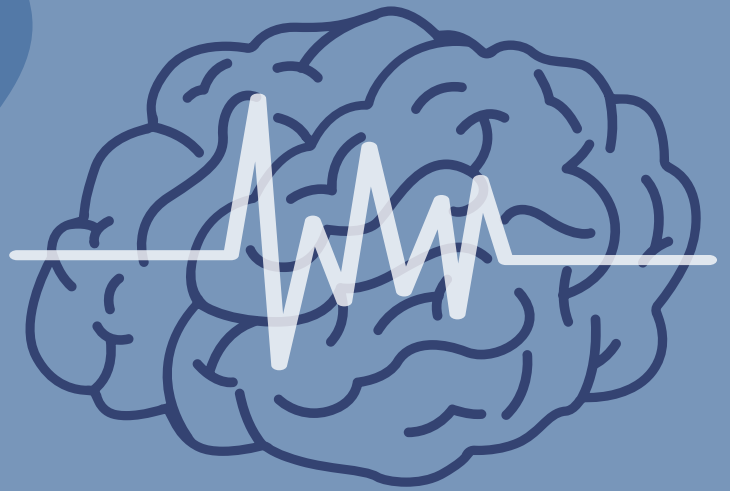
Comparison of ABR Wave V Amplitudes from Low-Intensity Tone-Pips and Clicks using Different Electrode Montages



By: Choo Wen Yan (Bob)
Thesis Supervisor: Prof. William H. Martin

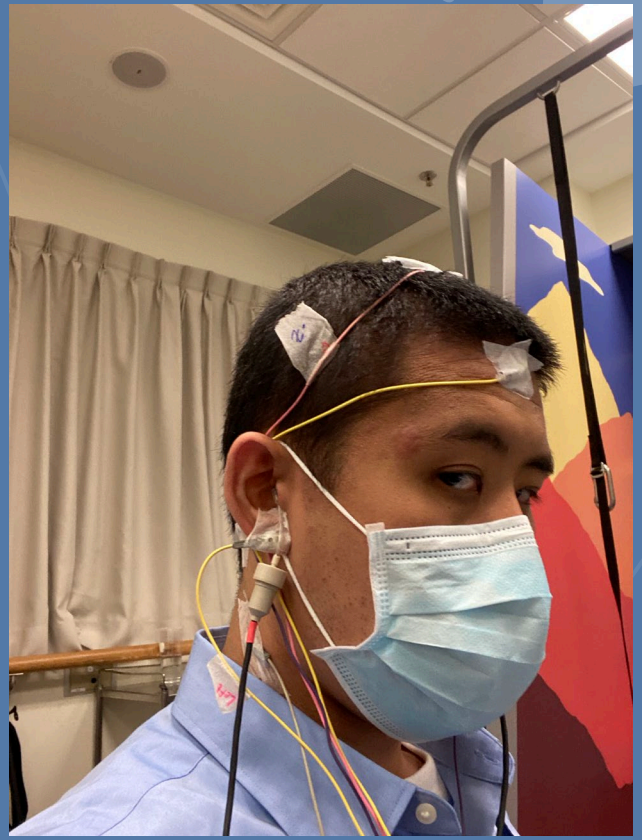
01

INTRODUCTION & BACKGROUND

WHAT WE KNOW - AUDITORY BRAINSTEM RESPONSE (ABR)

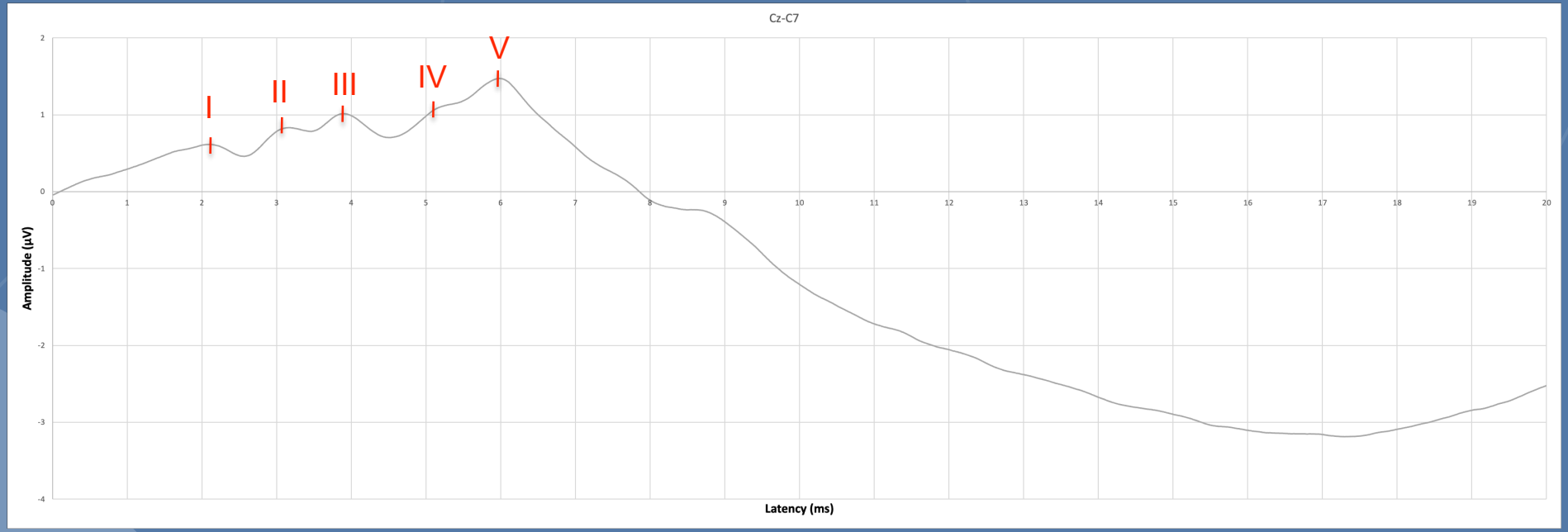
- Part of our standard audiometric test battery for estimating hearing thresholds of patients who cannot or will not cooperate with behavioural hearing test.

