Auditory Brainstem Evoked Potentials in Objective Audiometric Assessment

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Principles of objective audiometry

- Record the physiological activity of the auditory system, non-invasively
- Electrical activity from the pathway indicates activation of generators by sound

Therefore, assesses :

Sensitivity of generators to the stimulus used

Not hearing!

Challenges

Optimize:

- Physiological signal recorded
- Acoustic stimulus used

To provide the most information on auditory function

Constraints

- Test duration (sedation, expensive equipment)
- Non-invasiveness
- Sensitivity
- Specificity

Clinical setting

Typical patients requiring objective audiometry:

- Difficult-to-test and non-cooperative adults
- Neonates and infants

Information typically sought:

- Threshold at different frequencies
- Site of lesion

Tests available

- Auditory Brainstem Evoked Potentials (ABRs)
- Middle-Latency (MLRs)
- Steady-State responses (SSRs: ABRs and MLRs)
- Long latency cortical evoked potentials

Non-invasive Electrophysiological Tests of Auditory Sensitivity

Evoked Potential	Stimulus	Frequency Specificity (Hz)	Detection Threshold (dB)	Intersubject Variability	Vigilance Effects
Brainstem	Click	2000-4000	5-10	+	-
	Tone	500-8000	15	+	-
Middle-Latency	Transient	250-8000	20-30	++	++
	Steady-State	250-8000	20-30	++	++
Long-Latency	Tone	250-8000	15	+++	+++
	Speech	Speech	15	+++	+++

Candidates for objective audiometry

ABRs stand out:

- Smallest intersubject variability
- Least affected by vigilance and sedation
- Smallest difference between detection threshold and behavioral thresholds

Moreover…

ABRs reflect function of sites most often affected in hearing loss:

- Cochlea
- Cerebello-pontine angle

Therefore…

ABRs stand the best chance to directly detect and locate hearing impairments and estimate their severity

The added bonus

ABR latencies are sensitive to:

- Audiogram shape
- Conductive hearing loss

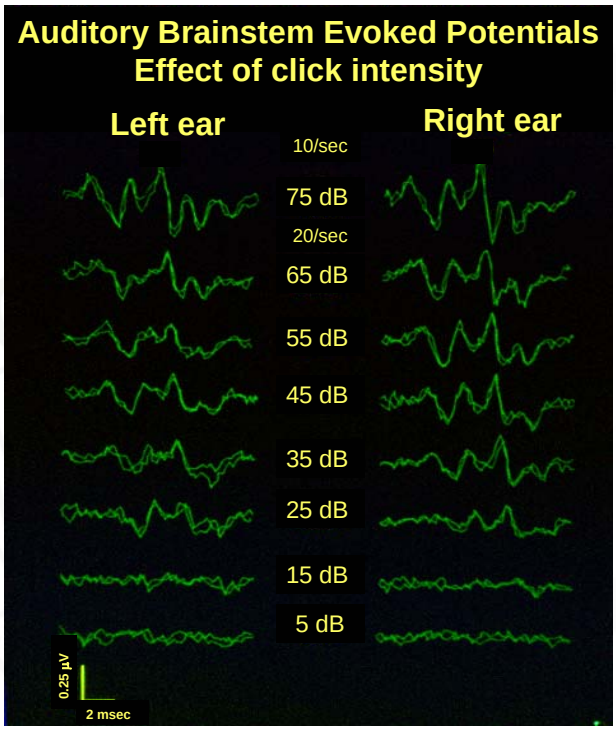
Thus can provide such information in addition to detection threshold

