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Non-sedated ABR evaluation

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Vivosonic Inc., Toronto, Canada

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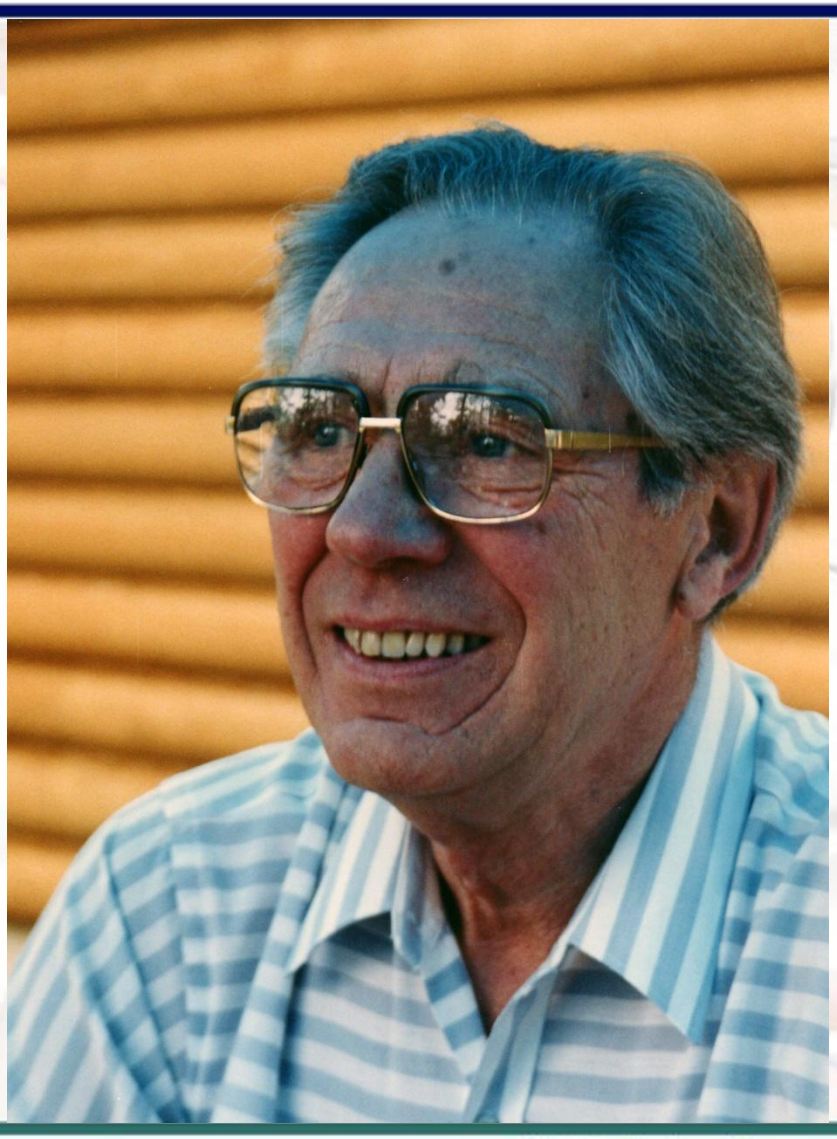
Remembering Prof. Poul Madsen (1923-1997)

Collaboration with Poul Madsen, then an Adjunct Professor at the *Institute of Biomedical Engineering*, University of Toronto, in 1996-1997, led to the development of our technologies.

November 14th, 2007, marked 10 years since Prof. Madsen passed away.

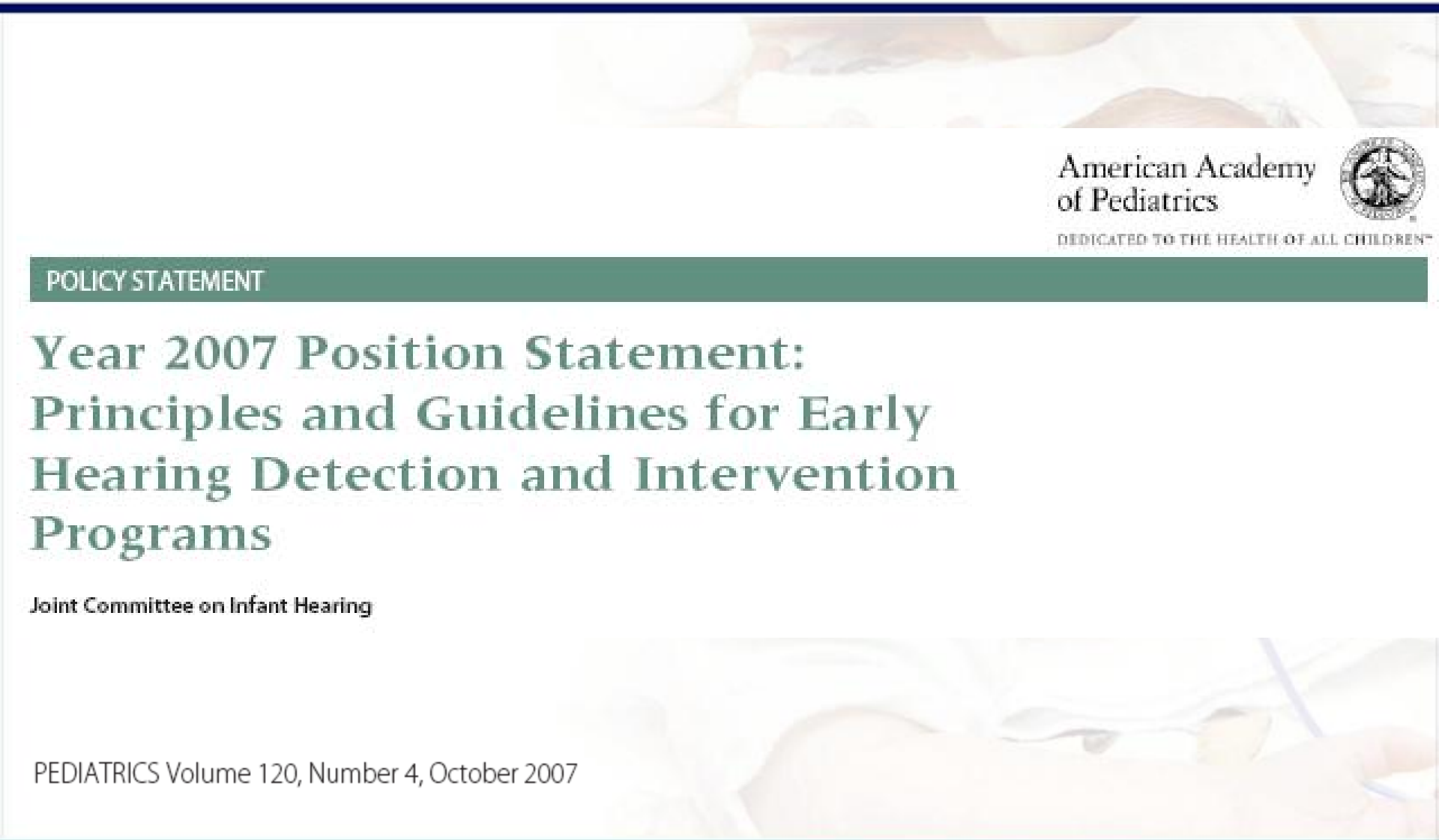
We will always remember Poul's enormous contribution to the field of diagnostic Audiology – Madsen Electronics, the first commercial Impedance and ABR instruments.



Presentation outline

- Year 2007 JCIH Position Statement endorsement of ABR in audiological evaluation of infants
- The problem of noises in ABR: Physiological Artifacts and Extraneous noises in ABR
- Recording technologies reducing artifacts and noises in ABR
- Statistical techniques helping clinicians obtain ABR results
- Sufficiency criteria
- Conclusions
- Questions and answers

The Joint Committee on Infant Hearing (JCIH) released the *Year 2007 Position Statement: Principles and Guidelines for Early Hearing Detection and Intervention Programs* in October 2007



http://aappolicy.aappublications.org/cgi/reprint/pediatrics;120/4/898.pdf

Year 2007 JCIH Position Statement endorsed ABR, OAE, and 1000 Hz probe-tone tympanometry for evaluation at age 0-6 months

Audiological assessment from **birth to 6 months** of age should include:

- Child and family history.
- **Frequency-specific ABR** with **air-conducted** and **bone-conducted tone bursts** – to determine the degree and configuration of HL in each ear for fitting of amplification devices.
- **Click-evoked ABR** with **condensation** and **rarefaction** polarity stimulus if there are indicators of neural HL – to determine if a cochlear microphonic is present, and all infants who demonstrate “no response” on tone-burst ABR.
- DPOAE or TEOAE.
- Tympanometry with 1000-Hz probe tone.
- Clinical observation of auditory behavior, which alone is not adequate for determining the presence of hearing loss and fitting of amplification devices.

Year 2007 JCIH Position Statement endorsed confirmatory audiological test battery at age 6-36 months

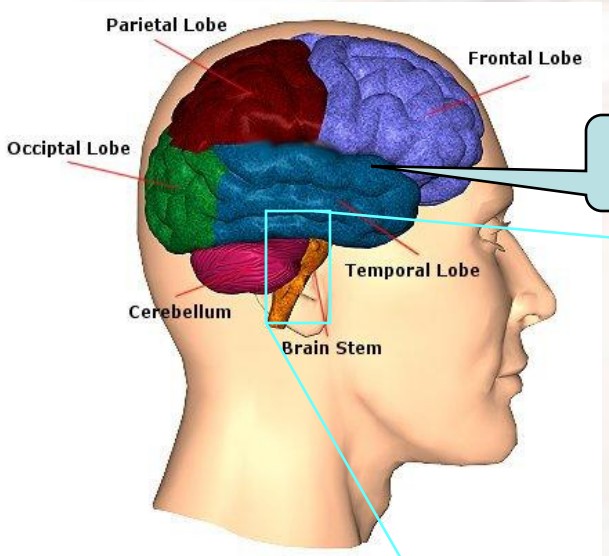
For subsequent testing of infants and toddlers at **6 – 36 months** of age the confirmatory test battery includes:

- Child and family history.
- Parental report of auditory and visual behaviors and communication milestones.
- Behavioral audiometry (visual reinforcement or conditional-play) – pure-tone and speech-detection and –recognition measures.
- OAE.
- Acoustic immittance (tympanometry and acoustic reflex).
- **ABR** if **responses to behavioral audiometry are not reliable** or if **ABR testing has not been performed in the past**.

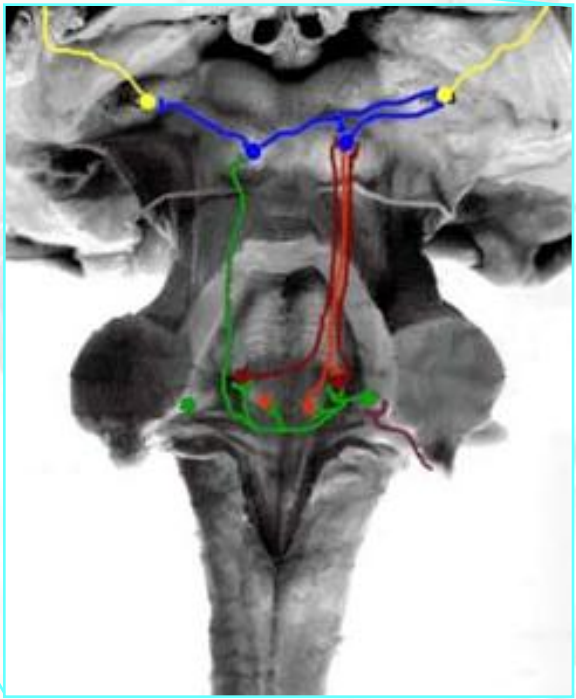
ABR originates from the Auditory **Neural** System

Auditory Evoked Potentials (AEPs)
Any electrical potential that is produced by the auditory system and that can be recorded *in vivo*, mostly from the scalp.

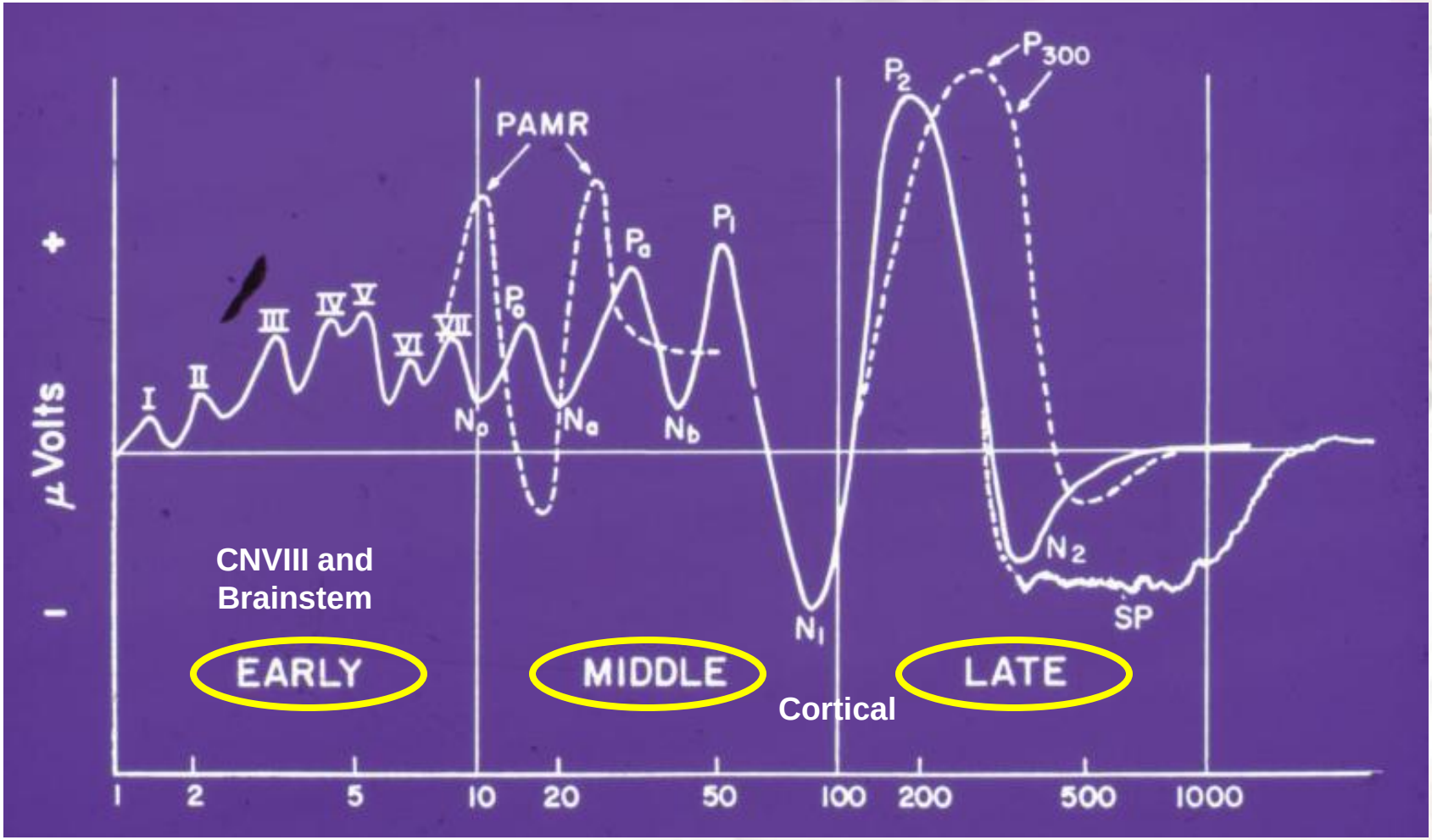
Auditory Brainstem Response (ABR)
Generated by the Auditory Nerve (Cranial Nerve VIII) and ascending auditory pathways of the brainstem.



