Brain, Body & Mind
Frontal asymmetry & EEG

QF IV XF
MX VX MK

Alexander Jones

&

Jon Silas

Module Surveys

Middlesex University London


How to give feedback on your modules

How can I complete the module survey?

— Student Survey Portal

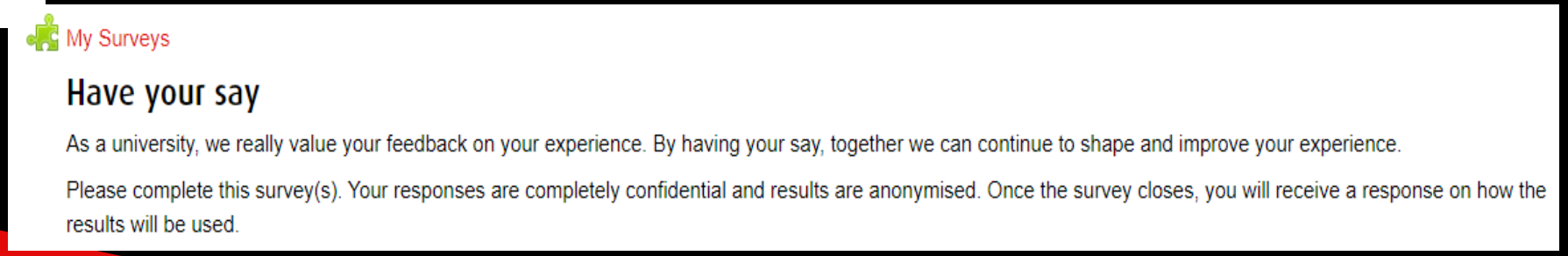
https://mdx.surveys.evasysplus.co.uk

SCAN ME

— MDXapp (My Surveys)

— MyLearning (Homepage)

— Email with a link from ‘Hosting@evasys.co.uk'



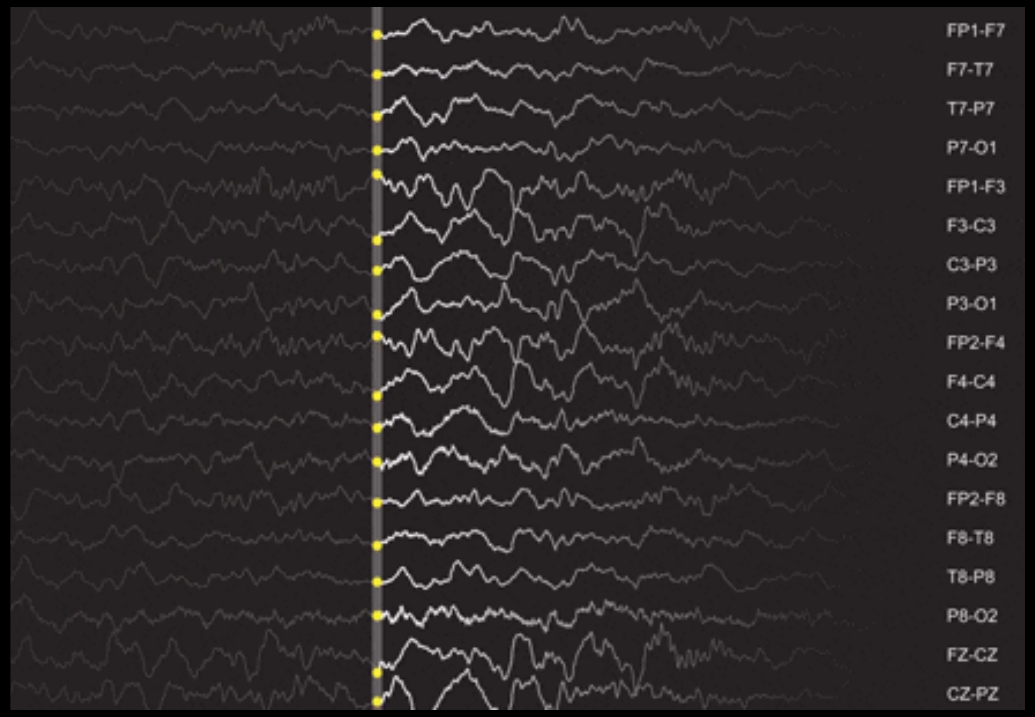
Middlesex University London

Outline

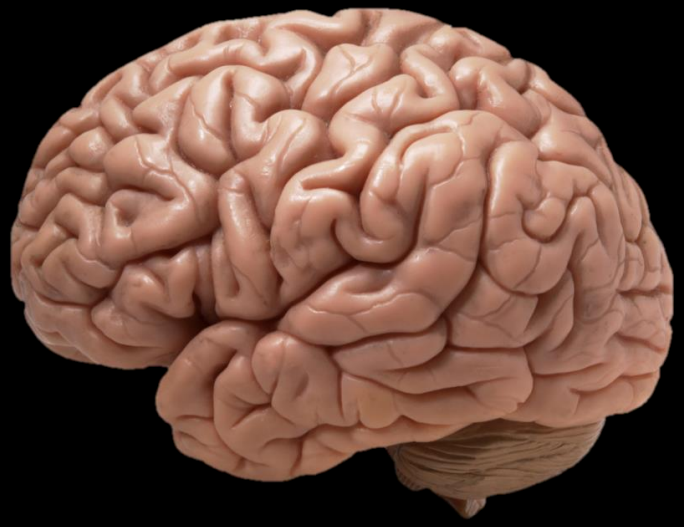
- Part 1 – What is EEG
- Part 2 – EEG Frequencies
- Part 3 – Event-related potentials (ERPs)
- Part 4 – Frontal EEG asymmetry and individual differences

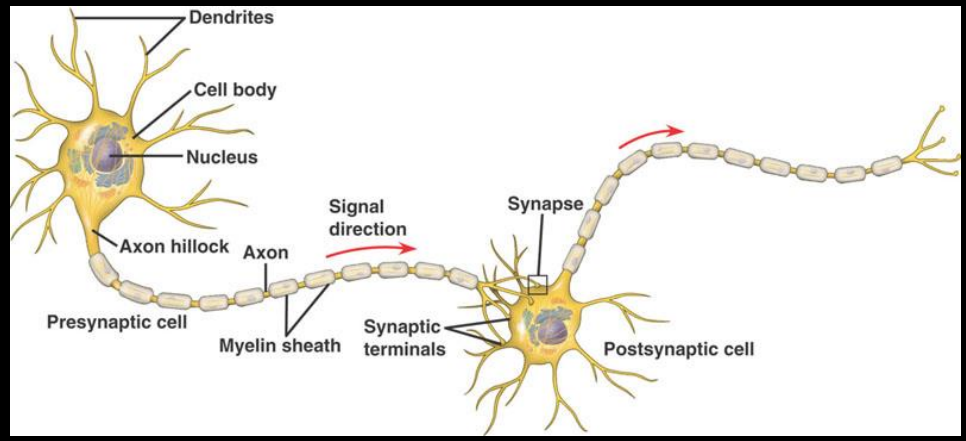
Part 1 – What is EEG?

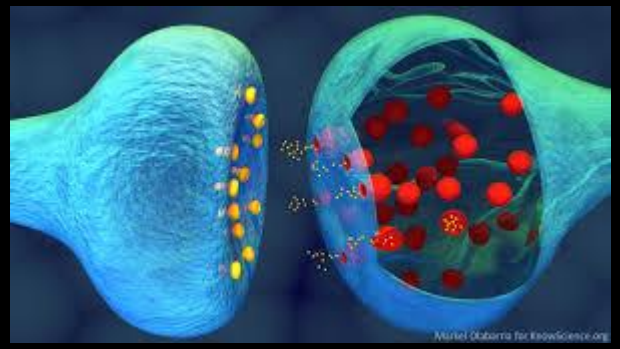
Electroencephalography -EEG



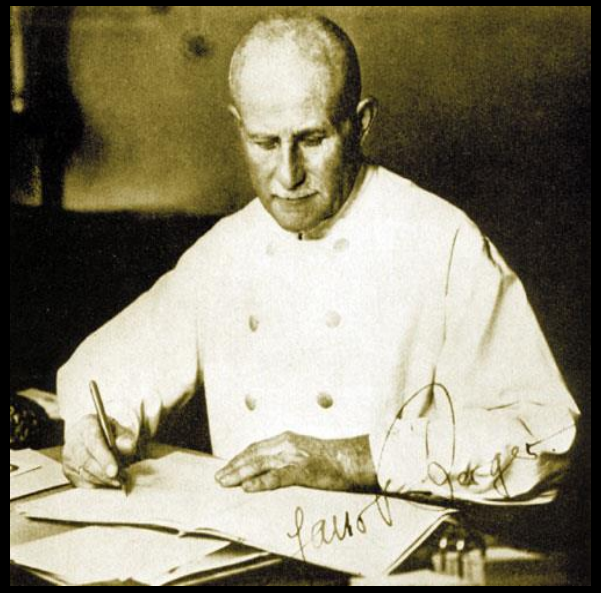
The brain




Dendrites
Cell body
Nucleus
Axon hillock
Axon
Signal direction
Synapse
Presynaptic cell
Myelin sheath
Synaptic terminals
Postsynaptic cell



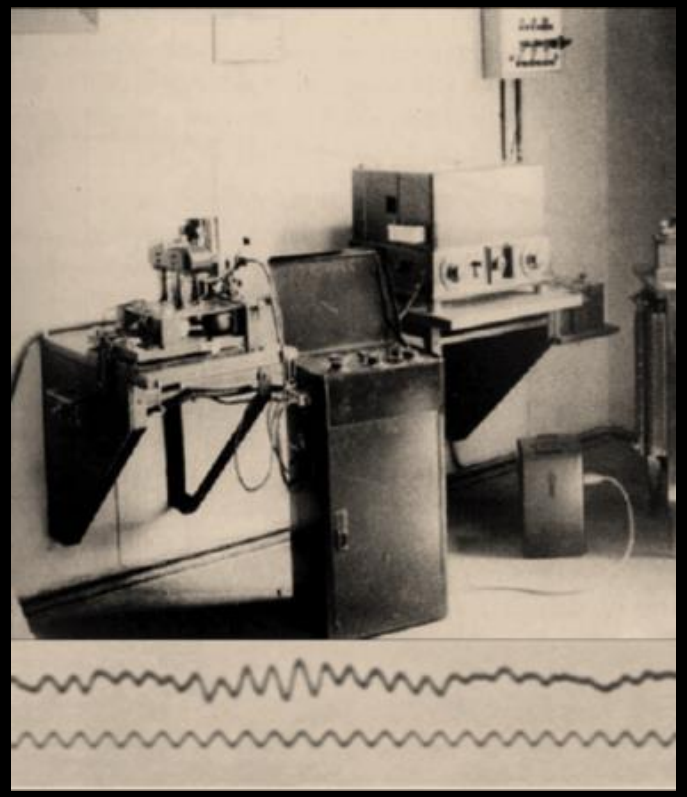
Brief history



- 1875 – Richard Caton recorded electrical current from the exposed brains of rabbits and monkeys.
- 1912 – Vladimir Pravdich-Neminsky publishes the first animal electrical changes recorded from the surface of the scalp.
- 1924 – Hans Berger used radio equipment to amplify electrical activity from a human as measured on the scalp.

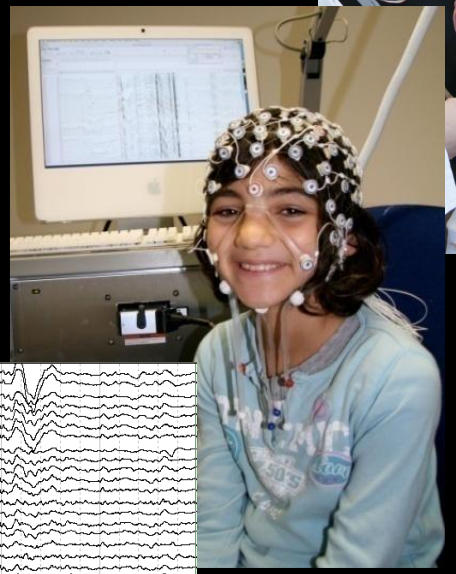
Brief history

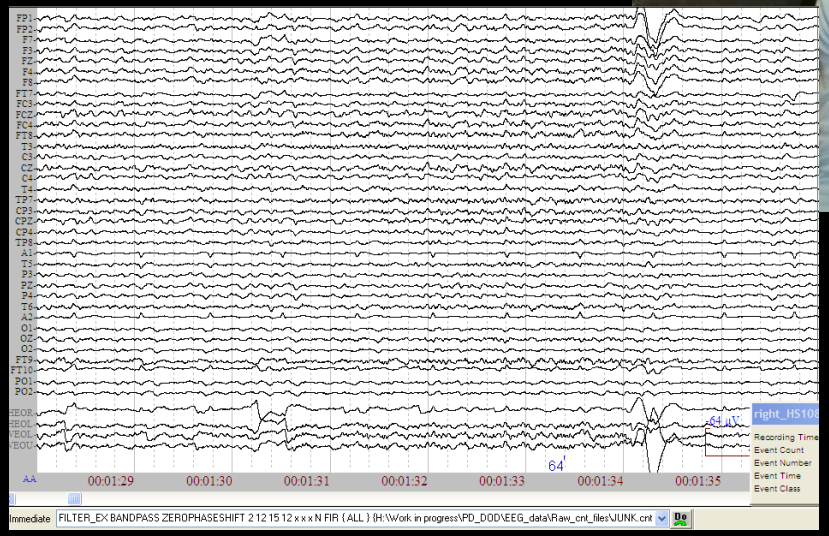
- Initial recording was the tracing of pen on paper.
- Visual inspection of data.
- Peak counting.



