# Hearing Thresholds Measurement by CAEP using the HEARLab® system


**By: Sonia Jaya**

# Background

- **Electrophysical tests**
  - ABR – tests up till brainstem, shorter latencies
  - CAEP – tests up till cortex, longer latencies
- **HearLab Instrument**
  - Developed by National Acoustic Laboratories (NAL)
  - Incorporates Hotellings $T^2$ statistical processing for determining threshold
- **Normative data**
  - On CAEP detection via automated paradigms
  - None for the Singapore population
  - NAL- (Australian population)

# Relevant Study

- A similar study (Van Dun, Dillon, & Seeto, 2015) from NAL, on estimating hearing thresholds was conducted using HearLab

**Table 2.** Mean difference, and standard deviation, between cortical tone-burst and behavioral pure-tone thresholds (in dB) for four audiometric frequencies. Behaviorial thresholds subtracted from CAEP thresholds.

| | 500 Hz | 1000 Hz | 2000 Hz | 4000 Hz | all |
|---|---|---|---|---|---|
| **Pure-tones with outliers** | 11.2 ± 7.7 | 10.8 ± 9.4 | 10.3 ± 11.8 | 8.7 ± 11.4 | 10.3 ± 10.2 |
| **Pure-tones without 4% outliers** | 10.8 ± 7.1 | 9.7 ± 7.3 | 8.3 ± 7.1 | 7.4 ± 8.8 | 9.1 ± 7.7 |

**Differences:**

- **Caucasian group**
- **No control group**
- **Age range**
- **No 3kHz**

# Aims & Hypothesis

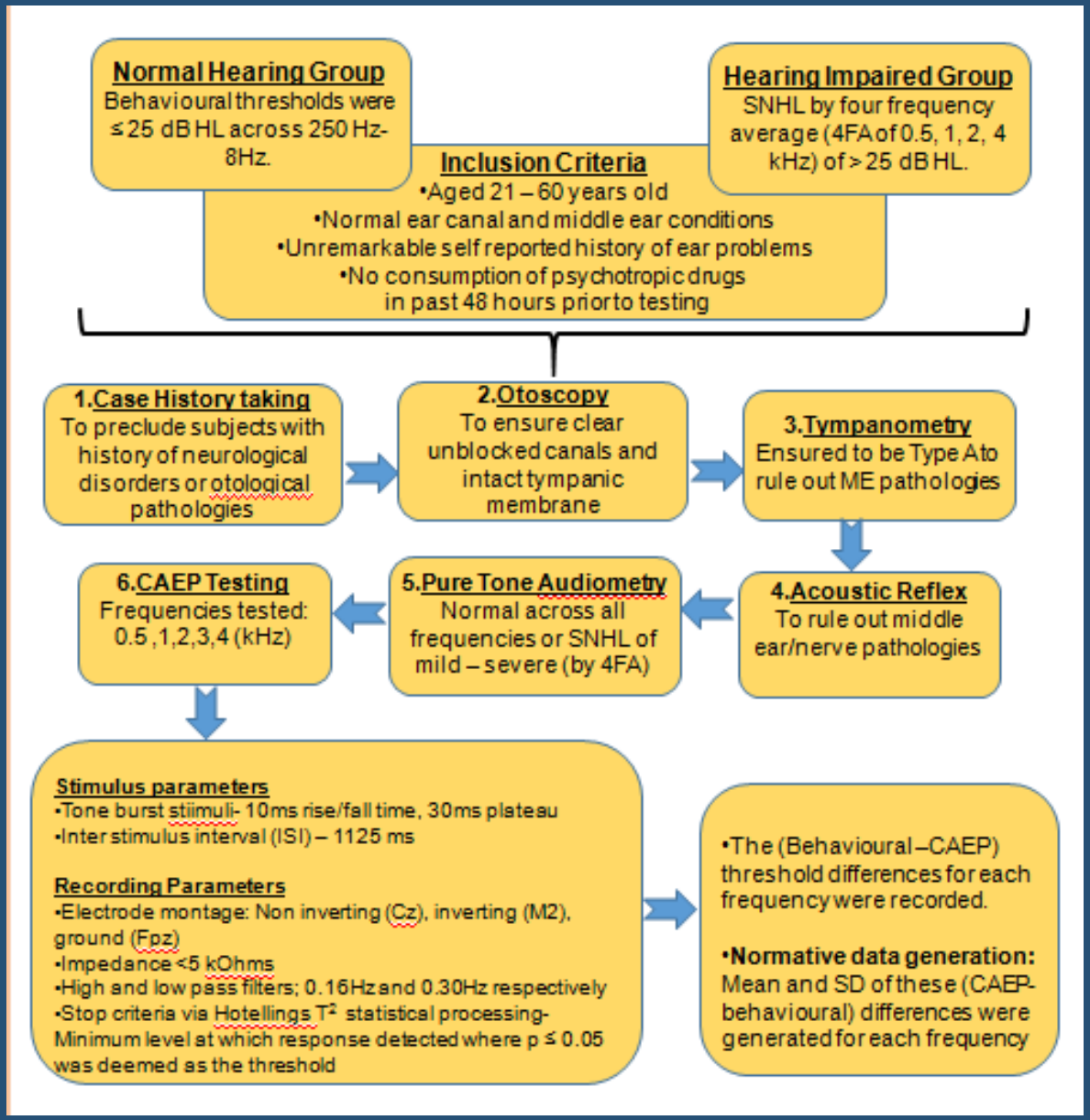
Aim: To generate normative data of the correction factors to accurately approximate the behavioural hearing thresholds, which would be specific to the Singapore population.