Auditory cortex

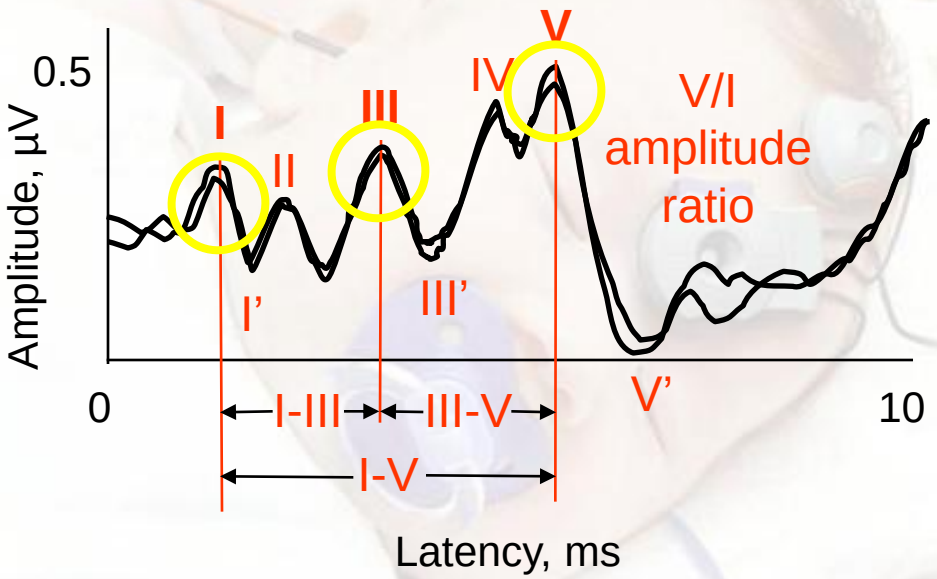


ABR is the *earliest* and *smallest* Auditory Evoked Potential



Diagnostic use of ABR requires clear wave *morphology* at higher stimulus levels (80-90 dB nHL)

- Response is generated by Acoustic Nerve and Brainstem nuclei
- Characteristic wave morphology with known generators
- Stimulus: Click 80-90 dB nHL
- ABR is a composite of synchronous responses of a large number of neurons
- Elicited by the stimulus onset, unlike pure tones (PT), hence, PT & ABR may disagree (as in Auditory Neuropathy)
- Diagnostic value:
  - Latencies of Waves I, III, V
  - I-III, III-V, I-V intervals
  - V/I amplitude ratio
- Has established level-specific latency norms for Waves I, III, and V – for various age groups, from newborns through adults



NOTE:

Microvolt (µV) – one millionth of a Volt

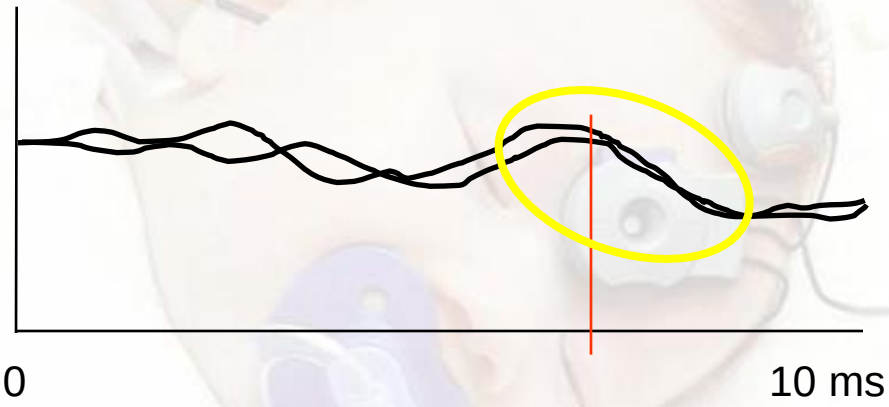
Millisecond (ms) – one thousandth of a second

Latency – time after stimulus onset

Multiple publications by J. Hall III, L. Hood, D. Stapells, and others.

Hearing threshold estimation with ABR is based on finding the *lowest stimulus level* at which a *RESPONSE* is detectable

- **Established relationships between ABR and pure-tone (PT) thresholds**
- **Well researched, established and recommended protocols**
- **Frequency-specific**
- **Stimuli are tone bursts rather than click stimuli: typically 500, 1000, 2000, 4000 Hz (needed for HA fitting)**
- **Levels vary to find the threshold**
- **Looking for Response threshold**
- **Approx 10-20 dB higher than pure-tone HL and 10-15 higher than click HL**
- **Technically similar to screening click-ABR, but stimulus levels vary**
- **Detect thresholds up to 80-90 dB HL**
- **Applications**
  - **infant post-screening assessment**
  - **non-cooperative or difficult-to communicate patients: malingerers, language barrier**



CLINICAL NOTE:

In retro-cochlear pathology, Wave V may be absent and thus cannot be used for threshold estimation. Therefore, frequency-specific threshold estimation based on Wave V latency is meaningful only if Wave V is present in diagnostic click ABR

Multiple publications by Jay Hall III, Yvonne Sininger, David Stapells, and others.

Common technique to recognize ABR is repeating the test (or recording in 2 memory buffers) and inspect for visible repeatability

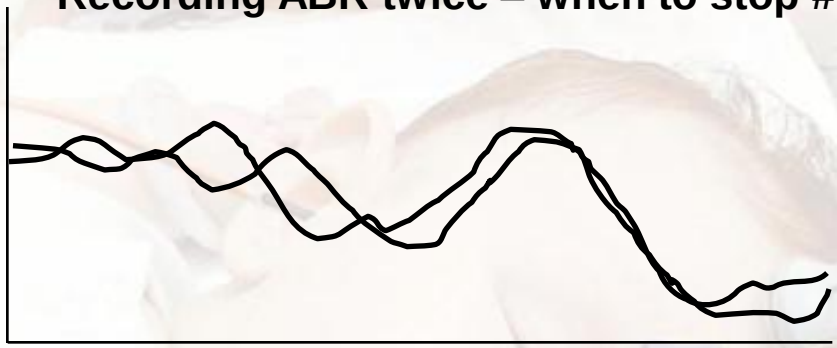
- *"If it doesn't replicate, you must investigate…"*

  Dr. Jay Hall III, Ph.D.

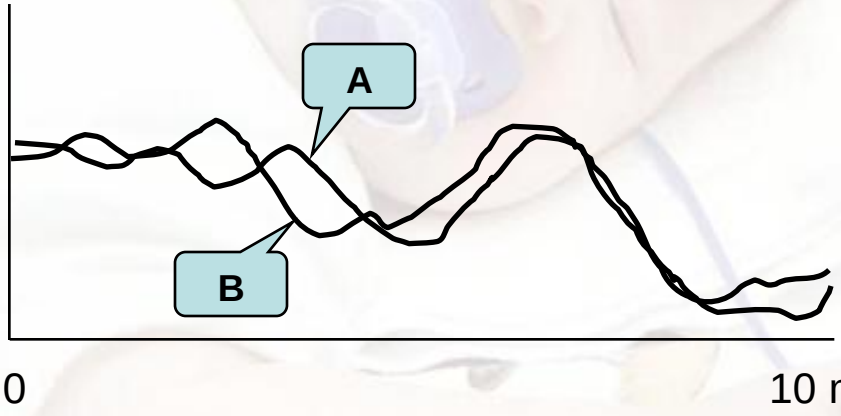
- **Problem with "repeating": you DON'T know whether the first waveform is "good enough" will be repeatable, i.e. you don't know when to stop averaging trace #1, while "standard" 2000 may not be enough if ABR is very small (like near threshold) or if noise is very high.**

- **Recording in A & B memory buffers saves time, as repeatability can be checked in real time while running a single test. Particularly, this is important when the two tests do not repeat requiring more runs**

Recording ABR twice – when to stop #1?



Recording ABR in 2 memory buffers – A & B



Clinicians experience significant frustrations with ABR

ABR is often difficult to administer for many clinicians, particularly in harsh clinical environments such as NICU, hospital floor, doctor's office, and Operating Room (OR):

- **Noise is reported by 84 % of U.S. clinics as their FRUSTRATION # 1*)**
- **Noise artifacts lead to unclear results and long test times – up to 90-120 min, typically 45-60 min per test**
- **Long test time results in low patient throughput and difficulty of intra-operative monitoring**
- **Abrading the skin, to reduce impedance, increases the risk of infection **)**
- **The above factors result in higher risks of misdiagnosis, infection, and operating costs, and reduce diagnostic value of ABR, particularly in medium and small clinics and private practices that do not have shielded rooms and sedation facilities**

*) Tannenbaum (2005). **) Ferree et al. (2001)

Physiological artifacts and extraneous contaminate ABR signal

Physiological *artifacts* – from the patient

- ***Brain (EEG)***
- ***Eyes* (EOG)**
  - **Electric dipole movements (ENG) – very large**
  - **Ocular muscles (EMG)**
- ***Skeletal* muscles (EMG)**
- ***Heart (mostly in infants) (ECG or EKG)***

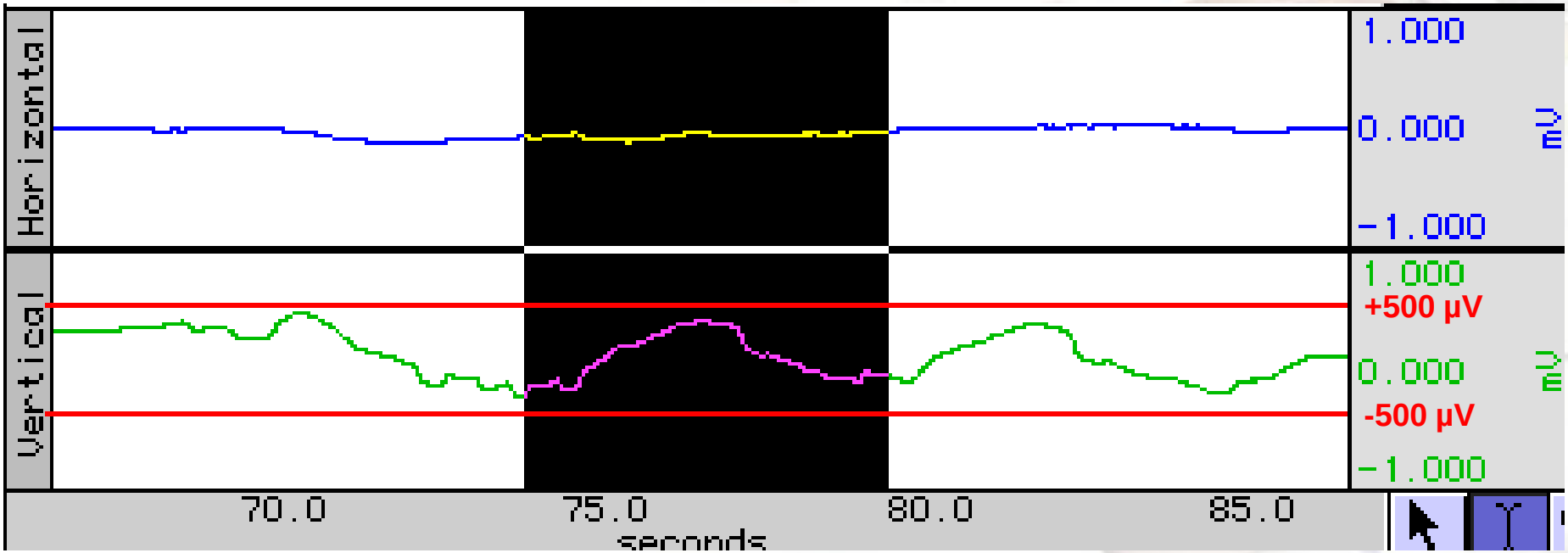
Extraneous *interferences* – from outside the patient

- ***Electric and magnetic field-induced interferences***
  - **Electric field-inducted noise (EF)**
  - **Magnetic field-induced noise (MF)**
- ***Radio-frequency interferences (RF)***
- ***Conducted power-line noise: 50 or 60 Hz and their harmonics***

