Research methods in neuroscience

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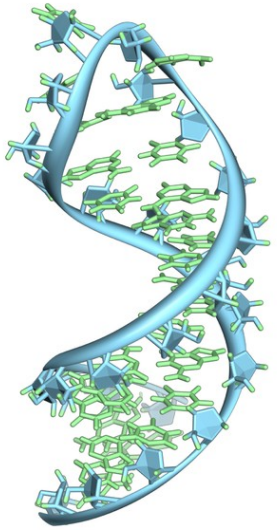
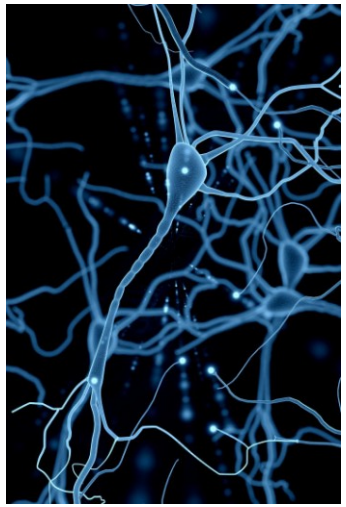
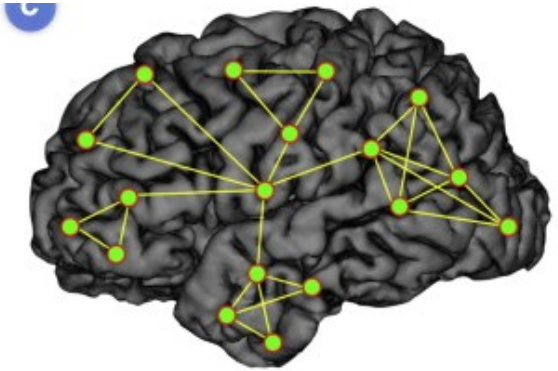
Contents

- Overview and approaches to measurement
- Electrophysiology: EEG, iEEG...
- MRI & fMRI (Petra Zemánková, PhD)
- TMS & rTMS (Pavlína Linhartová)
- MAFIL lab visit: practical demonstration

Breadth of neuroscience



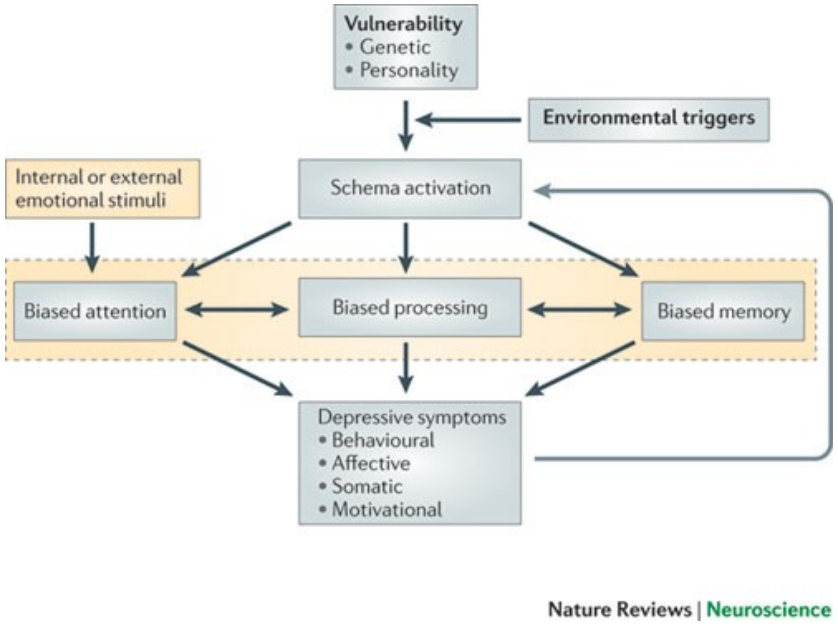




Questions we can ask

Basic research

- What does it do? How does it work?



e.g. cognitive modelling

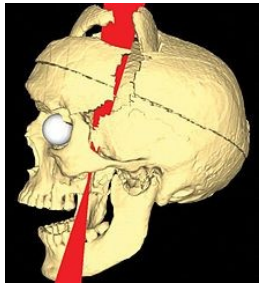
Applied research

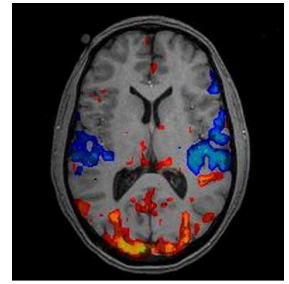
- What can we influence? How?