- To be used on the adults in Singapore who cannot be tested behaviourally

Hypothesis

- The correction factors determined would not be significantly different from those by NAL
- Data from the hearing impaired group would be significantly different from the normal hearing group

# Methods


Normal Hearing Group
Behavioural thresholds were ≤ 25 dB HL across 250 Hz-8Hz.
Hearing Impaired Group
SNHL by four frequency average (4FA of 0.5, 1, 2, 4 kHz) of > 25 dB HL.
Inclusion Criteria
•Aged 21 – 60 years old
•Normal ear canal and middle ear conditions
•Unremarkable self reported history of ear problems
•No consumption of psychotropic drugs in past 48 hours prior to testing
1.Case History taking
To preclude subjects with history of neurological disorders or otological pathologies
2.Otoscopy
To ensure clear unblocked canals and intact tympanic membrane
3.Tympanometry
Ensured to be Type A to rule out ME pathologies
4.Acoustic Reflex
To rule out middle ear/nerve pathologies
5.Pure Tone Audiometry
Normal across all frequencies or SNHL of mild – severe (by 4FA)
6.CAEP Testing
Frequencies tested: 0.5 ,1,2,3,4 (kHz)
Stimulus parameters
•Tone burst stiimuli- 10ms rise/fall time, 30ms plateau
•Inter stimulus interval (ISI) – 1125 ms
Recording Parameters
•Electrode montage: Non inverting (Cz), inverting (M2), ground (Fpz)
•Impedance <5 kOhms
•High and low pass filters; 0.16Hz and 0.30Hz respectively
•Stop criteria via Hotellings T² statistical processing- Minimum level at which response detected where p ≤ 0.05 was deemed as the threshold
•The (Behavioural –CAEP) threshold differences for each frequency were recorded.
•Normative data generation: Mean and SD of these (CAEP-behavioural) differences were generated for each frequency

# Results

- Total subjects: 30
- NH group (15 subjects)
  - 5 males and 10 females with a mean age of 28.7 years (*SD* = 7.91)
- HI group (15 subjects)
  - 9 males and 6 females with a mean age of 45.7 years (SD = 11.6)

Analysed results in the following ways:

- i) Mean Differences & S.D
- ii)Stacked Histogram data
- iii) Scatterplot & linear regression data

For the 3 groups:

- Combined NH & HI group
- HI group only
- NH group only

# i) Mean (CAEP – behavioural) diff & S.D

a)

| Frequency (Hz) | 500 | 1000 | 2000 | 3000 | 4000 |
|---|---|---|---|---|---|
| Mean difference (dB) | 6.7 | 8.6 | 13.9 | 15.7 | 15.9 |
| SD (dB HL) | ± 5.1 | ± 6.1 | ± 5.8 | ± 6.7 | ± 6.5 |
| Mean & SD without outliers | 6.7 ±5.1 | 8.0 ±5.4 | 13.0 ±4.9 | 13.8 ±4.8 | 13.9 ±5.0 |

b)

| Frequency (Hz) | 500 | 1000 | 2000 | 3000 | 4000 |
|---|---|---|---|---|---|
| Mean differences (dB) | 5.1 | 6.1 | 12.4 | 13.5 | 13.1 |
| SD (dB HL) | ± 4.2 | ± 4.9 | ± 4.7 | ± 6.2 | ± 5.6 |
| Mean & SD without outliers | 5.1 ± 4.2 | 6.1 ± 4.9 | 12.4 ± 4.7 | 12.4 ± 5.4 | 12.6 ± 5.2 |

c)

| Frequency (Hz) | 500 | 1000 | 2000 | 3000 | 4000 |
|---|---|---|---|---|---|
| Mean differences (dB) | 7.1 | 9.5 | 14.7 | 17.1 | 17.4 |
| SD (dB HL) | ± 5.5 | ± 6.8 | ± 6.4 | ± 7.4 | ± 6.2 |
| Mean & S.D without outliers | 7.1 ± 5.5 | 8.5 ± 5.7 | 14.0 ± 5.9 | 14.6 ± 5.3 | 14.9 ± 5.7 |