PHYSIOLOGICAL ARTIFACTS

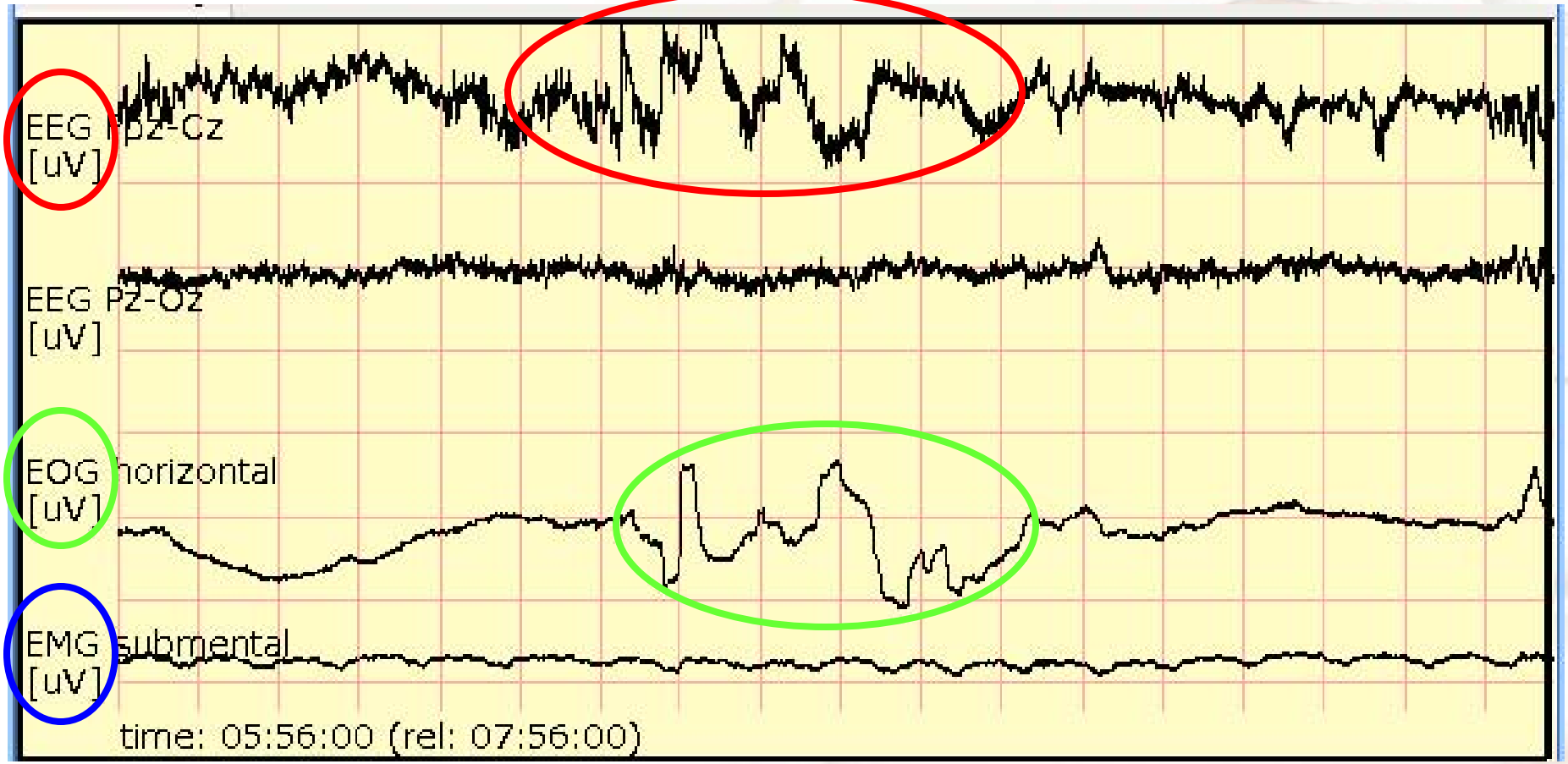
are coming from the patient, independent from the environment, and thus cannot be “shielded”

Ocular motions may introduce very large low-frequency electric artifacts (EOG) – up to ±500 µV



Source: http://www.biopac.com/lesson.cgi?action=view&item=STUDENT_LAB%3A10

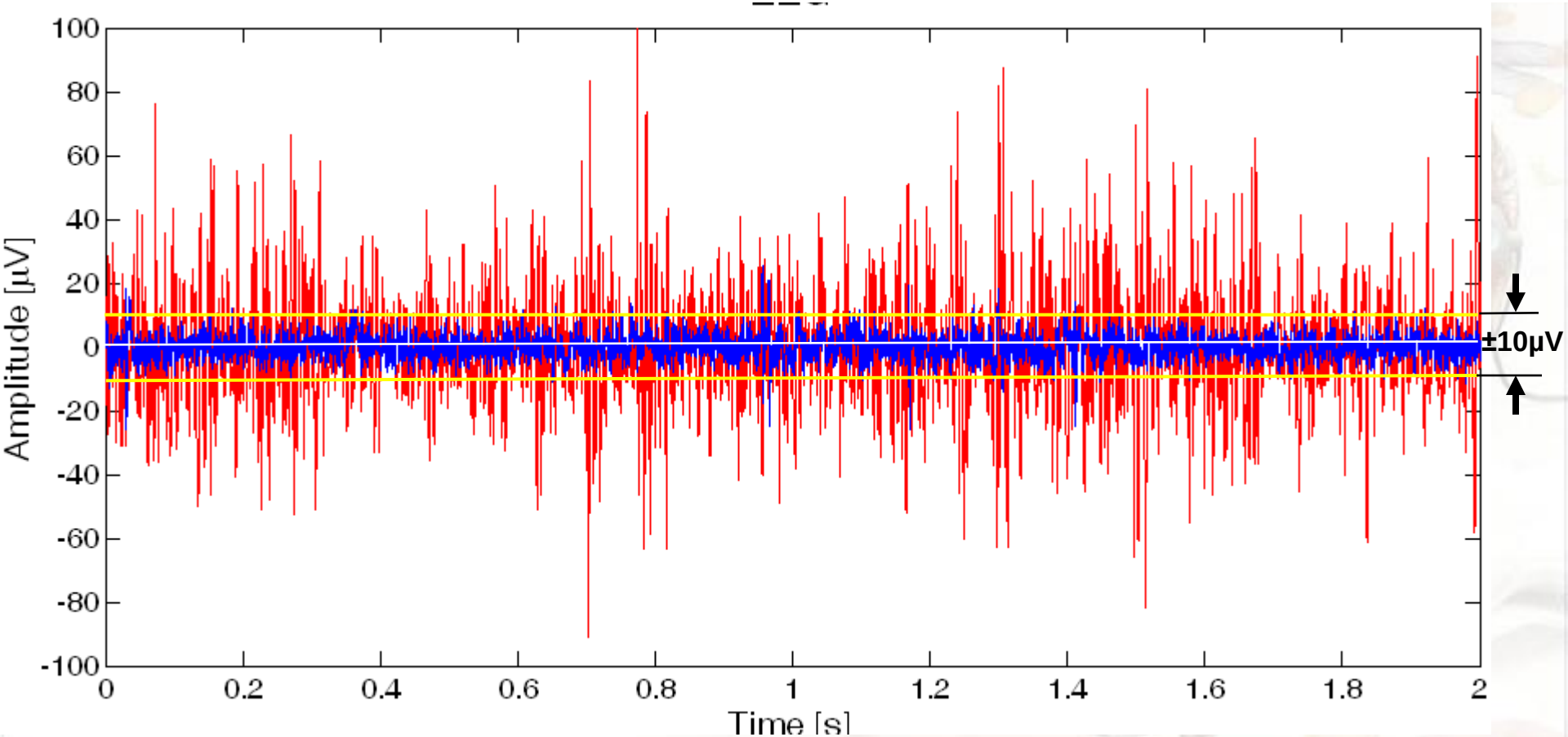
Even in sleep, when EMG is low, EEG and EOG may introduce very large low-frequency artifacts



Source: http://www.neurotraces.com/InPractice/sounds00/node6.html

Myogenic (muscle) artifacts largely contaminate EEG in ABR recording during muscular activity

EEG samples in ABR recording from an adult subject

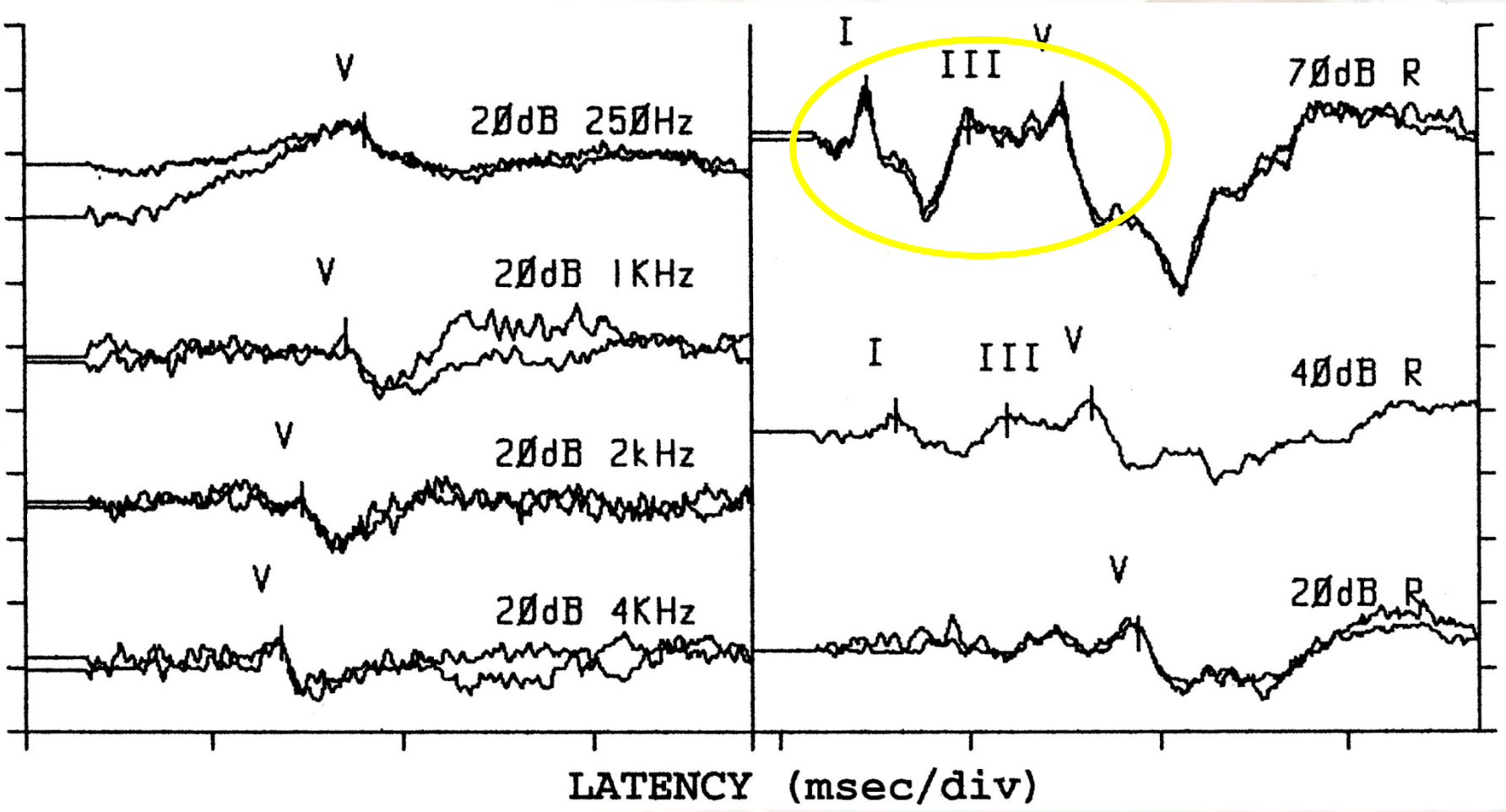


Blue – sitting still. Red – sitting and suckling water from a "sports" bottle.
ABR stimulus: 70 dB nHL click, repetition rate 33.8/s

Experiment conducted by: Kurtz, Steinman (2006).

Conventional ABR recordings often do not allow high accuracy of peak latencies even in normal-hearing subjects

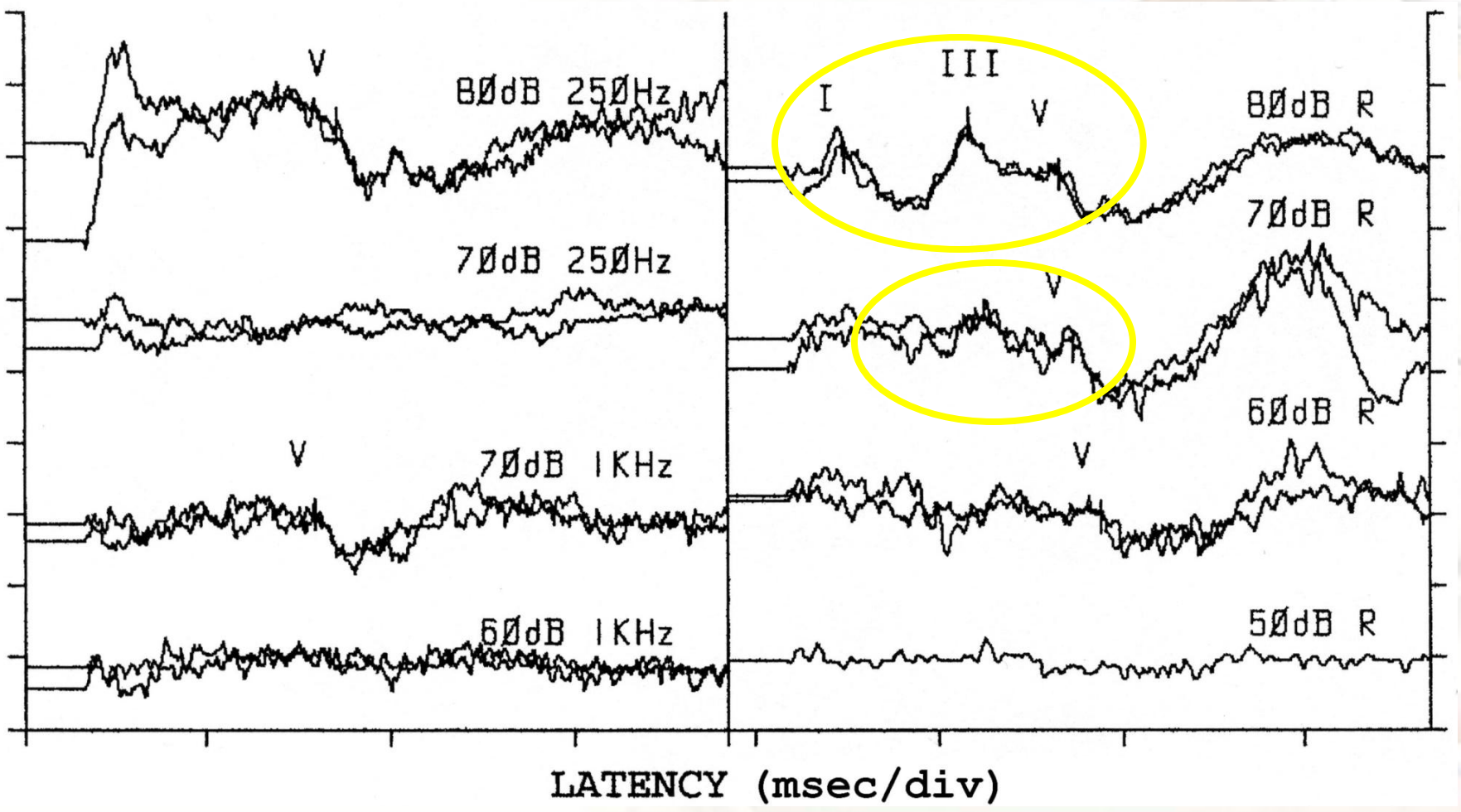
Example of tone-burst and click-ABR from a normal-hearing subject



Source of image: Gorga et al. (2006)

Even lower accuracy of ABR is often observed in hearing-impaired patients, which makes applying norms difficult

Example of tone-burst and click-ABR from a hearing-impaired patient



Source of image: Gorga et al. (2006)

ABR tests in pediatric patients often require sedation or anesthesia which need special monitoring and management

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Guidelines for Monitoring and Management of Pediatric Patients During and After Sedation for Diagnostic and Therapeutic Procedures: An Update

American Academy of Pediatrics, American Academy of Pediatric Dentistry, Charles J. Coté, Stephen Wilson and the Work Group on Sedation