e.g. Brain-computer interface, cognitive enhancement

Methods of studying the nervous system (how we get answers)

- 1. Examining case studies—identifying interesting events that have occurred naturally and using these events to develop hypotheses that can be tested in future experiments
- 2. Screens—performing unbiased searches for anatomical structures, neurons, proteins, or genes that could play a role in a subject of interest
- 3. Description—using techniques that allow a scientist to observe the nervous system without manipulating any variables
- 4. Manipulation—testing hypotheses by determining the effect of an independent variable on a dependent variable
  - loss-of-function (also called “necessity”')
  - gain-of-function (also called “sufficiency”)



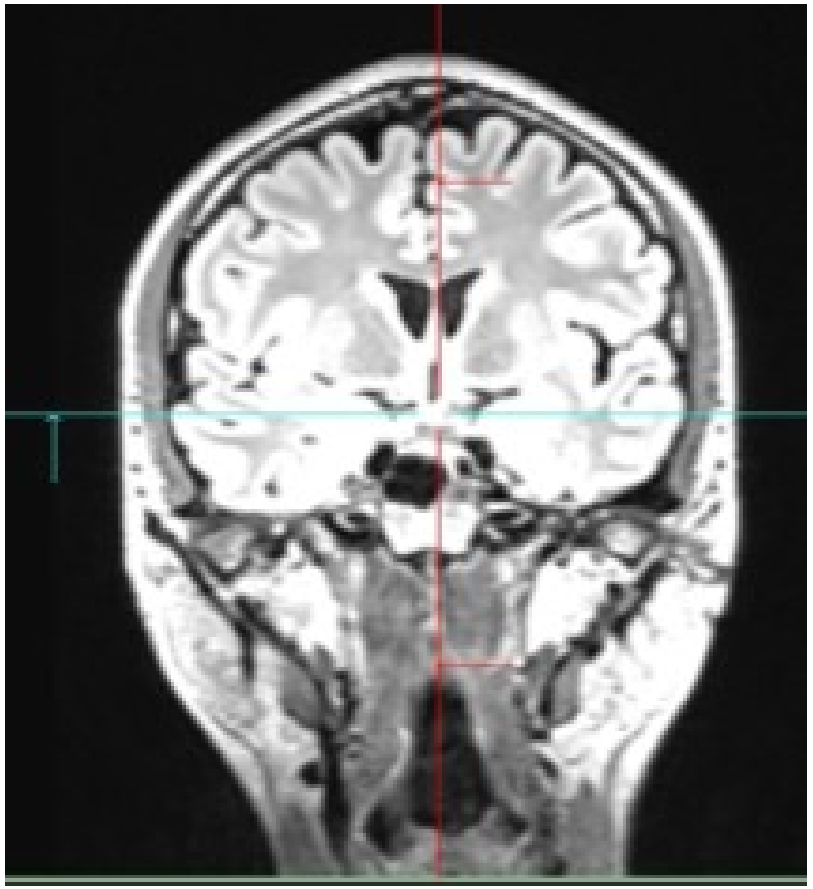


Blobs...but why?