a) Combined NH & HI
b) HI group only
c) NH group only

- Trend between the groups
- Trend across frequencies

# 1) Comparison between HI & NH groups

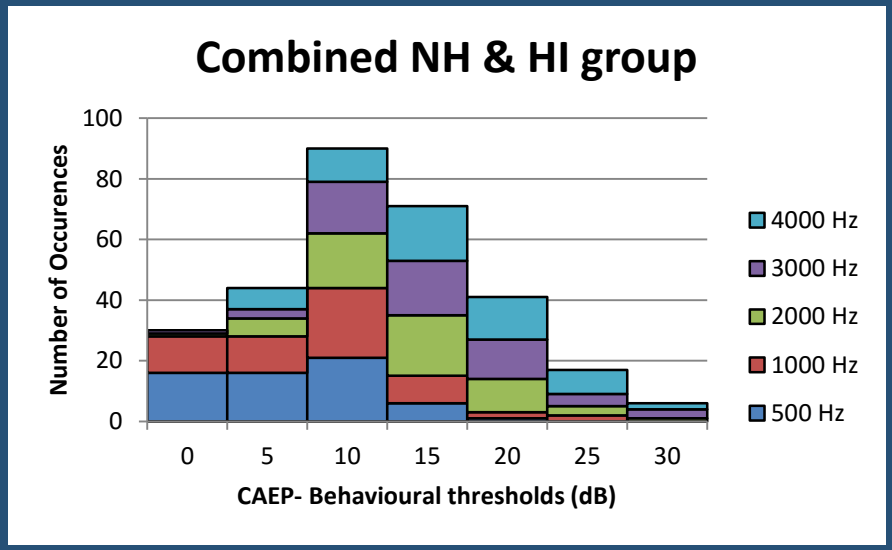
## i)Mean & SD data

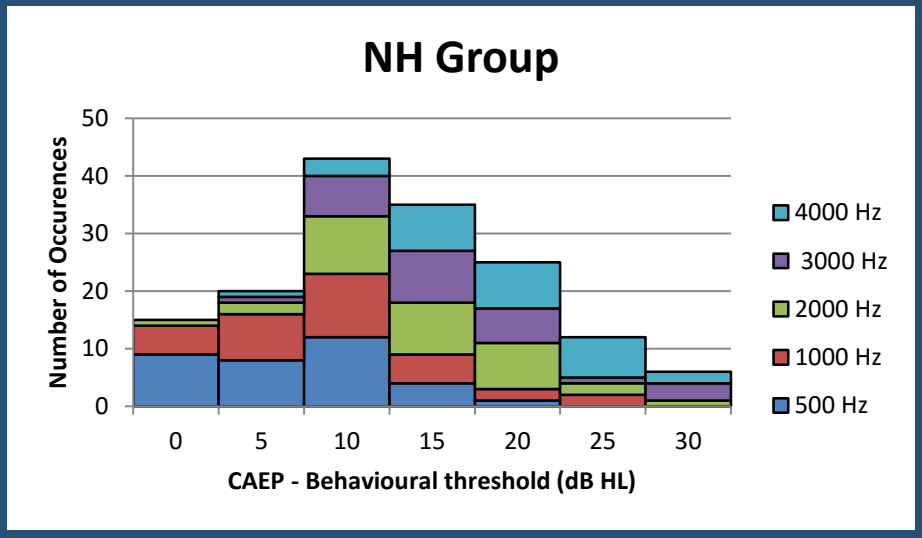
- Mean differences (incl. outliers) between CAEP thresholds and behavioural thresholds were within:
  -16 dB in the Combined group
  -17 dB in the NH group
  -14 dB in the HI group

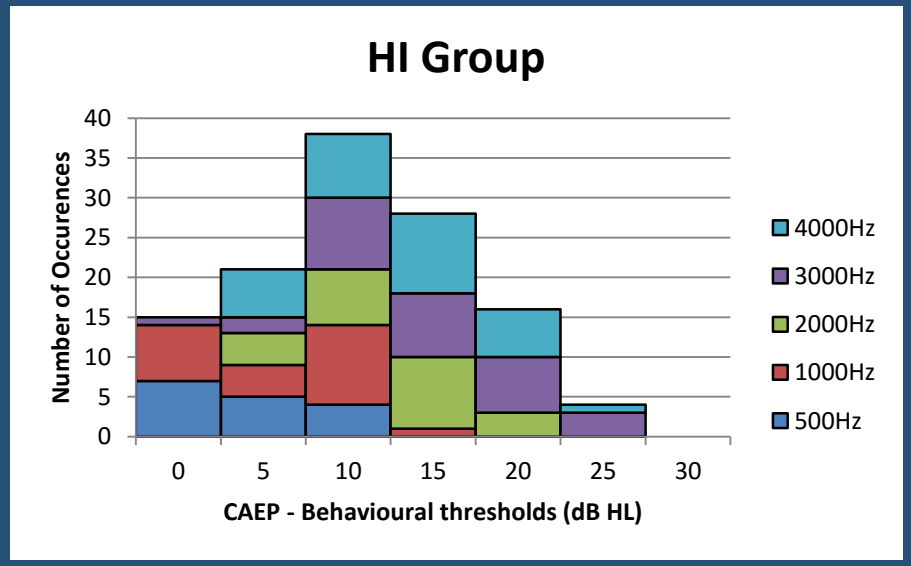
- Mean differences (w/o outliers) were within:
  -14 dB in the Combined group
  -15 dB in the NH group
  -13 dB in the HI group
- Most studies have suggested that threshold estimation is accurate *within 15 dB in adults*.