The main drawback

Inferior frequency specificity compared to other objective methods

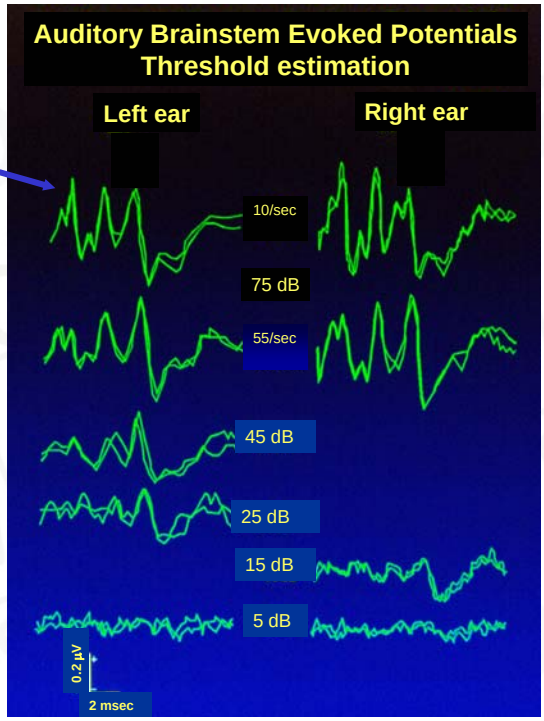
Recommended protocol

- Measure peak latencies to high-intensity and determine normalcy
- Record in response to decreasing click intensities down to detection threshold
- Attribute latency prolongations to either high-tone hearing loss or conductive hearing loss, based on other evidence (e.g., frequency-specific OAEs, otoscopy, tympanometry)



Saving time

- No need to decrease intensity by small steps
- Start at high intensity, if clear – decrease to mild levels
- On second ear, if same at high level - approach first ear threshold



Begin with Left ear

Normal looking responses to high-intensity

High click rate helps verify peak identity

Proceed to moderate Intensities. Responses indicate, at most, mild loss

Proceed to near-normal threshold to estimate threshold

Normal looking responses to high-intensity (like left ear)

Skip moderate intensities

Proceed to near-threshold intensities

Estimate threshold

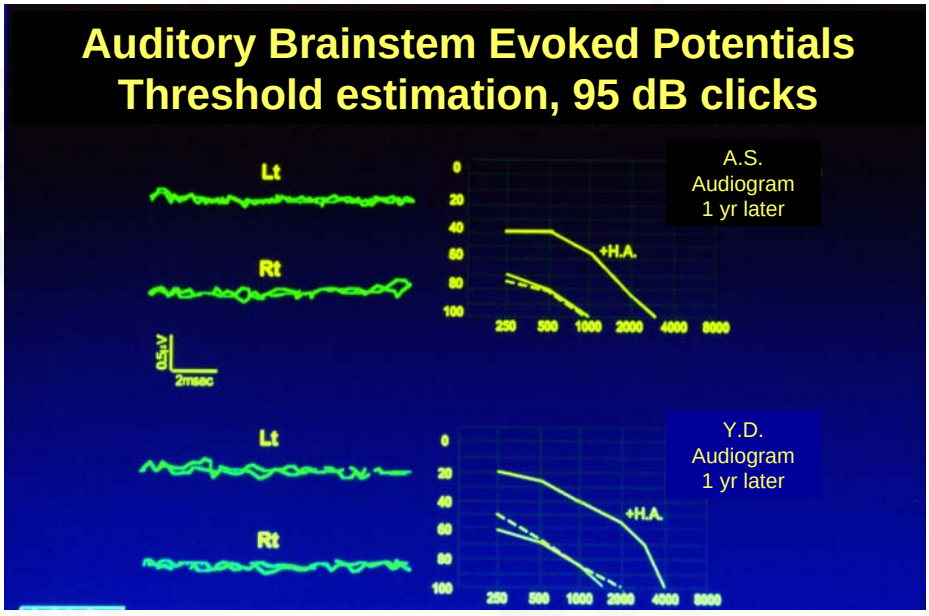
Pitfalls

Present ABRs do not indicate normal hearing:

- Possible lesion more centrally
- Possible hearing loss to other stimuli

Absent ABRs indicate impairment but do not mean deafness:

- Auditory Neuropathy?
- Residual hearing to low frequencies or to higher intensities than tested



An extreme example

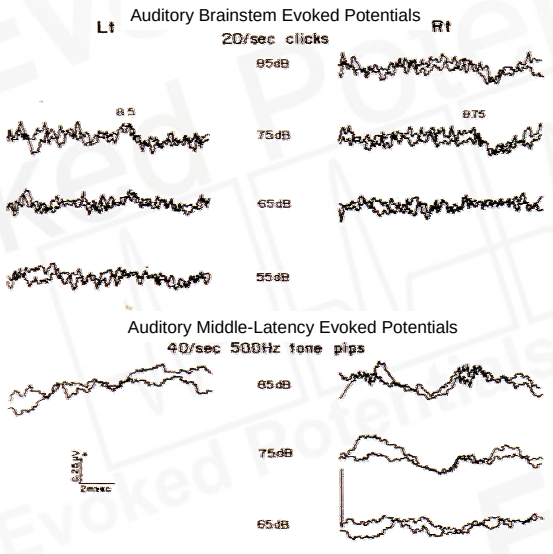
Contradicting behavioral-ABR results:

A 1yr old infant presenting:

- High-risk factors
- Audiometric impression: only moderate HL
- Absence of ABRs in another lab

Auditory Evoked Potentials
Threshold Determination

D.E. ♂ 1 yr



Familial deafness
Sibling with renal failure
Impression of moderate H.L.
Normal Otoscopy, tympanometry
Other lab – no ABRs
Contradicting EP-Audio results

The explanation

ABRs reflect activation by the sound used:

- Clicks at different labs – differ in spectral content
- Different clicks activate different frequencies

Thus:

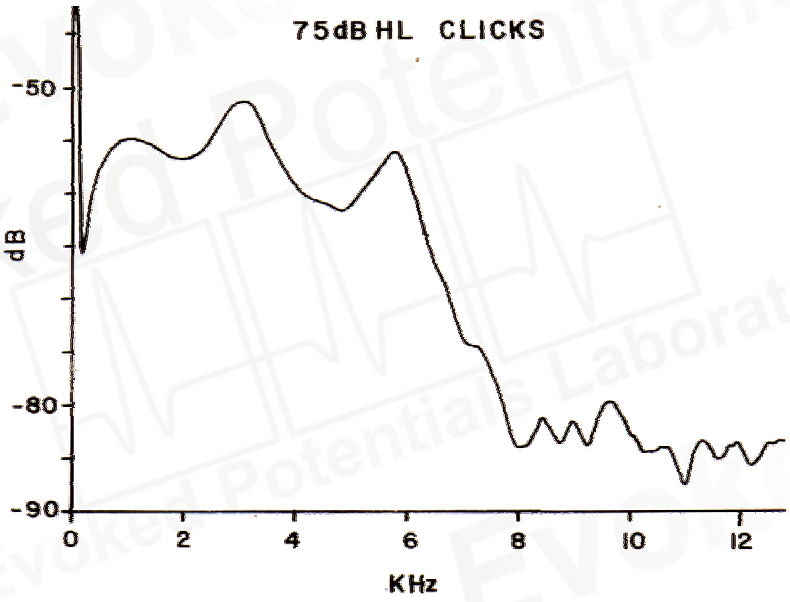
Different clicks activate the same audiogram differently

Spectral comparison of clicks

Clicks where DE was subsequently tested:

- Flat spectrum up to 6-8 kHz
- High energy at lower frequencies

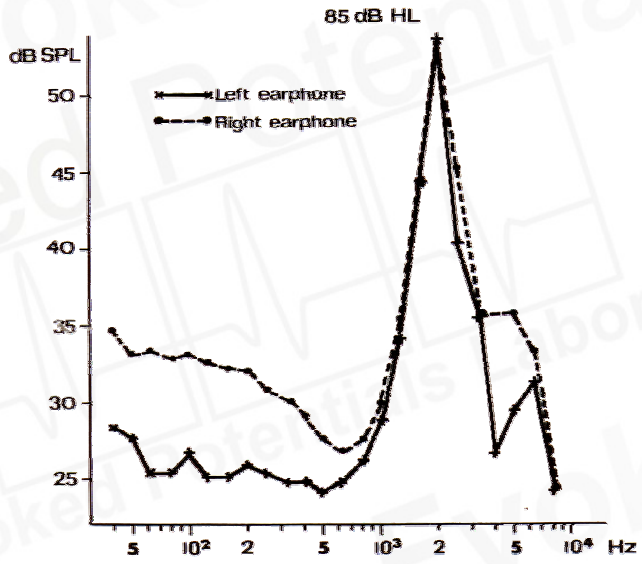
Acoustic Spectrum
Second lab's click



Clicks where DE was initially tested:

- Spectral peak at 1,000Hz - 8,000Hz
- Sharp drop at lower frequencies

Acoustic Spectrum
First lab's click

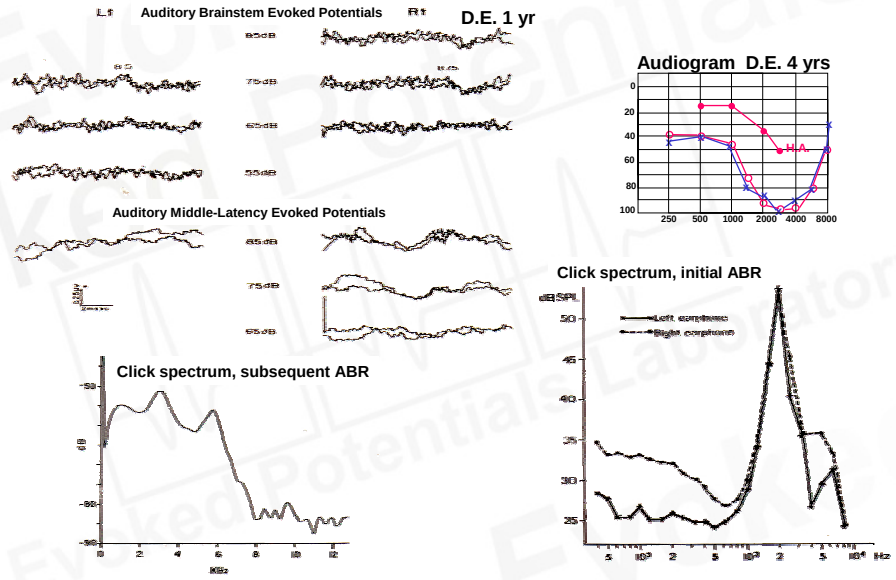


Hindsight

When DE was 4 yrs old, audiogram showed:

- Severe hearing loss between 1,000 and 8,000 Hz
- Precisely the mirror image of click spectrum in initial lab
- Sufficient low frequency function to evoke late and low-amplitude ABRS in subsequent lab

Click / audiogram interactions to evoke ABRs



Overcoming the main drawback

The latter example underscores the main drawback of ABRs:

- Inferior frequency specificity

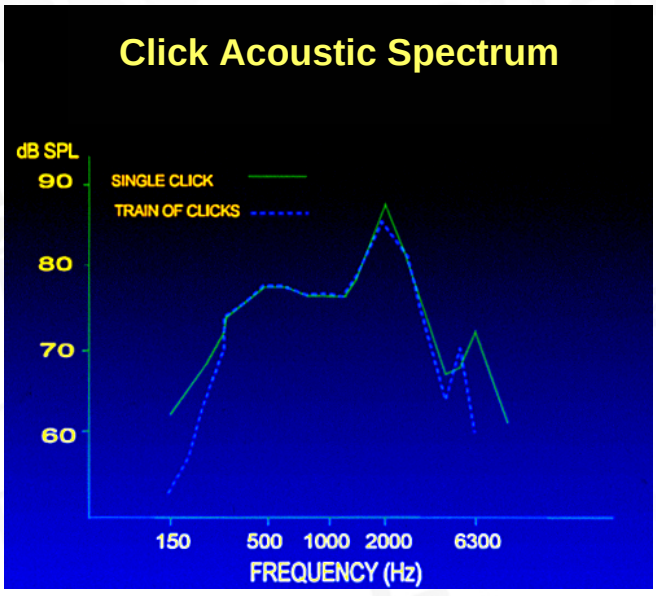
To overcome this drawback, <u>time permitting,</u> *use more frequency-specific methods*:

- Pure tone ABRs
- Derived Responses
- Steady-state potentials

The ‘Derived Response’

- The benchmark of frequency-specific ABRs
- Time-consuming and rarely used clinically
- Explains latency effects of audiogram shape