- Uses electrodes placed over various locations on the scalp (electrode montage) to record brain activity in response to frequency-specific tonal stimuli.



WHAT WE KNOW - AUDITORY BRAINSTEM RESPONSE (ABR)

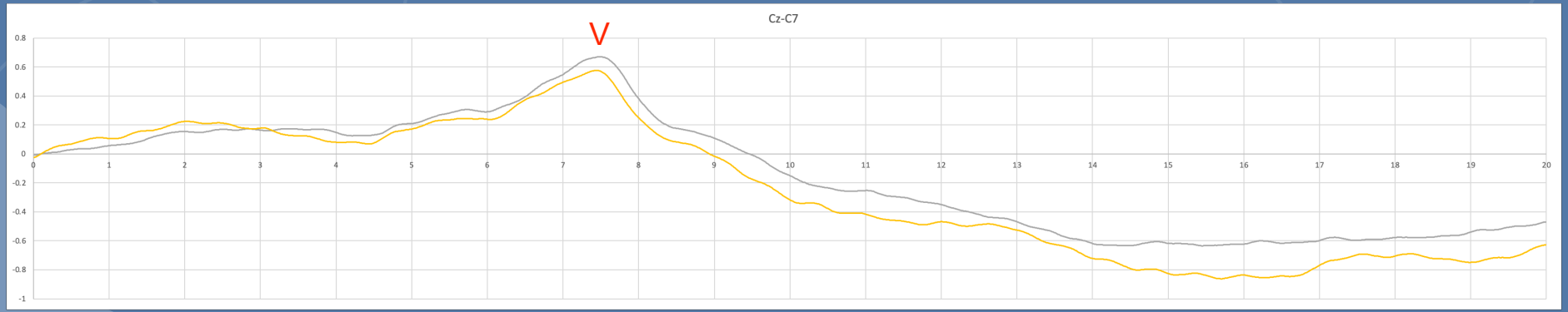
- Represented by the 5 waves (I - V) which are generated by different neural structures along the auditory pathway.



WHAT WE KNOW - AUDITORY BRAINSTEM RESPONSE (ABR)

- Capable of estimating down to within 20 dB of an individual's behavioural hearing thresholds.

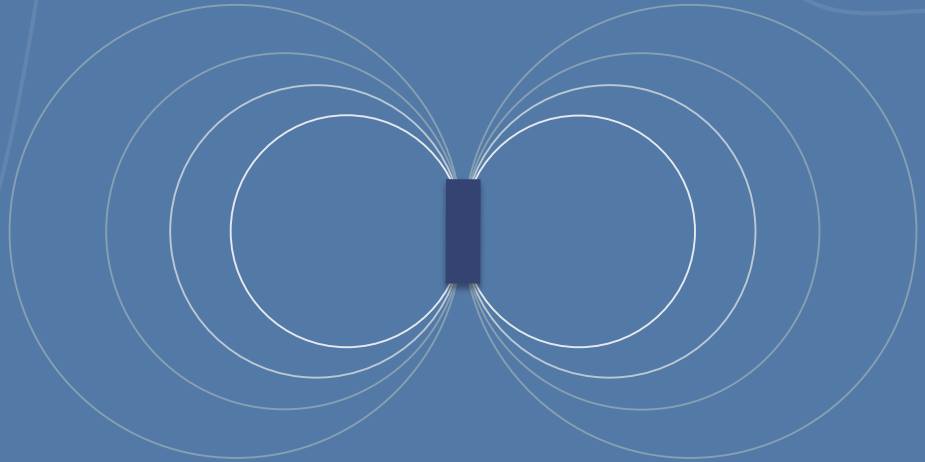
- Estimation of thresholds using ABR is achieved by the accurate and repeatable identification of wave V at the lowest possible stimulus intensity.