Techniques we use to get the answers

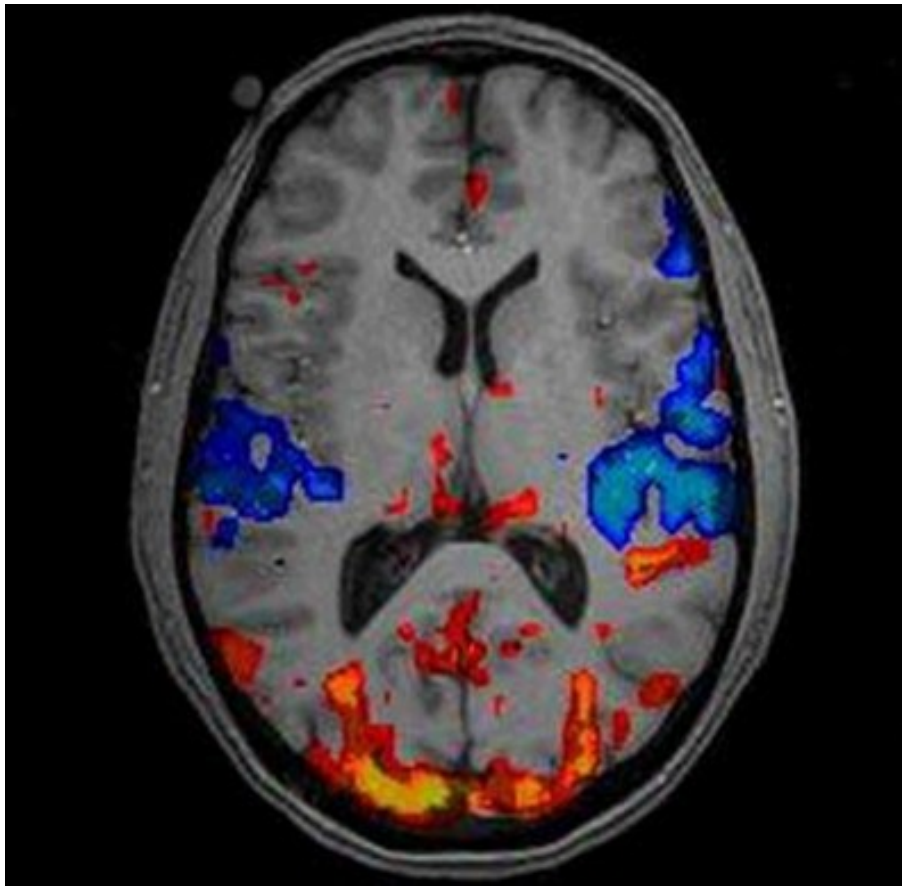
- Structural / functional
- Invasive / non-invasive
- Task-dependent / resting-state
- In vivo / post mortem
- Observation/manipulation(perturbation)
- Fast event or long-therm development
- Microscopic to whole-brain scale

Structure



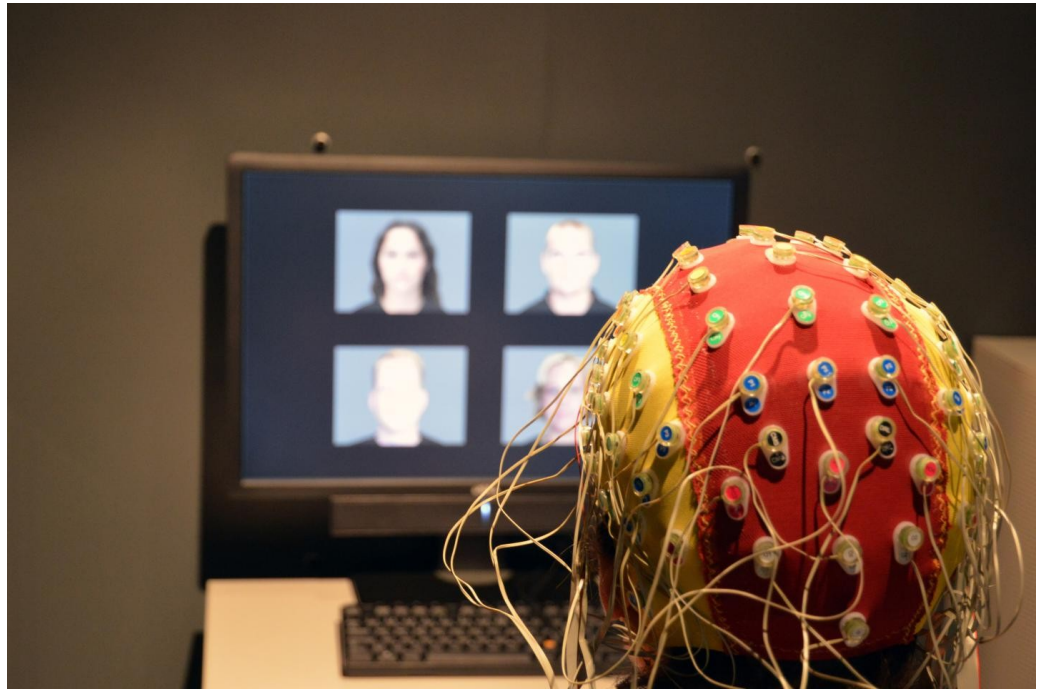
structural MRI

Function



Functional MRI (fMRI)