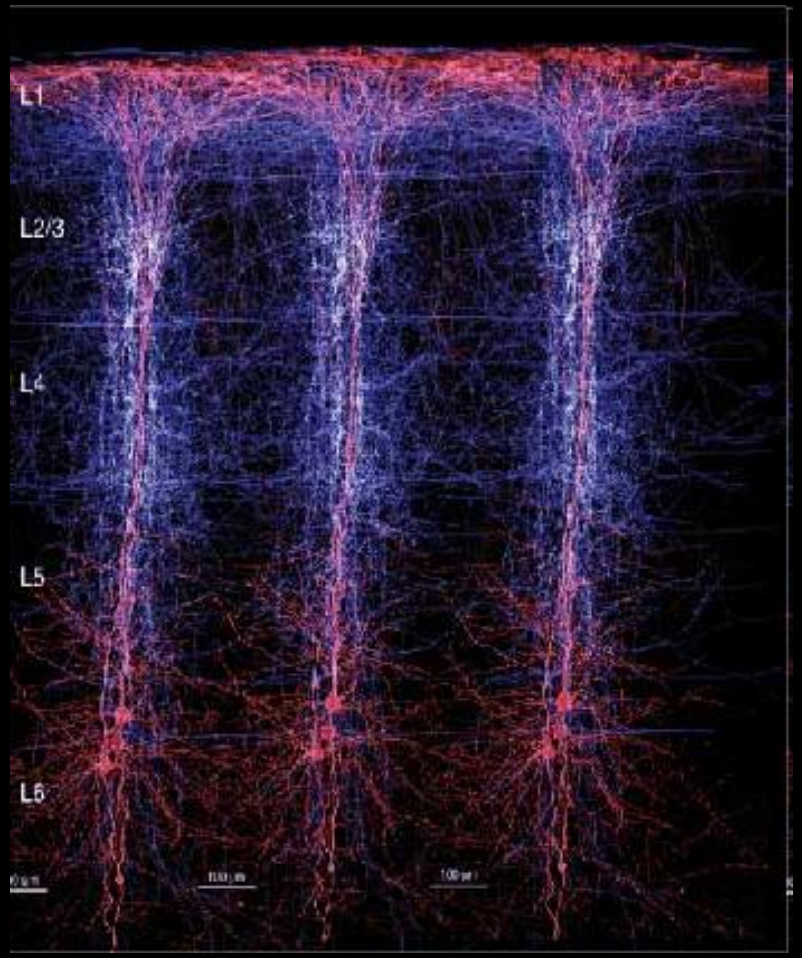
Modern day EEG

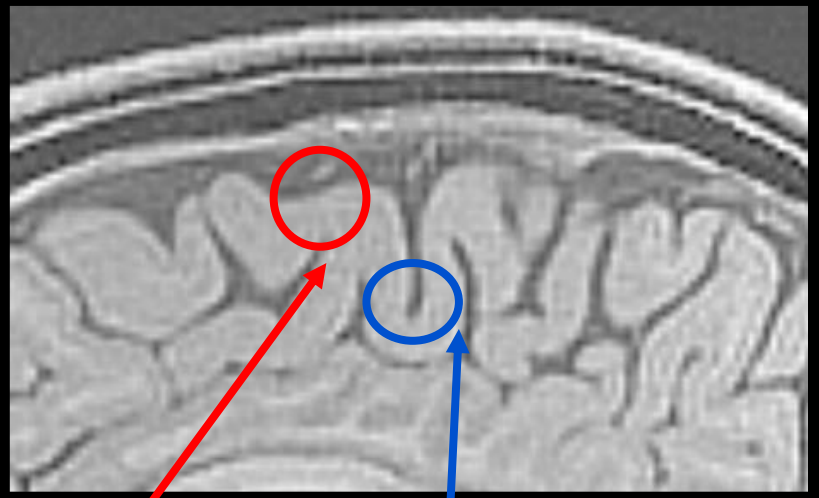
- High density electrode array
- High quality amplifiers
- Digitization

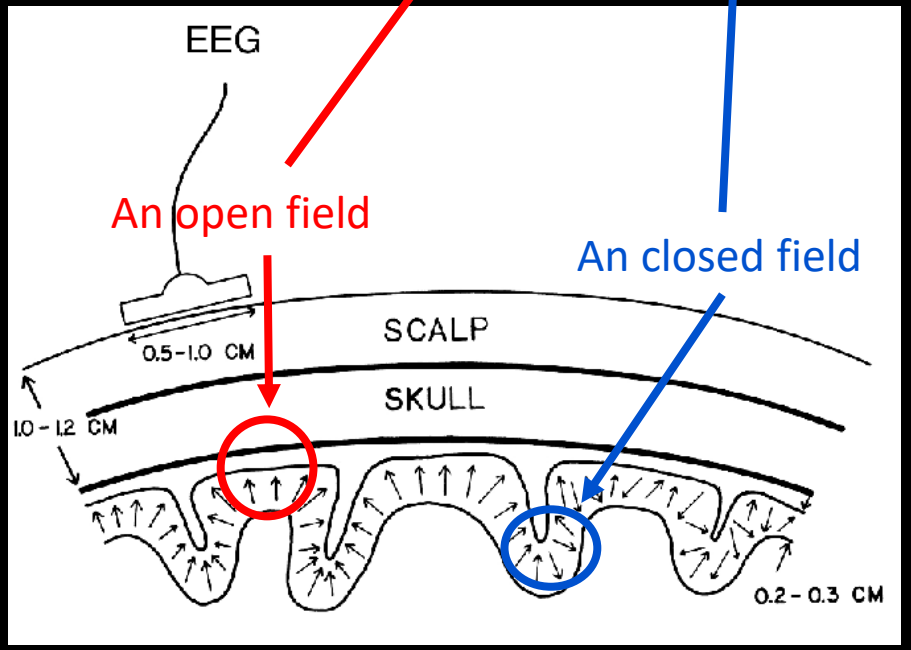




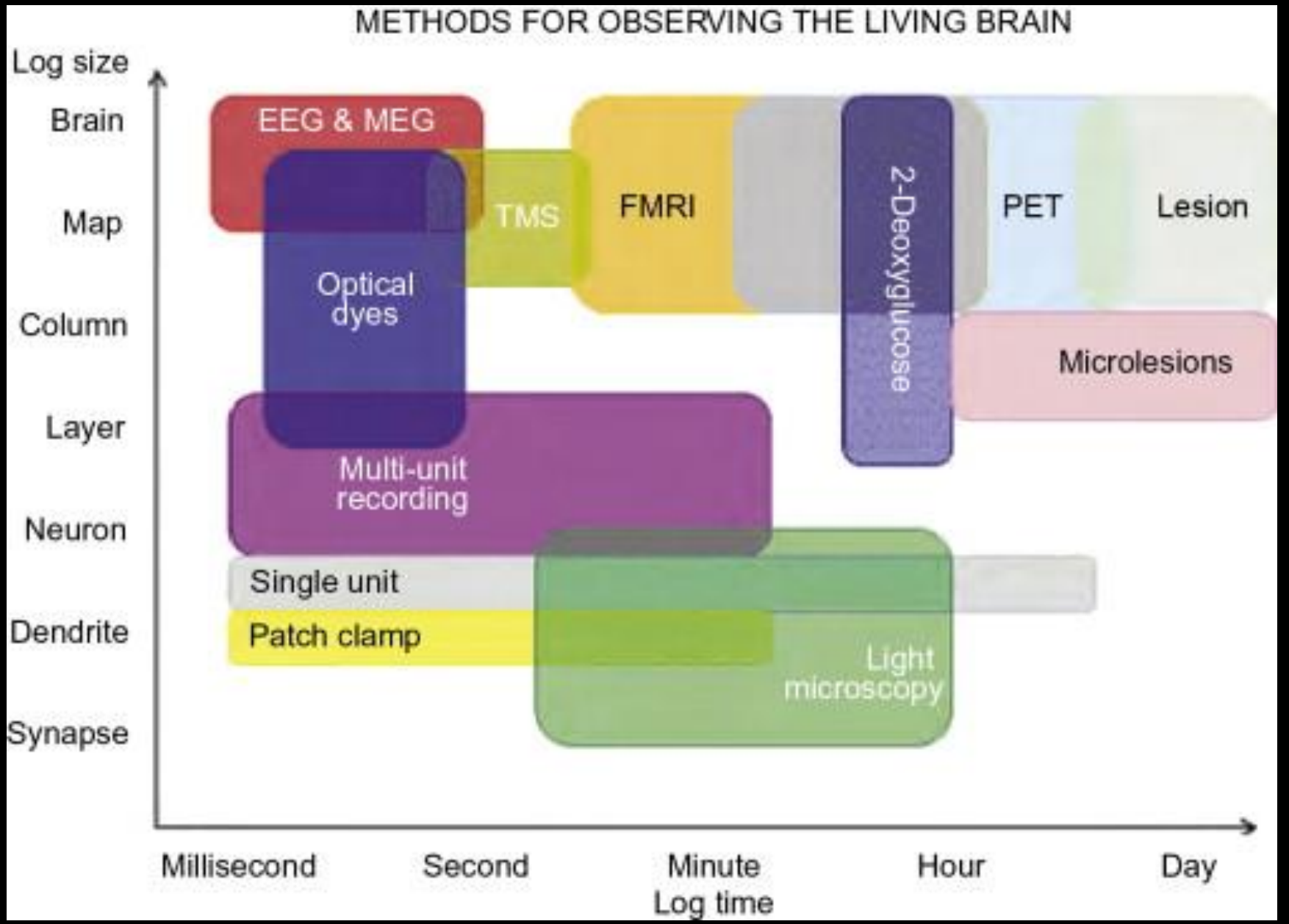
Current flow in the brain





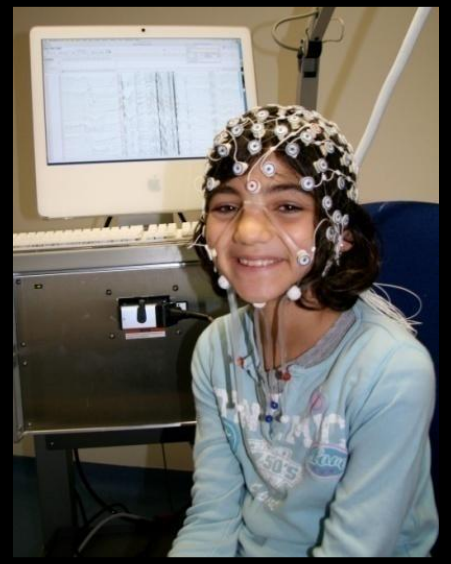


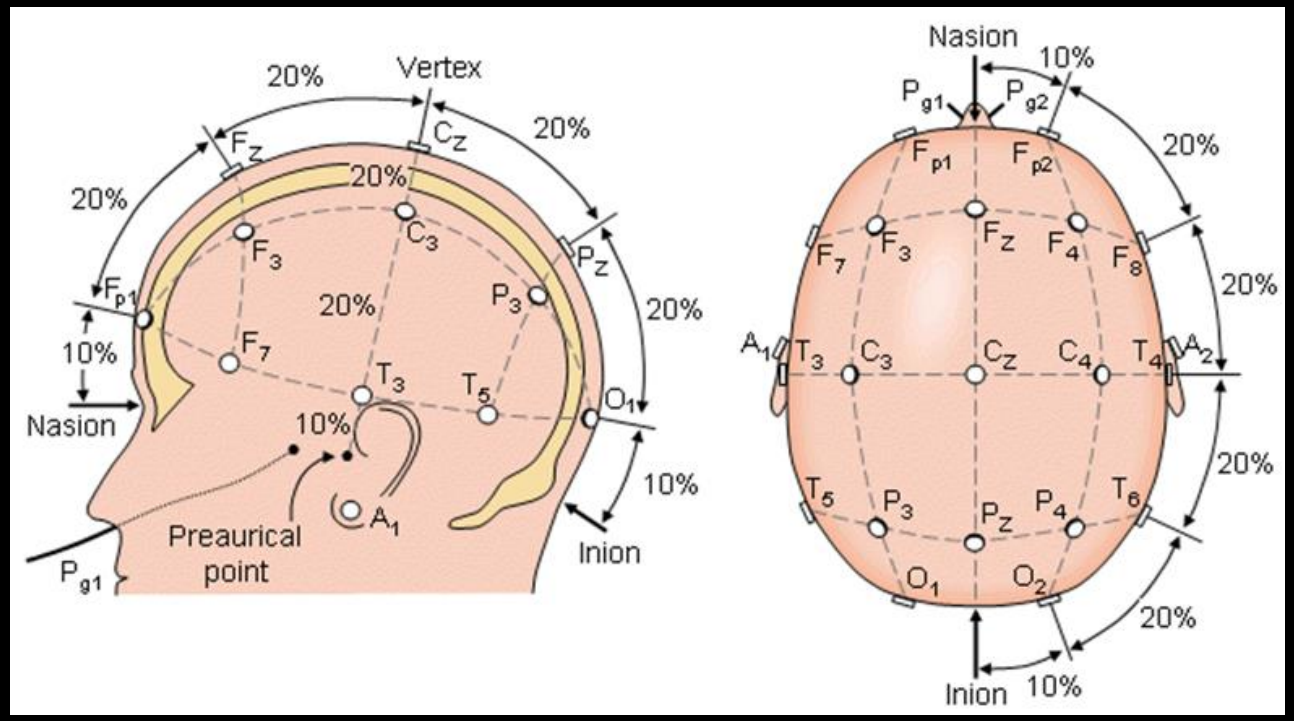
Deep parts of the brain are not well sampled

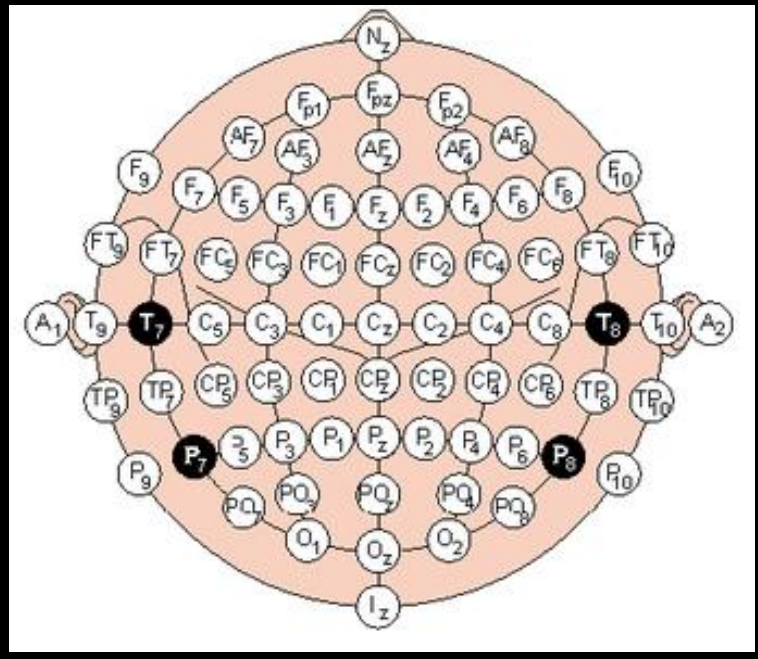

METHODS FOR OBSERVING THE LIVING BRAIN
Log size
Brain
Map
Column
Layer
Neuron
Dendrite
Synapse
EEG & MEG
TMS
FMRI
2-Deoxyglucose
PET
Lesion
Optical dyes
Microlesions
Multi-unit recording
Single unit
Patch clamp
Light microscopy
Millisecond
Second
Minute
Hour
Day
Log time

How does it work?

- A net/cap with an array of electrodes is placed on the scalp.







How does it work?

- A low level of impedance (resistance) is achieved by applying some form of conductive material to the electrodes and usually abrading the scalp.
- The electrical signal is then amplified.
- The amplified electrical signal is then digitized (sampled) and recorded on a computer.