Clicks have a wide spectrum



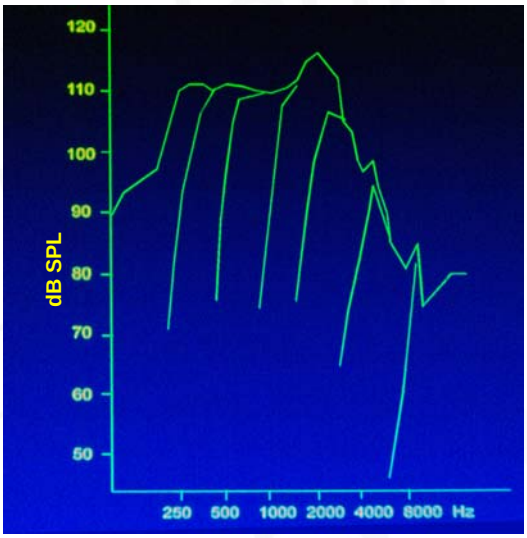
White noise has the same spectrum

- White noise intensity can be adjusted to just mask the neural responses to clicks
- If white noise is then high-pass filtered: click frequencies lower than high-pass setting will be ‘de-masked’

Thus:

Clicks with high-passed masking noise evoke ABRs to frequencies below the high-pass setting

High-pass filtered masking noise

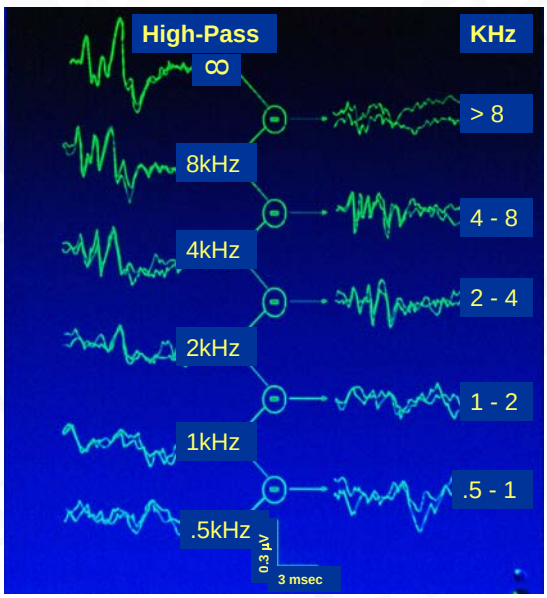


Narrow-band frequency-specific ABRs

Assuming linear summation of neural responses to different frequencies:

- Frequency-specific ABRs can be derived by waveform subtractions between responses to clicks with different high-passed masking

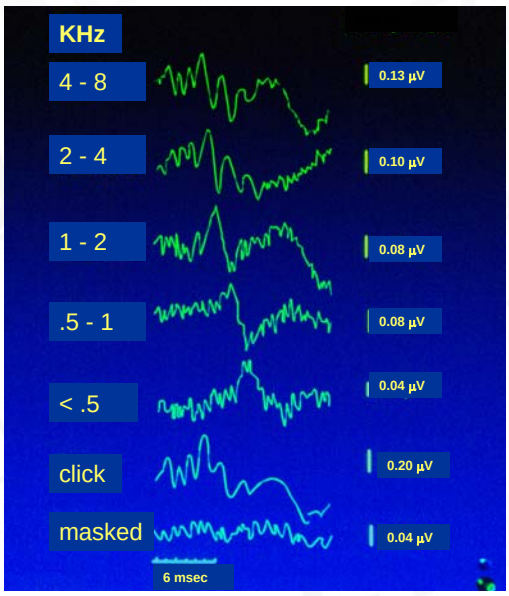
Auditory Brainstem Evoked Potentials



Frequency-Specific ABRs

- Wide-band click-evoked ABRs are mostly high-frequency responses
- Increasing latencies and lower amplitudes to lower frequencies
- High-tone loss will evoke low-amplitude, long-latency ABRs

Auditory Brainstem Evoked Potentials Derived Responses

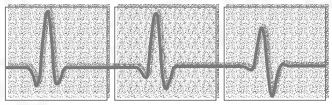


In summary

- Click ABR detection thresholds offer best auditory threshold estimation
- Least intra- and inter-subject variability
- Record to decreasing click intensities down to detection threshold
- Attribute latency prolongations to:
  high-tone or conductive hearing loss
  based on OAE screening, otoscopy, tympanometry
- Time permitting – use frequency-specific methods

Thank you!

And do visit our web site at
www.technion.ac.il/eplab



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