



# Revealing the Potential of Aided Cortical Testing: What Audiologists Should Know



Janna Brubacher, Au.D. Reg. CASLPO

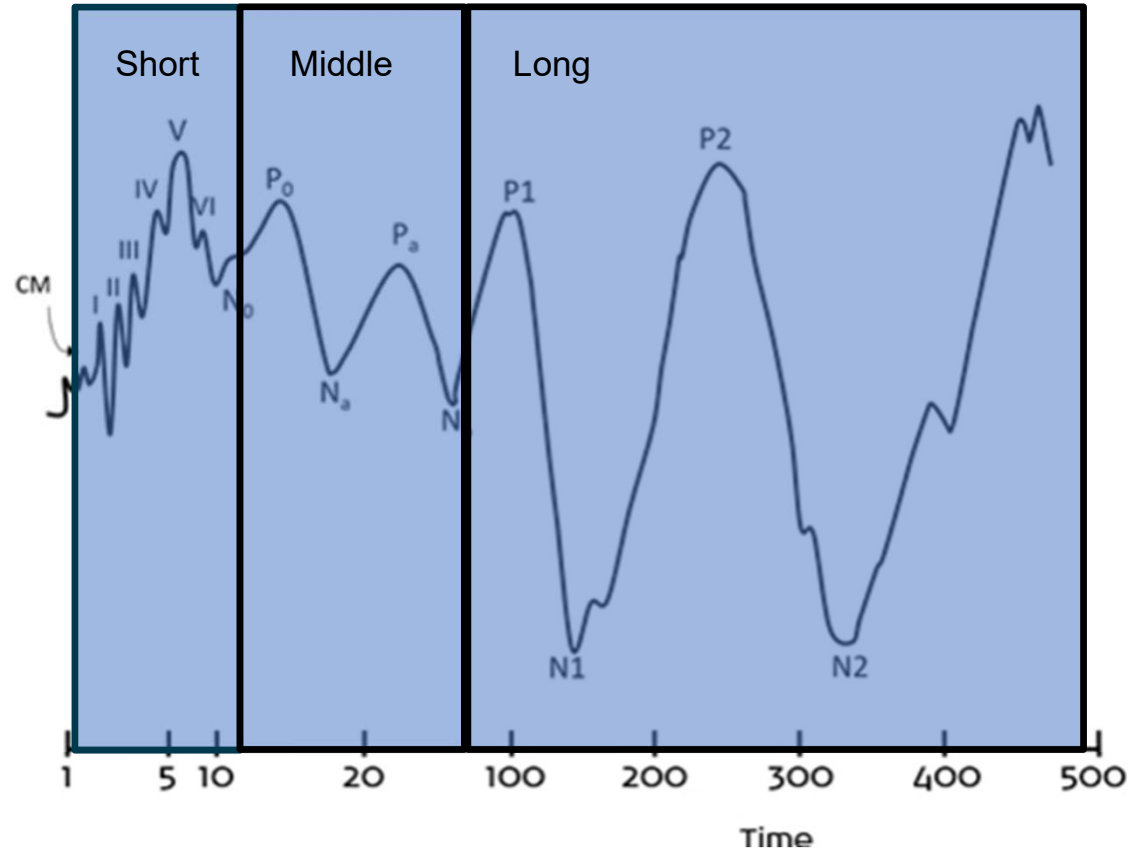
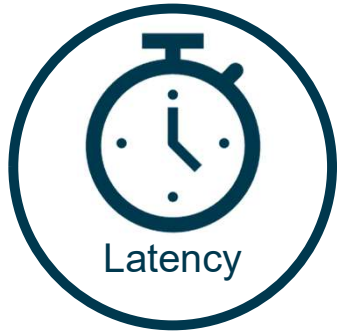


## Learning Objectives

- Understand Aided Cortical Testing
- Explain the need for Aided Cortical Testing
- Identify the Target Population for Aided Cortical Testing
- Demonstrate the Process for Aided Cortical Testing
- Interpret Cortical Testing Waveforms