Raw EEG


Fp1-Avg
Fp2-Avg
F3-Avg
F4-Avg
C3-Avg
C4-Avg
P3-Avg
P4-Avg
O1-Avg
O2-Avg
F7-Avg
F8-Avg
T3-Avg
T4-Avg
T5-Avg
T6-Avg
A1-Avg
A2-Avg
Fz-Avg
Cz-Avg
Pz-Avg
Eog-Avg

End part 1

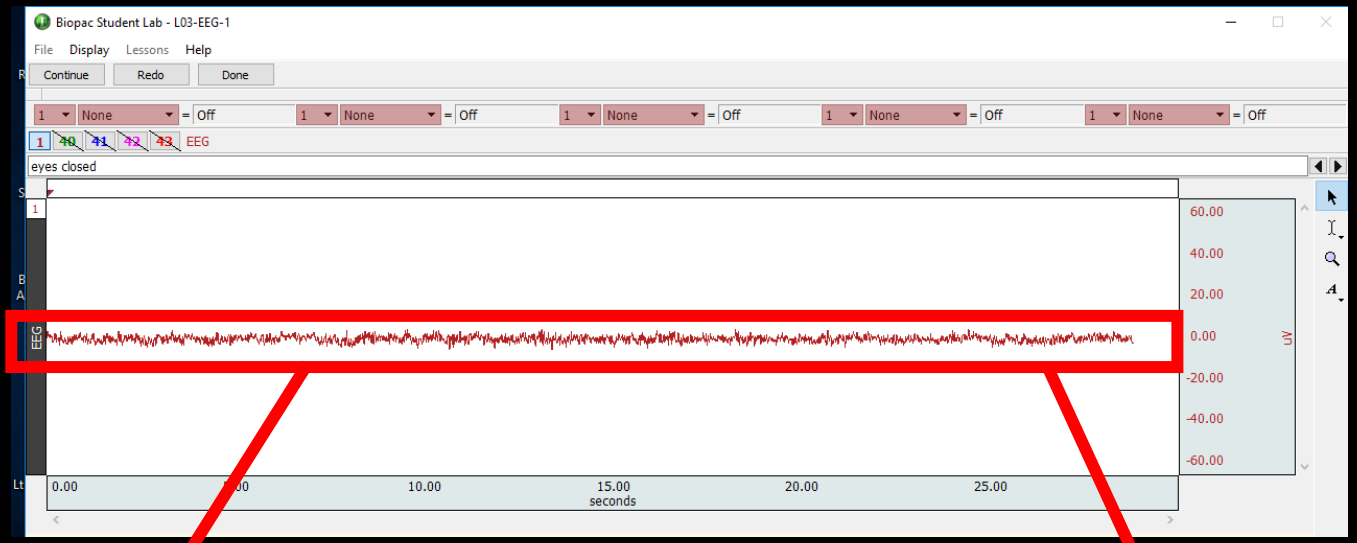
PSY2006/4041
EEG Frequencies

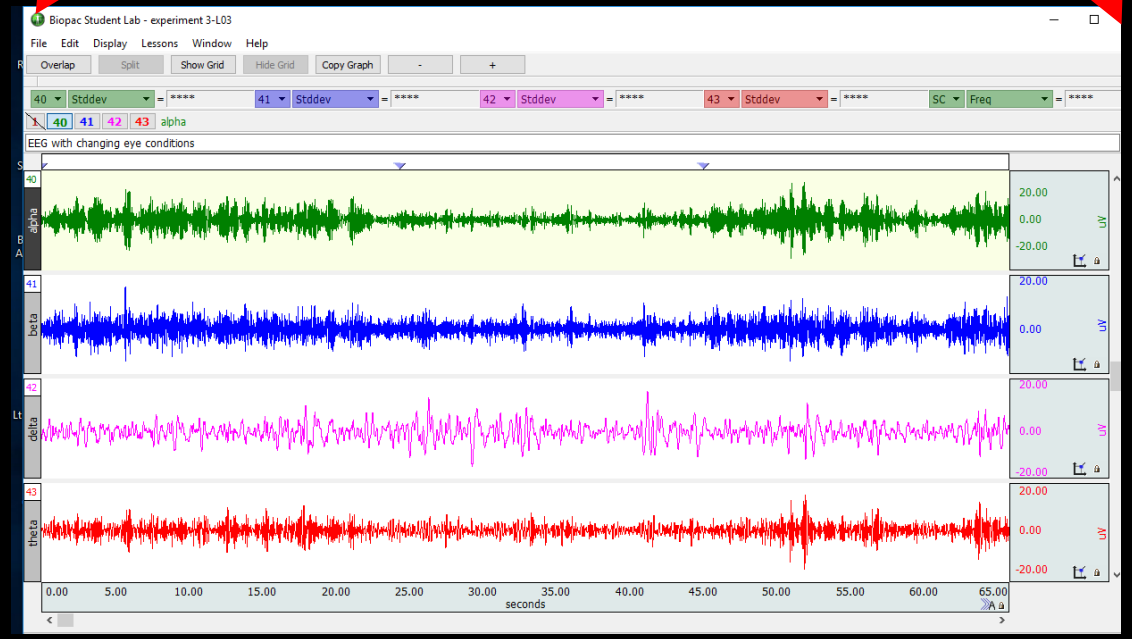
Part 2

Raw EEG

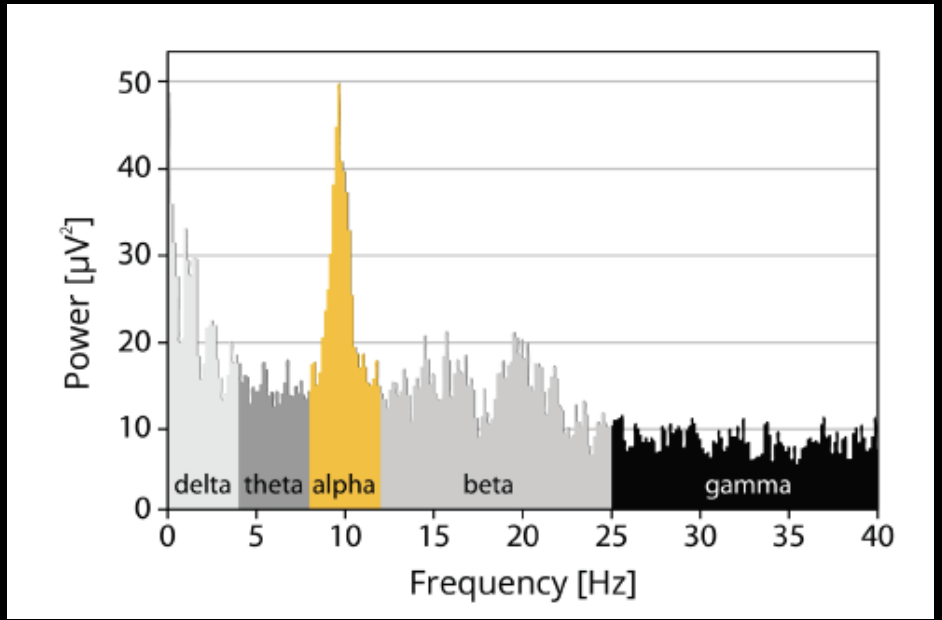

Fp1-Avg
Fp2-Avg
F3-Avg
F4-Avg
C3-Avg
C4-Avg
P3-Avg
P4-Avg
O1-Avg
O2-Avg
F7-Avg
F8-Avg
T3-Avg
T4-Avg
T5-Avg
T6-Avg
A1-Avg
A2-Avg
Fz-Avg
Cz-Avg
Pz-Avg
Ecg-Avg

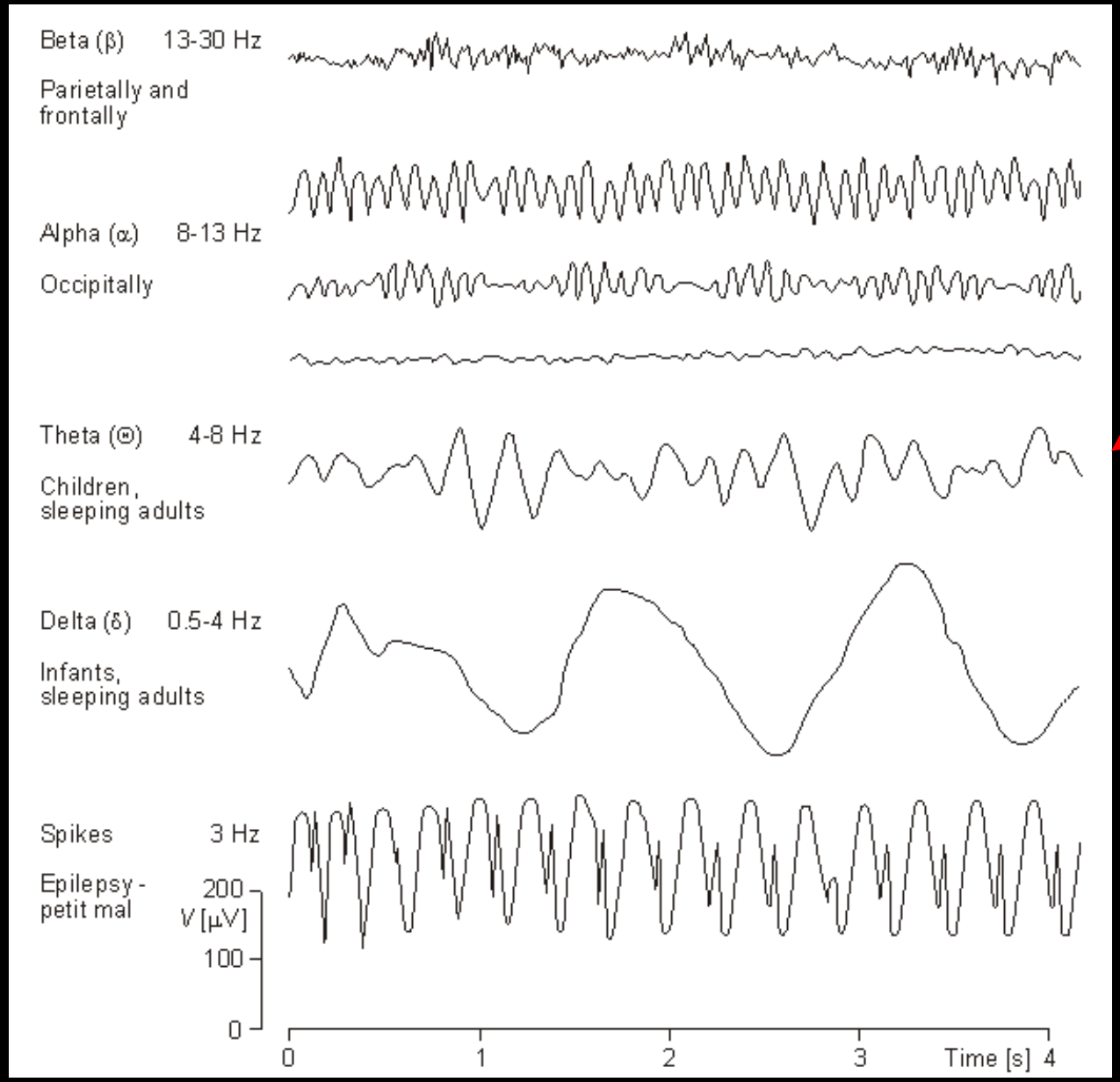
Raw EEG





Rhythm	Typical Frequencies (Hz)
alpha	8-13
beta	13-30
delta	1-5
theta	4-8





Movement

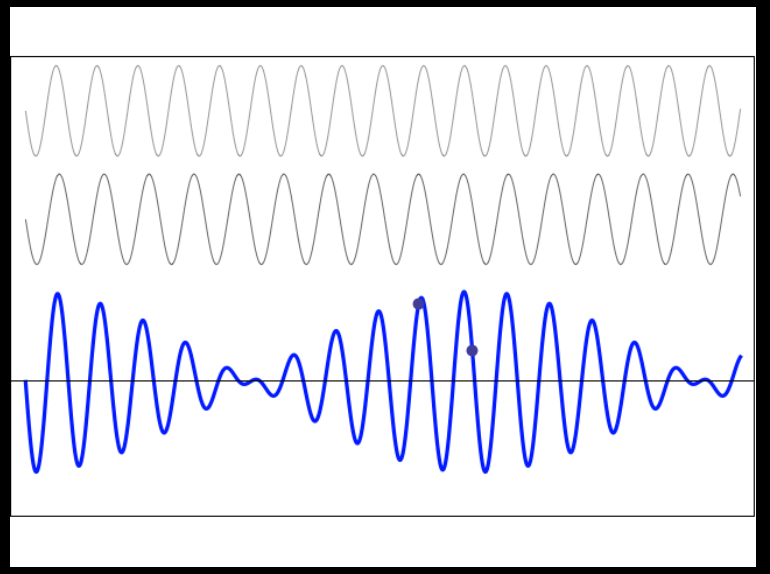
Vision/attention/WM

Memory

Sleep

Epilepsy

Frequency changes



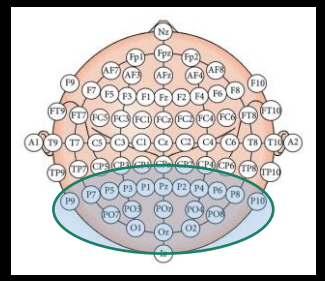
- In most cases:
  - High power at any particular frequency reflects neuronal synchrony/synchronisation.
  - Low power reflects neuronal asynchrony/desynchronisation.
- Synchrony reflects and idling state & asynchrony reflects cortical processing.
- High power = less neuronal activity