# 1ii) Stacked Histogram Data

- Proportion of CAEP thresholds ≤ 10dB of behavioural thresholds -Across groups
- Proportion of outliers ( >25dB elevation)



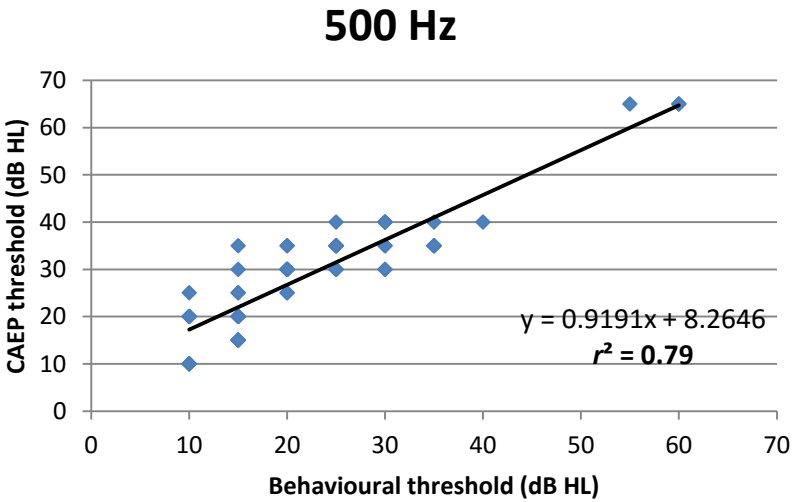



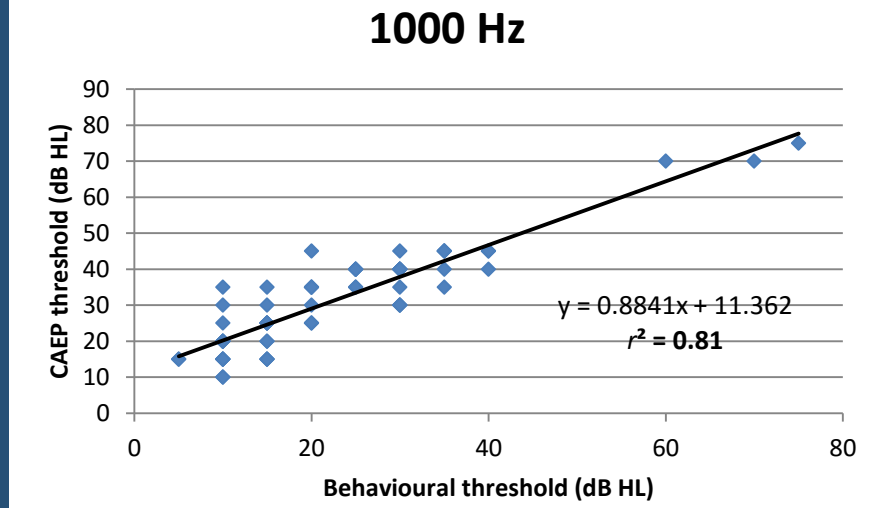
# 1ii) Stacked histogram data

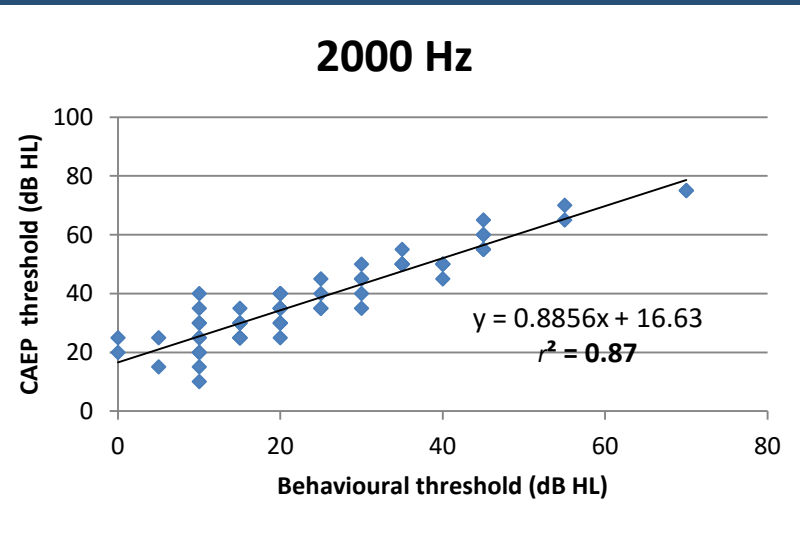
- The HI group had the highest proportion of CAEP thresholds which were within 10 dB of behavioural thresholds (60%) as compared to the NH group (50%)and the combined group (55%).
- There were most outliers observed for the NH group followed by the combined group (CAEP exceeded the behavioural thresholds by up to 30 dB), and lowest for the HI group (CAEP thresholds were elevated up to 25 dB)

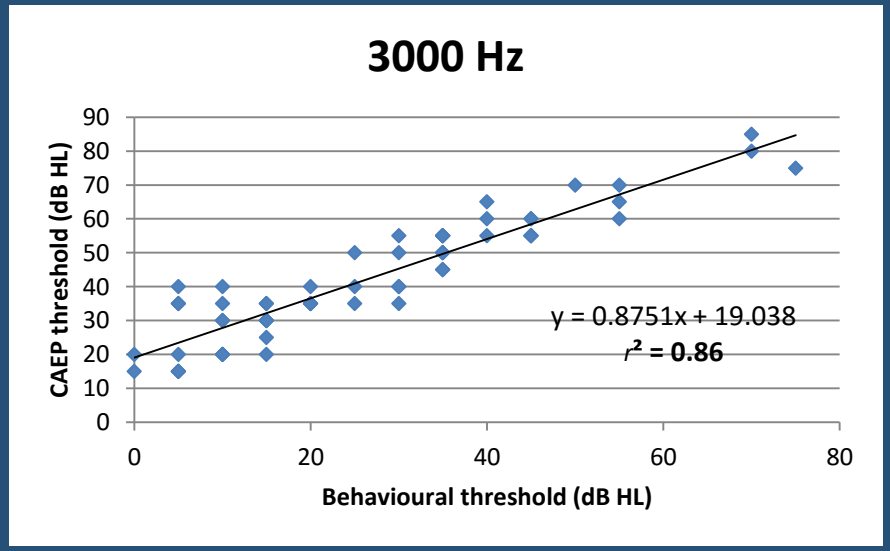
# 1iii) Scatterplot & Linear regression data