Pediatrics 2006;118;2587-2602
DOI: 10.1542/peds.2006-2780

PEDIATRICS Volume 118, Number 6, December 2006

http://aappolicy.aappublications.org/cgi/reprint/pediatrics;118/6/2587.pdf

AAP Guidelines: Sedation and anesthesia impose serious risks on the child

Sedation of pediatric patients has serious associated risks, such as hypoventilation, apnea, airway obstruction, laryngospasm, and cardiopulmonary impairment.[2,6,22,45,46,54,60–69] These adverse responses during and after sedation for a diagnostic or therapeutic procedure may be minimized, but not completely eliminated, by a careful preprocedure review of the patient's underlying medical conditions and consideration of how the sedation process might affect or be affected by these conditions.[54] Appropriate drug selection for the intended procedure as well as the presence of an individual with the skills needed to rescue a patient from an adverse response are essential. Appropriate physiologic monitoring and continuous observation by personnel not directly involved with the procedure allow for accurate and rapid diagnosis of complications and initiation of appropriate rescue interventions.[46,51,54]

NEW ABR TECHNIQUES:
Recording in non-sedated patient in any clinical environment

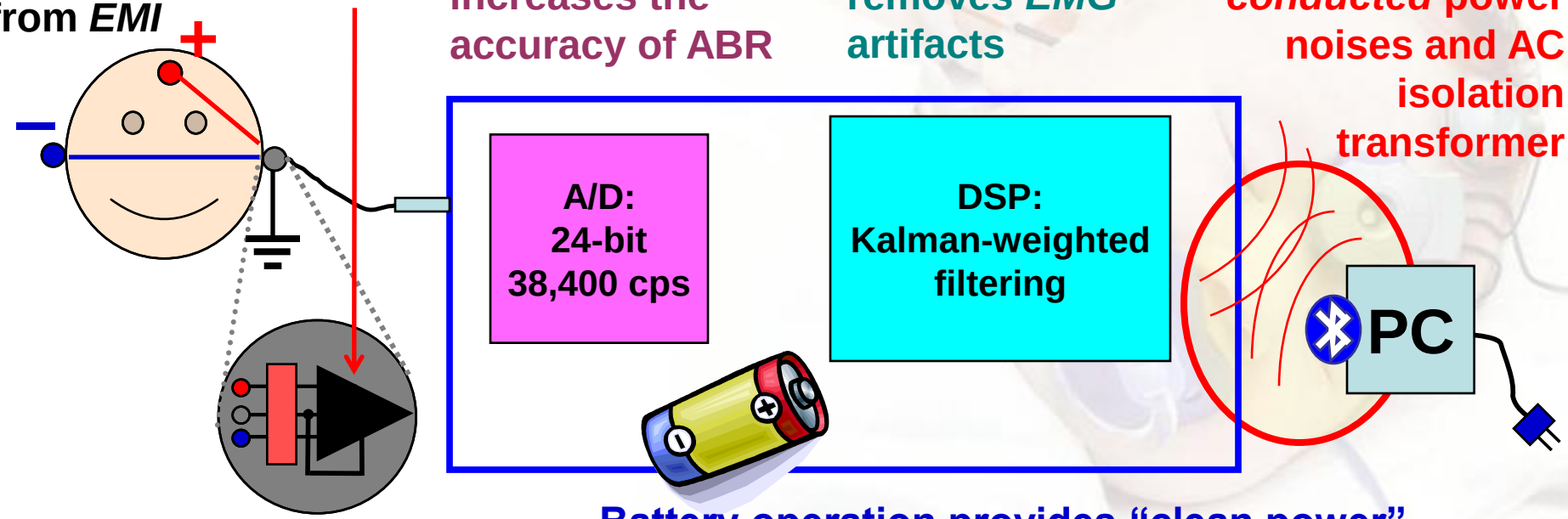
A combination of new techniques was employed to eliminate interferences and artifacts in ABR

In-situ **amplification – on the ground electrode – protects from *EMI***

High-resolution A/D conversion increases the accuracy of ABR

Kalman-weighted filtering in DSP removes *EMG* artifacts

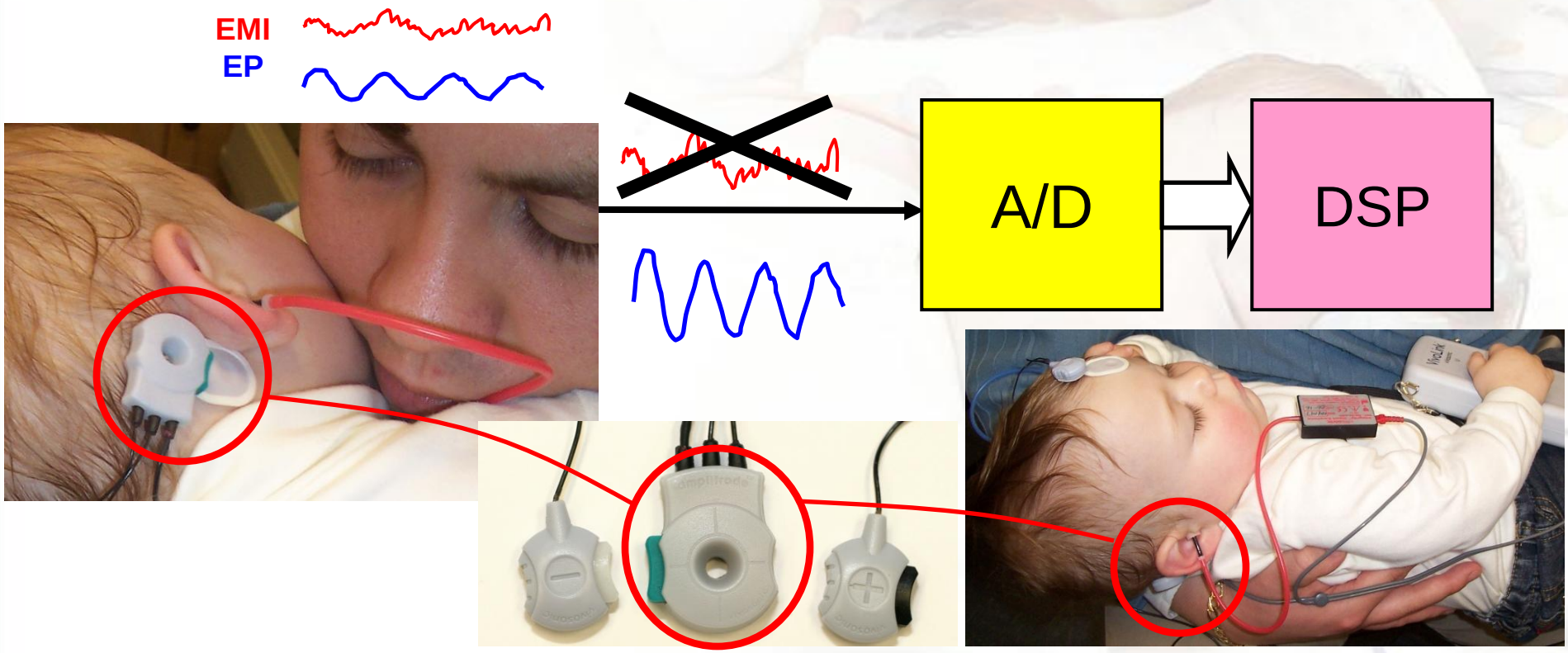
Wireless interface eliminates *conducted* power noises and AC isolation transformer



Battery operation provides "clean power"

In-situ **band-pass filtering eliminates *EOG, ECG and EEG* artifacts, and *RF* interference**

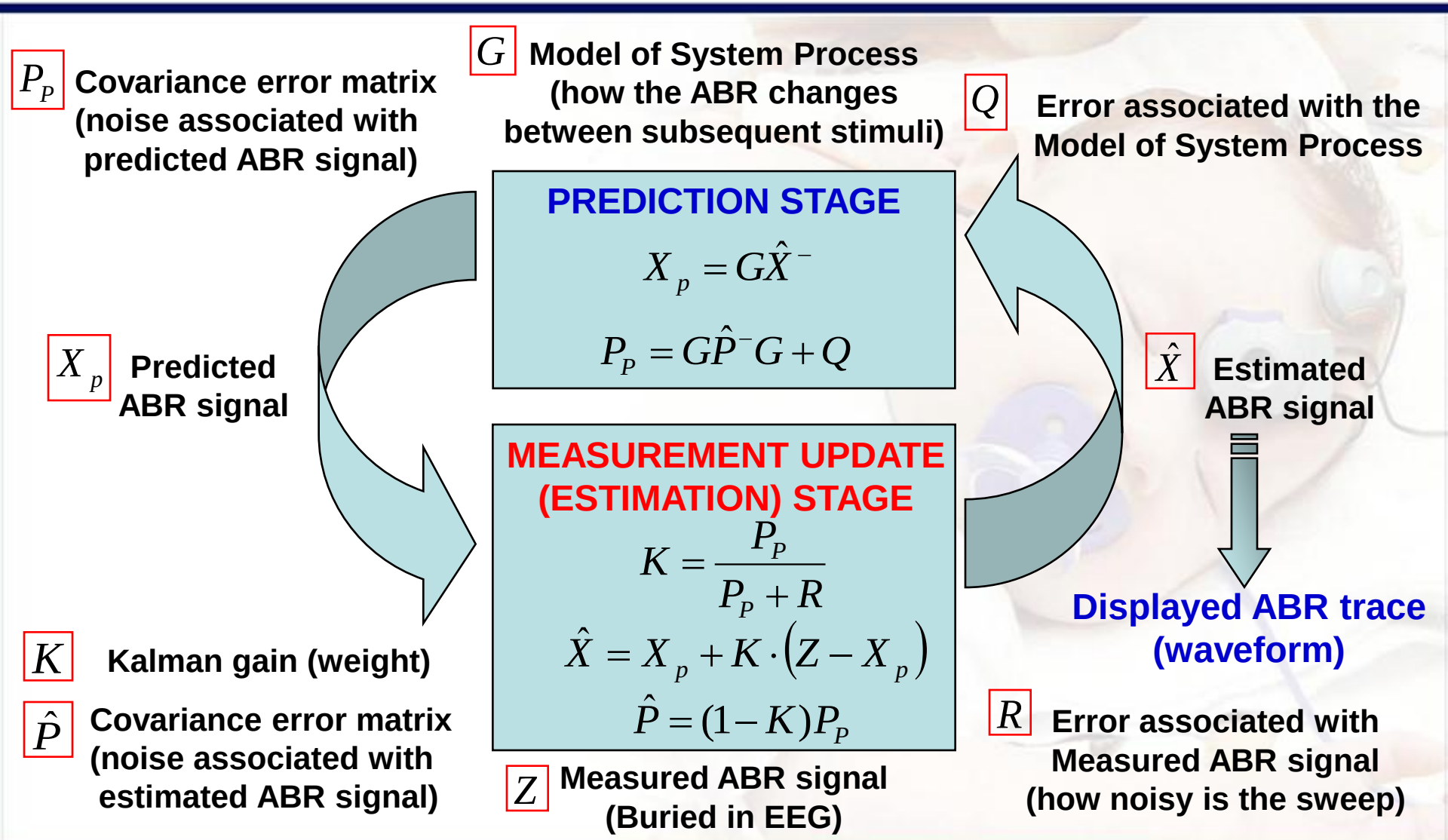
In-situ amplification mostly eliminates electric (EF) and largely reduces magnetic (MF) field-induced noises



In-situ, electrode-mounted **pre-amplifier, the Amplitrode™, eliminates the ground lead, with the other leads very short and shielded.**

This significantly reduces electric and magnetic field-induced interferences and enables a clearer EP signal at the amplifier output.

Kalman filter estimates ABR signal by extracting the signal from *each* sweep – with *no* rejection



24-bit A/D conversion significantly increases the dynamic range, resolution and reduces the error of ABR signal representation

Quantization steps for ±0.5 mV (500 µV) reference, i.e. maximum artifact

# Bits	# Divisions	Resolution/Div	Max % Error	Max PPM Error
8	2^7=128	3.9 µV	0.78	7812.00
16	2^{15}=32,768	15.3 nV	0.003	30.50
20	2^{19}=524,288	0.95 nV	0.00019	1.90
24	**2^{23}=8,388,608**	**0.06 nV**	**0.000012**	**0.12**

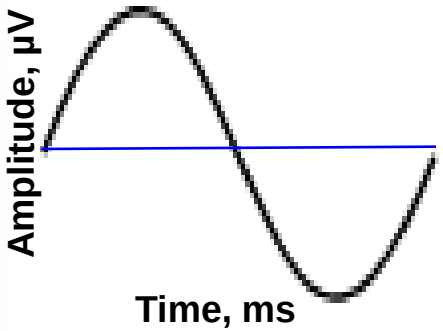
2^{24}=16,777,216 divisions

~ 0.06 nV/div

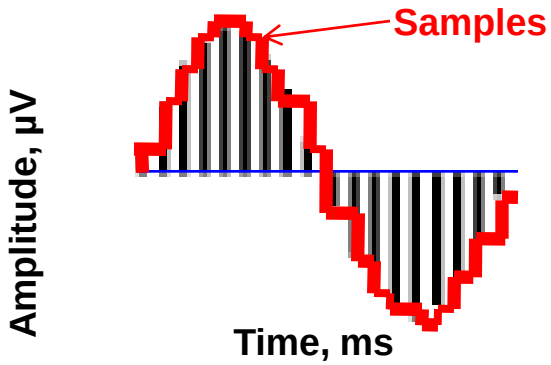
~ 5,000 divisions for a 0.3 µV ABR signal

Adapted from Bohn (1997): http://www.rane.com/note137.html

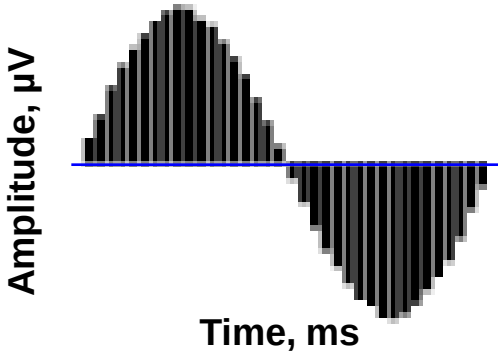
High sampling rate (samples per cycle), increases the precision of ABR waveform in the time domain



A cycle of a sine signal



Signal cycle digitized at 18 samples per cycle



Signal cycle digitized at 36 samples per cycle

Examples of sampling rates:

24-bit DVD-quality: 192 ks/s = 9.6 s/c at the highest frequency, 20 kHz

HD-ABR: 38.4 ksps = 13 spc at the highest frequency, 3000 Hz

High A/D resolution and sampling rate result in high ABR resolution – High-Definition ABR™

High-definition ABR is illustrated by an example of visual image resolution*)