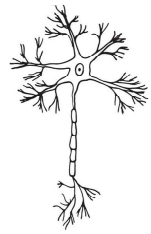
What is Aided  
Cortical  
Testing







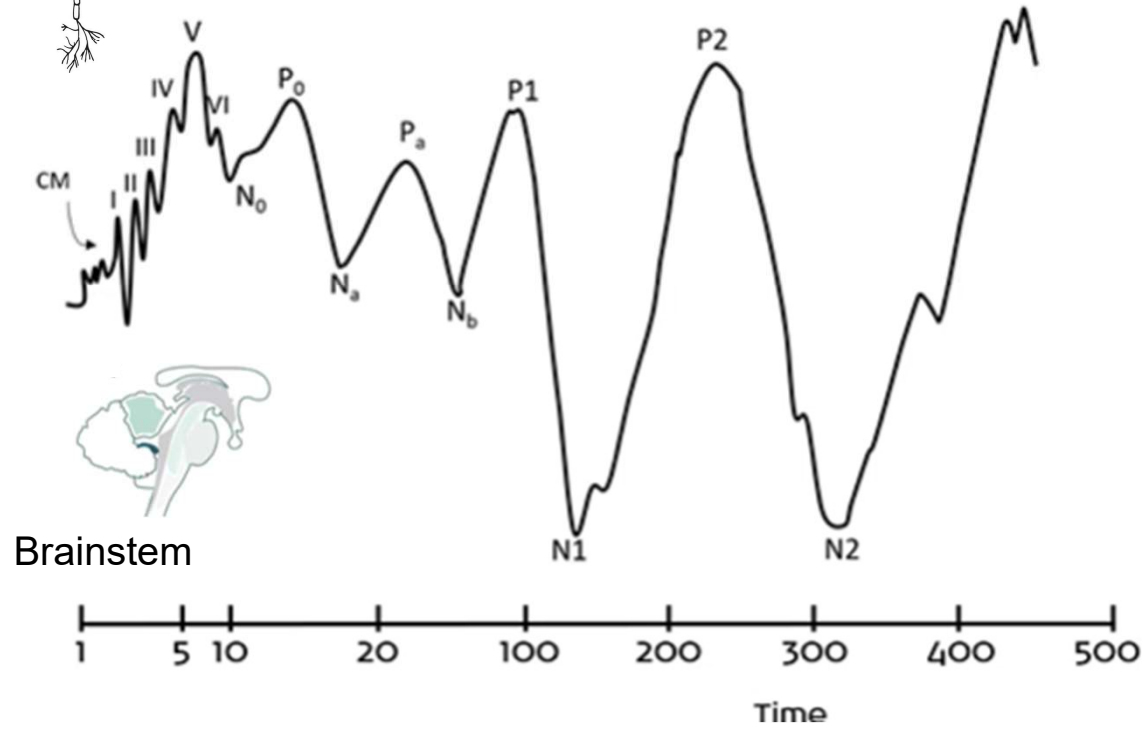
Auditory Nerve



Thalamus

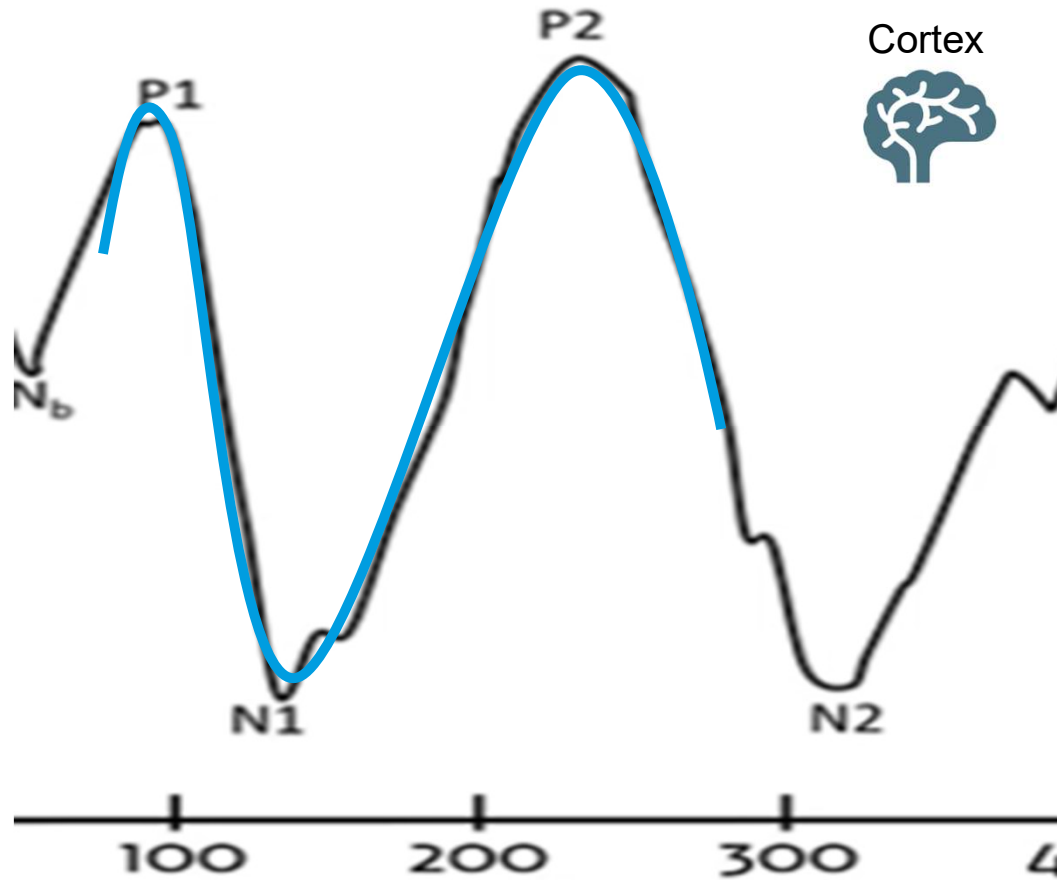


Cortex

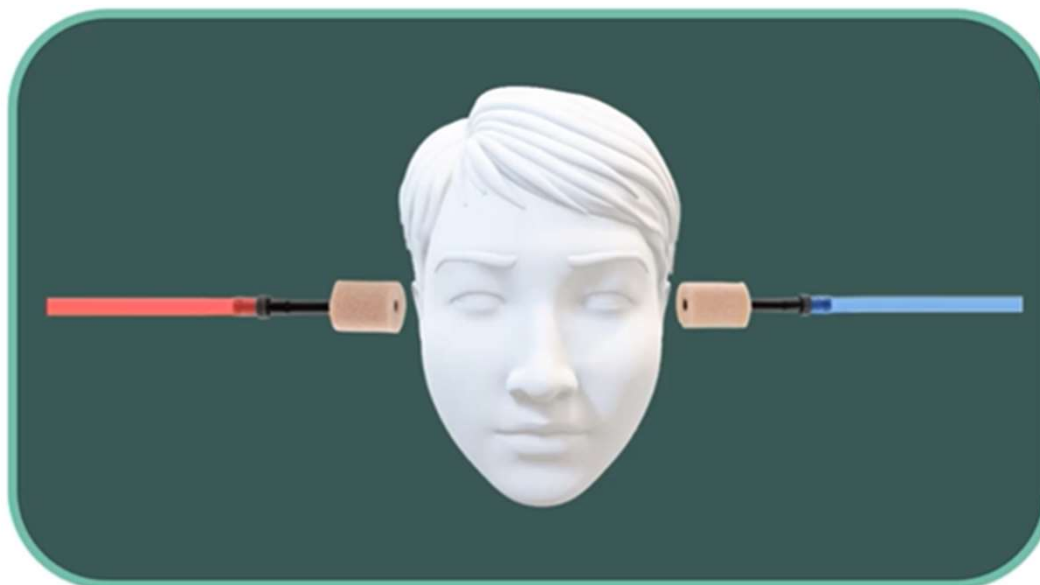




- Slow vertex response (SVR)
- N1-P2 Response
- Cortical evoked response audiometry (CERA)
- Cortical auditory evoked potential (CAEP)
- Auditory late response (ALR)
- Auditory cortical response (ACR)
- Mismatch negativity (MMN)
- P300