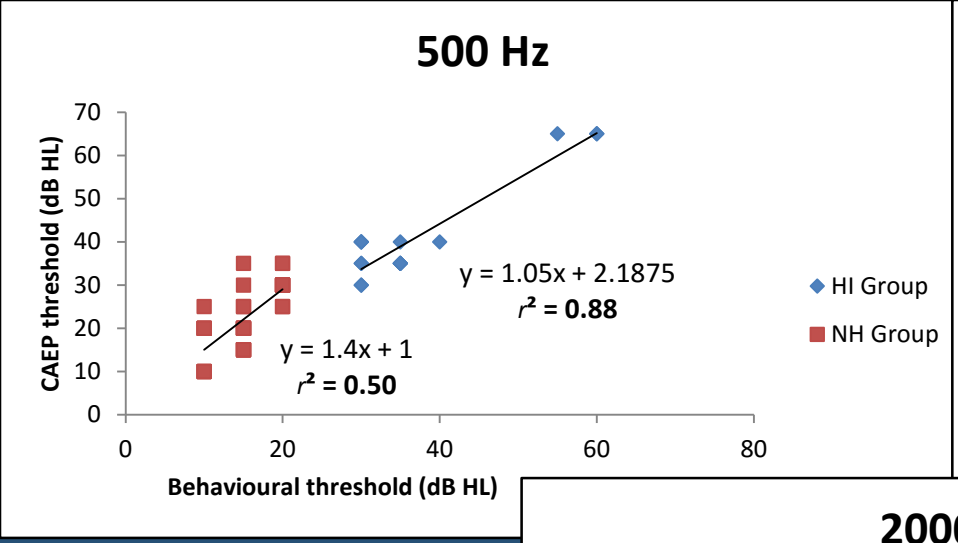
## - For Combined NH & HI Group

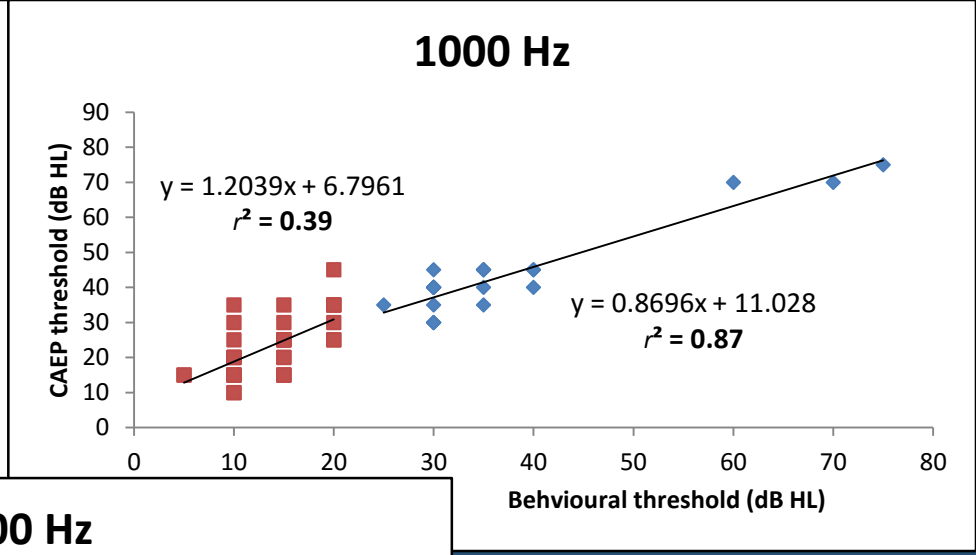


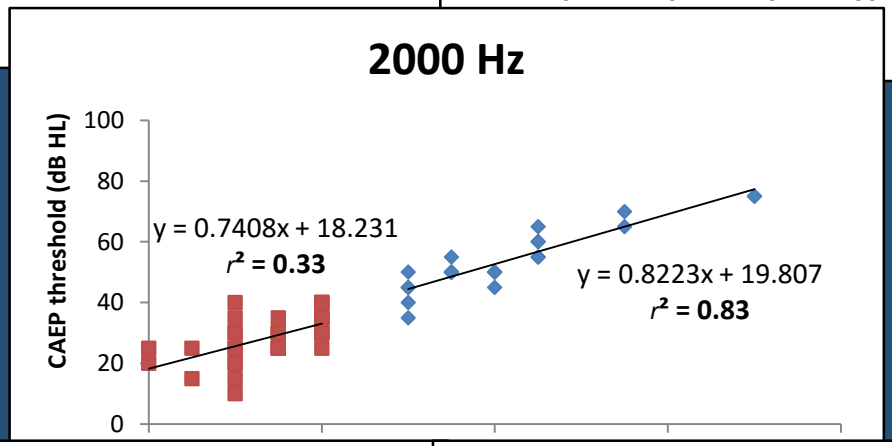


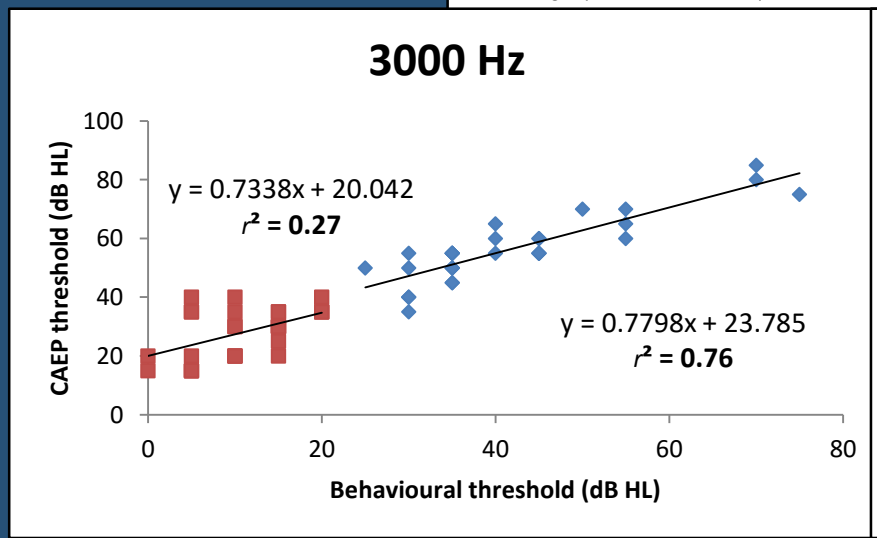



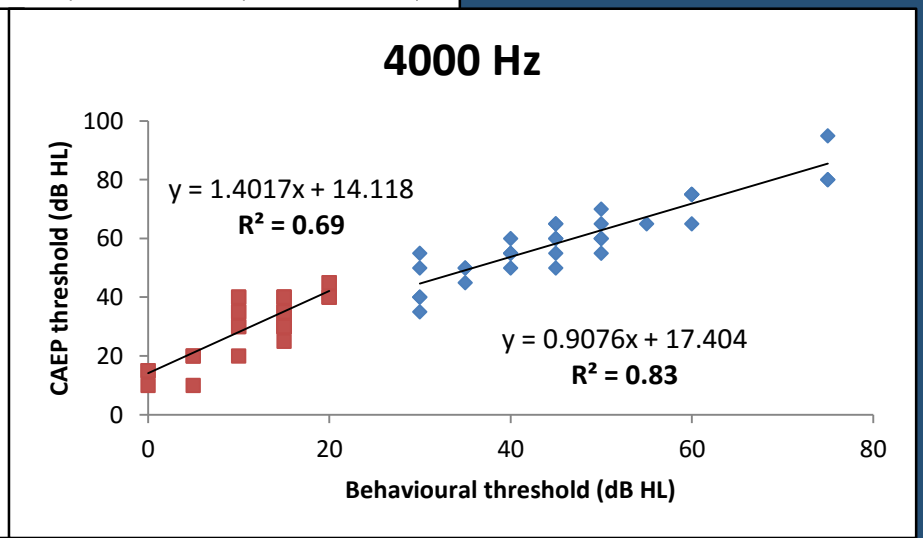

## iii) Linear Regression data

-For HI group only

-For NH group only



# 1iii) Linear regression data

- The HI group had significant correlation between the CAEP thresholds and behavioural thresholds, with high $r^2$ values ranging from 0.76 to 0.88 across all five frequencies.

- The NH group had poorer correlation between CAEP and behavioural thresholds across all frequencies.

# Discussion

- 1)The differences in results observed between the HI group and the NH group in this study

- 2)Comparison between the HI group data from this study and the data generated by NAL

- With regards to:
- i) Mean Differences & S.D
- ii)Stacked Histogram data
- iii) Scatterplot & linear regression data

# Discussion point 1:

- The HI group had lower CAEP thresholds resulting in lower mean differences and better correlation with behavioural thresholds than NH group.
  - This has been attributed to recruitment. Owing to the damaged inner hair cells, a *steeper loudness growth curve is* seen in individuals with a recruiting hearing loss.
  - A smaller sensation level is sufficient to incite a response, resulting in lower thresholds recorded (Hall, 1991; Lightfoot, 2016).

## Discussion point 2:

- With regards to the trend across the frequencies, the mean (CAEP – behavioural) differences is more elevated in the high frequencies (2000 Hz – 4000 Hz).