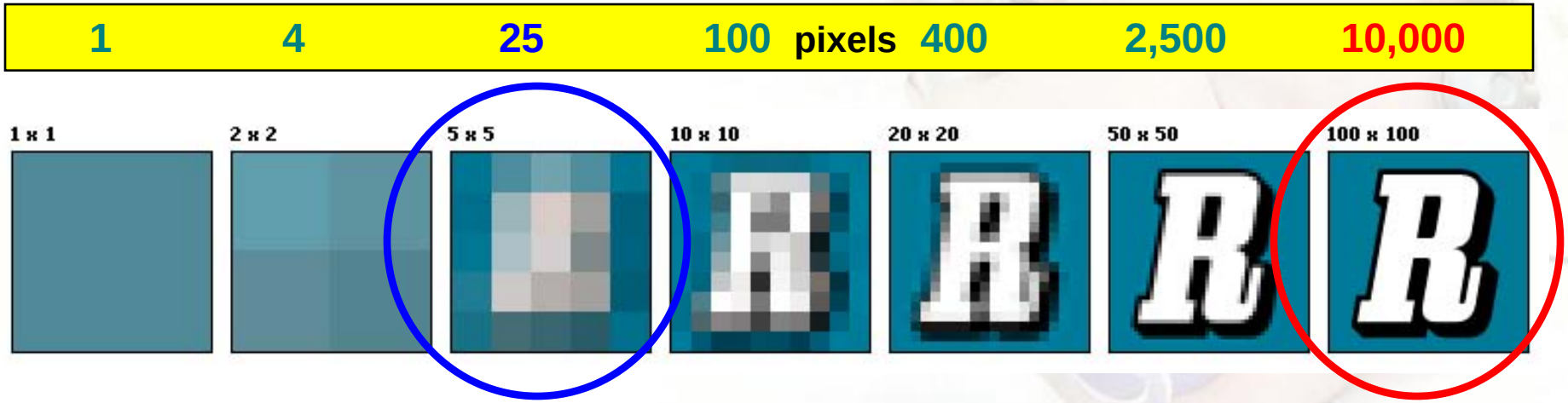


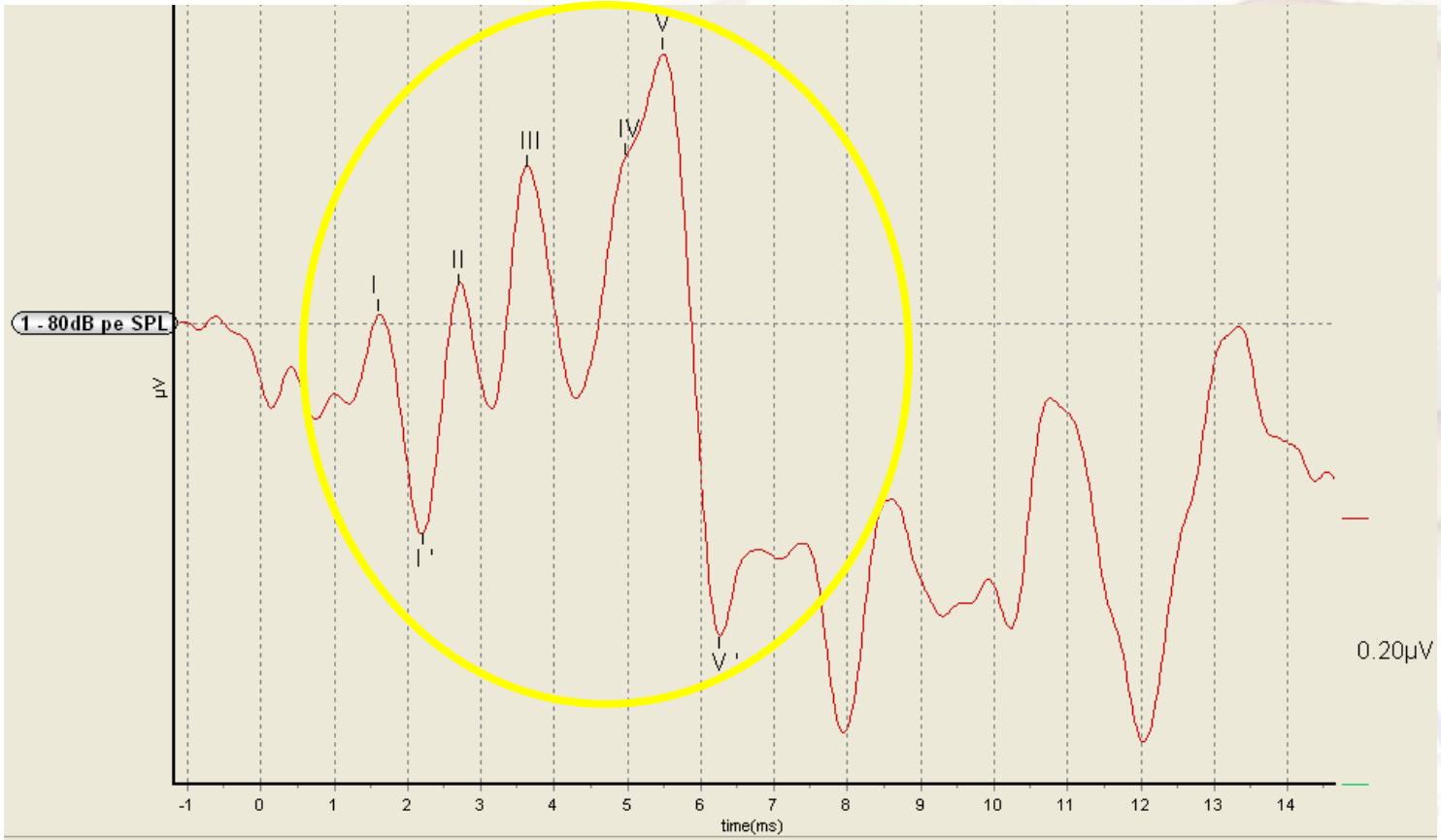
Image illustrating conventional ABR resolution with 16-bit A/D and low sampling rate 25 pixels

Image illustrating Integrity™ ABR resolution with 24-bit AD and high sampling rate 10,000 pixels

*) Source: http://en.wikipedia.org/wiki/Image_resolution

High-definition ABR™ enables clear determination of diagnostically valuable ABR waves

Click-ABR waveform, recorded from RE of a normal-hearing subject at 80 dB nHL, shows clear morphology with precisely measurable wave latencies



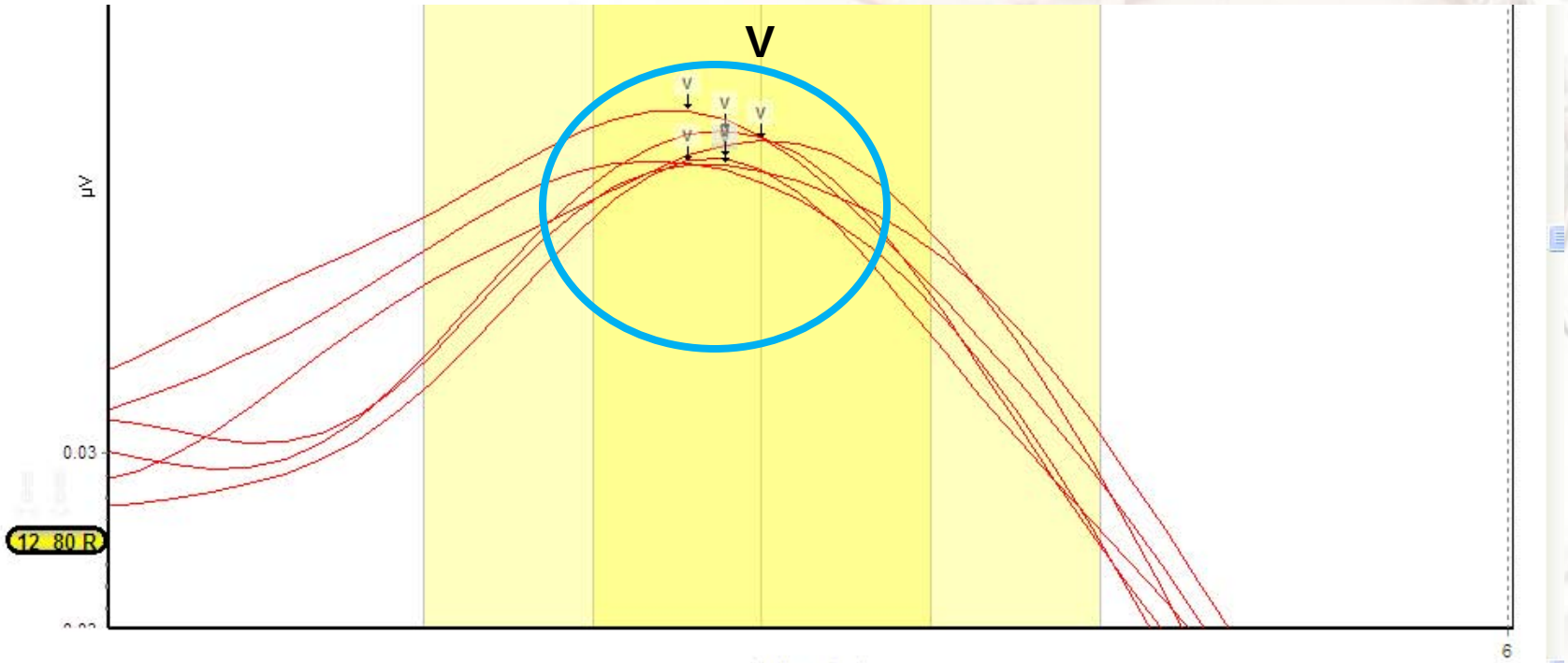
Test Conditions	I ms	I ' ms	II ms	III ms	IV ms	V ms	V ' ms	I-III ms	III- V ms	I-V ms	I-I' µV	V-V' µV	V
1. Right ear, ER3-14A - Foam, Regular, 13mm, Pro=St. George's click, Contra, Click, ER-3A, Pol=Alt, Alg=Kal, Sta=Awake, N=4368,0%, Corr=0.66	1.60	2.20	2.69	3.63	4.96	5.48	6.24	2.03	1.85	3.88	0.17	0.45	

Zooming-in the HD-ABR enables very precise measurement of ABR wave latencies and comparison with normative data

Example of a zoom-in of 6 ABR waveforms from the RE of a HF-HL patient at 80 dB nHL

Wave V norms for adults at 80 dB nHL

-2SD -1SD Mean +1SD +2SD



Test Conditions	I ms	I' ms	II ms	III ms	IV ms	V ms	V' ms	I-III	III-V	I-V	I-I' µV	V-V'	V/I	Stat-S	Stat-E	Corr.
8 80 R: Right ear, ER3-14A - Foam, Regular,																
9 80 R: Right ear, ER3-14A - Foam, Regular,						5.44										
10 80 R: Right ear, ER3-14A - Foam, Regular,						5.44										
11 80 R: Right ear, ER3-14A - Foam, Regular,																
12 80 R: Right ear, ER3-14A - Foam, Regular,						5.44										

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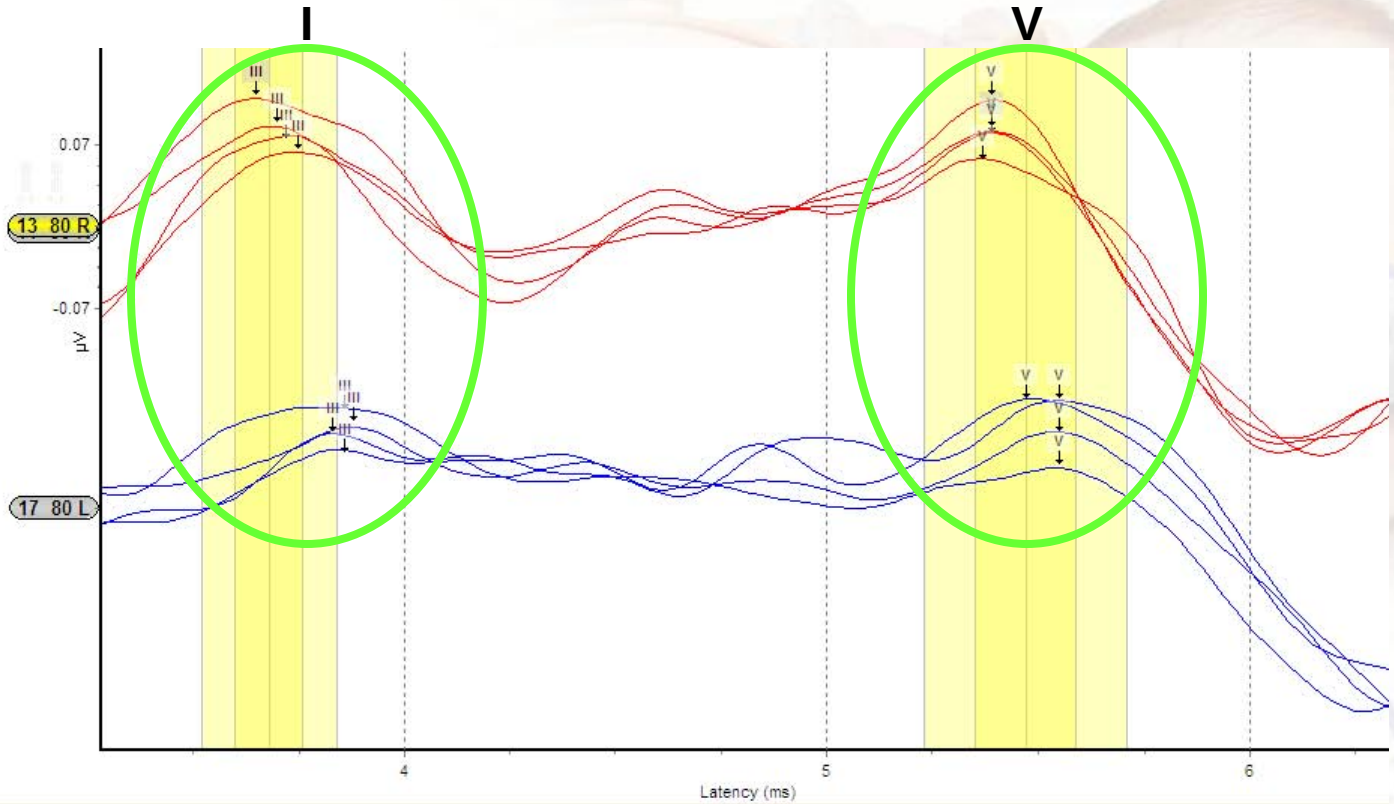
clinical efficiency through innovation

HD-ABR™ enables detecting very small inter-aural difference of ABR wave latencies