&

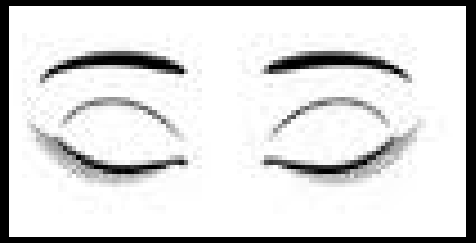
- Low power = greater neuronal activity

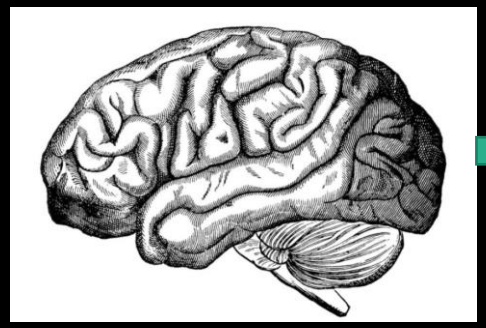
Not always true

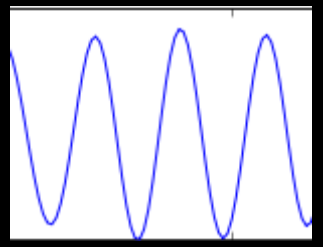
Occipital alpha



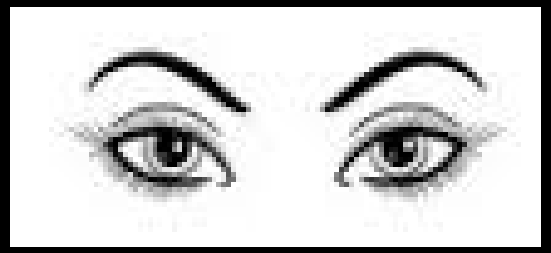
Eyes closed

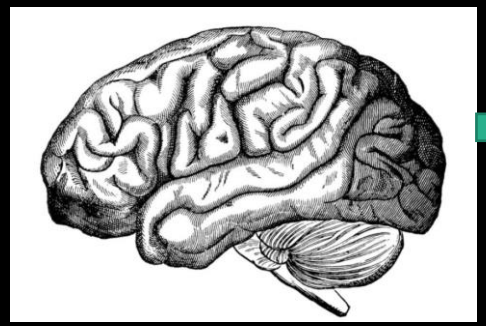


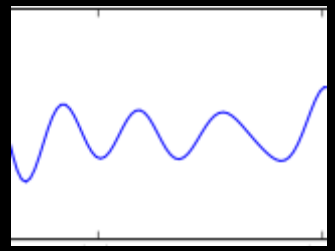




Eyes open







Occipital alpha & attention

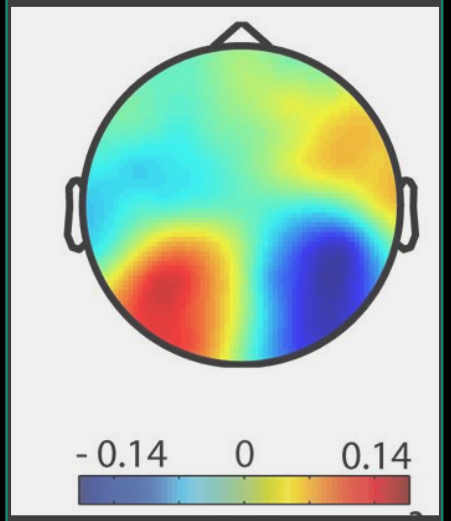
Cue

<

Attention

Target

X



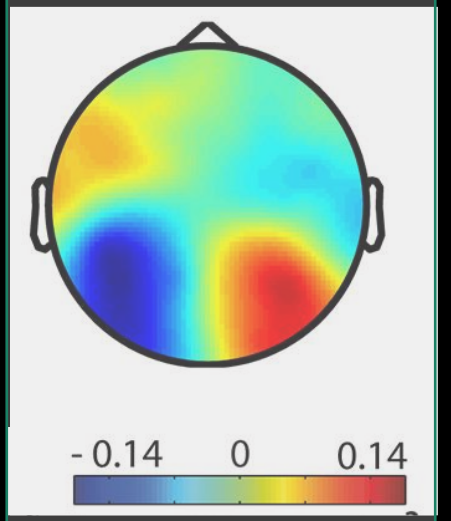
Cue

>

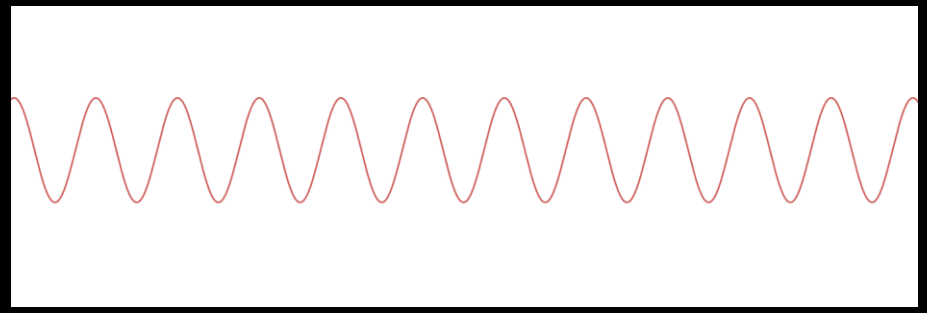
Attention

Target

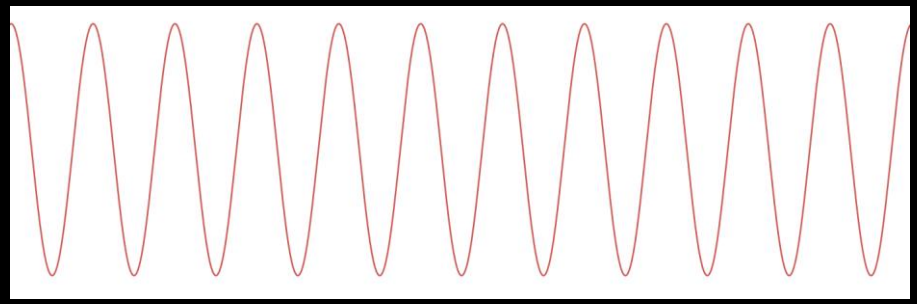
X



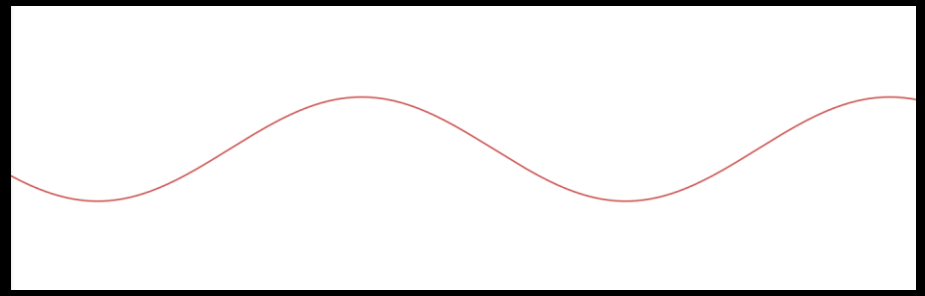
Van Diepen, Mazaheri & Geng (2016)



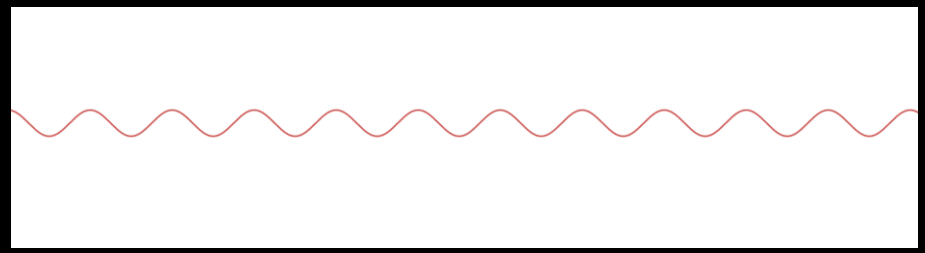
A



B



C



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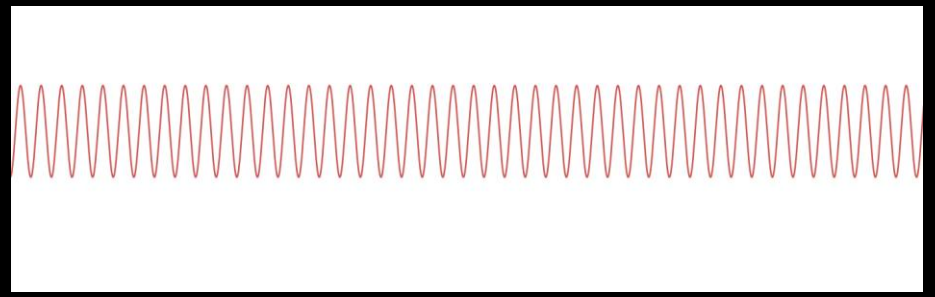


End part 2

PSY2006/4041
ERP

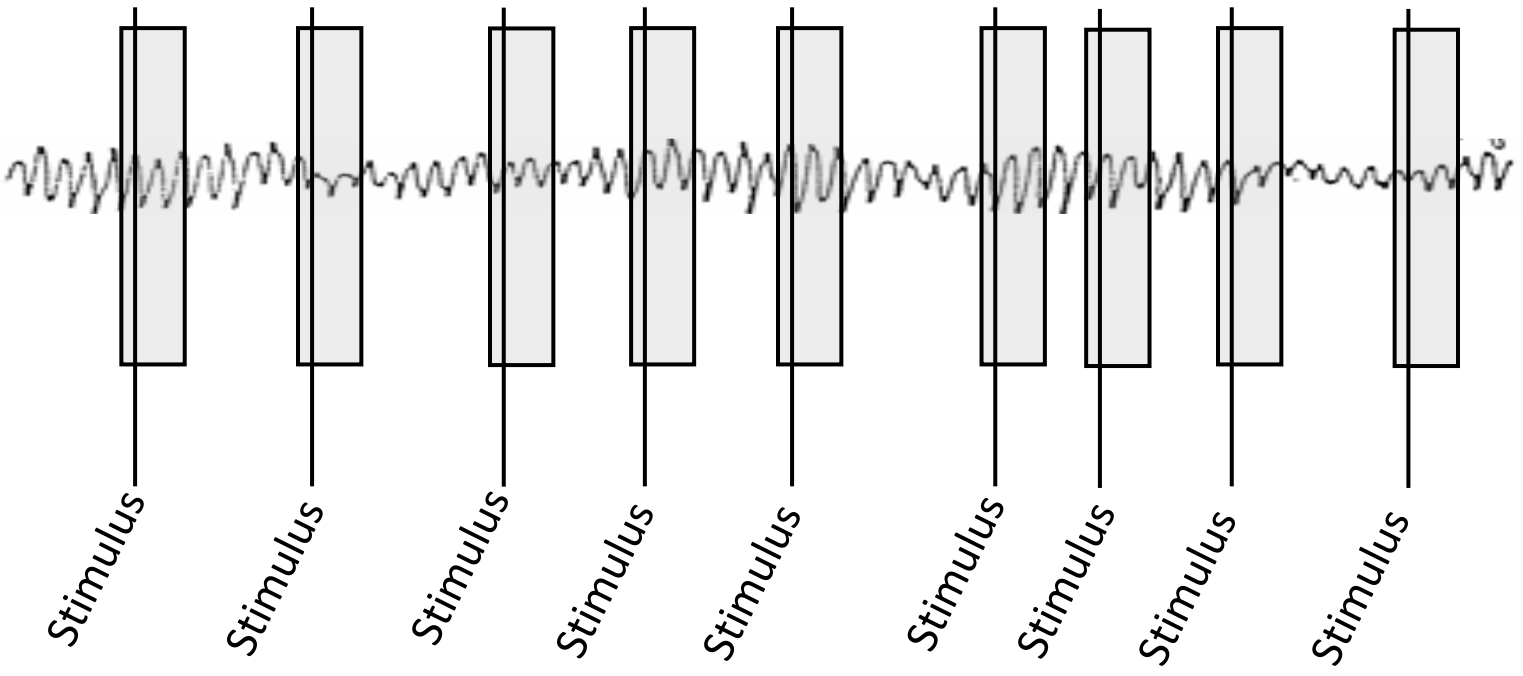
Part 3

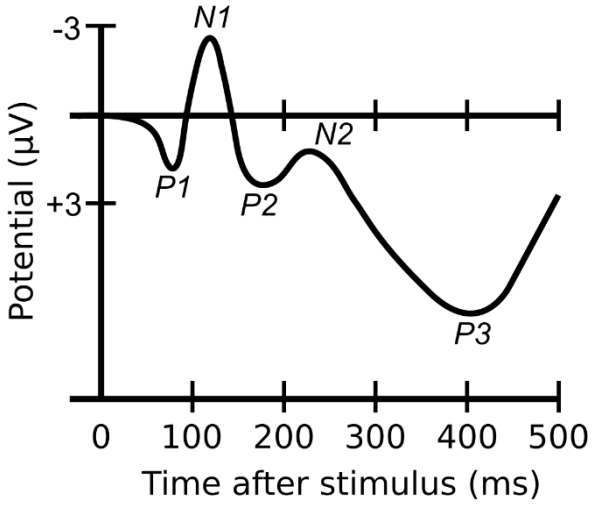
Raw EEG


Fp1-Avg
Fp2-Avg
F3-Avg
F4-Avg
C3-Avg
C4-Avg
P3-Avg
P4-Avg
O1-Avg
O2-Avg
F7-Avg
F8-Avg
T3-Avg
T4-Avg
T5-Avg
T6-Avg
A1-Avg
A2-Avg
Fz-Avg
Cz-Avg
Pz-Avg
Eog-Avg

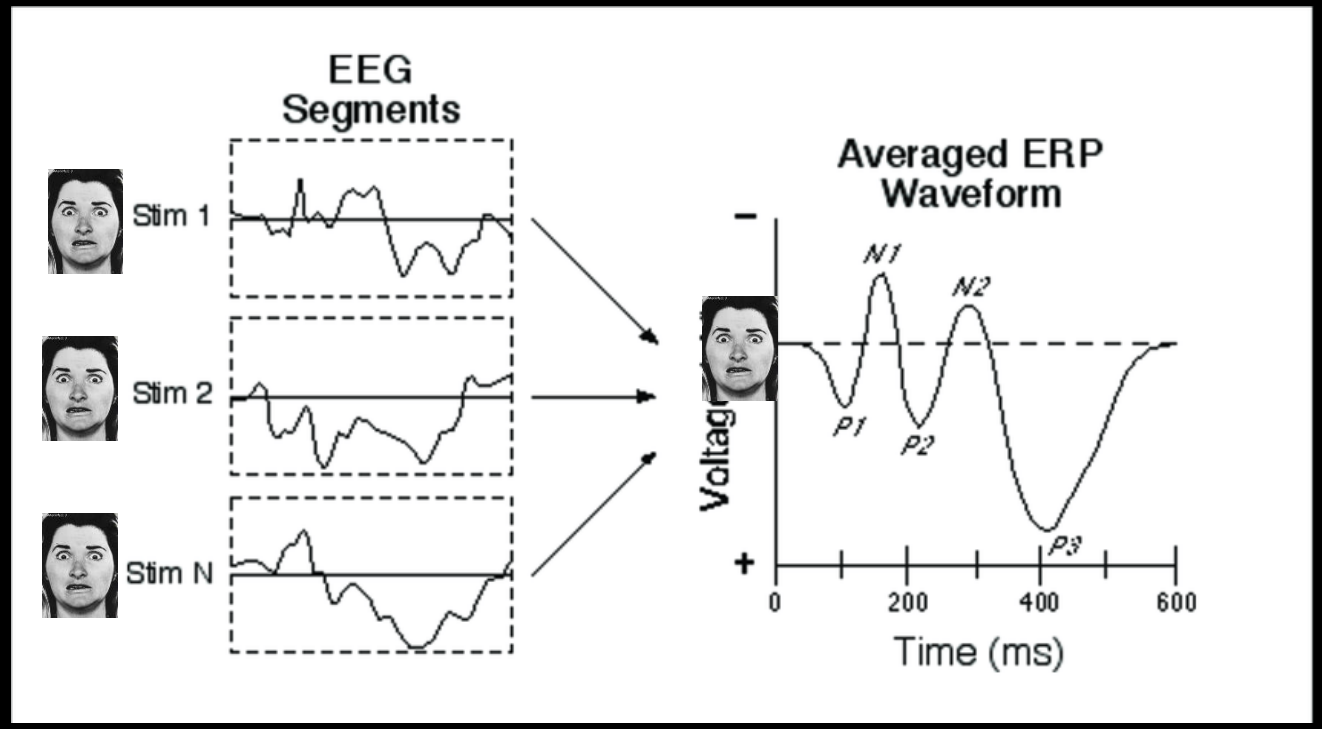
Event Related Potentials (ERPs)

- Most common paradigm used in current EEG research.
- Interested in ‘waveform’ of EEG during specific task.
- EEG is averaged over many repeated trials.