- Some possible reasons:
  - This trend may be due to the small sample size
  - There has been evidence showing that N1-P2 amplitudes are larger in the low frequencies and smaller in the high frequencies (Antinoro, Skinner & Jones 1969; Ross et al., 1998)
  - Other confounding factors causing elevated CAEP thresholds

# 2) Comparison with NAL study

## i)Mean & SD data

| | 500 Hz | 1000 Hz | 2000 Hz | 4000 Hz | all |
|---|---|---|---|---|---|
| Pure-tones with outliers | 11.2 ± 7.7 | 10.8 ± 9.4 | 10.3 ± 11.8 | 8.7 ± 11.4 | 10.3 ± 10.2 |
| Pure-tones without 4% outliers | 10.8 ± 7.1 | 9.7 ± 7.3 | 8.3 ± 7.1 | 7.4 ± 8.8 | 9.1 ± 7.7 |

NAL data:

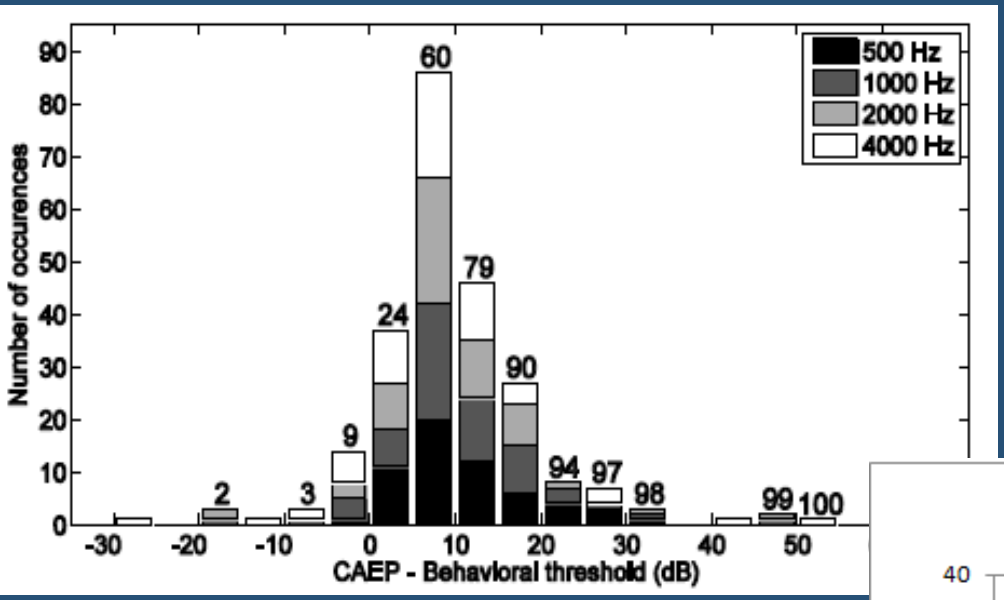
- On average at 10dB mean differences
- Do not vary much according to frequency
- Large SD range

| Frequency (Hz) | 500 | 1000 | 2000 | 3000 | 4000 |
|---|---|---|---|---|---|
| Mean differences (dB) | 5.1 | 6.1 | 12.4 | 13.5 | 13.1 |
| SD (dB HL) | ± 4.2 | ± 4.9 | ± 4.7 | ± 6.2 | ± 5.6 |
| Mean & SD without outliers | 5.1 ± 4.2 | 6.1 ± 4.9 | 12.4 ± 4.7 | 12.4 ± 5.4 | 12.6 ± 5.2 |

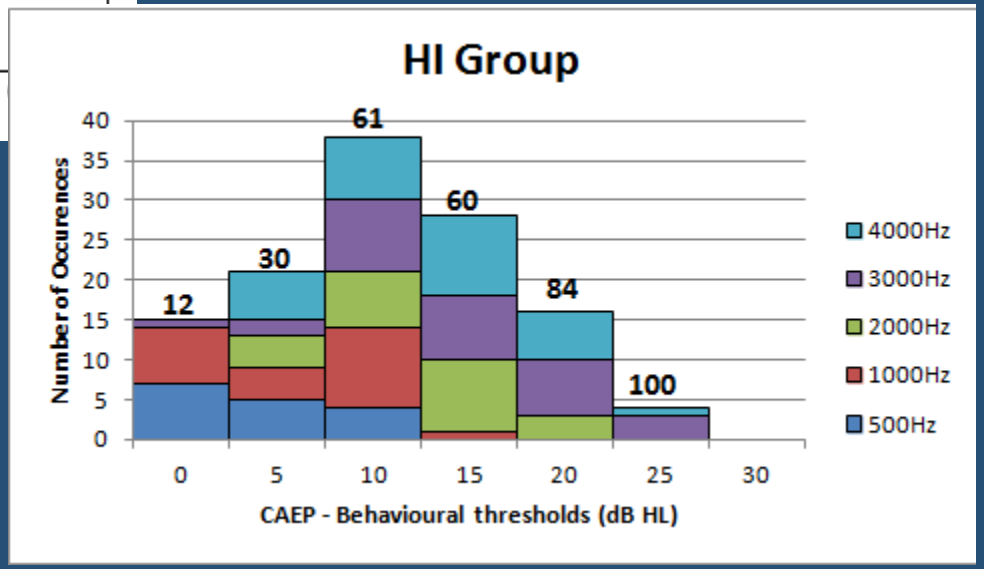
Current study (HI Group):

- Within 13dB across all freq
- More elevated in high frequencies
- Small SD range