WHAT IS SUGGESTED

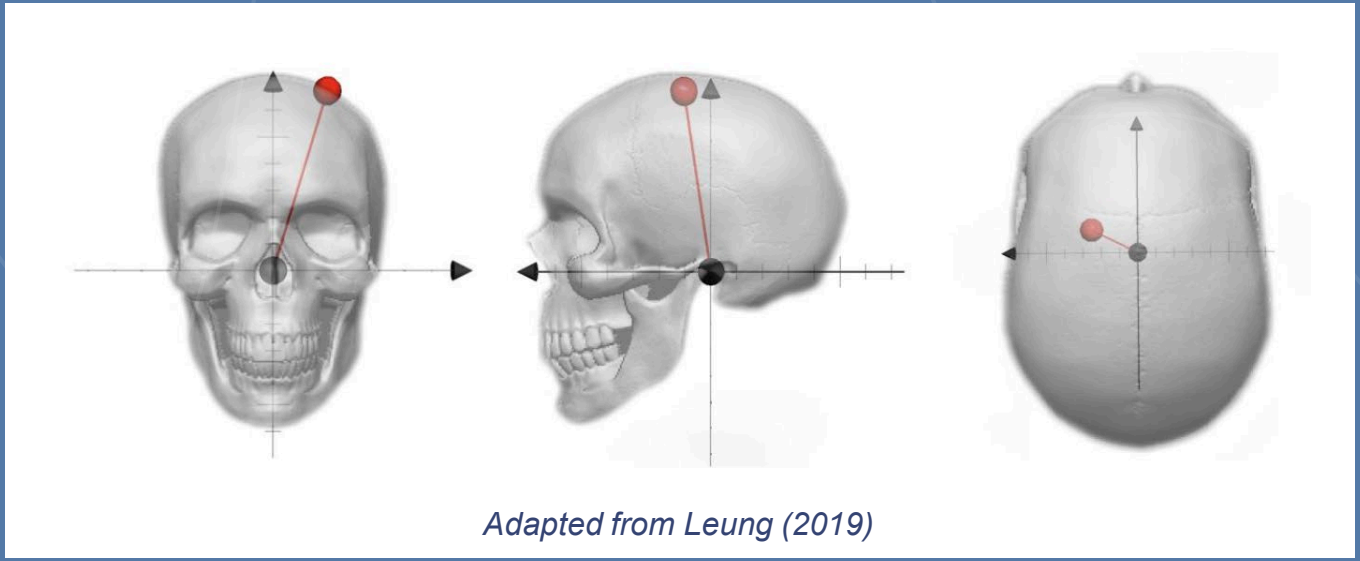
- Dipoles that correspond to the individual waves are oriented in different directions, and when activated, generates an electrical field around it.

- When placing electrodes at either ends of the dipole of interest, the maximum voltage should be obtained.



WHAT IS SUGGESTED - LEUNG (2019)

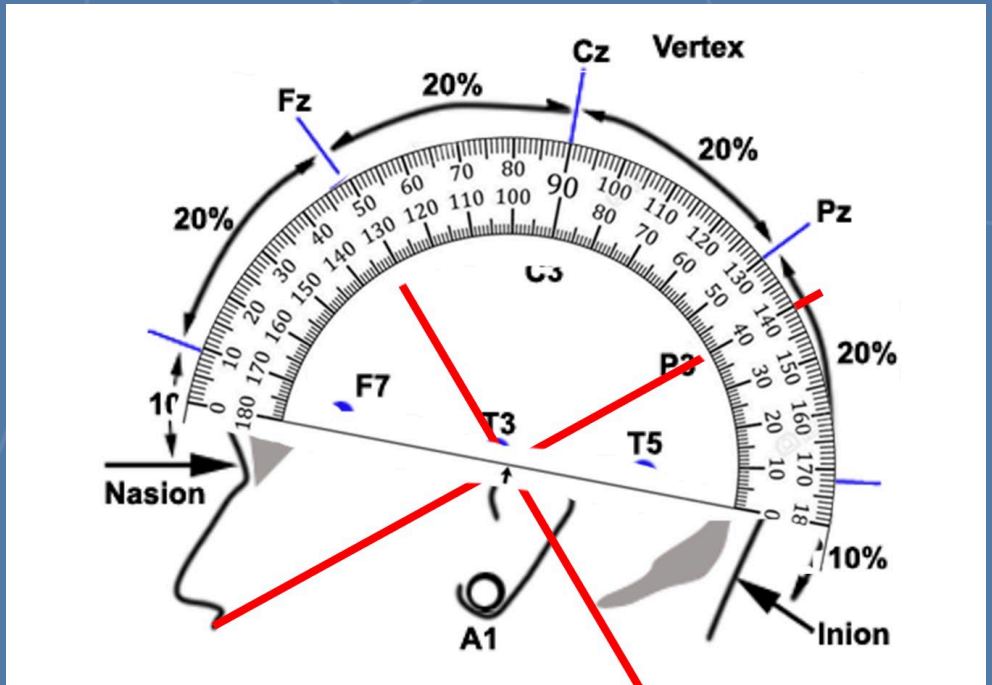
- Leung used the 3-Channel Lissajous Trajectory (3-CLT) and discovered that not only does the wave V dipole point vertically with a slight deviation towards the contralateral ear, the orientation remains relatively consistent across different stimulus types and intensities.