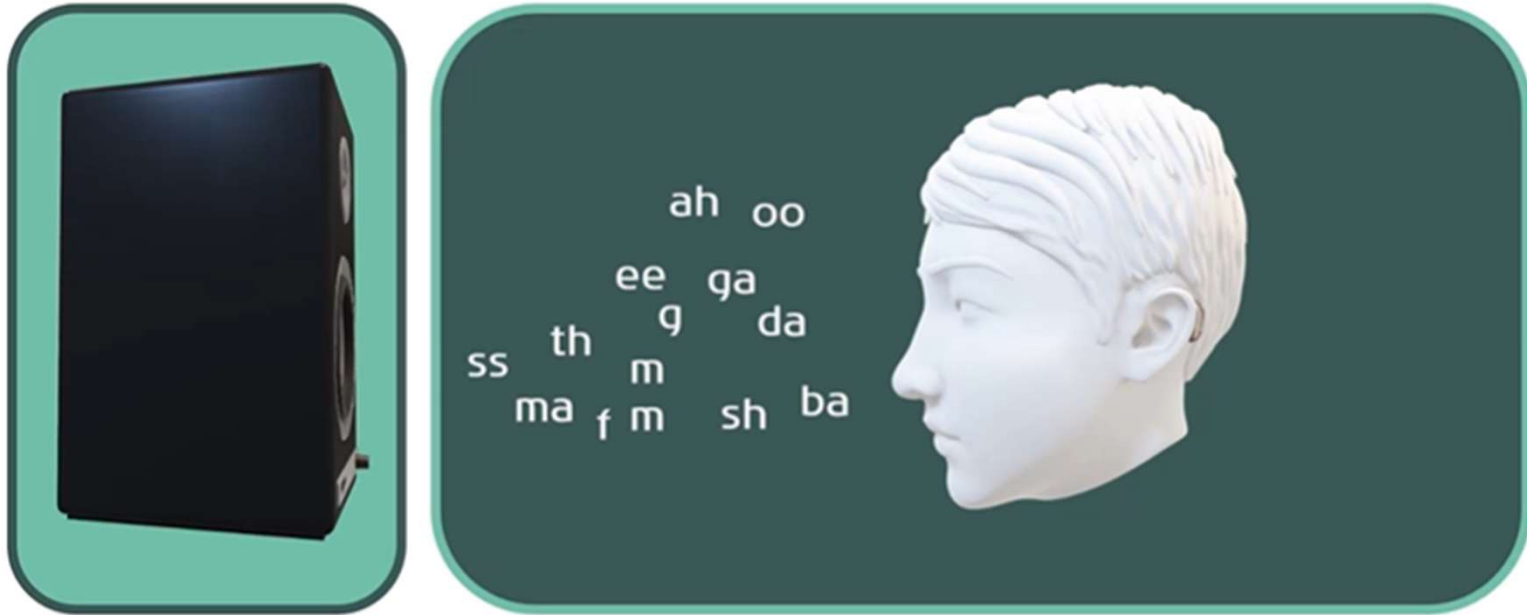


# d Threshold CAEP





# Aided Cortical Test



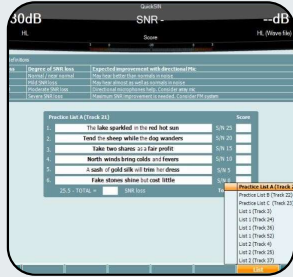


Why perform  
aided cortical  
testing





Audiogram



Speech in Noise Testing



Hearing Aid Selection



Test Box Measures



Real Ear Measures

How do we  
know if the  
hearing aid is  
doing the job  
properly





## Outcome measures

- Self-reporting measures
- Validated questionnaires
- Input of other people in patient's life
- Direct speech testing with the patient, and speech-in-noise testing with the hearing aids
- But what if the patient can't do any of these outcome measures?



## Aided cortical – an objective validation

- An objective method to validate the benefit of a fitted hearing aid or cochlear implant in patients who cannot subjectively respond to a hearing test, by measuring a patients cortical responses to speech-like sounds



Who is suitable  
for Aided  
Cortical  
testing?





## Infants and young children

- Infants aged 3 to 7 months
- Young children not doing aided VRA for whatever reason, to assess aided benefit
- ANSD children post ABR / pre-behavioural. What can they hear?
- Severe to profound losses. Is the hearing aid working or do they need a CI?
- CI users, with some limitations





## Older children

- Not performing reliable behavioural testing
- Complex needs, developmental delay, disabilities
- Non-organic hearing losses

Consider:  
ABR  
ASSR  
Threshold  
Cortical







## Adults

- Adults with complex needs who cannot perform traditional behavioural testing – aided or unaided
- Cochlear implant candidates – deriving benefit from their hearing aids?
  - Cross-check for behavioural testing
- CI users, with some limitations

Consider:  
ABR  
ASSR  
Threshold  
Cortical

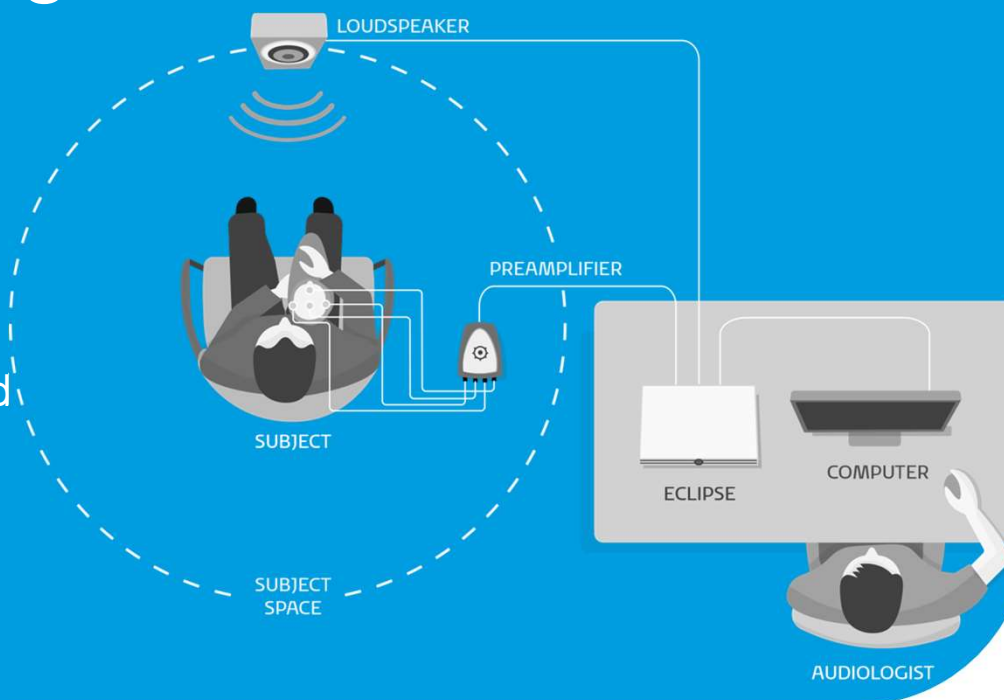
How Do I  
Perform Aided  
Cortical  
Testing





