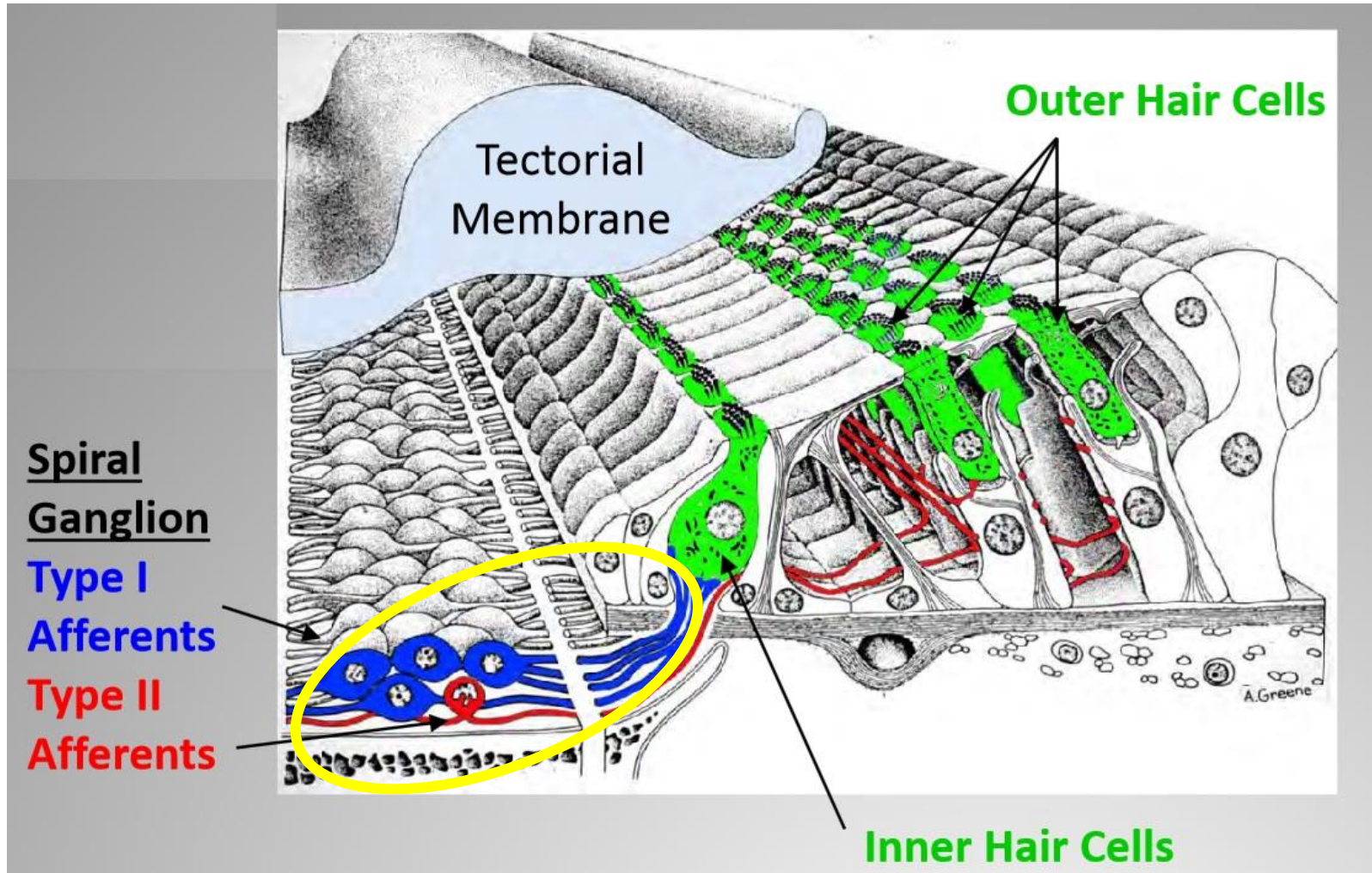
1. Event-Related Potential (Oddball Paradigm)
2. Bridges Exogenous/Endogenous- “Acoustic Change detector” (Kraus). “Pre-attentive.”
3. Negative deflection after N_2 (~ 100-300 ms)
4. Difference curve derived from Rare and Frequent
5. Useful for psychiatric cases (like schizophrenia).
6. Not widely used for clinical auditory purposes.