Adapted from Leung (2019)

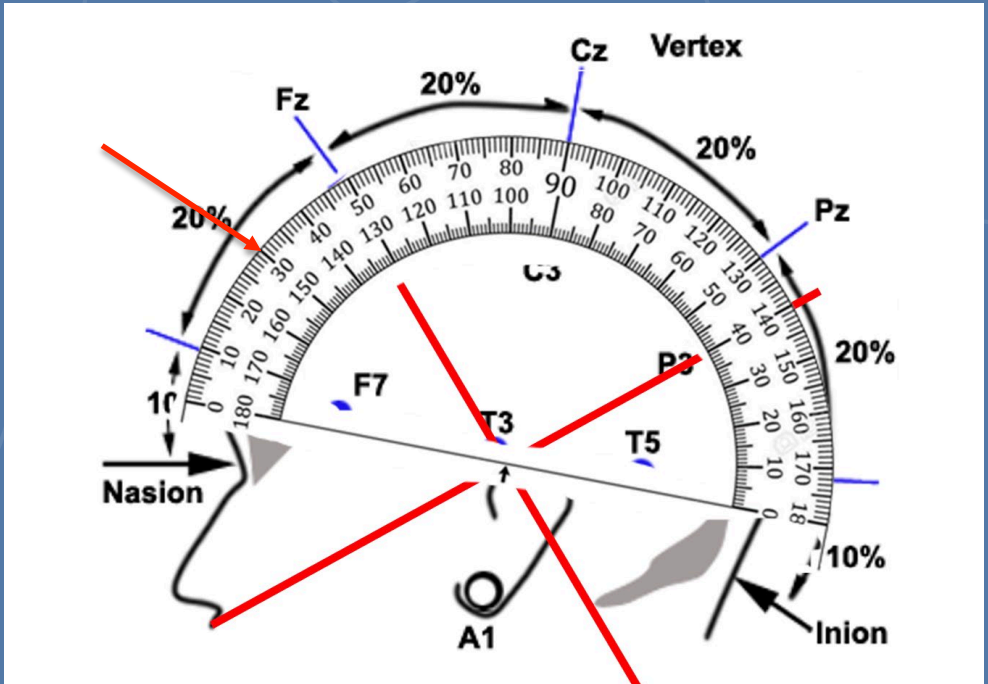
WHAT IS SUGGESTED - LEUNG (2019)

- Voltage distribution over the scalp obeys a cosine function (Stegeman et al., 1997).



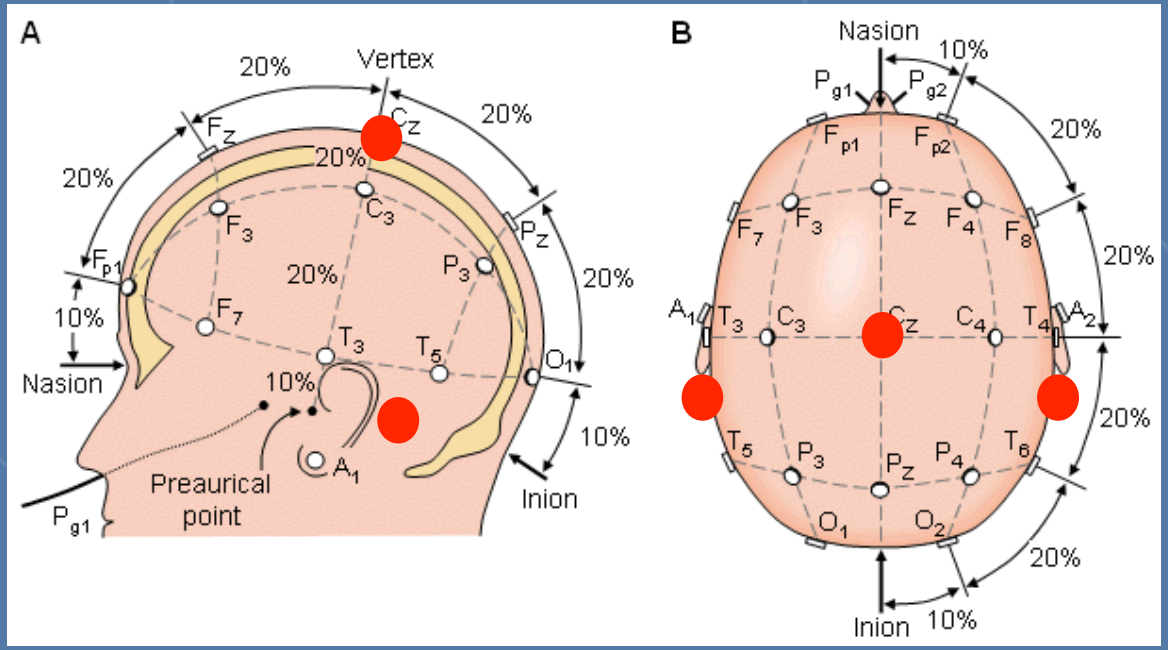
WHAT IS SUGGESTED - LEUNG (2019)

- By moving the electrode from a high forehead position (described as 60° anterior from the vertex) to the vertex, a 50% increase in amplitude could be achieved.



WHAT IS SUGGESTED - LEUNG (2019)

- A montage consisting of an electrode on the vertex (Cz) and an electrode on each mastoid combined to form a single electrode (Linked) would likely be sufficient to record the largest wave V amplitudes.



WHAT THE PROBLEM IS

- Although many studies have been done to compare the effects of electrode montages on the ABR wave V amplitude, most studies either:

1. Investigated using either clicks or stimuli that resembles that of a click (e.g. 4000 Hz single-cycle sign wave).

2. Utilised high-intensity stimuli.

AIM OF THIS STUDY

- Serves as a direct extension to Leung's (2019) study.

1. To determine if the wave V amplitude recorded using Leung's recommended montage (Cz-Linked) is significantly larger than the currently used montage in the clinic.

2. To determine if the wave V amplitude recorded by a third montage (Cz-C7) will be significantly larger than the other 2 montages.