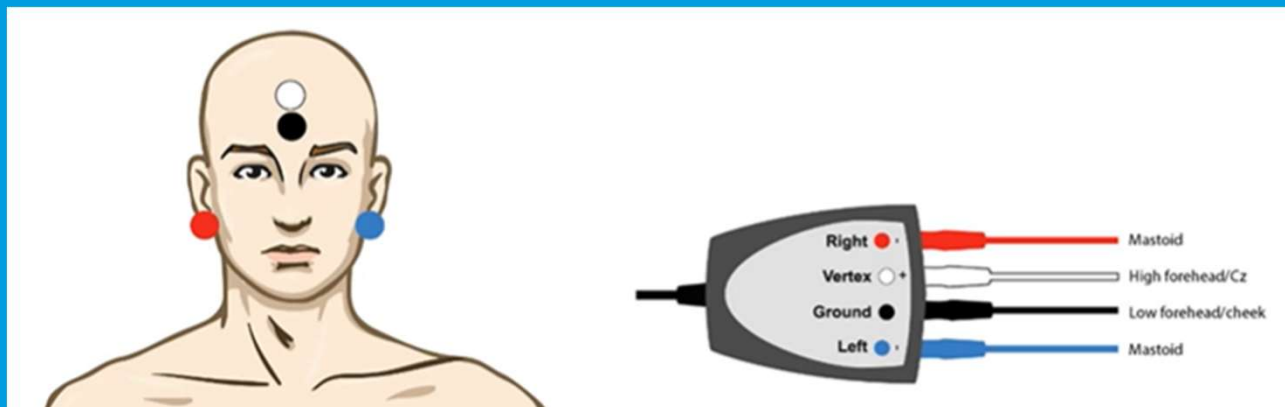
# How to perform Aided Cortical testing

- Field speaker delivers signal/stimuli
- Electrodes place on patient to measure the cortical response
- Awake patient activated with movie, toys, etc.