Task-dependent

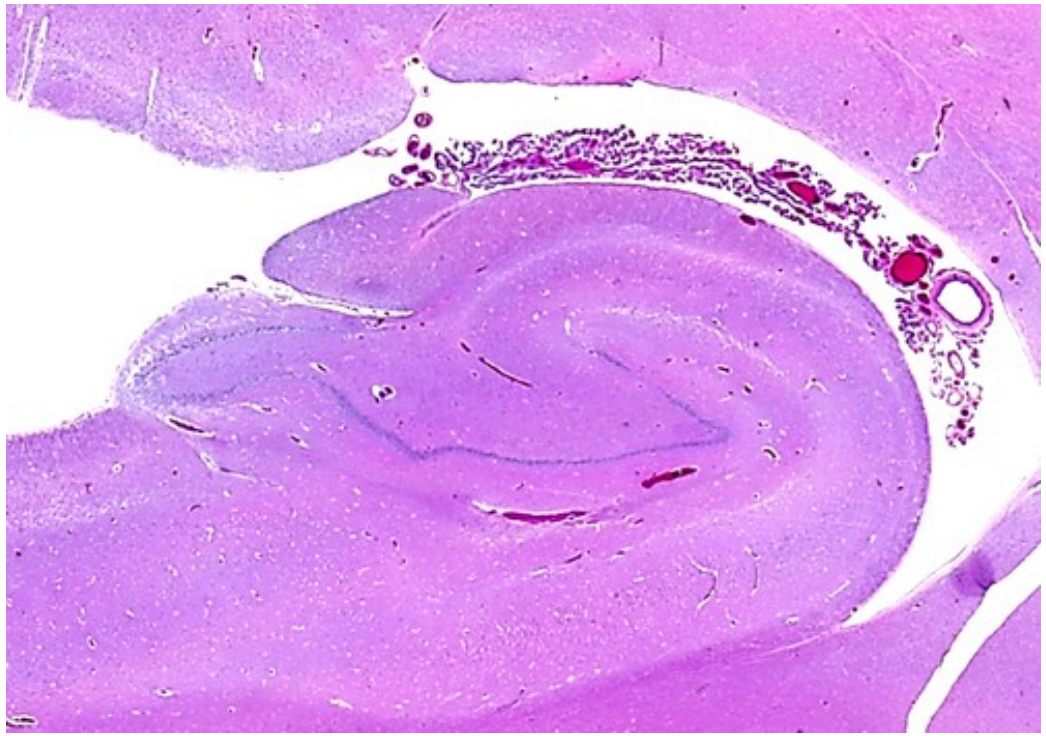


Resting state

In vivo

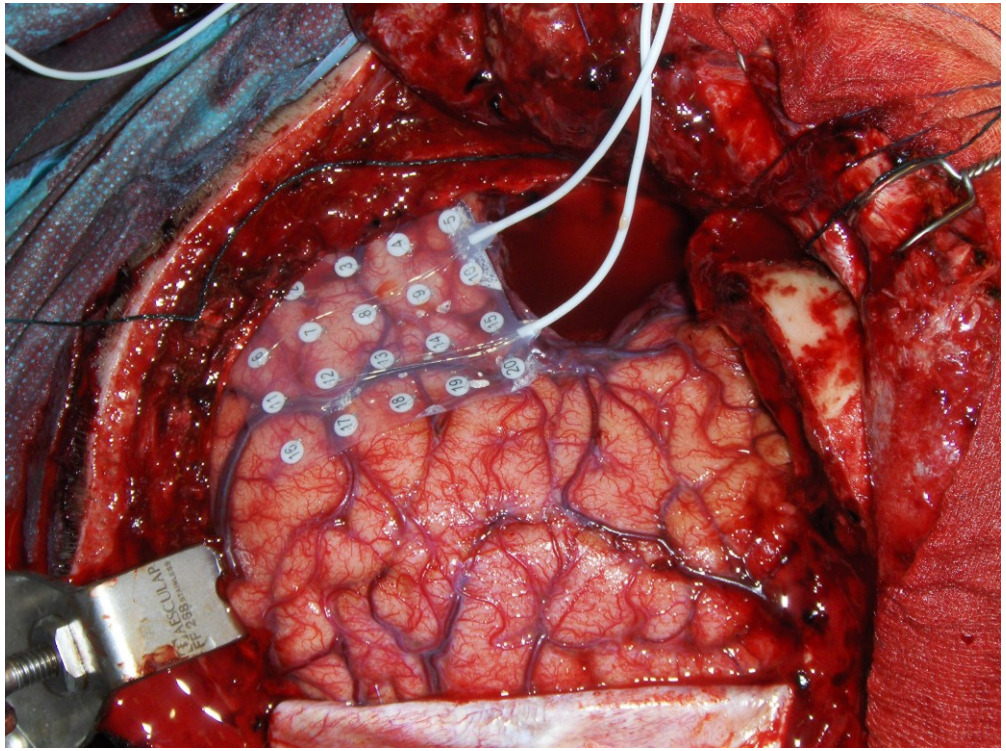