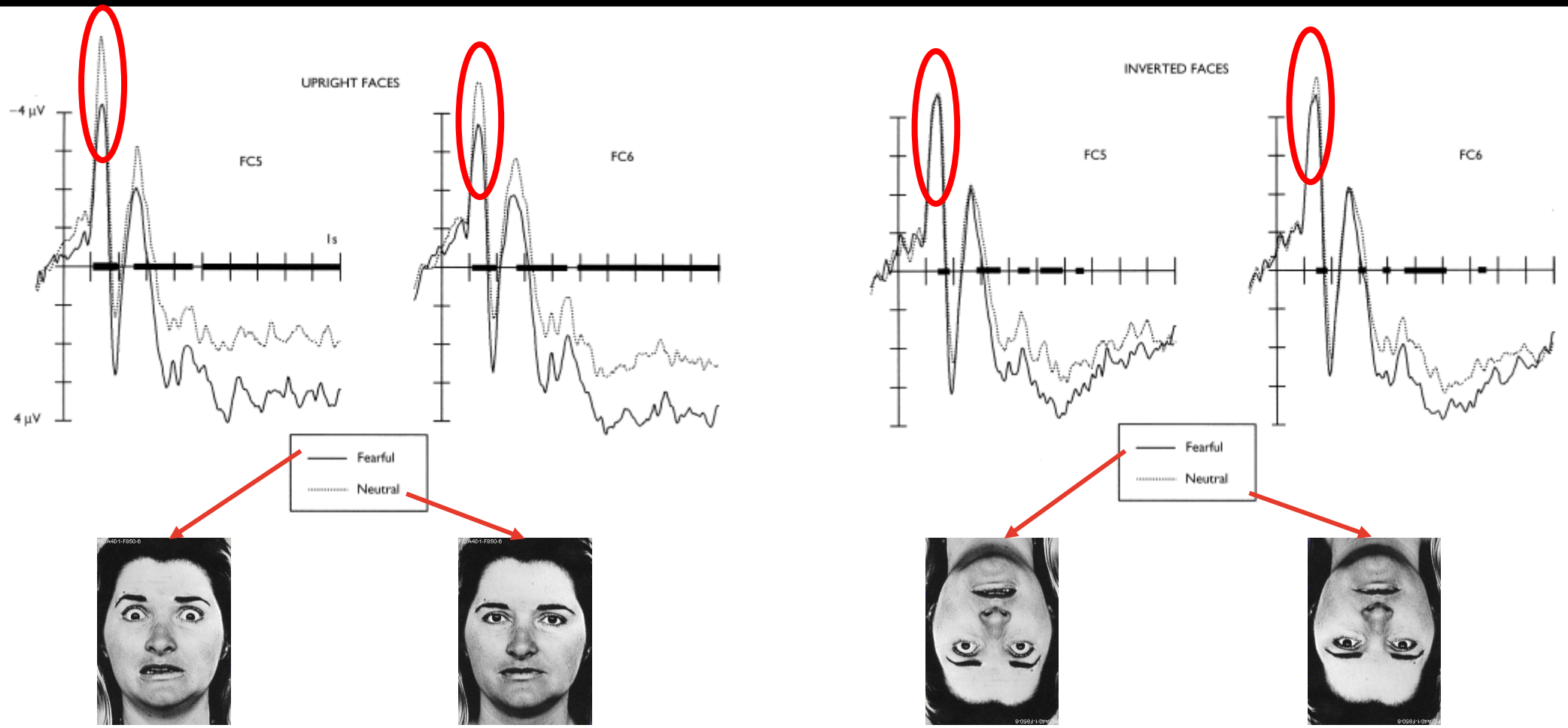




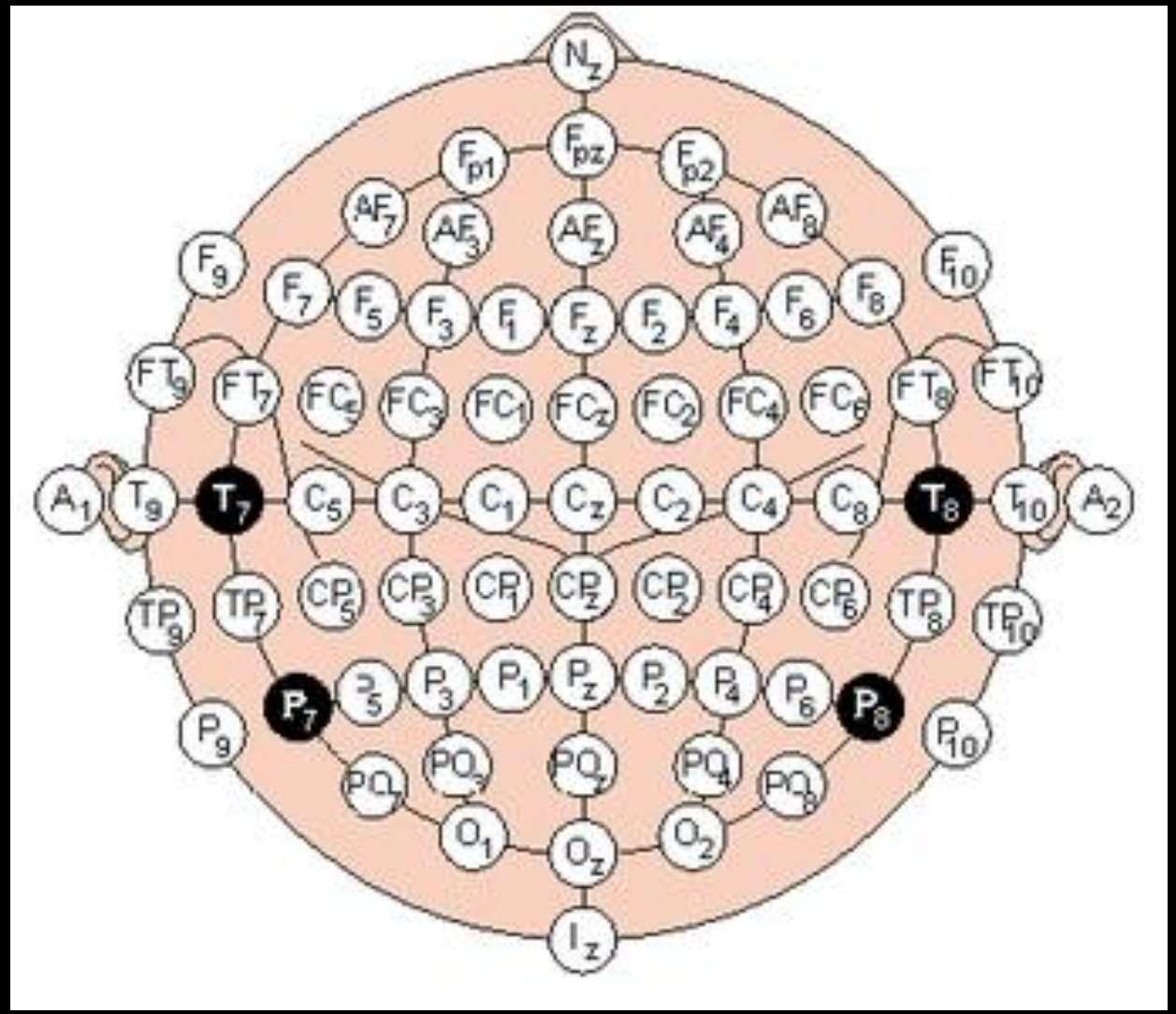
Event Related Potentials (ERPs)

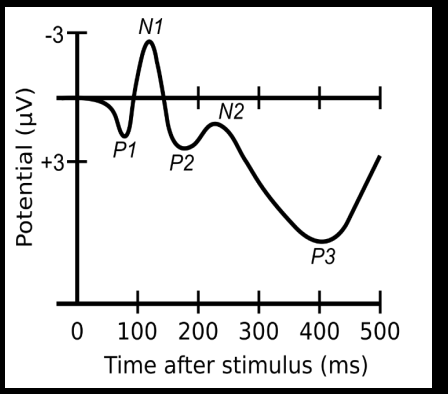


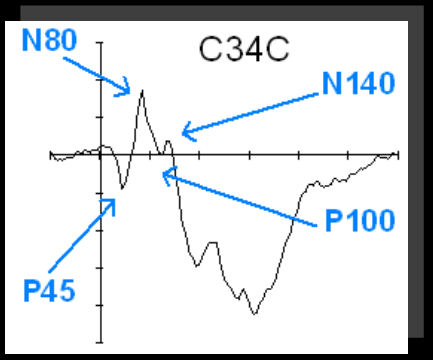
Emotional face processing

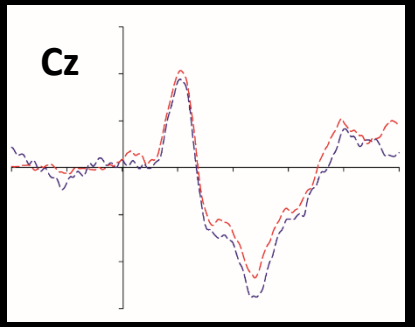


Eimer, M., & Holmes, A. (2007). Event-related brain potential correlates of emotional face processing. Neuropsychologia, 45(1), 15–31. https://doi.org/10.1016/j.neuropsychologia.2006.04.022


Nz
Fp1
Fpz
Fp2
AF7
AF3
AFz
AF4
AF8
F9
F7
F5
F3
F1
Fz
F2
F4
F6
F8
F10
FT9
FT7
FC5
FC3
FC1
FCz
FC2
FC4
FC6
FT8
FT10
A1
T9
T7
C5
C3
C1
Cz
C2
C4
C8
T8
T10
A2
TP9
TP7
CP5
CP3
CP1
CPz
CP2
CP4
CP6
TP8
TP10
P9
P7
P5
P3
P1
Pz
P2
P4
P6
P8
P10
PO7
PO3
POz
PO4
PO8
O1
Oz
O2
Iz


-3
+3
Potential (μV)
N1
P1
N2
P2
P3
0
100
200
300
400
500
Time after stimulus (ms)

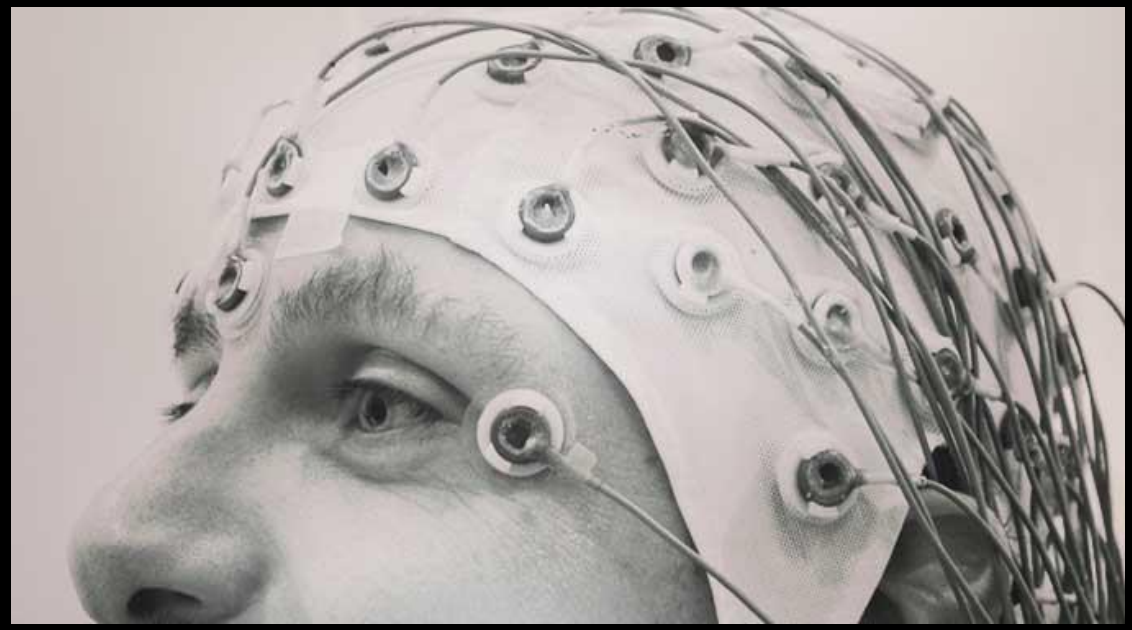

N80
C34C
N140
P100
P45


Cz

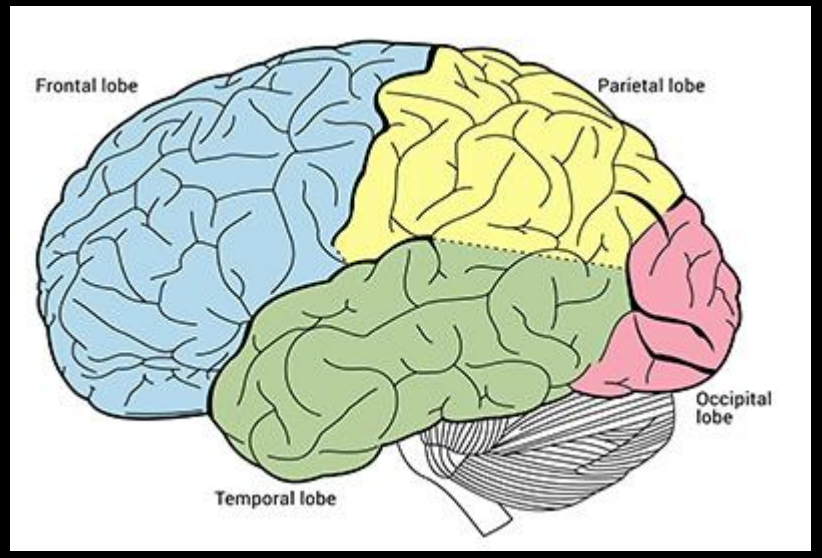
End part 3

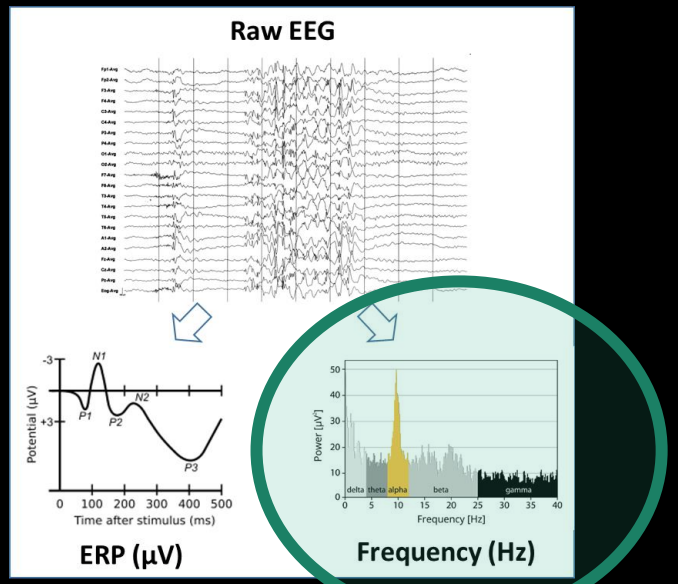
Frontal EEG asymmetry & Individual differences