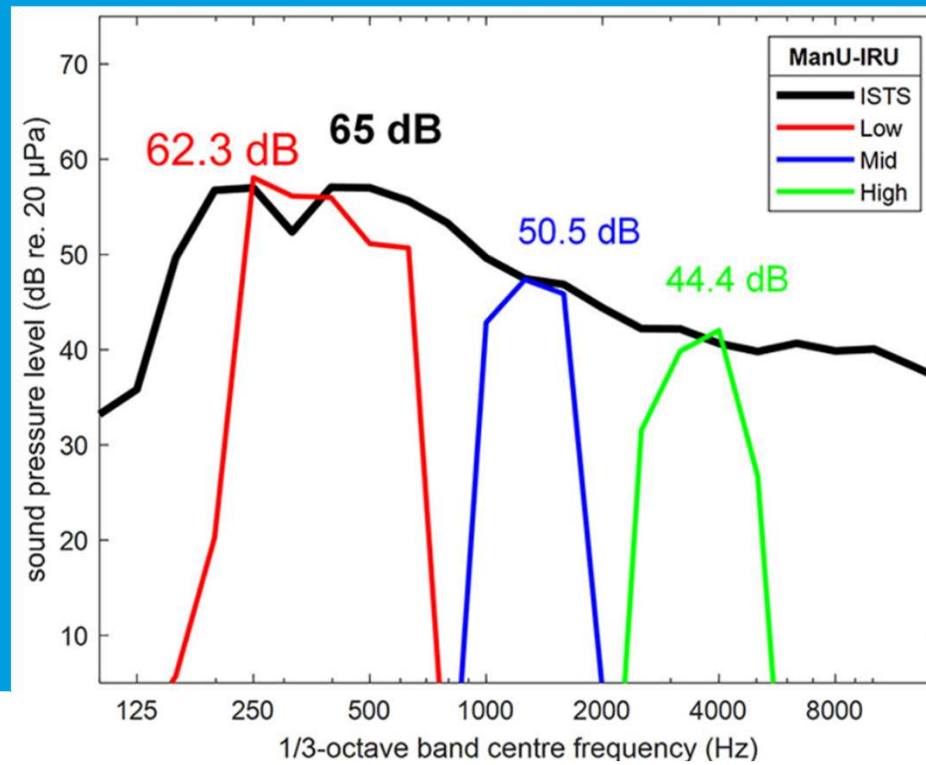
# Electrode Placement





# Speech sounds

- ManU-IRU
- HD-Sounds
- Ling 6





# Eclipse

- Aided Cortical

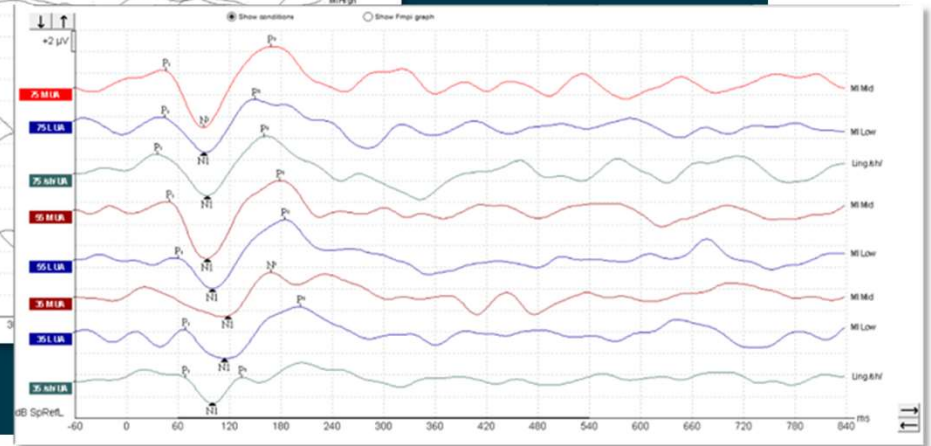
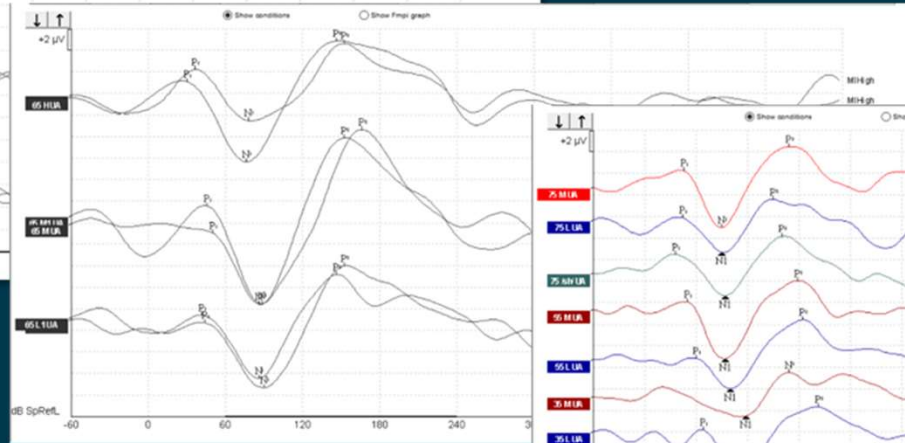
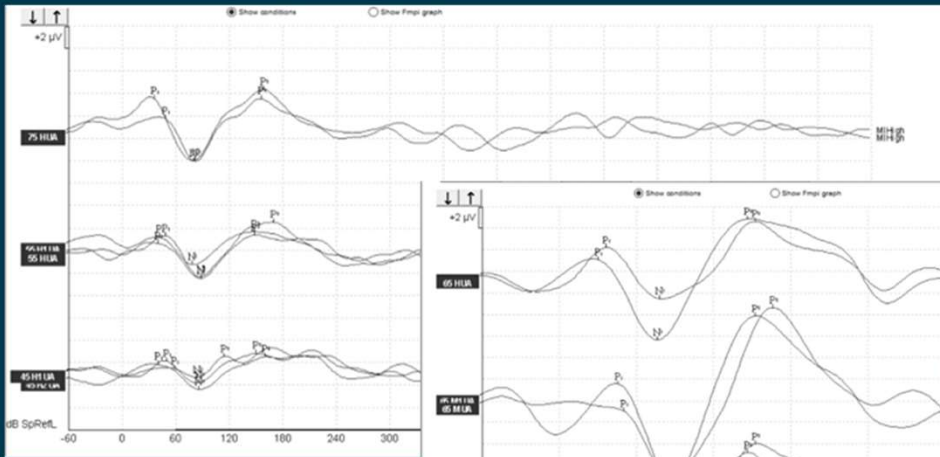
How to perform  
aided cortical  
on a child  
or infant



How do we  
identify cortical  
responses?