fMRI

Post mortem



histology

Invasive

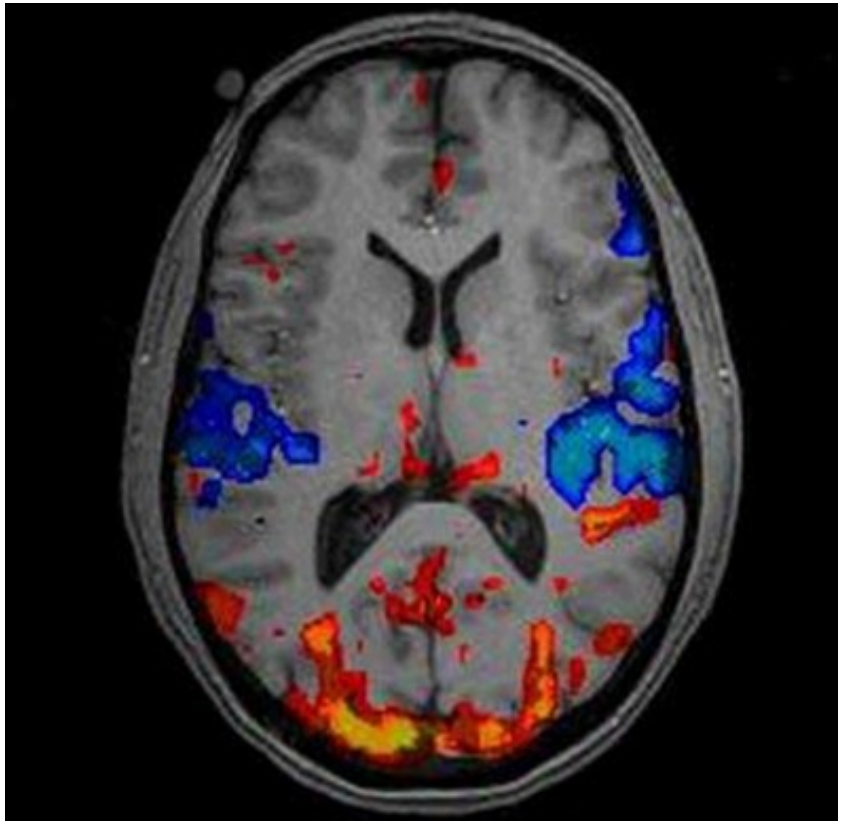


ECoG: electrocorticogram