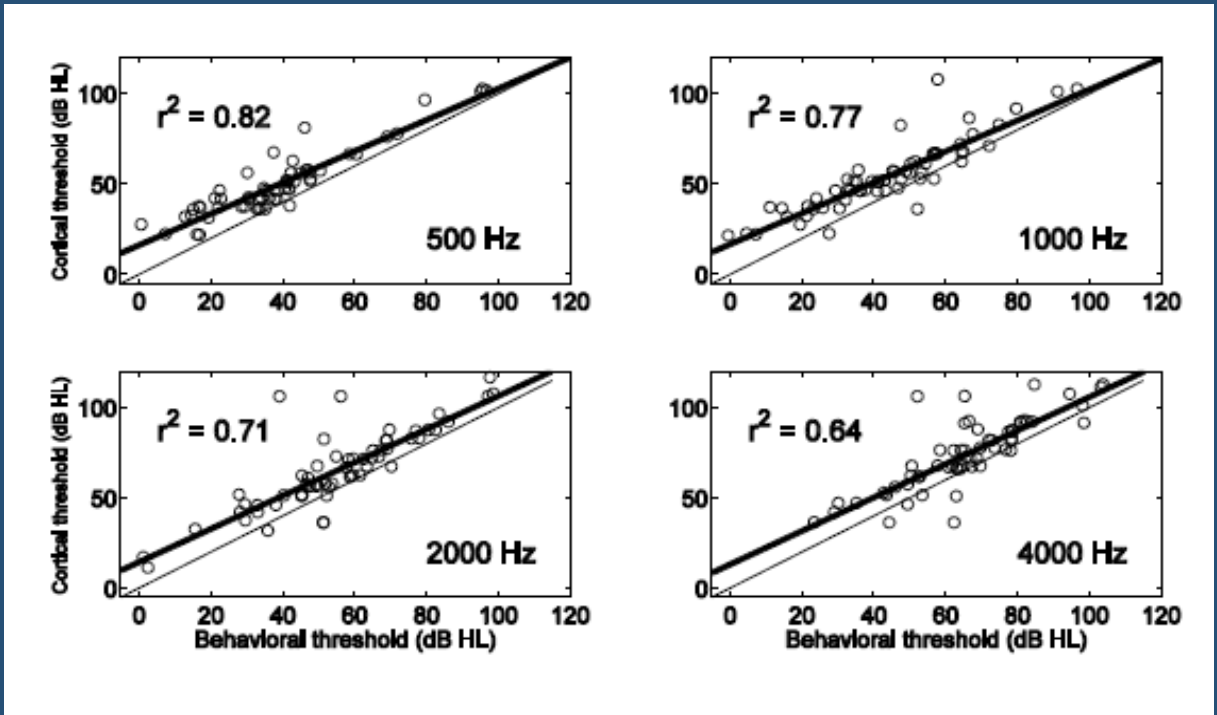
# ii)Stacked Histogram data




- The % of CAEP thresholds which were within 10dB of behavioural thresholds
- Number and value of outliers



# 2iii) Linear regression data




- As the $r^2$ values are close to 1.0, there is significant correlation between CAEP and behavioural thresholds, with the degree of significance decreasing slightly for the higher frequencies.

- These values are similar to the current study  HI group $r^2$ values in the current study. The $r^2$ values were 0.88, 0.87, 0.83, 0.76, 0.83 for the frequencies 500 Hz, 1000 Hz, 2000 Hz, 3000 Hz and 4000 Hz respectively.

# Limitations/Confounding factors -Test related factors

- **Sample Size**
  - With a smaller sample size, the range of the responses may be smaller and few outliers may cause a shift of the mean /SD
- **Electrical noise**
  - At high electrical noise levels -> SNR may be reduced and waveform morphology is affected -> system may not be able to detect the presence of the waveform amidst the noise
- **Impedance**
  - Factors which could affect the impedance are the oiliness of the skin, and the thickness and oiliness of hair on the scalp, which particularly affects the Cz electrode retention
- **Hearing Loss level**
  - Small sample size of 15 hearing impaired participants, with mostly mild-moderate levels of losses -> the results in this study for the hearing impaired group may not be applicable to all degrees of loss

# Limitations/Confounding factors -Subject related factors

- Subject age effects
  - As adults advance in age, there is a general increase in latency and decrease in amplitude (Callaway, 1975) and shorter P2 latencies
- Gender
  - Onishi and Davis (1965) reported that CAEP amplitude tended to be larger for females compared to males
- State of arousal and sleep
  - The wave morphology and amplitude is more variable and are also differentially affected between awake states and the various sleep stages
- Attention
  - An increase in attention to the stimulus results in an increase in amplitude of the N1 wave of up to 50 percent

# Learning points/ Suggestions for future research

- Bigger sample size
- Equal no. of males and females
- Degree and type of loss
- Age limit
- Time slot (State of arousal/fatigue)
- Impedance

# Conclusion

- The CAEP thresholds were within 14 dB HL of behavioural thresholds across all frequencies for the HI group. This is comparable to that found in previous studies (Picton et al.,2011, Van Dun et al.,2015), suggesting threshold estimation in adults is accurate within 15 dB regardless of visual or automatic detection procedures.

- There is indication that the CAEP thresholds may be more accurate predictors of behavioural thresholds for HI subjects as compared to NH subjects.

The End !

Thank You ☺