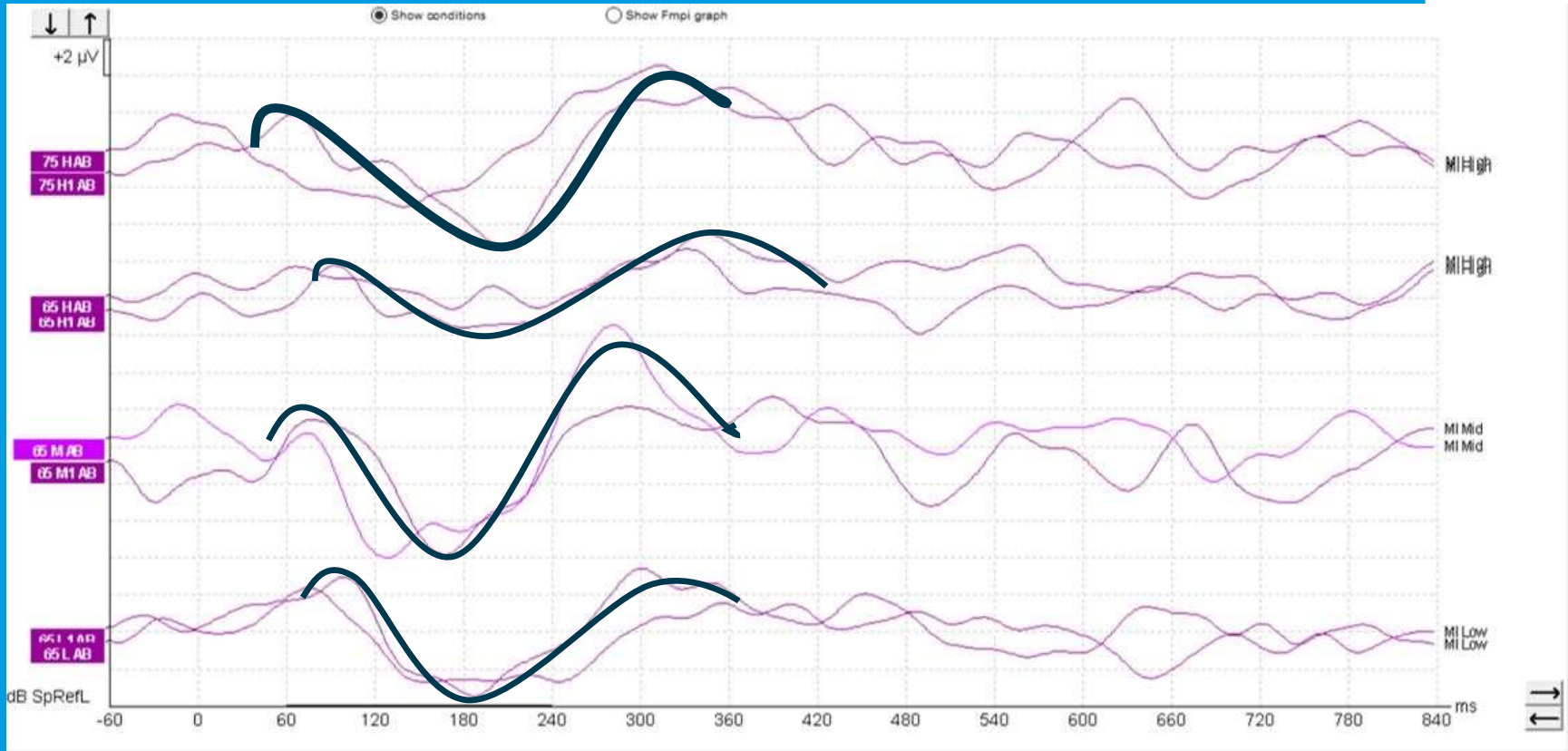


# d Adults

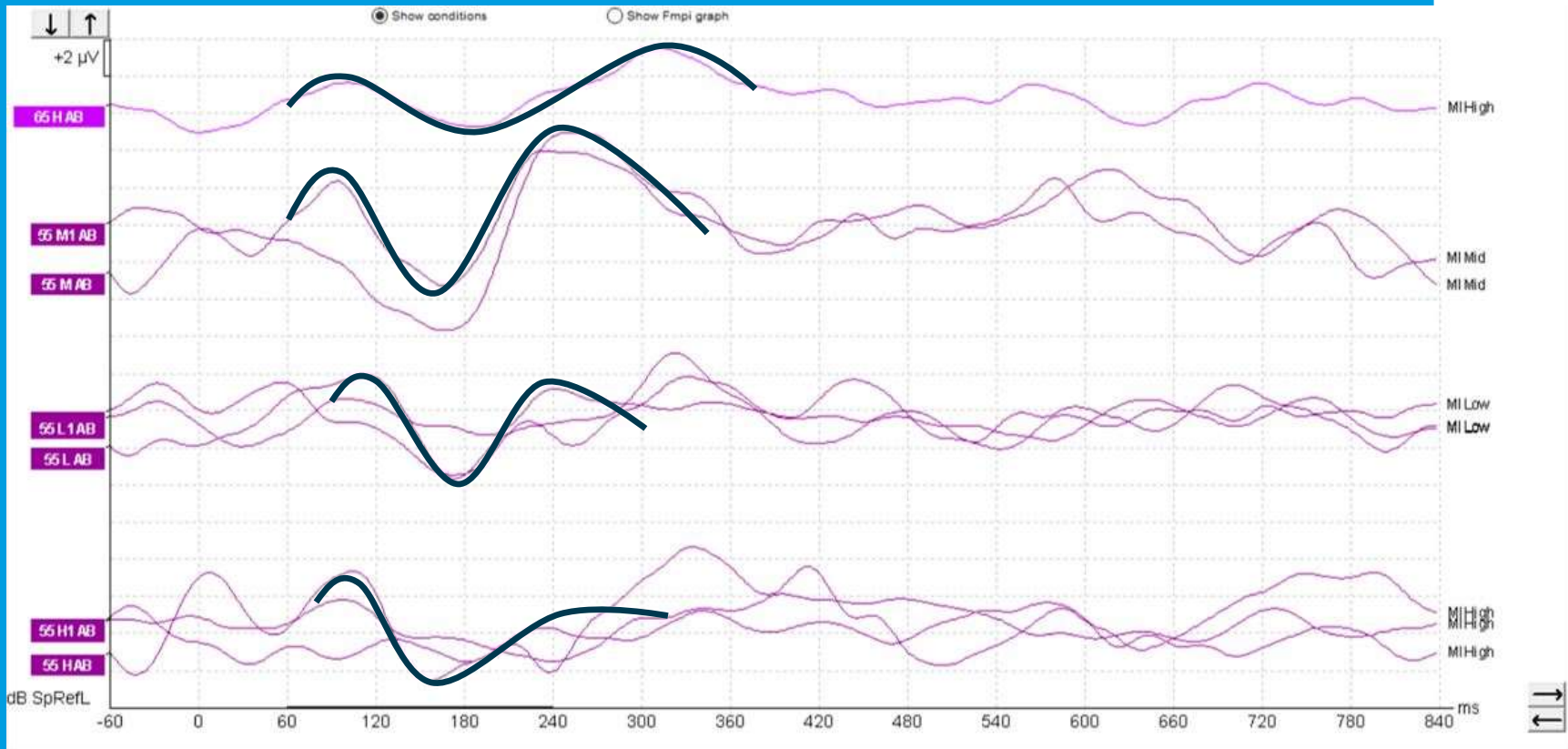




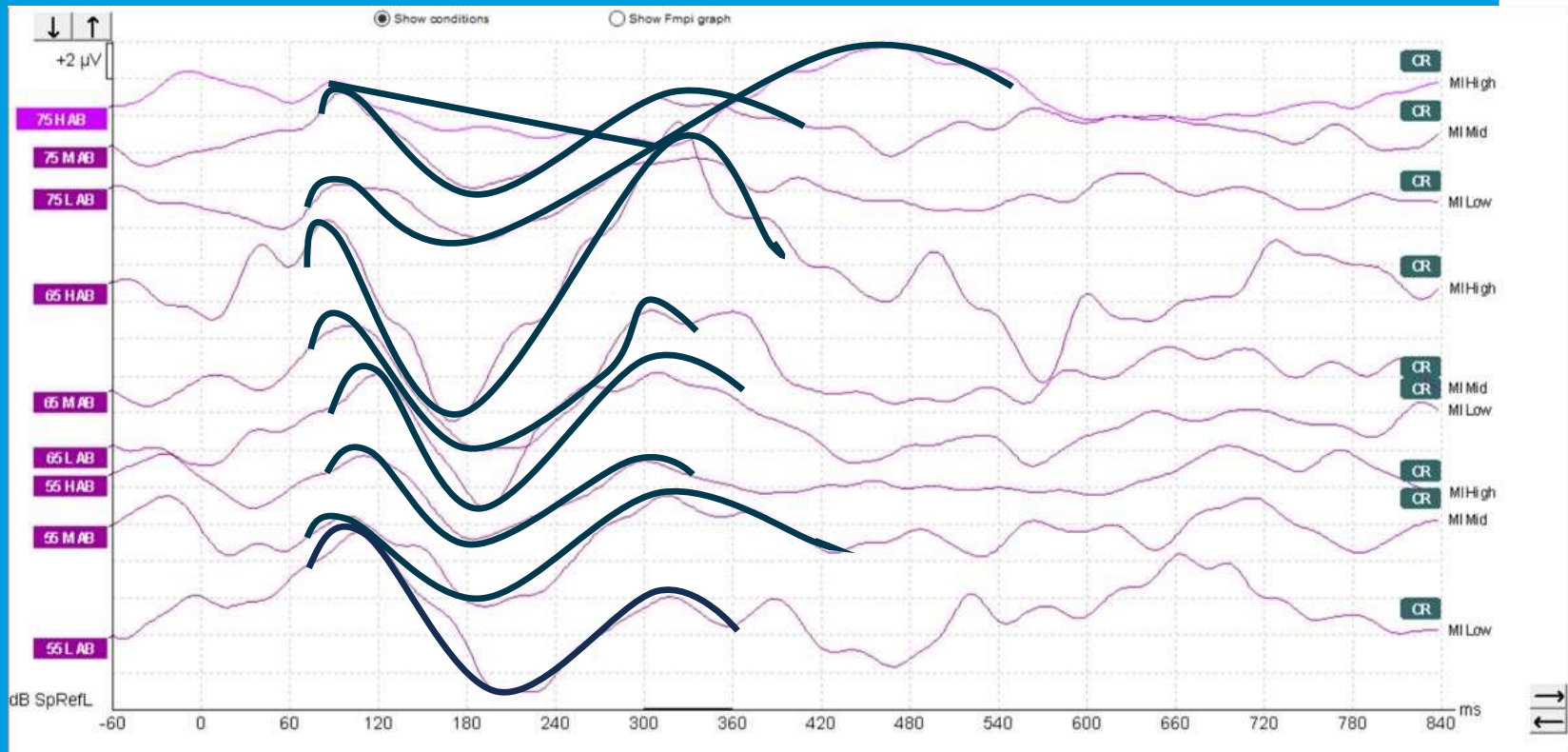
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# Fmpi detector