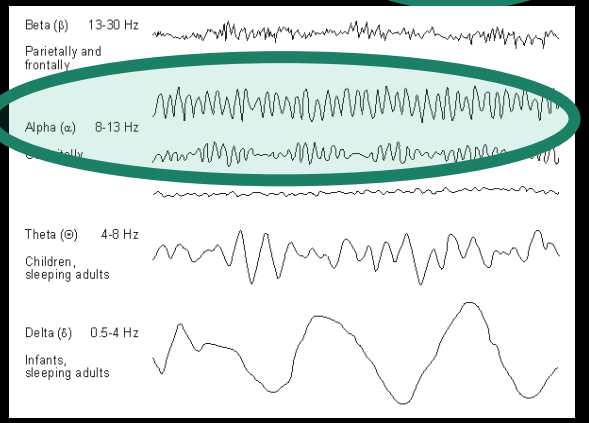
Part 4



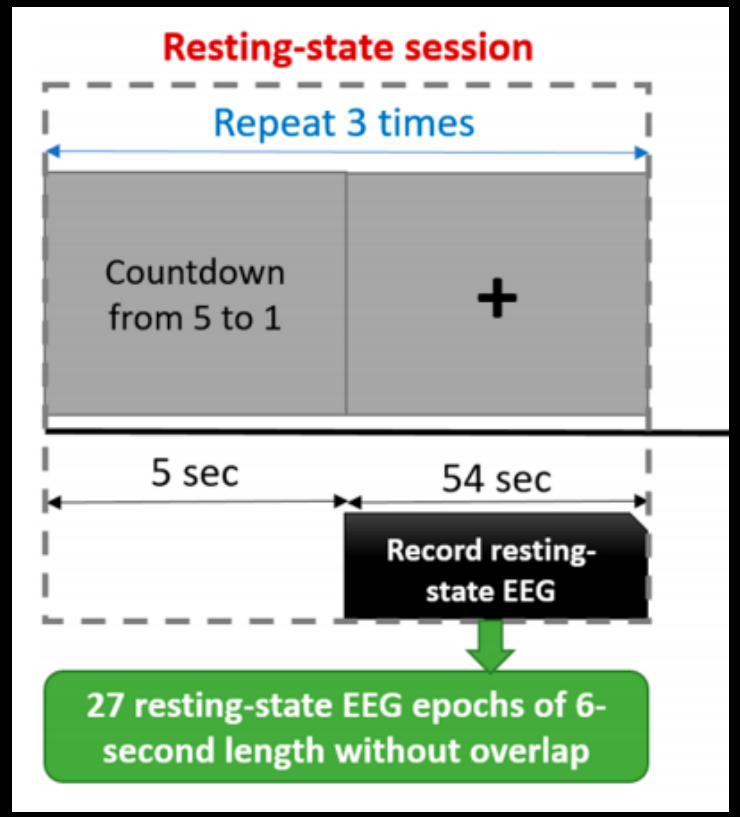
Frontal EEG asymmetry







Resting state



- Compare conditions
  - Pre & post intervention
  - Eyes-open eyes closed
  - Different environments
  - Emotional states

- Hemisphere asymmetry
  - Frontal alpha asymmetry index
    - Depression, anxiety, personality

This is NOT – left brain right brain!

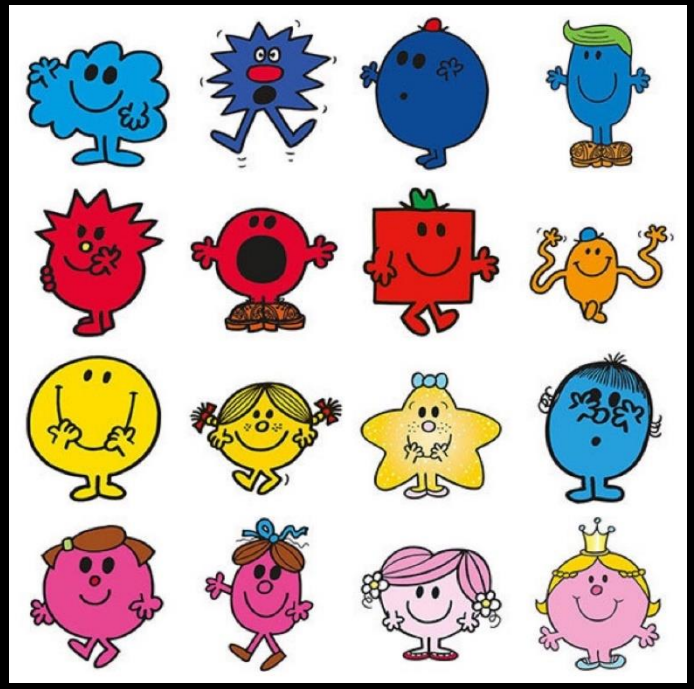
Individual differences (ID)

- ID – people differ in meaningful ways that can be measured and are linked to differences in behaviour, cognition and emotion.

- Differences in the brain are related to individual differences.

Correlation ≠ Causation

- Both are true:
  - Brain differences cause differences in personality
  - Differences in personality cause differences in the brain



ID & the brain

Rarely are causal connections of interest we can ask:

1. Do differences in the brain explain differences in personality

And

2. Do differences in personality explain differences in the brain

This provides:

1. A ‘bio-marker’ for personality traits

And

2. Explains some brain ‘plasticity’

Frontal asymmetry – depression biomarker

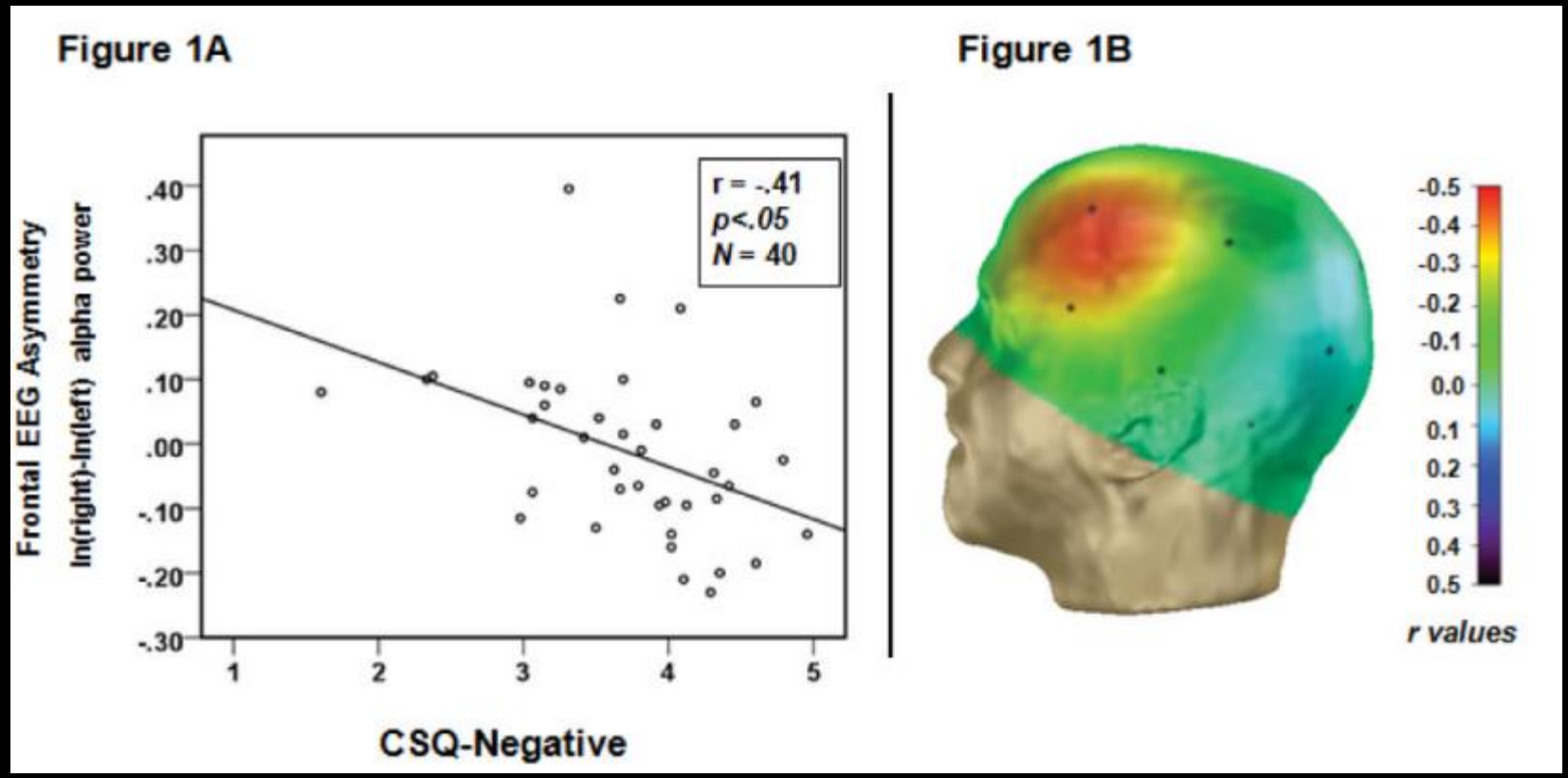
Nusslock et al., (2011). Journal of Abnormal Psychology

- Participants – no prior history of depression (N = 40)
- Baseline assessment - cognitive style and resting frontal brain asymmetry
- Three year interval
- Depression diagnostic interviews at follow up

Nusslock, R., Shackman, A. J., Harmon-Jones, E., Alloy, L. B., Coan, J. A., & Abramson, L. Y. (2011). Cognitive vulnerability and frontal brain asymmetry: Common predictors of first prospective depressive episode. *Journal of Abnormal Psychology*, *120*(2), 497.

Nusslock et al., (2011). Journal of Abnormal Psychology

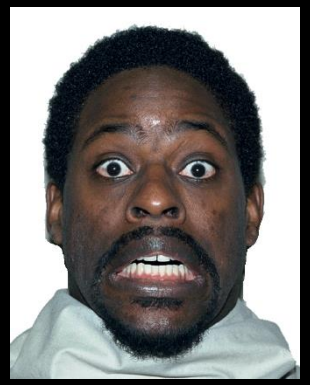
Resting state alpha asymmetry predicted vulnerability to depression at three year follow up interview.



Task related frontal asymmetry

- Depression is closely linked to emotion perception and expression.
- Depressed patients reliably report ‘flatter’ affect.
- EEG was measured while participants made facial expressions.

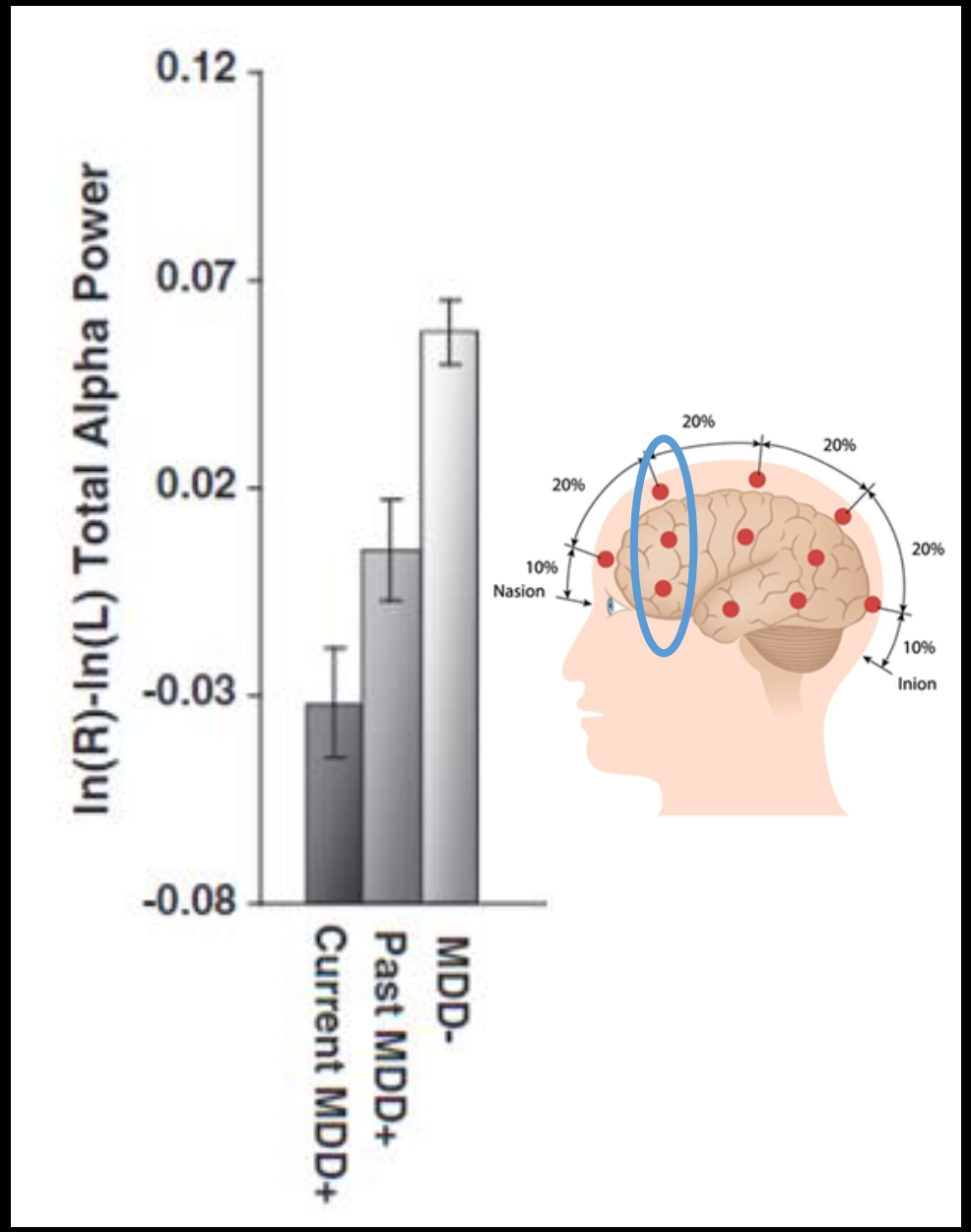





Stewart, J. L., Coan, J. A., Towers, D. N., & Allen, J. J. (2011). Frontal EEG asymmetry during emotional challenge differentiates individuals with and without lifetime major depressive disorder. *Journal of affective disorders*, *129*(1-3), 167-174.

Stewart et al. (2011)

- Frontal asymmetry is a useful marker of depression.
- During emotional expression production differences between groups are large.