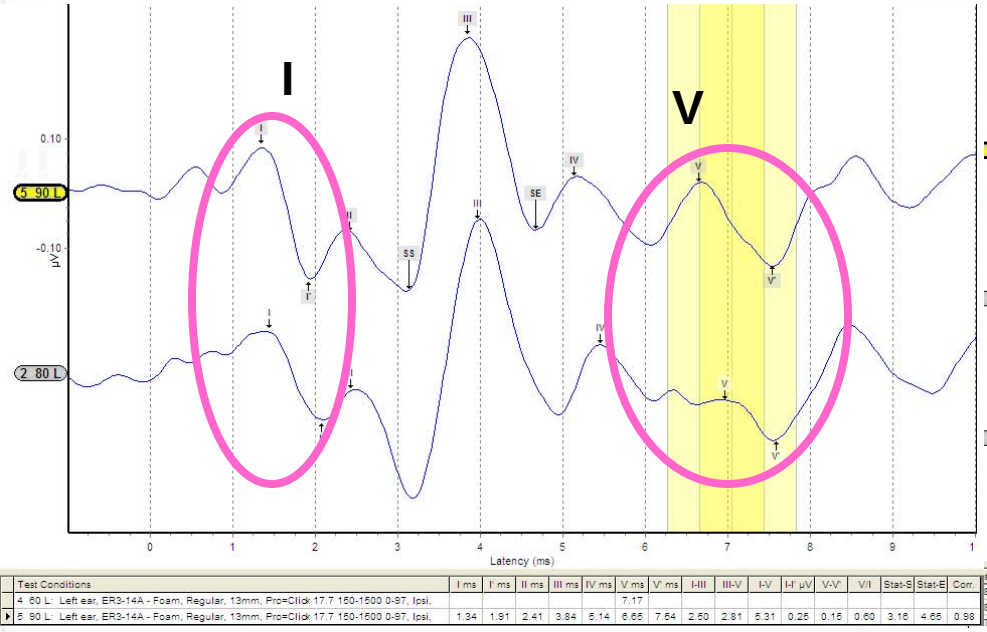
ABR waveforms recorded from a 79-year-old patient with moderate SNHL, showing clear inter-aural differences in Waves III and V



Test Conditions	I ms	I' ms	II ms	III ms	IV ms	V ms	V' ms	I-III	III-V	I-V	I-I' µV	V-V'	V/I	Stat-S	Stat-E	Corr
14 80 L: Left ear, ER3-14A - Foam, Regular, 13mm, Pro=Neurologic 150 -2400, Contra,	1.67			3.83		5.55		2.16	1.72	3.88						
15 80 L: Left ear, ER3-14A - Foam, Regular, 13mm, Pro=Neurologic 150 -2400, Contra,	1.77			3.88		5.55		2.11	1.67	3.78						
16 80 L: Left ear, ER3-14A - Foam, Regular, 13mm, Pro=Neurologic 150 -2400, Contra,	1.64			3.86		5.47		2.22	1.61	3.83						
17 80 L: Left ear, ER3-14A - Foam, Regular, 13mm, Pro=Neurologic 150 -2400, Contra,	1.64			3.86		5.55		2.22	1.69	3.91						
18 80 L: Left ear, ER3-14A - Foam, Regular, 13mm, Pro=Neurologic 150 -2400, Contra,																

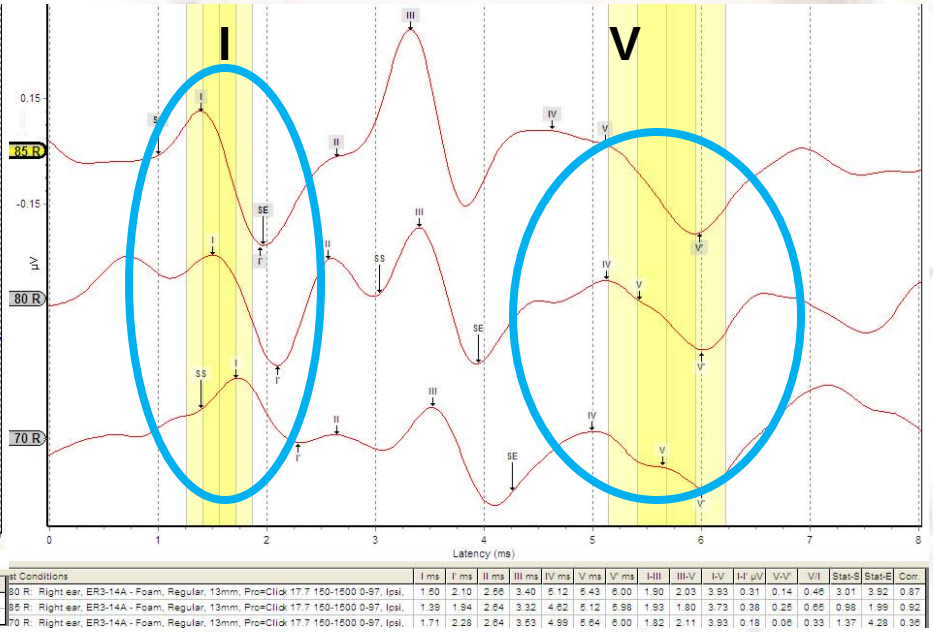
HD-ABR™ enables precise measurement of V/I amplitude ratio, which may indicate auditory maturation or abnormality

ABRs from LE of a 5-week-old, 8-week-premature, non-sedated, female NICU infant
80 and 90 dB nHL
(shown are norms for 80 dB nHL)



Test Conditions	I ms	I' ms	II ms	III ms	IV ms	V ms	V' ms	I-III	III-V	I-V	I-I' µV	V-V'	V/I	Stat-S	Stat-E	Corr.
4 60 L: Left ear, ER3-14A - Foam, Regular, 13mm, Pro=Click 17.7 150-1500 0-97, Ipsi,						7.17										
5 90 L: Left ear, ER3-14A - Foam, Regular, 13mm, Pro=Click 17.7 150-1500 0-97, Ipsi,	1.34	1.81	2.41	3.84	5.14	6.65	7.54	2.50	2.81	5.31	0.25	0.15	0.60	3.16	4.65	0.98

ABRs from RE of a 3.5-year-old, non-sedated male patient with Cerebral Palsy
70, 80, 85 dB nHL
(shown are norms for 80 dB nHL)

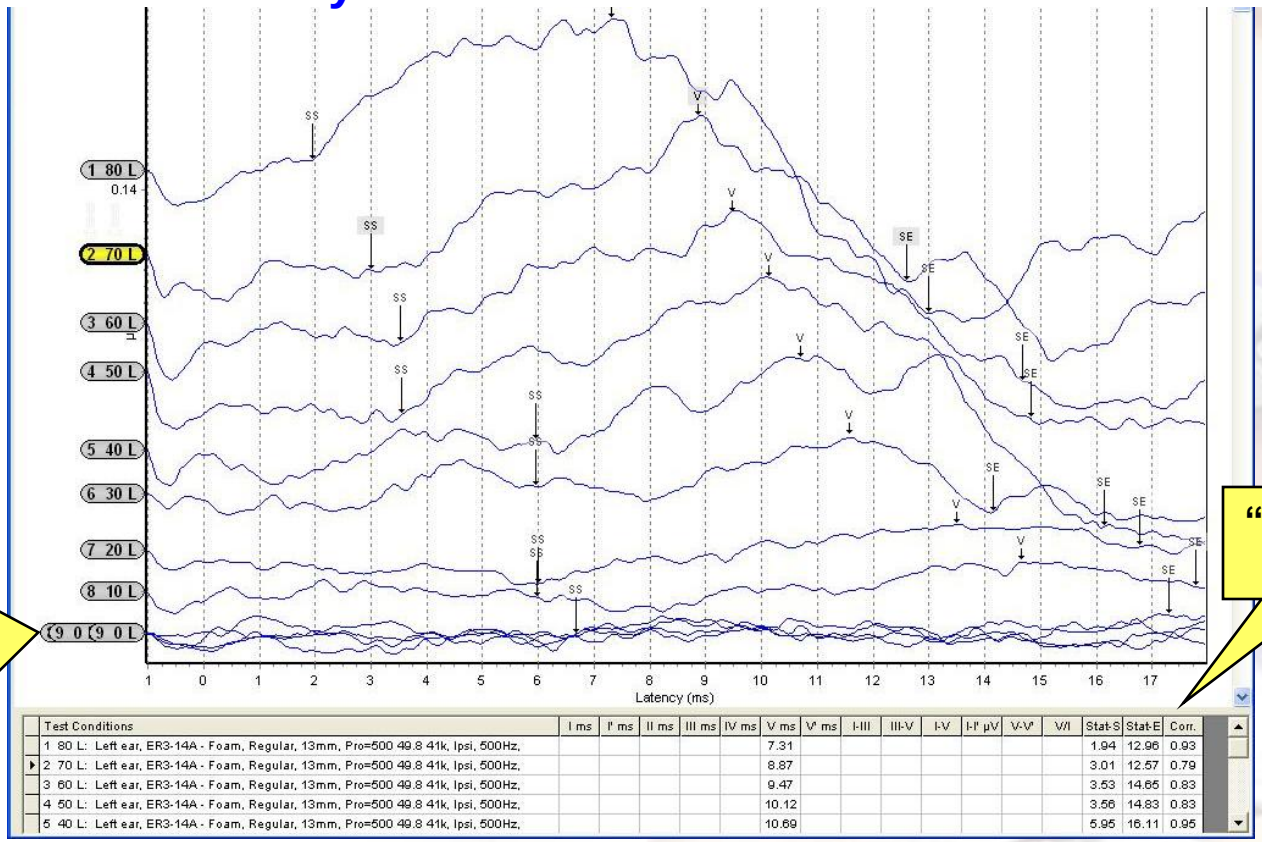


st Conditions	I ms	I' ms	II ms	III ms	IV ms	V ms	V' ms	I-III	III-V	I-V	I-I' µV	V-V'	V/I	Stat-S	Stat-E	Corr.
80 R: Right ear, ER3-14A - Foam, Regular, 13mm, Pro=Click 17.7 150-1500 0-97, Ipsi,	1.50	2.10	2.56	3.40	5.12	5.43	6.00	1.90	2.03	3.93	0.31	0.14	0.46	3.01	3.92	0.87
85 R: Right ear, ER3-14A - Foam, Regular, 13mm, Pro=Click 17.7 150-1500 0-97, Ipsi,	1.39	1.94	2.64	3.32	4.62	5.12	5.98	1.93	1.80	3.73	0.38	0.25	0.65	0.98	1.99	0.92
70 R: Right ear, ER3-14A - Foam, Regular, 13mm, Pro=Click 17.7 150-1500 0-97, Ipsi,	1.71	2.28	2.64	3.53	4.99	5.64	6.00	1.82	2.11	3.93	0.18	0.06	0.33	1.37	4.28	0.36

In both cases, V/I ratio is measured precisely, and is significantly < 1.0
V/I > 1.0 is characteristic for normal ABR.

Tone-burst HD-ABR allows precise *frequency-specific* threshold estimation, to 5-10 dB above subjective threshold

Example of 500 Hz tone-burst ABR from LE of a normal-hearing 34-year-old adult, clearly identifiable to 10 dB nHL



Test Conditions	I ms	I' ms	II ms	III ms	IV ms	V ms	V' ms	I-III	III-V	I-V	I-I' µV	V-V'	V/I	Stat-S	Stat-E	Corr.
1 80 L: Left ear, ER3-14A - Foam, Regular, 13mm, Pro=500 49.8 41k, Ipsi, 500Hz,						7.31								1.94	12.96	0.93
2 70 L: Left ear, ER3-14A - Foam, Regular, 13mm, Pro=500 49.8 41k, Ipsi, 500Hz,						8.87								3.01	12.57	0.79
3 60 L: Left ear, ER3-14A - Foam, Regular, 13mm, Pro=500 49.8 41k, Ipsi, 500Hz,						9.47								3.53	14.65	0.83
4 50 L: Left ear, ER3-14A - Foam, Regular, 13mm, Pro=500 49.8 41k, Ipsi, 500Hz,						10.12								3.56	14.83	0.83
5 40 L: Left ear, ER3-14A - Foam, Regular, 13mm, Pro=500 49.8 41k, Ipsi, 500Hz,						10.69								5.95	16.11	0.95

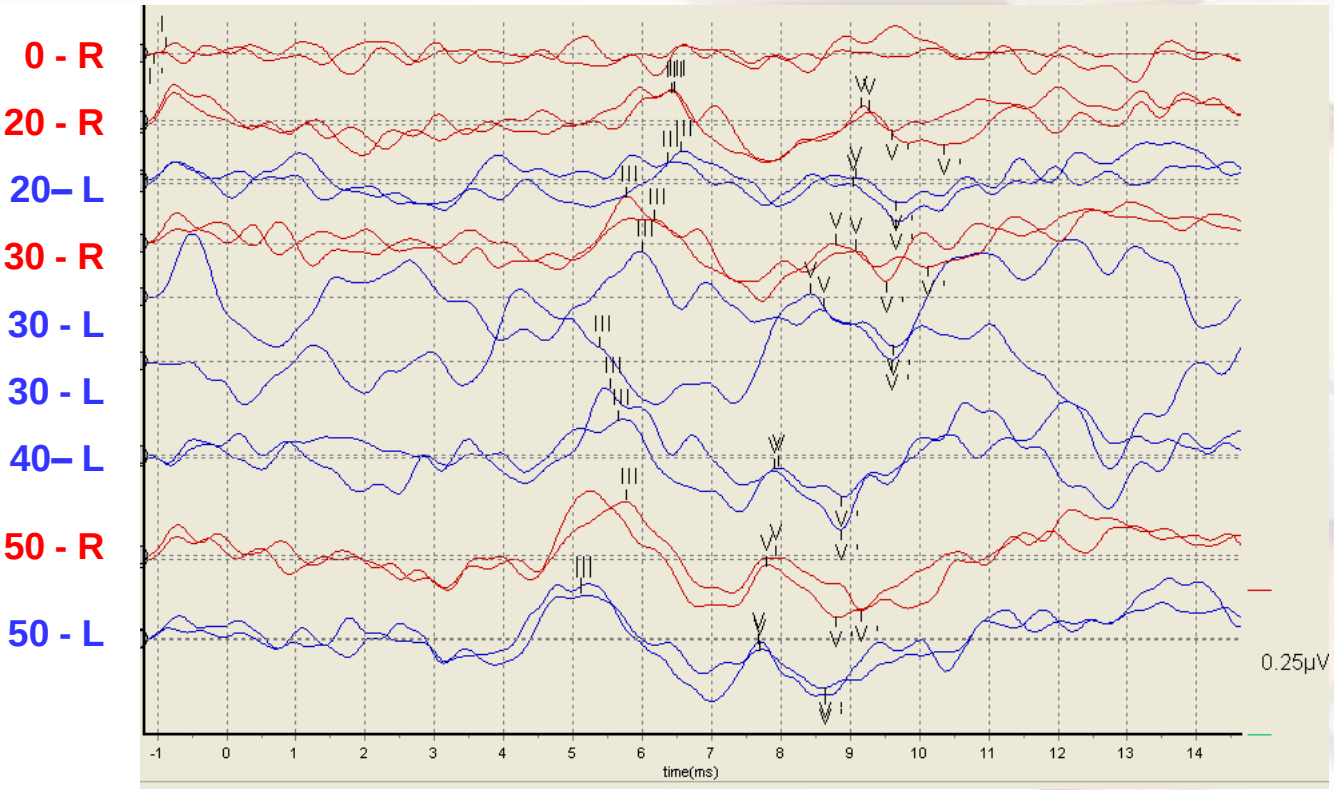
A-B traces at all stimulus levels match the 0 dB nHL (no stimulus) trace, i.e. EEG noise

"Running" CC

The user runs a test until A-B "flattens out" to below 0.03-0.05 µV.