HYPOTHESIS

Hypothesis 1

Cz-C7 montage will yield the largest and significantly larger wave V amplitudes compared to the other 2 montages.

Hypothesis 2

Cz-Linked montage will yield significantly larger wave V amplitudes as compared to the clinically used montage.

02

METHODOLOGY

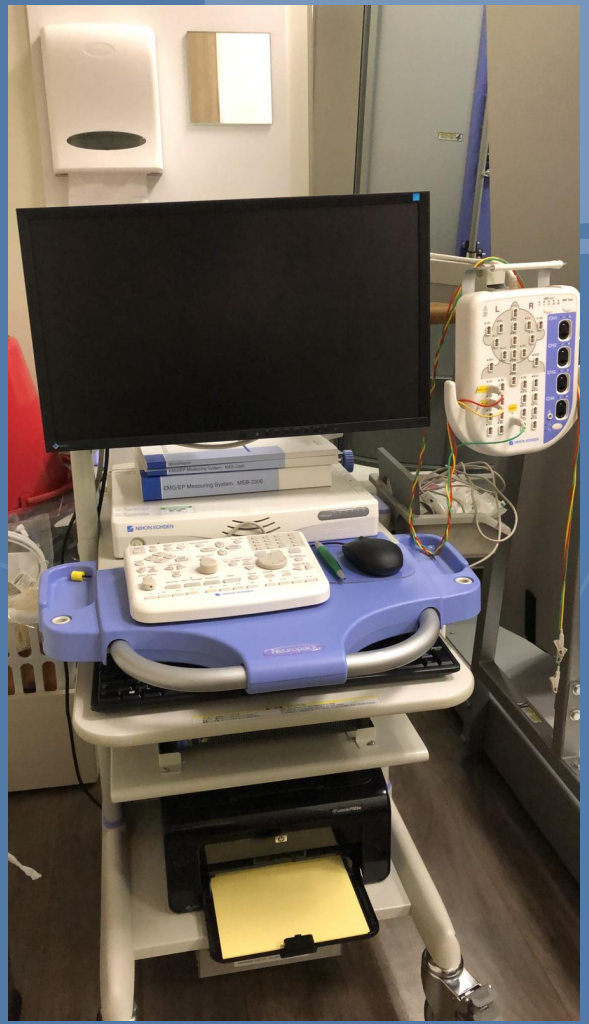
METHODOLOGY

- Subject Size: 20 normal-hearing adults (neurologically intact)

- Hearing screened at 25 dB HL across 500 Hz to 4000 Hz in both ears using Creare Wireless Audiometer

METHODOLOGY

- Evoked Potential machine used: Nihon Kohden MEB-2300
- Thresholds obtained in response to tonebursts (500 Hz - 4000 Hz) and clicks for sensation level (SL) calculation
- Silver disc electrodes applied to several areas on the head and neck forming 3 electrode montages (Impedance kept < 3000 Ω)



METHODOLOGY

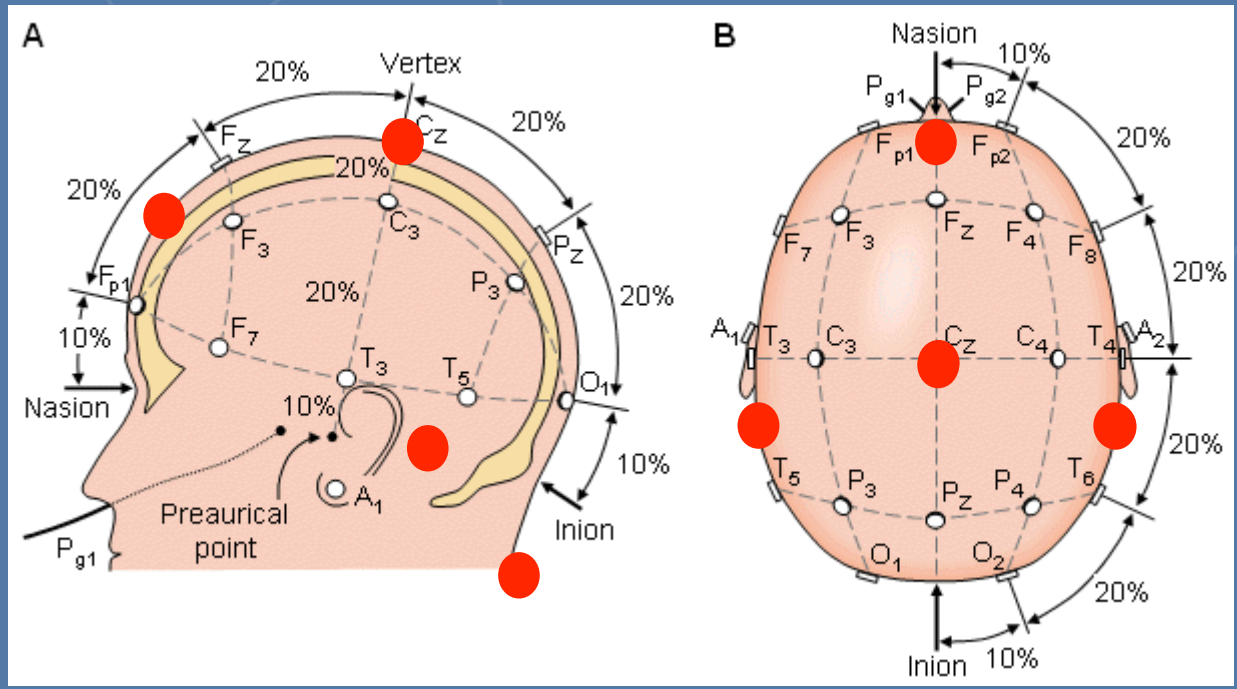
Montages:

1. Cz-Linked (suggested by Leung)

2. Fpz′-M2
   (simulate a clinically used montage)

3. Cz-C7
   (extra for comparison)

Ground electrode: Base of the neck (contralateral to ear of stimulation)



METHODOLOGY

- Stimulus:
  - Tonebursts (2-1-2) at 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz at 25 dB SL
  - Clicks (100 µs) at 25 dB SL and 80 dB nHL
- Right ear stimulation using proprietary insert phones
- Rate: 40/s (alternating polarity)
- Filter settings: 10 Hz - 1500 Hz

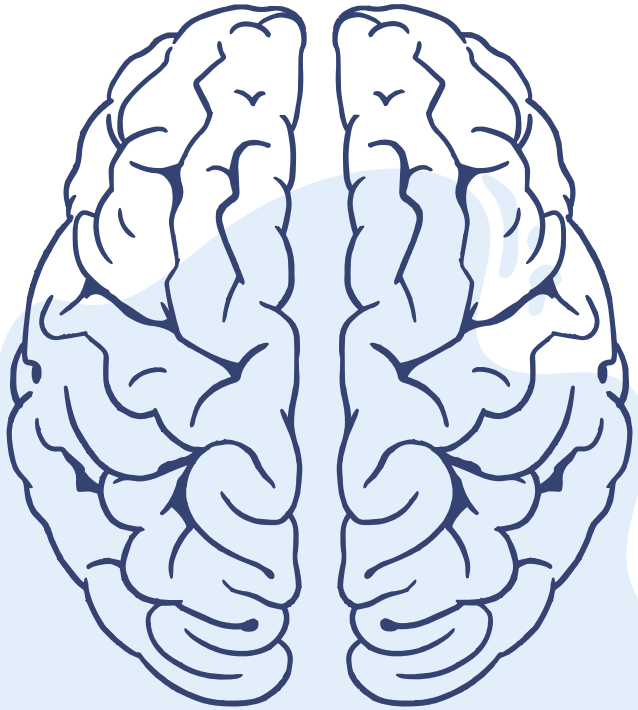
METHODOLOGY

- Sequential recordings (i.e. montage 1 + 2 at 25 dB SL -> montage 3 at 25 dB SL). Alternating between participants to limit order bias.
- 8000 sweeps per average, 2 averages per stimulus condition.
- Averaged into single trace for each stimulus condition, for each montage (each individual).

METHODOLOGY

- Amplitude measured from Wave V peak (chosen base on latency) to the trough that follows.
- Grand averaged amplitudes obtained for each condition, for each montage, for all subjects.
- Statistical comparison between individual montages done using one-tailed Paired t-test (criteria for significance set at $p \leq 0.05$).