Childhood risk of depression

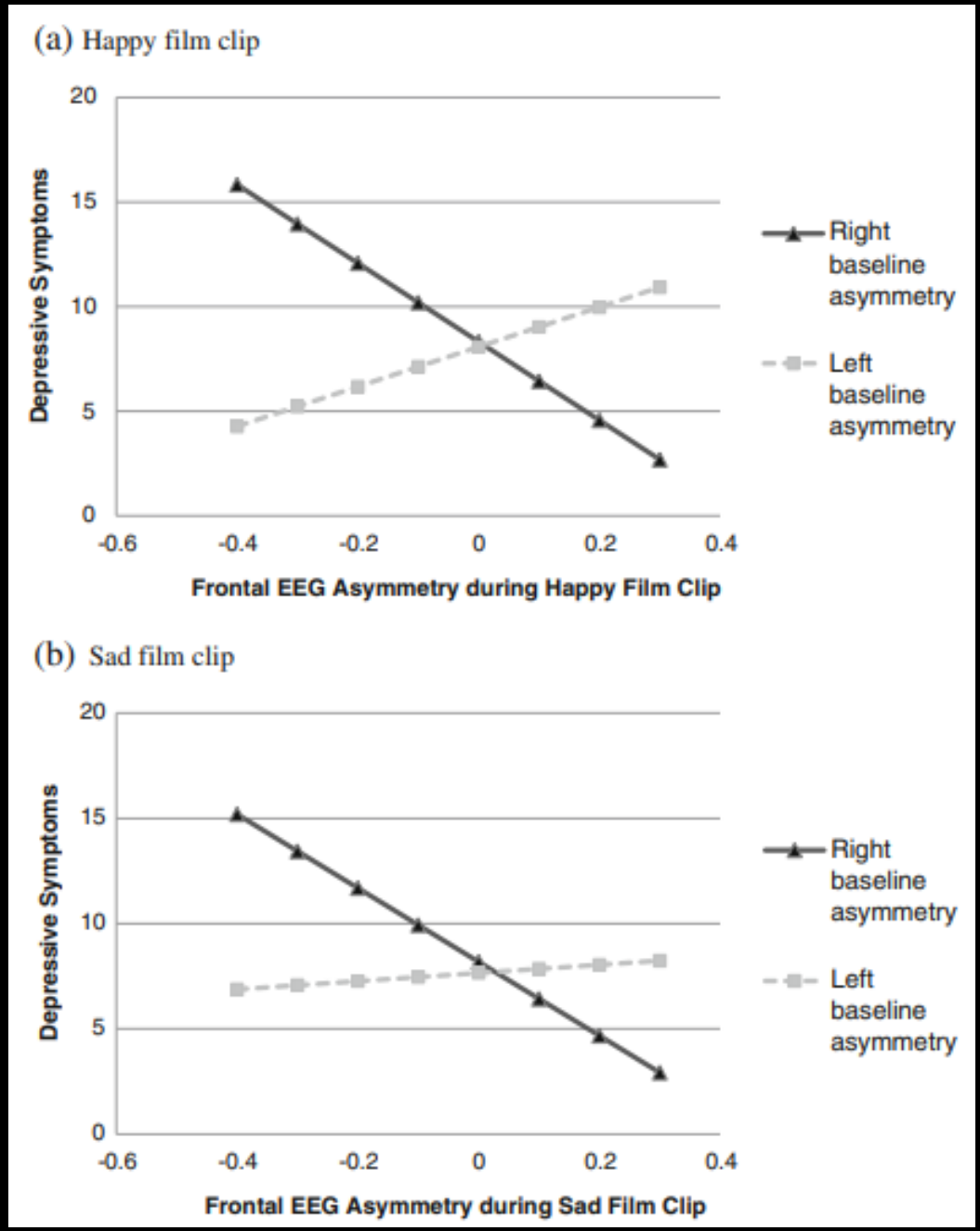
- Participants were 73 children, 43 of whom had mothers with childhood onset depression (COD).
- Children's EEG was recorded at baseline and while watching happy and sad film clips.
- Depressive symptoms were measured using parent-report of Children's Depression Inventory.

Feng, X., Forbes, E. E., Kovacs, M., George, C. J., Lopez-Duran, N. L., Fox, N. A., & Cohn, J. F. (2012). Children's depressive symptoms in relation to EEG frontal asymmetry and maternal depression. *Journal of abnormal child psychology*, *40*(2), 265-276.

Feng et al. (2012)

- Frontal alpha asymmetry during the observation of an emotional film was related to depressive symptoms in children.

- The relationship was stronger for those who had baseline right asymmetry.



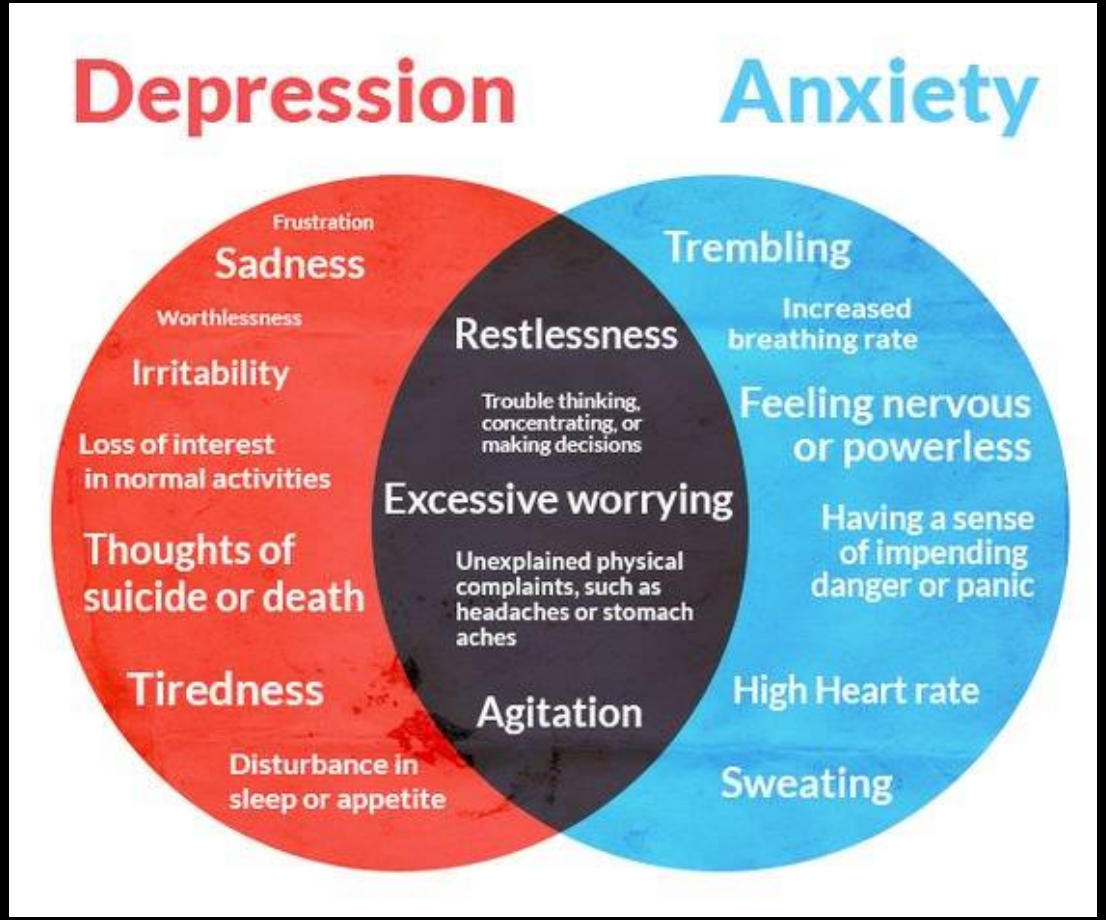
Depression & alpha asymmetry – Implications

- Alpha asymmetry is predictive of depression vulnerability – *long term.*
- Task related activity is strongly related to depression.
- Alpha asymmetry can predict depressive symptoms in children.

Alpha asymmetry = a possible biomarker for <u>depression</u>

Anxiety

- Anxiety and depression often *comorbid*.
- Symptomology overlaps.
- But anxiety and depression are separate mental health issues.
- Critically many uniquely anxious symptoms are associated with the peripheral nervous system.



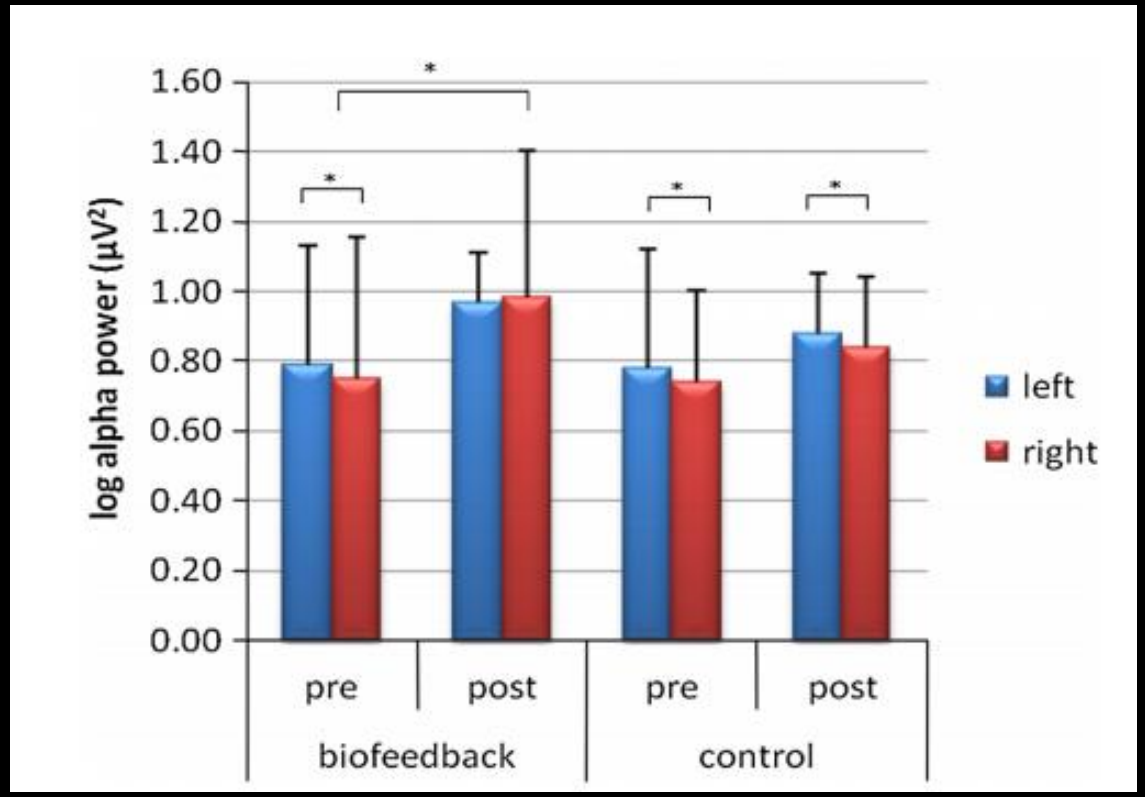
Using bio-feedback to modify anxiety

- 41 athletes divided into biofeedback and control group.

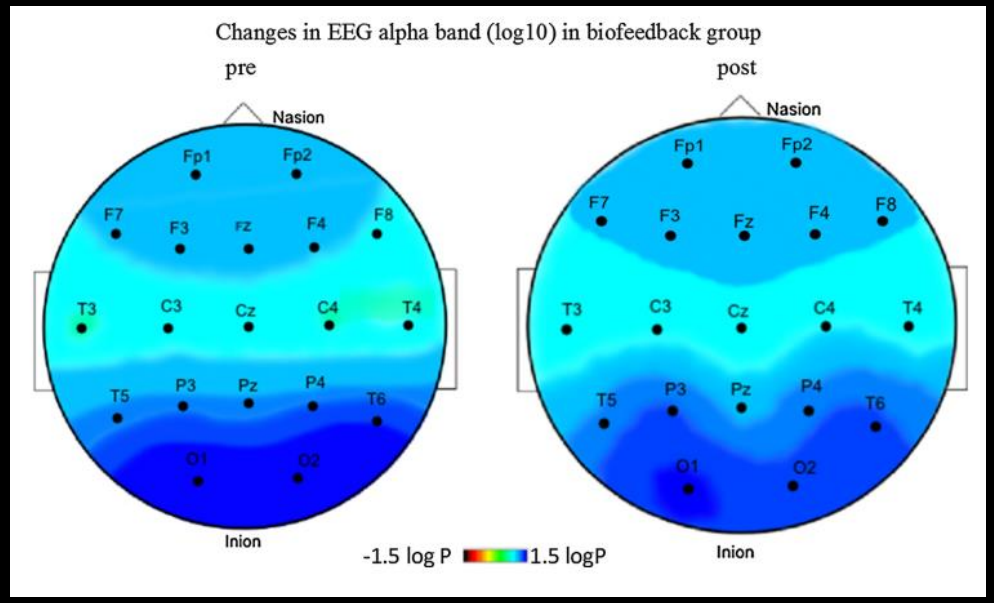
- Before & after measures taken:
  - Frontal alpha asymmetry
  - Anxiety scale

Dziembowska, I., Izdebski, P., Rasmus, A., Brudny, J., Grzelczak, M., & Cysewski, P. (2016). Effects of heart rate variability biofeedback on EEG alpha asymmetry and anxiety symptoms in male athletes: A pilot study. *Applied psychophysiology and biofeedback*, *41*(2), 141-150.

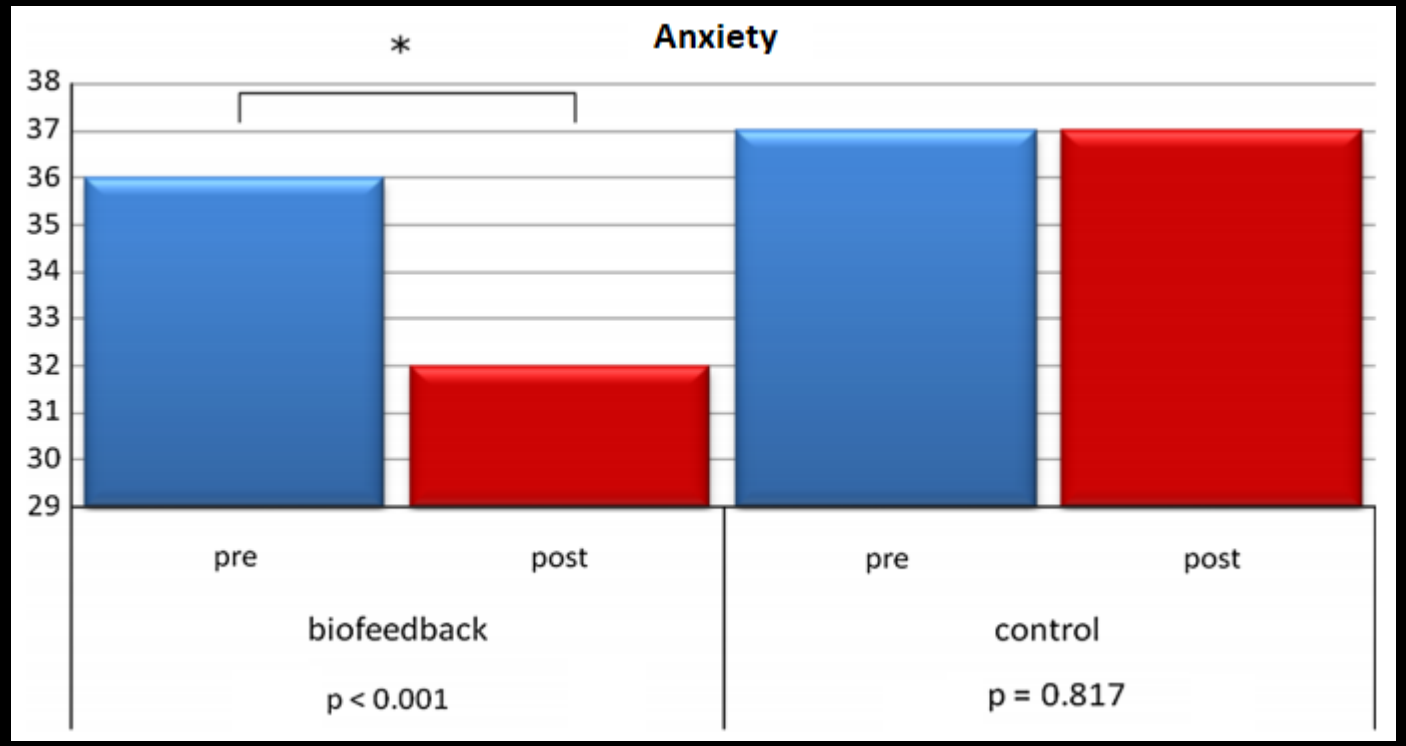
Dziembowska et al. (2016) – EEG findings



Critically – in the biofeedback group only, alpha asymmetry changes after intervention.