Auditory Neuropathy Spectrum Disorder (ANSD)



Auditory Neuropathy Spectrum Disorder (ANSD)



Etiological Factors for ANSD:

Genetic 40 % (Sininger, 2002): Non-Syndromic

- Otoferlin protein, critical for IHC synapses > 8th nerve
 - Pejvakin: IHCs, Pillar cells in cochlea and spiral ganglion
 - Diaph₃ gene > autosomal dominant AN.
 - Protein helps maintain cell polarity & shape; post-synaptic dendritic spines. IHC 1st, then OHC
- Profound SNHL by 50-60's.

Syndromic: Charcot-Marie-Tooth; Friedreich's Ataxia
Genetic ANSD is usually progressive

Acquired (perinatal): may be permanent or transient (recovery)

- Prematurity (m= 32 weeks)
- Hyperbilirubinemia

Acquired (misc): Infection, Malign.,
Post-traumatic

Diagnostic Findings for ANSD:

Normal pure-tone thresholds OR mild/severe loss.

Present Otoacoustic Emissions (OAEs)

Abnormal/Absent MEMRs-Ipsi and Contra

Present Cochlear Microphonic (CM) in the ABR (R/C)

Absent/Abnormal ABR response (beyond CM)

MRI / CT frequently normal

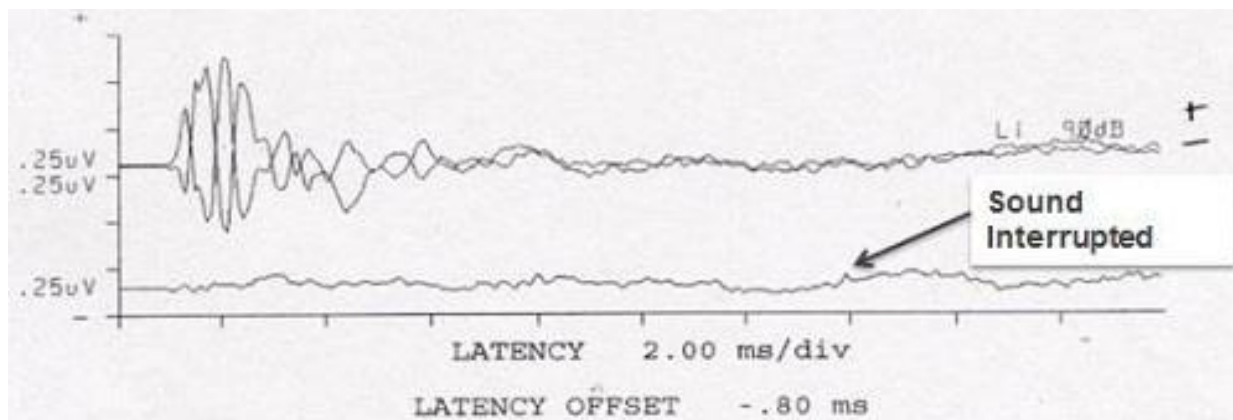
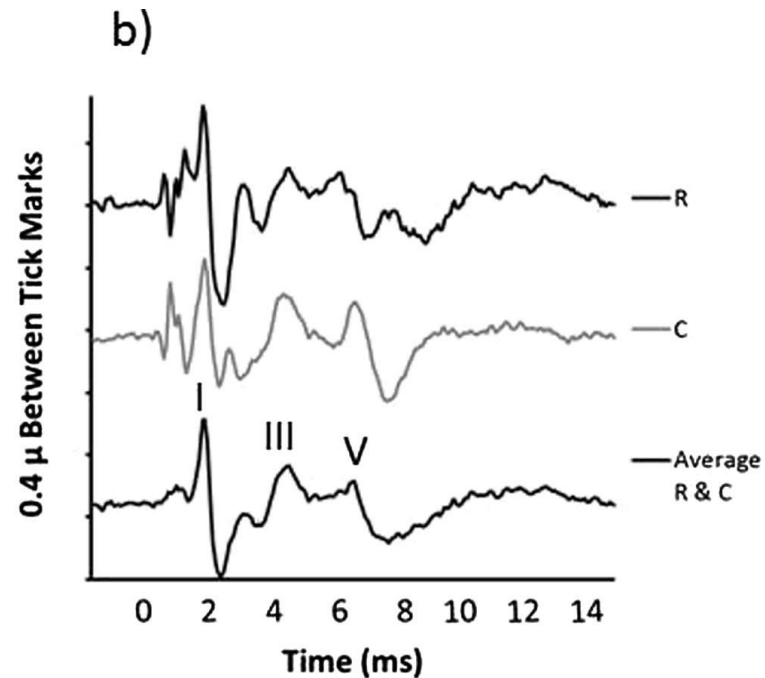
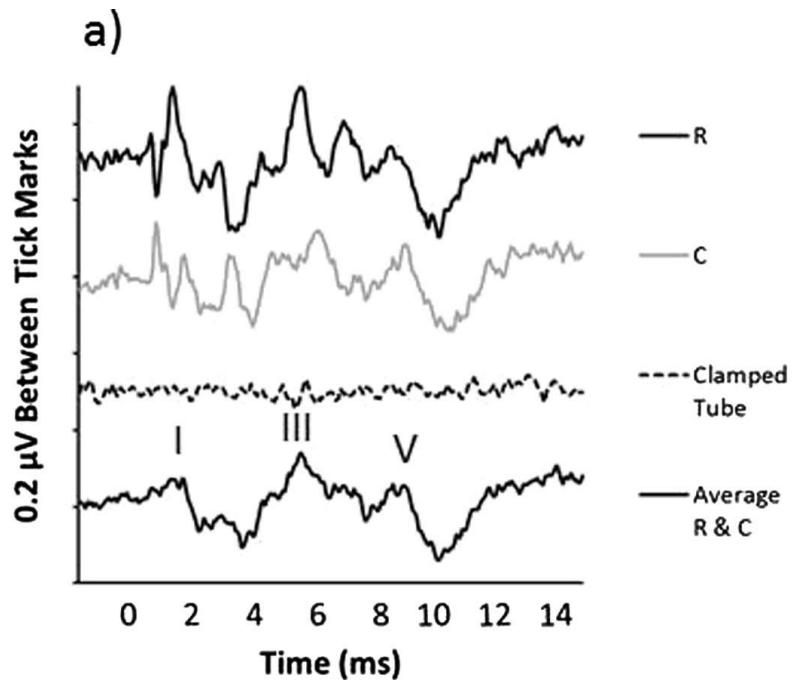
54% Comorbidity with other developmental probs.

(AD[H]D, ASD, Visual, Emotion/Behavior, CP, Seizures, apraxia, ear dysplasia)

Berlin & Hood: RX a Preaudiometric Triage:

Tympanometry, MEMRs, OAEs

ANSD: ABR Findings





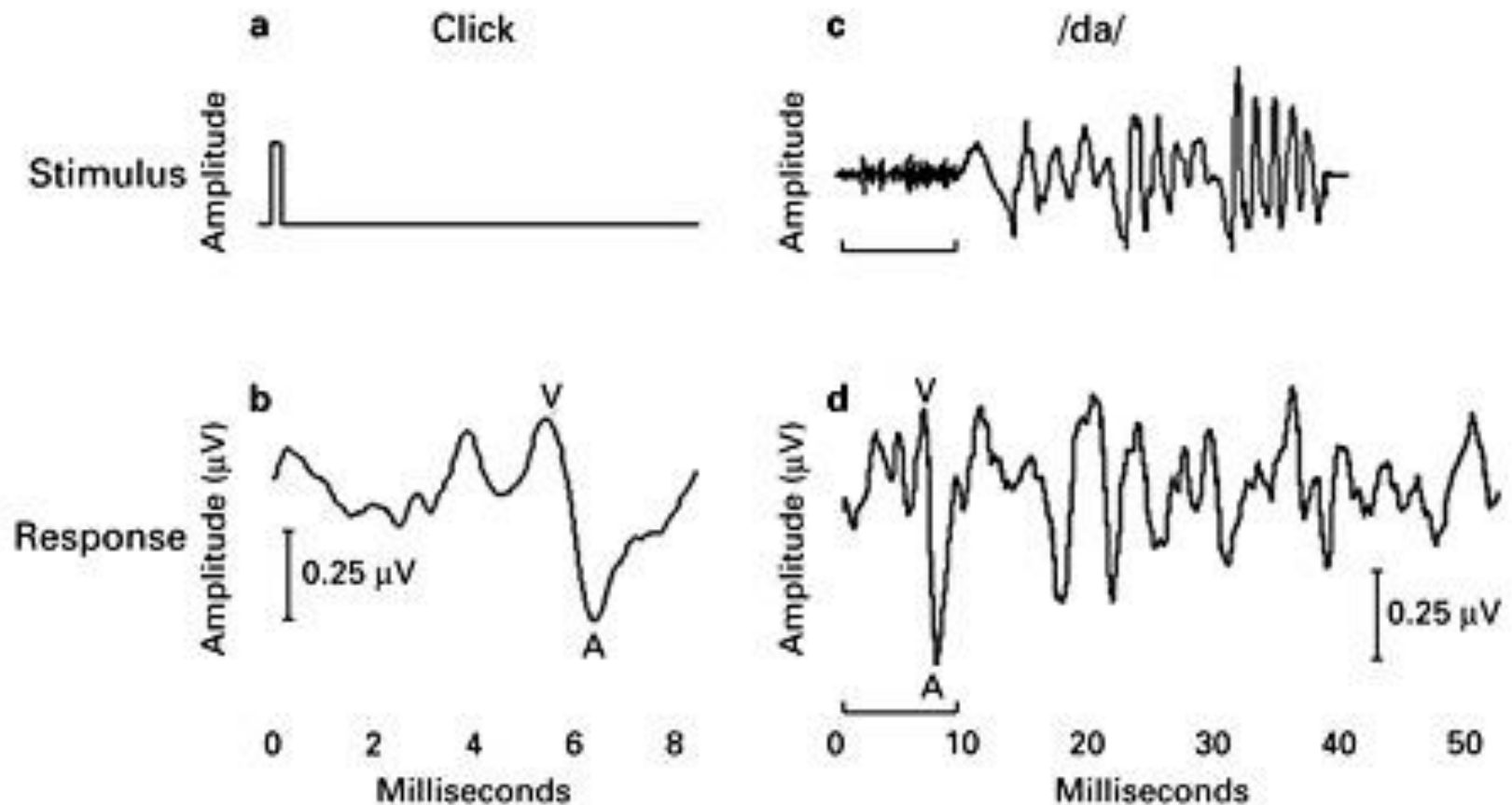
Michael O. Webb, M.S., CCC-A, FAAA /
Neuroaudiology & CAPD Specialist
EAR-Central, PLLC / Hereford, Arizona
mowebb.earc@gmail.com
www.EAR-Central.com

Thanks!



Supplemental Slides.

Complex ABR (e.g., Speech-Evoked)



Complex ABR (e.g., Speech-Evoked)

- Nina Kraus, Ph.D. (Northwestern/ Brainvolts)
- Largely done in research-oriented labs
- Looks at sustained functions, as opposed to instantaneous.
- Complex stimuli, longer time capture
- FFR
- Pre-pub NIH tutorial (Skoe & Kraus) EH, June 10

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2868335/>

Complex ABR (e.g., Speech-Evoked)