"Running" CC value is continuously updated, and CC > 0.75 indicates the response

New techniques enable recording clear, repeatable ABR in non-sedated patients – down to the threshold



5-weeks old, premature infant girl did not pass screening with a conventional ABR screener, was impossible to test with a conventional ABR analyzer due to very large artifacts. Integrity™ recorded clear ABR to 20-50 dB nHL clicks on both ears with new technologies.

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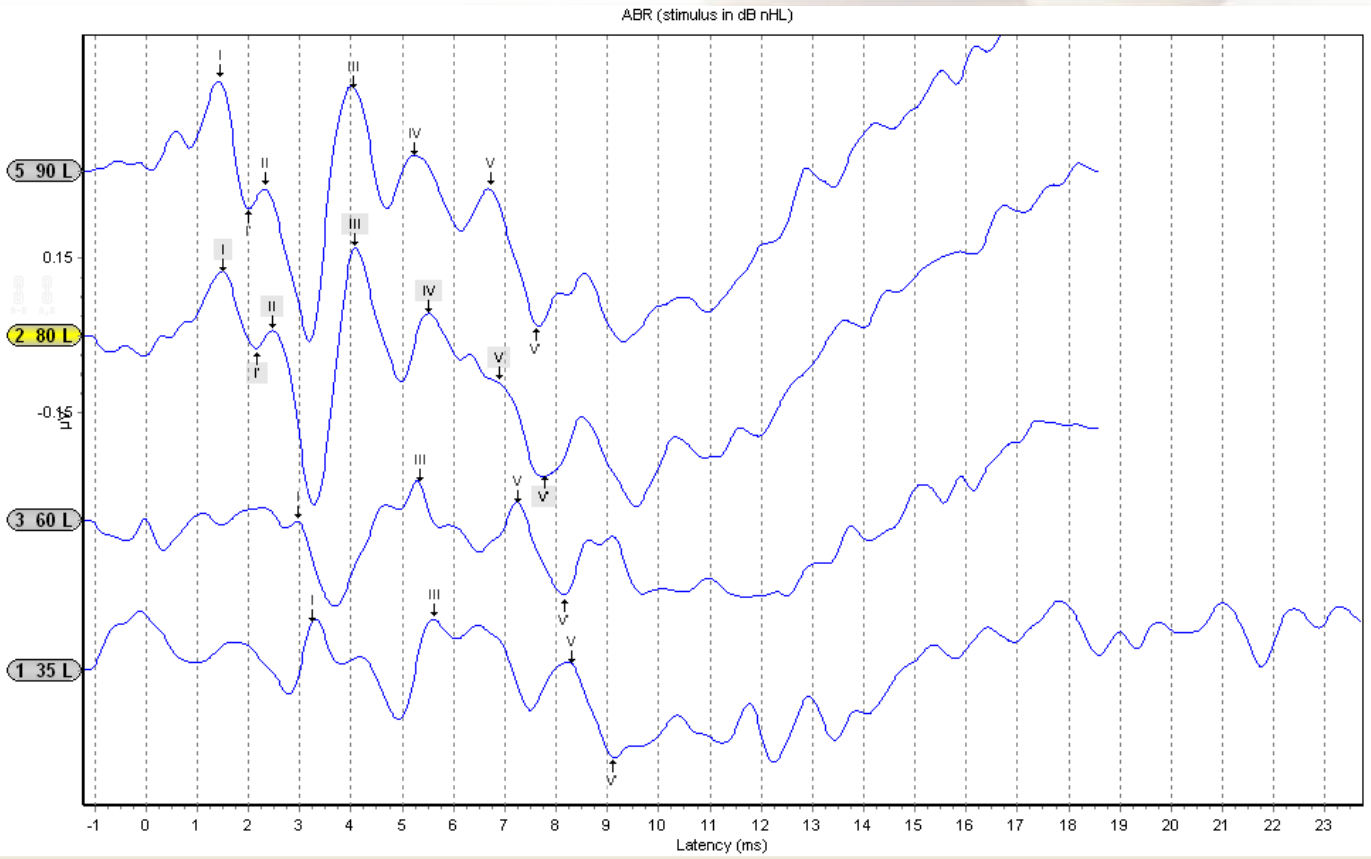
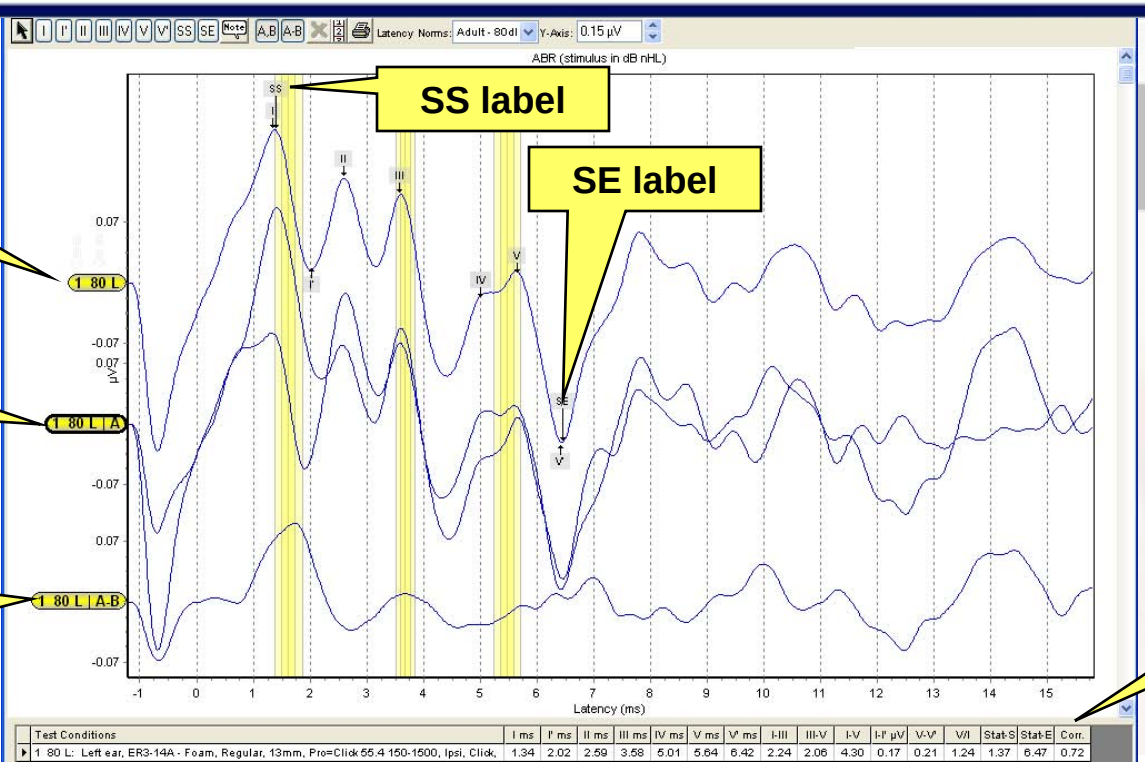
New techniques enable recording clear ABR in electromagnetically harsh conditions



Non-sedated, premature 10-week-old infant girl, in a large hospital **NICU**, suckling on her pacifier. Conventional ABR results unattainable. Integrity™ allowed recording clear ABR to 35-90 dB nHL clicks.

New statistical techniques help identifying physiological responses in the waveforms

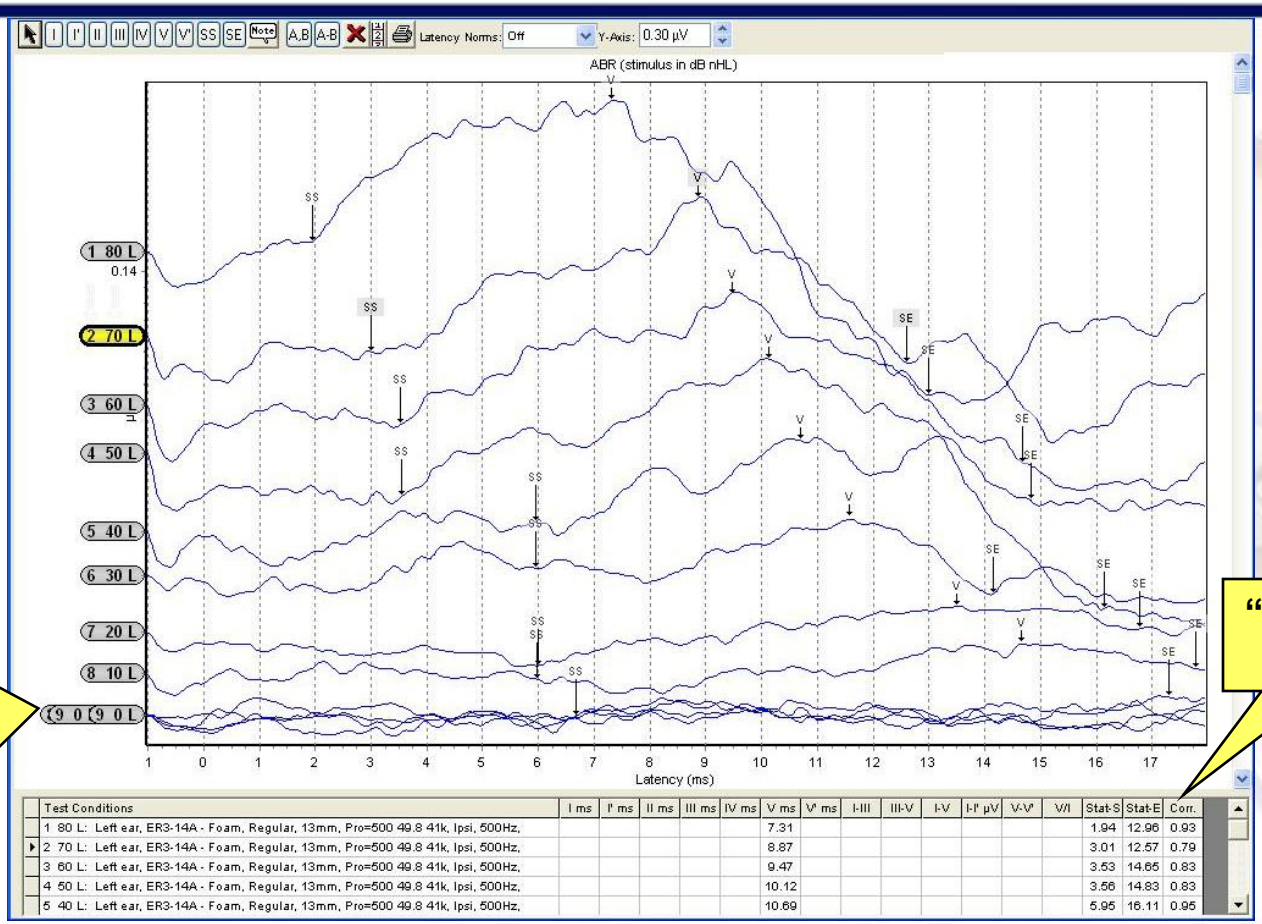


A (even sweeps) & **B** (odd sweeps) buffers show response repeatability within each test run – instead of repeating each test – and saves test time.

A-B (the difference between A and B) shows EEG noise floor – helps identify the response.

Correlation coefficient (**CC**) between user-defined **Statistics Start** (**SS**) and **Statistics End** (**SE**) labels – helps detecting response.

New recording and statistical techniques enable precise *frequency-specific* threshold estimation



A-B traces at all stimulus levels match the 0 dB nHL (no stimulus) trace, i.e. EEG noise

"Running" CC

The user runs a test until A-B "flattens out" to below 0.03-0.05 µV.

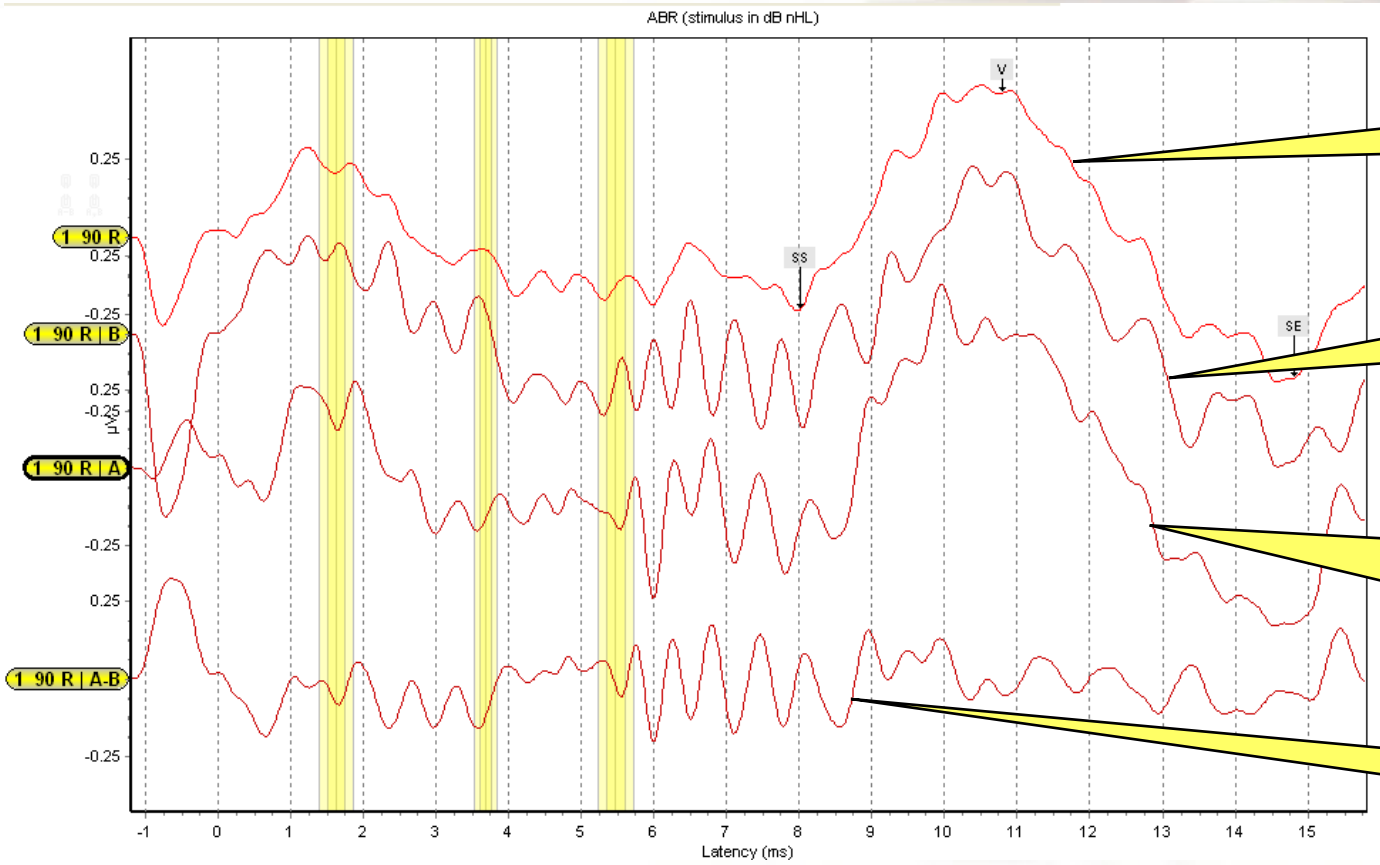
"Running" CC value is continuously updated, and CC > 0.5 indicates the presence of response, as in this sample **500 Hz** tone-burst ABR clearly identifiable to 10 dB nHL.