- Optimized for faster detection of responses (less recordings needed)
- Displays detector value as a percentage for clear guidance
- Stop measurement when reaching response confidence of 95% or 99%

**A novel method to detect auditory evoked potentials - the Fmpi**  
 Jaime A. Undurraga<sup>1,4</sup>, Michael Chesnaye<sup>2</sup>, David Simpson<sup>3</sup>, James Harte<sup>1,3</sup>, Søren Laugesen<sup>1</sup>

**IRU**  
 Interacoustics Research Unit

**Introduction**  
 Hearing screening is critical to early detection and intervention in the case of hearing loss. Auditory brainstem responses as well as auditory steady-state responses are well-established and standardized objective screening measurements. In addition to screening, auditory evoked potentials (AEPs) - subcortical and cortical - offer an attractive alternative to fix hearing and device and to provide information beyond the simple detection of speech (e.g., speech discrimination) in infants. Despite direct clinical impact, AEPs continue to provide important basic understanding of auditory processing in the brain. Whilst the benefits of using AEPs and their impact are clear, their reliability and potential clinical implementation are dependent on the detector method used and the inherent properties of the background neural activity present in the test subject's brain, which can vary across subjects. To solve this problem in real-time implementations, as well as the need of false detections can be high, a conservative approach, based on specific assumptions about the underlying noise, is typically used. Whilst this helps to control error rates, it leads to slower detection and potentially inflated morbidity to detecting responses. Exhaustive bootstrapping methods offer a much more reliable and adaptive approach, but they come with a substantial computational burden, limiting their clinical impact. Here, we introduce and validate a novel approach for AEP detection, referred to as the Fmpi method. This approach provides improved detection and controlled error rates by exploiting the meaning-dependent characteristics of the background neural activity.

**Methods**  
 The average response can be expressed as:  

$$S(t) = w^T X(t) + w^T BN(t) - X(t) + RN(t) \quad (1)$$

$$T(t) = w^T S(t) = w^T X(t) + w^T BN(t) - X(t) + RN(t) \quad (2)$$
 For weighted averaging  $w$  and  $w_{avg}$  are given by:  

$$w = \frac{1}{\sqrt{2\pi}} \frac{1}{\sigma} e^{-\frac{1}{2\sigma^2} (\frac{t}{T})^2} \quad (3)$$

$$w_{avg} = \frac{1}{\sqrt{2\pi}} \frac{1}{\sigma} e^{-\frac{1}{2\sigma^2} (\frac{t}{T})^2} \quad (4)$$
 The signal to noise ratio (SNR) is given by:  

$$SNR = \frac{\sigma_X^2}{\sigma_{BN}^2 + \sigma_{RN}^2} - 1 \quad (5)$$
 A first approach consists of estimating the residual from the variance across epochs:  

$$\hat{\sigma}_{BN}^2 = \frac{1}{N} \sum_{n=1}^N \frac{1}{\sigma_X^2} \left( \frac{1}{\sigma_X^2} (x(n,t) - T(t))^2 \right) \quad (6)$$
 A second approach consists of estimating the residual from the variance within epochs:  

$$\hat{\sigma}_{RN}^2 = \frac{1}{M} \sum_{m=1}^M \frac{1}{\sigma_X^2} \left( \frac{1}{\sigma_X^2} (x(n,t) - T(t))^2 \right) \quad (7)$$
 The probability of the F-value is given by:  

$$p = 1 - F_{CDF}(F, \nu_1, \nu_2) \quad (8)$$

$$F = \frac{\frac{\hat{\sigma}_{BN}^2}{\sigma_X^2}}{\frac{\hat{\sigma}_{RN}^2}{\sigma_X^2}} \quad (9)$$

$$\nu_1 = \frac{2M}{\sigma_X^2} \quad \nu_2 = \frac{2N}{\sigma_X^2} \quad (10)$$

**Simulations**  
 Figure 1: AEP simulation. Left, positive detection under stationary Gaussian noise. Right, signal to noise ratio. A total of 100 epochs, each of 50 samples, were simulated using a sampling rate of 5000 Hz. Values were obtained every 10 epochs (shown in red) with a total of 10000 simulations for each epoch block.  
 Figure 2: Cortical simulation. Left, positive detection under stationary Gaussian noise. Right, signal to noise ratio. A total of 100 epochs, each of 50 samples, were simulated using a sampling rate of 5000 Hz. Values were obtained every 10 epochs (shown in red) with a total of 10000 simulations for each epoch block.  
 Figure 3: ABR simulation. Left, positive detection under stationary Gaussian noise. Right, signal to noise ratio. A total of 100 epochs, each of 50 samples, were simulated using a sampling rate of 5000 Hz. Values were obtained every 10 epochs (shown in red) with a total of 10000 simulations for each epoch block.  
 Figure 4: ABR simulation under non-stationary white noise (left) and pink noise (right). A detection rate of 0.99 was achieved. All methods used a 200ms epoch length and an average window of 50ms. A sampling rate of 5000 Hz was employed. Data were binned between 7 and 30 Hz.  
 Figure 5: Cortical simulation under non-stationary white noise (left) and pink noise (right). A detection rate of 0.99 was achieved. All methods used a 100ms epoch length and an average window of 50ms. A sampling rate of 5000 Hz was employed. Data were binned between 7 and 30 Hz.