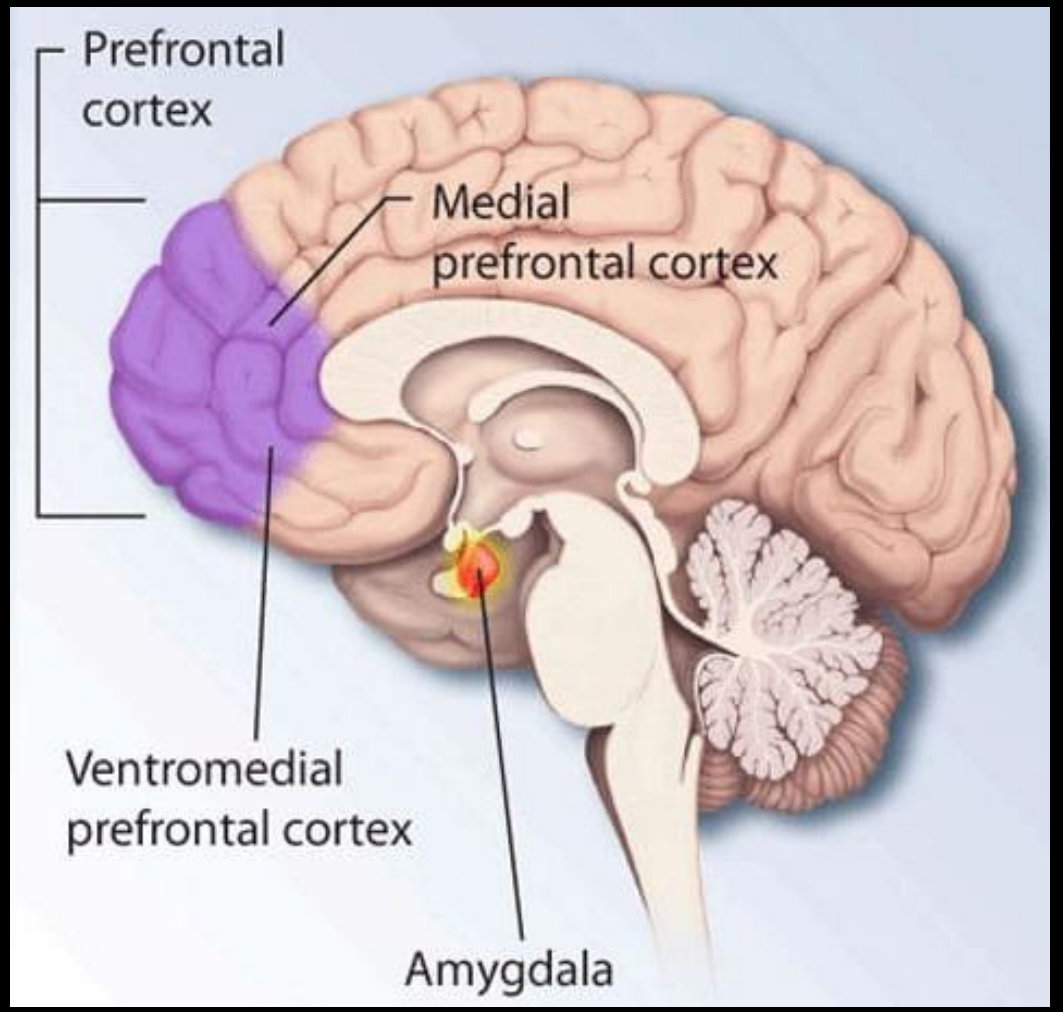
Dziembowska et al. (2016) – anxiety findings



Importantly – after biofeedback training participants reported feeling less anxious.

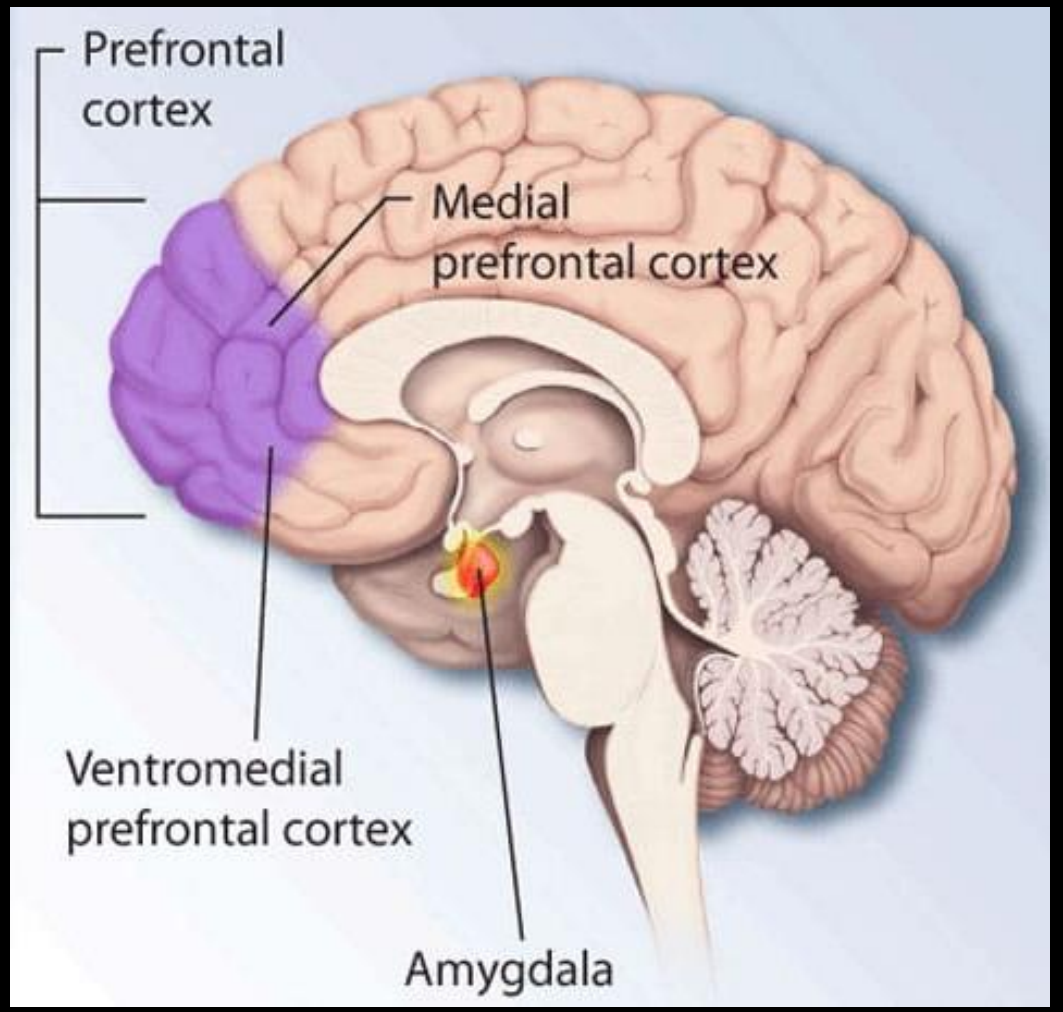
Brain asymmetry and emotion?

- EEG is asymmetrical, but why?
- EEG measurement is largely Prefrontal cortex (PFC) activity
- PFC is heterogenous both anatomically and functionally
- PFC important in emotion and motivation



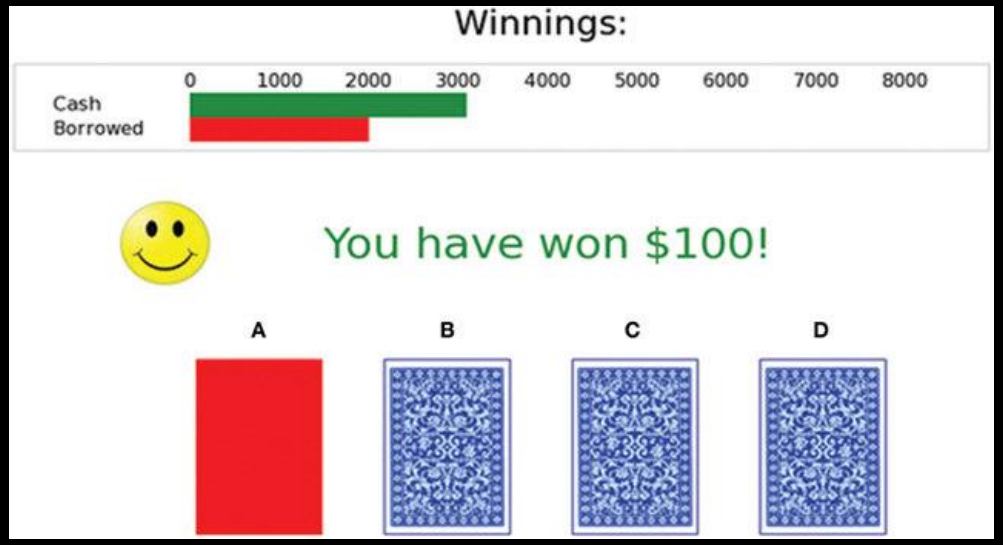
PFC and emotion

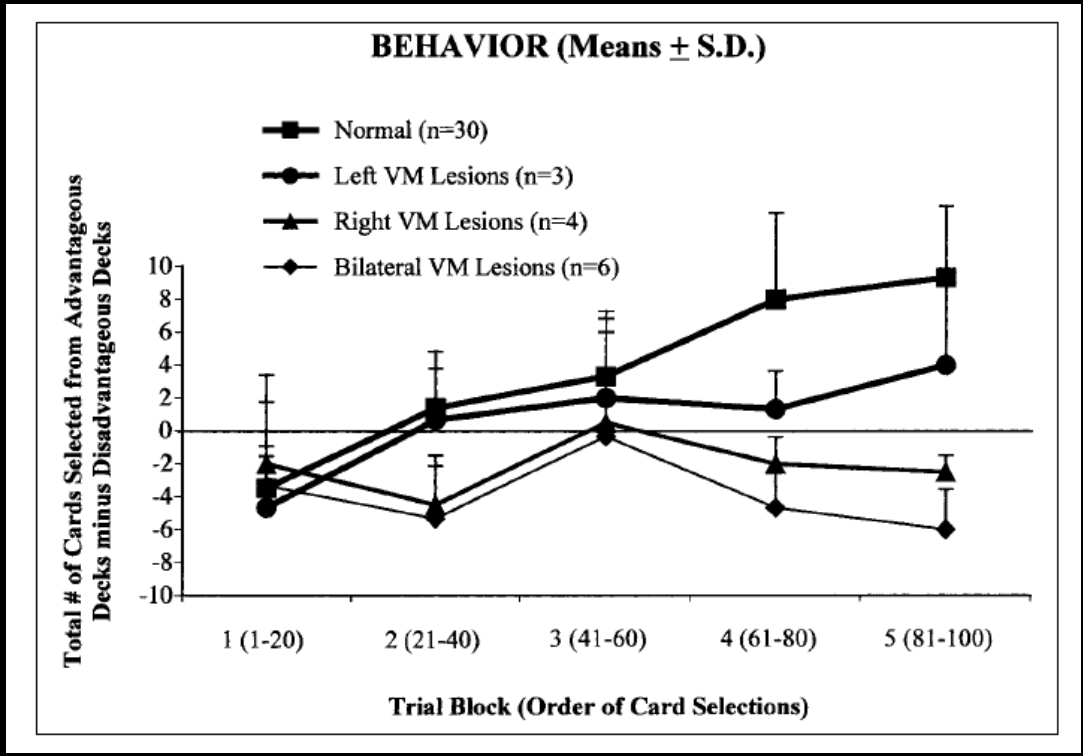
- PFC not *the* centre for emotion but small part of a large and complex circuit (Davidson et al., 2003)
- PFC, amygdala, hippocampus, insula and anterior cingulate play different but complementary roles in emotion
- PFC anatomically directly connects to amygdala
- Left PFC inhibits amygdala (Davidson, 2002, *Biol. Psychiatry*)



PFC and patients

- Patients with right PFC damage, but not left, have abnormalities in emotion-related decision making (Tranel et al., 2002; Clarke et al, 2003)
- Right PFC sensitive to punishment and when damaged, cues of threat and danger not processed and leads to impulsive behaviour.





Tranel et al., (2002) *Cortex*

Higher left PFC activity and wellbeing

- Left PFC activity linked to wellbeing
- Individuals with higher LPFC compared to right activity
  - lower stress hormone cortisol (Kalin et al., 1998, *Beh. Neurosci*)
  - Higher antibodies in response to influence vaccine
- Individuals with higher left PFC activity – more positive profile of biological indicators.
- Higher left activity more resilient and coping

Higher left PFC activity and anger – paradox?

- Anger associated with LPFC activity
  - Anger in infants (not crying) increased left sided frontal EEG activity (Fox and Davidson, 1998, *Dev. Psychol.*)
- Anger elicited in specific context associated with left sided PFC activation
  - Harmon-Jones And Sigelman (2001) provided insults on essays – increased LPFC activity
  - Approach-withdrawl explanation (Harmon-Jones, 2004, *Biol. Psychol*.)
  - Anger related situations with obstacles in the way of goals
  - Negative anger associated with other brain regions

Summary & Conclusion

- EEG – records underlying brain activity
- Raw EEG analysed with ERP or frequencies
- EEG frequencies typically include alpha, beta, delta, gamma and theta
- Associated with different cognitive functions
- Recording resting state EEG linked to individual differences
- Frontal EEG asymmetry associated with depression, anxiety, creativity and more
- PFC particularly involved in generating differences in emotion and motivation