03

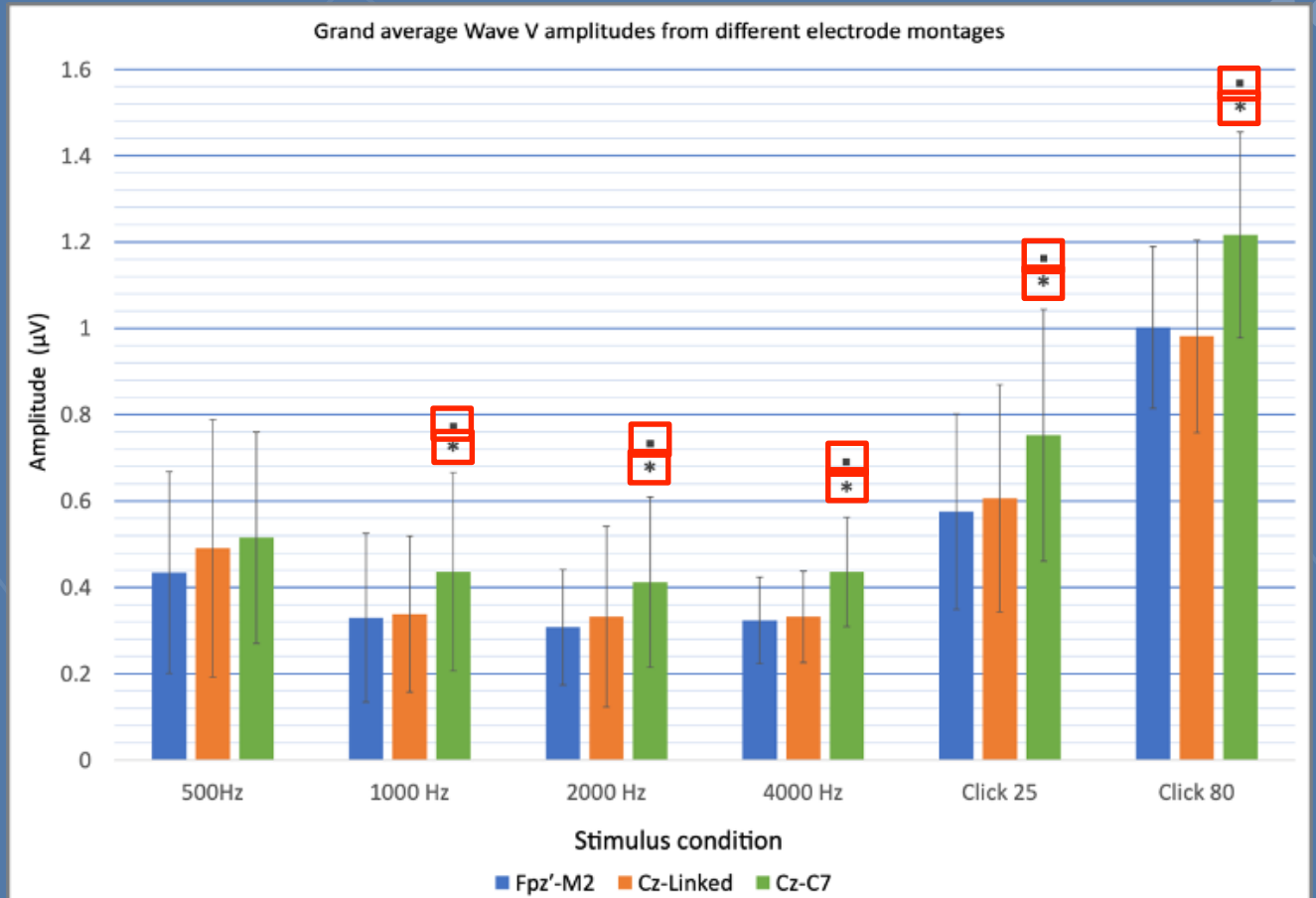


RESULTS

GRAND AVERAGED AMPLITUDES

Montages:		Cz-Linked		Fpz'-M2		Cz-C7	
Stimulus conditions:	Number:	Grand Avg (μV)	SD (μV)	Grand Avg (μV)	SD (μV)	Grand Avg (μV)	SD (μV)
Clicks 80 dB nHL	15	0.98	0.26	1.00	0.23	1.22	0.29
Clicks 25 dB SL	14	0.61	0.22	0.58	0.19	0.75	0.24
500 Hz Toneburst (25 dB SL)	16	0.49	0.30	0.43	0.23	0.52	0.24
1000 Hz Toneburst (25 dB SL)	13	0.34	0.18	0.33	0.20	0.44	0.23
2000 Hz Toneburst (25 dB SL)	14	0.33	0.21	0.31	0.13	0.41	0.20
4000 Hz Toneburst (25 dB SL)	18	0.33	0.11	0.32	0.10	0.44	0.13

STATISTICAL COMPARISON



AMPLITUDE PERCENTAGE COMPARISON

Montages:	Cz-Linked	Fpz'-M2	Cz-C7
Stimulus conditions:	**Amplitude percentage difference (referencing Fpz-M2)**		
Clicks 80 dB nHL	-2.03	0.00	21.41
Clicks 25 dB SL	5.38	0.00	30.77
500 Hz Toneburst (25 dB SL)	12.81	0.00	18.47
1000 Hz Toneburst (25 dB SL)	2.53	0.00	32.22
2000 Hz Toneburst (25 dB SL)	7.94	0.00	34.02
4000 Hz Toneburst (25 dB SL)	2.57	0.00	34.71
Averaged percentage difference for 25 dB SL tonebursts	6.46	0.00	29.85

04

DISCUSSION

HYPOTHESIS

Hypothesis 1

Cz-C7 montage wi d
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PROVEN

*Except for 500Hz

Hypothesis 2

Cz-Linked monta
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DISPROVEN

LIMITATIONS

1. Small Sample Size

2. The Great Evil - Noise

41% INCREASE IN AMPLITUDE?

- Base on the high-forehead electrode location (Fpz′) used in this study (54° degrees anterior to the vertex), the difference in amplitude should be about 41%.

Cz-Linked: 6.5%

Cz-C7: 30%

WHY DIDN'T WE SEE THIS 41%

STEGEMAN ET AL (1997)

"If a reference electrode is located at the dipole's midpoint defined as the zero potential line and the active electrode is positioned sequentially along any radius beginning at three times the interdipolar spacing from the sphere's center to its wall, there is a continuous decrease in the amplitude of the recorded waveform".

41% INCREASE IN AMPLITUDE?

Cz-Linked (6.5%):

- The linked-mastoid electrode might be at the dipole's midpoint.

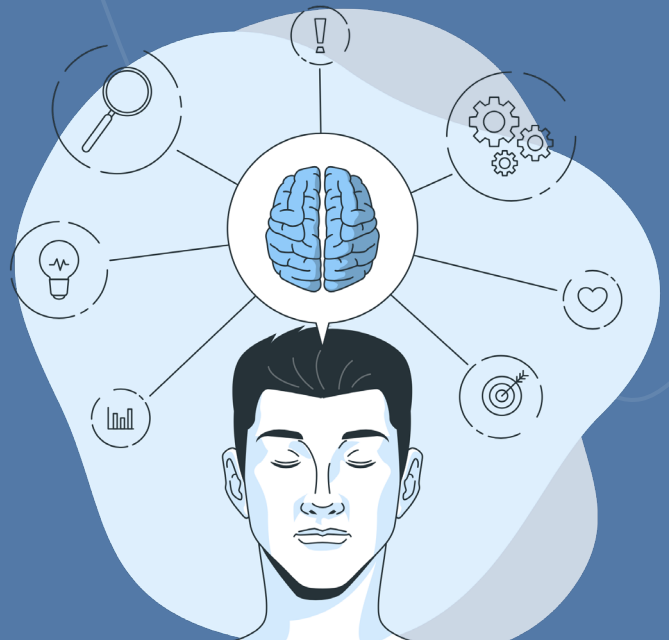
Cz-C7 (30%):

- The suggested 41% increase could be based on a ideal homogenous volume conductor.
- Human skull is far from ideal (air-filled sinuses in the forehead; indentations of the orbits of the eyes, etc).