**Adult cortical data from infants**  
 To test the Fmpi we reanalyzed adult cortical recordings we had with synthetic speech stimuli [3, 7].  
 Figure 6: Adult cortical detection rates. On top, SNR (0.1, 0.5) and bottom high-frequency (0.1, 0.5) speech [3]. All methods used a 100ms epoch length and an average window of 50ms. A sampling rate of 5000 Hz was employed. The resulting F1 rate and 10 binned F2 rates were binned between 7 and 30 Hz. The number of samples is indicated by the number above the bars.

**Cortical data from adults**  
 The Fmpi detector was also tested in normal-hearing (NH) and hearing-impaired (HI) adults responses evoked via vowel-like frequency discrimination.  
 Figure 7: Cortical detection rates in vowel-like discrimination. On top, hearing-impaired (HI, n=20) and bottom, normal-hearing (NH, n=20) responses to vowel-like discrimination (vowel with offset) responses, from 1 (offset) to 4 (step) to 6 (step) to 8 (step) to 10 (step) to 12 (step) to 14 (step) to 16 (step) to 18 (step) to 20 (step) to 22 (step) to 24 (step) to 26 (step) to 28 (step) to 30 (step) to 32 (step) to 34 (step) to 36 (step) to 38 (step) to 40 (step) to 42 (step) to 44 (step) to 46 (step) to 48 (step) to 50 (step) to 52 (step) to 54 (step) to 56 (step) to 58 (step) to 60 (step) to 62 (step) to 64 (step) to 66 (step) to 68 (step) to 70 (step) to 72 (step) to 74 (step) to 76 (step) to 78 (step) to 80 (step) to 82 (step) to 84 (step) to 86 (step) to 88 (step) to 90 (step) to 92 (step) to 94 (step) to 96 (step) to 98 (step) to 100 (step) to 102 (step) to 104 (step) to 106 (step) to 108 (step) to 110 (step) to 112 (step) to 114 (step) to 116 (step) to 118 (step) to 120 (step) to 122 (step) to 124 (step) to 126 (step) to 128 (step) to 130 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## Detection

- Morphology of the CAEP can vary considerably from one infant to the next (BSA, 2022)
- Objective detection methods... are very valuable in interpreting infant CAEP responses (BSA, 2022)
- HEARLab indicates a response is present by showing a p-value smaller than 0.05)
- Eclipse module also has a detection algorithm known as fmpi



## Detection

- Look at the statistical variance of the wave form in relation to the estimated residual noise of the waveform
- How do they estimate the residual noise
- Fsp – one single point on the waveform
- Fmp – expanded to use multiple points, 5 points of data on the waveform on ABR
- Fmpi – make sue of every point on the waveform – use 250 data points to determine the residual noise
- i = individualized, takes into account the background EEG – actually records EEG and uses it in calculation of residual noise, record more responses in less time

# d Detection

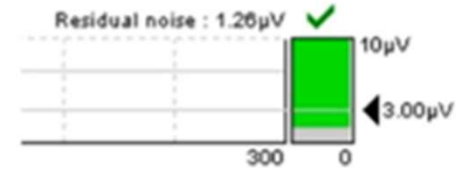


For infants in a relaxed state, noise voltages are typically around  $3.4 \mu\text{V}$  after 100 epochs (Carter et al, 2010)

HEARLab

- > 3.6 ●
- 3.2 - 3.6 ●
- < 3.2 ●

Eclipse





## Waveform labelling

CR

Clear Response

Fmpi >95%

RN does not matter

Acceptable  
morphology





## Waveform labelling

**RA**

Response Absent

Fmpi <95%

RN low

Repeated waveform

No clear waveform



## Waveform labelling

**INC**

Inconclusive

Fmpi <95%

RN high

Continue testing to  
reduce RN

**!Single RA trace is INC!**

Aided Cortical  
Research





# Ladies in the Van



OPEN

## Aided Cortical Auditory Evoked Potentials in Infants With Frequency-Specific Synthetic Speech Stimuli: Sensitivity, Repeatability, and Feasibility

Anisa S. Visram,<sup>1,2</sup> Michael A. Stone,<sup>1,2</sup> Suzanne C. Purdy,<sup>3</sup> Steven L. Bell,<sup>4</sup> Jo Brooks,<sup>1,2</sup>  
Iain A. Bruce,<sup>2</sup> Michael A. Chesnaye,<sup>4</sup> Harvey Dillon,<sup>1,5</sup> James M. Harte,<sup>6,7</sup>  
Caroline L. Hudson,<sup>1,2</sup> Søren Laugesen,<sup>6</sup> Rhiannon E. Morgan,<sup>1,2</sup> Martin O'Driscoll,<sup>2</sup>  
Stephen A. Roberts,<sup>1</sup> Amber J. Roughley,<sup>1,2</sup> David Simpson,<sup>4</sup> and Kevin J. Munro<sup>1,2</sup>

**Objectives:** The cortical auditory evoked potential (CAEP) test is a candidate for supplementing clinical practice for infant hearing aid users and others who are not developmentally ready for behavioral testing. Sensitivity of the test for given sensation levels (SLs) has been reported to some degree, but further data are needed from large numbers of infants within the target age range, including repeat data where CAEPs

**Conclusions:** By addressing the clinical need to provide data in the target age group at different SLs, we have demonstrated that aided CAEP testing can supplement existing clinical practice when infants with hearing loss are not developmentally ready for traditional behavioral assessment. Repeat testing is valuable to increase test sensitivity. For clinical application, it is important to be aware of CAEP response variability in



## Ladies in the Van

SL > 10 dB  
MF | HF  
94% | 79%

>99%  
completion

24 mins test  
time

Positive  
parental  
feedback



## Summary

- Objective validation of hearing aid fittings
- Reassuring
- Straightforward and easy to use
- Optimized hearing outcome
- Natural part of your clinical flow



Thank you!  
[jbru@diateccanada.com](mailto:jbru@diateccanada.com)

**Diatec Diagnostics**

*11-500 Trillium Dr.*

*Kitchener, ON*

*N2R 1A7*

Questions







# Why perform Aided Cortical Testing?

- Bridges the gap from fitting to behavioural testing
- Validate if a hearing aid or cochlear implant provides the necessary input