New statistical techniques provide the clinician with good stop criteria to obtain meaningful results

The clinician can stop the test based on the following Integrity™ criteria:

- **A** and **B** traces are **visually** repeatable
- **A-B** trace, which represents the residual **noise**, is **visually** flatter than the **A+B** (total average) trace
- **Correlation Coefficient** in the latency range of interest is larger than 0.5 (50%), which indicates a non-random response, preferably larger than 0.75 (75%)

Alternating-Split stimulus automatically administers Condensation (A) and Rarefaction (B) polarity clicks for CM identification in *neural* HL



Alt Split (A+B): Neural response

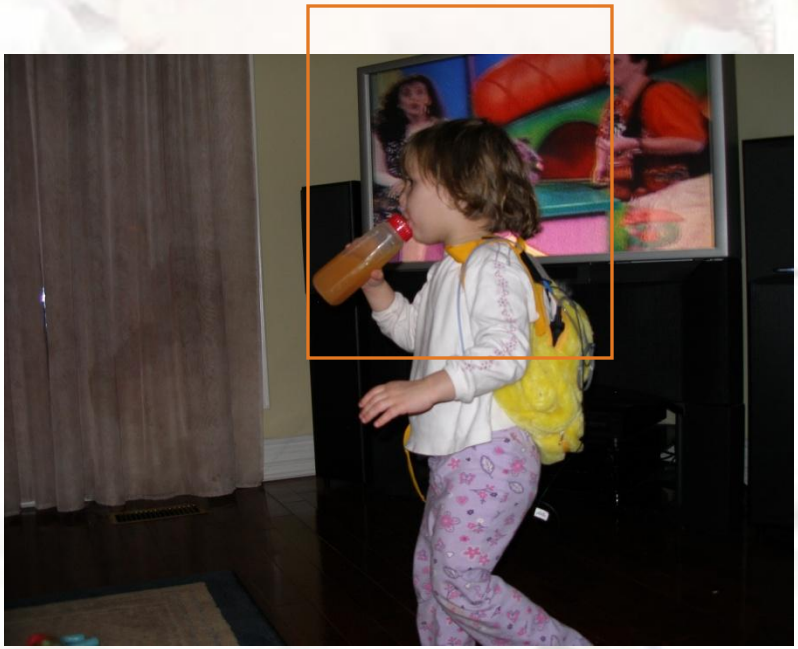
B (Rar): Neural response & CM

A (Con): Neural response (non-inverted) & CM (inverted)

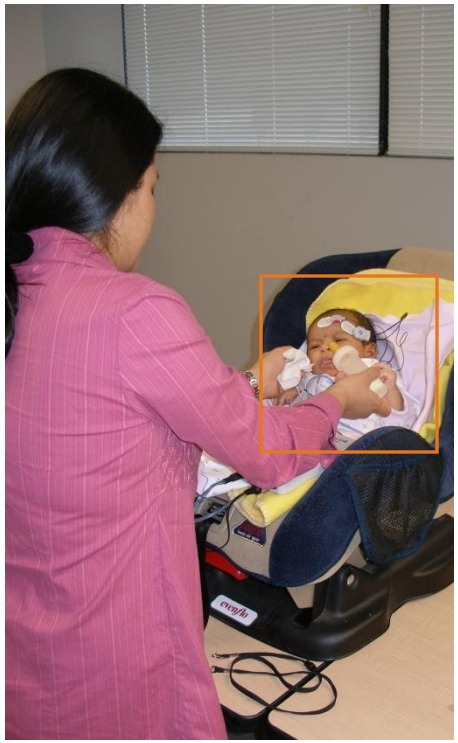
A-B: Non-neural (CM)

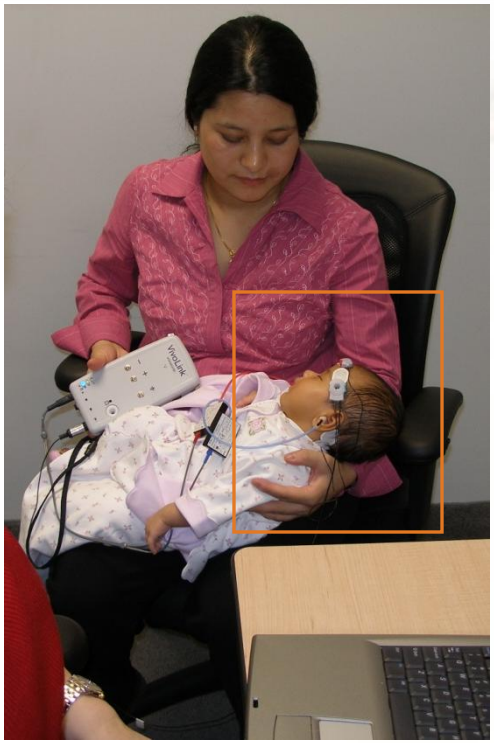
Right Ear of a 4-year-old boy with Auditory Neuropathy/Auditory Dys-synchrony. Left Ear with Cochlear Implant (CI). Candidate for a second CI for the Right Ear. 90 dB nHL click: A – Con, B – Rar, A+B – Neural, A-B – Non-neural (Cochlear Microphonic, CM)

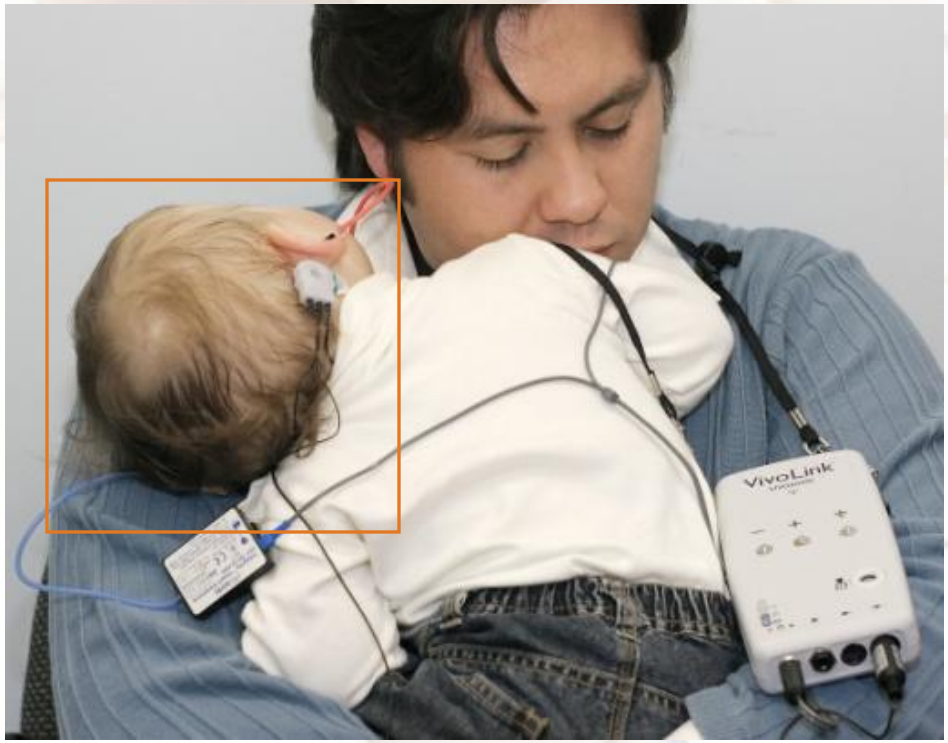
New techniques enable test patients in their natural environment, with the freedom to move around and feed



Testing newborns and infants is very patient- and parent-friendly in comforting hands of the parent or care-giver

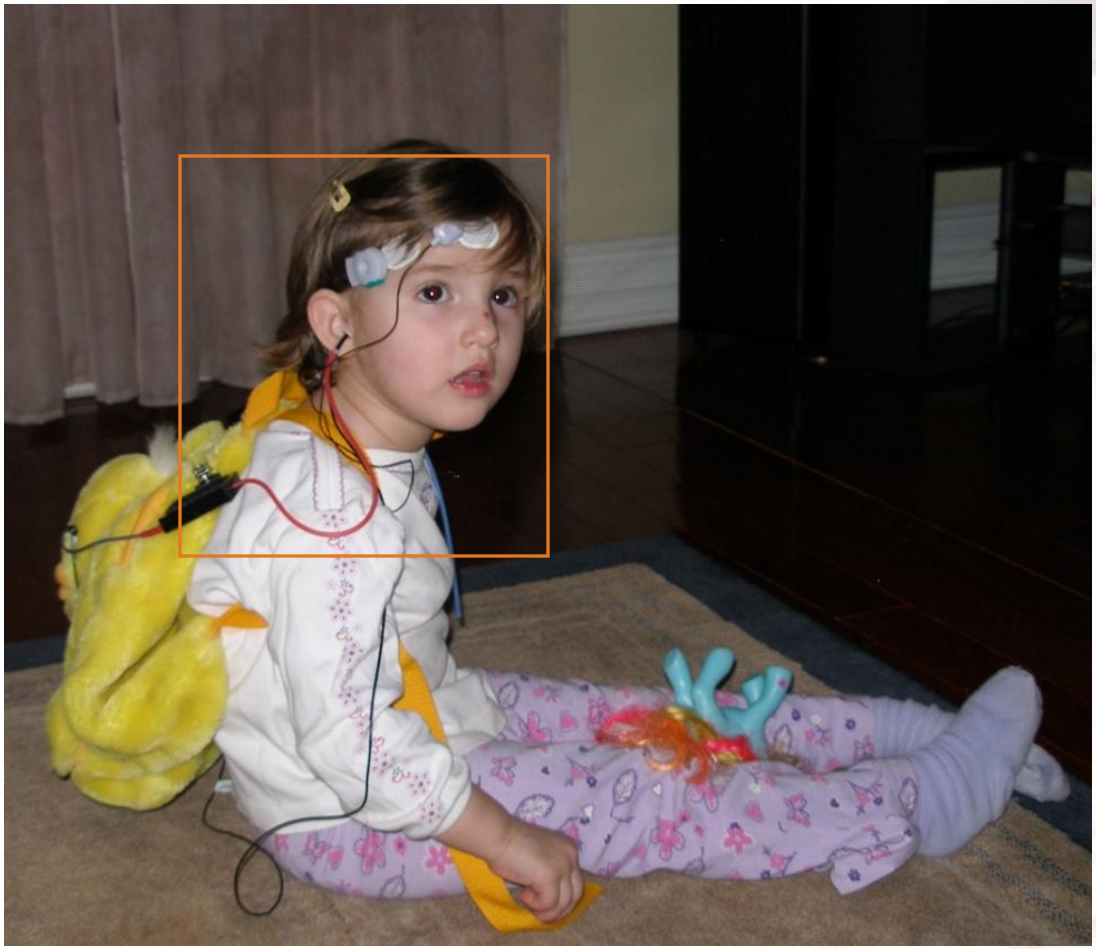






When testing newborns and infants, VivoLink™ is placed in the crib or a car seat, or held by the caregiver. The caregiver can comfort the child during the test, while the child can be bottle-feeding or even breast-feeding.

Testing toddlers, a challenging task, can be convenient



When testing a toddler, the VivoLink™ can be “stowed away” in the toy backpack or placed on the back as a backpack itself.

A good way to keep the child “quiet” is to occupy the child with toys, watching a cartoon, drawing

VivoLink™ attracted the 3-year-old female patient and allowed for a faster test.

Sometimes finding a position where the child feels safe works better than sedation

A 2-year-old girl was given 5 cc of Chloral Hydrate, then another 2 cc – with no sedative effect. She found a safe escape on the father's shoulders where she was successfully ABR-tested (at a private Otolaryngology clinic in Cairo, Egypt).

Hearing health care benefits: New techniques extend reliable, precise, practical ABR to all clinical settings and beyond

- **High diagnostic value**
  - Precise ABR latencies for neuro-diagnostics
  - Precise hearing thresholds for hearing aid fitting
- **Patients with physiological artifacts**
  - Children of all ages – with no sedation or anesthesia
  - Patients that *cannot* be sedated or anesthetized – due to health risks or because anesthesia is unavailable.
  - Restless, anxious adult patients: sleep apnea, anxiety, patients with pacemakers.
  - Mentally and physically challenged patients: Autism, Cerebral Palsy etc.
- **Environments with strong electro-magnetic interferences**
  - Neonatal intensive care units (NICU)
  - Intensive-care units (ICU) and Emergency Rooms.
  - Operating rooms (OR).
  - "Conventional" clinical settings – with *no* electro-magnetic shielding.
- **Testing at the patient's home**
  - Portability.
  - Certified EMI-Class B rating.

Conclusions

- New techniques enable practical ABR evluation in non-sedated patients.
- New techniques enable practical ABR in electro-magnetically harsh environments – with no shielded rooms (“Faraday cages”).
- New techniques enable high-definition (high accuracy) ABR.
- New techniques help identifying Cochlear Microphonic.
- New techniques help in all typical pediatric settings:
  - Private clinics: No need to refer out, no “lost to follow up”, timely evaluation and intervention – locally
  - Hospitals: Higher quality patient care, less risk to the patients
  - Universities: New research capabilities and student projects
- New techniques help effectively and efficiently implement the Year 2007 JCIH Position Statement on early hearing detection and intervention.

Thank you

for your interest

Best wishes

from

vivosonic