WHAT IS THE IMPORTANCE?

With a larger amplitude it could allow for:

1. Improvement in estimation accuracy of an individuals' behavioural thresholds.
2. Reduction in overall test time.



REDUCTION IN TEST TIME - LITERATURE

- Elementary Records of ABRs has shown that on average, wave V amplitude in response to high intensity stimuli is about 0.5 µV.
- Early records of ABR SNR is about 0.05:1.
- This means that on average, the noise floor is about 10 µV.
- An experienced clinician requires SNR of at least 2:1 to determine presence of wave V.

SCENARIO - COMPARING Cz-C7 & Fpz'-M2

Noise (assuming average): 10 μV

SNR requirement for detection: 2:1

Number of sweeps required:

- Cz-C7: $(2/0.045)^2 = 1975$
- Fpz'-M2: $(2/0.035)^2 = 3265$

Time taken for each average (assuming 40/s stimulus rate):

- Cz-C7: 1975/40 = 50s
- Fpz'-M2: 3265/40 = 82s

SCENARIO - COMPARING Cz-C7 & Fpz'-M2

Assuming the subject is over the age of 2, appropriate correction factors are used, and we are just looking to determine if hearing is WNL:

A typical ABR threshold estimation session:

- 1 average at 60 dB nHL @ 4 kHz
- 1 average at 40 dB nHL@ 4 kHz
- 2 averages at 20 dB nHL @ 4 kHz

4 averages per frequency x 4 frequencies x 2 ears = 32 averages in total

SCENARIO - COMPARING Cz-C7 & Fpz'-M2

Averaging time taken assuming 32 averages required:

- Cz-C7: 50s x 32 averages = 1600s = 27min
- Fpz'-M2: 82s x 32 averages = 2624s = 44min

Reduction in time from using Fpz'-M2 to using Cz-C7 = 44 - 27 = 17min

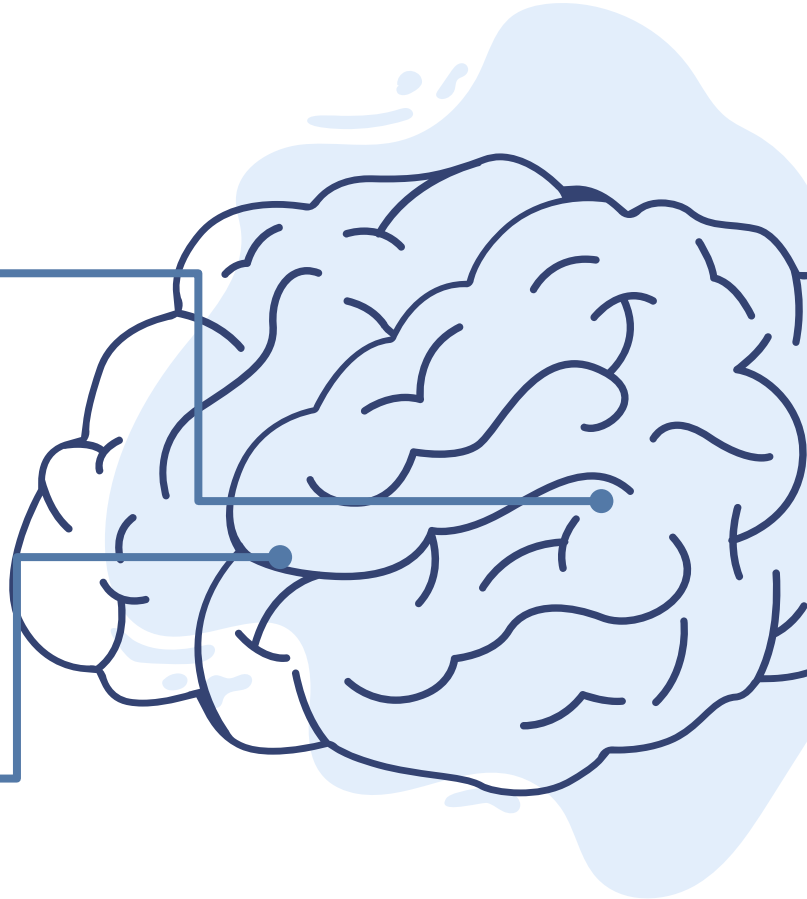
Which equates to about 40% reduction in test time.

SUBSTANTIAL REDUCTION!

05 CONCLUSION

Cz-C7 yielded significantly larger wave V amplitudes than compared to the other 2 montages. Using this montage could lead to a reduction in overall test time.

Future studies should look to replicate this study and Leung's (2019) study on the paediatric population.



THANK YOU!

Do you have any questions?
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