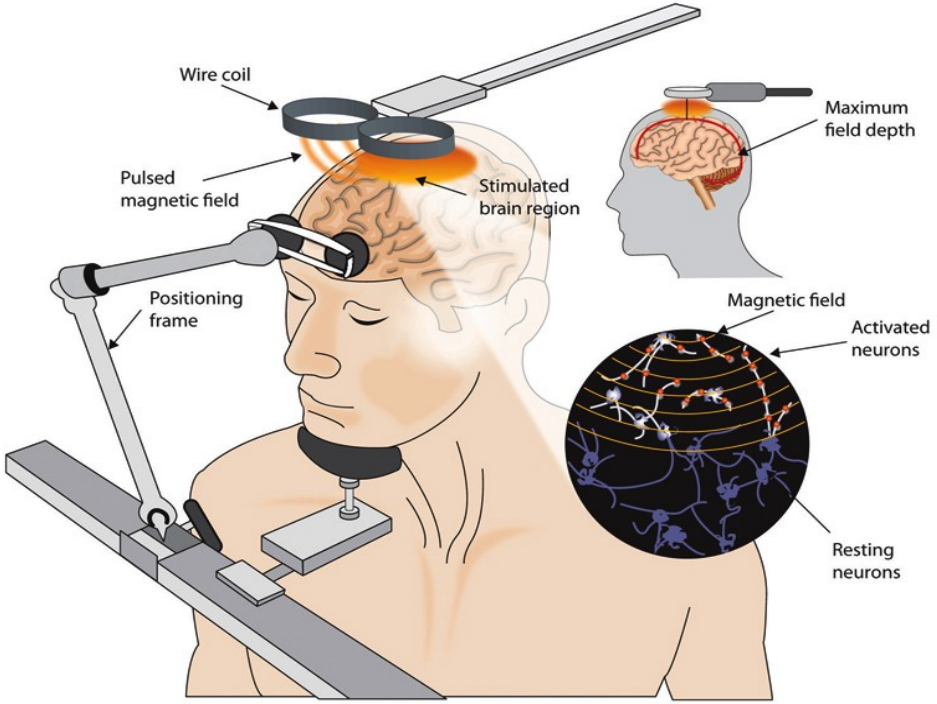
Non-invasive

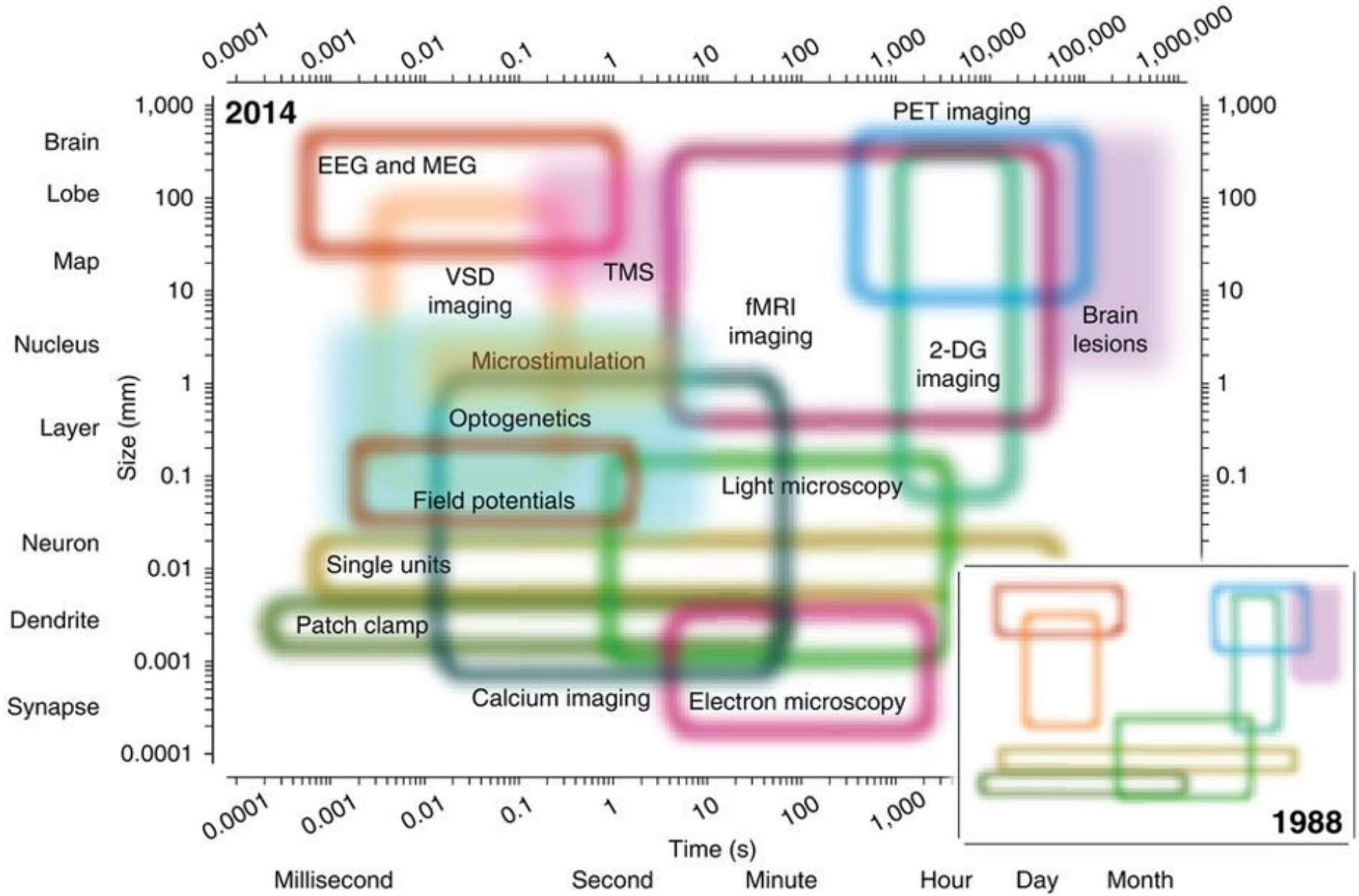
Scalp EEG

Observation



Manipulation



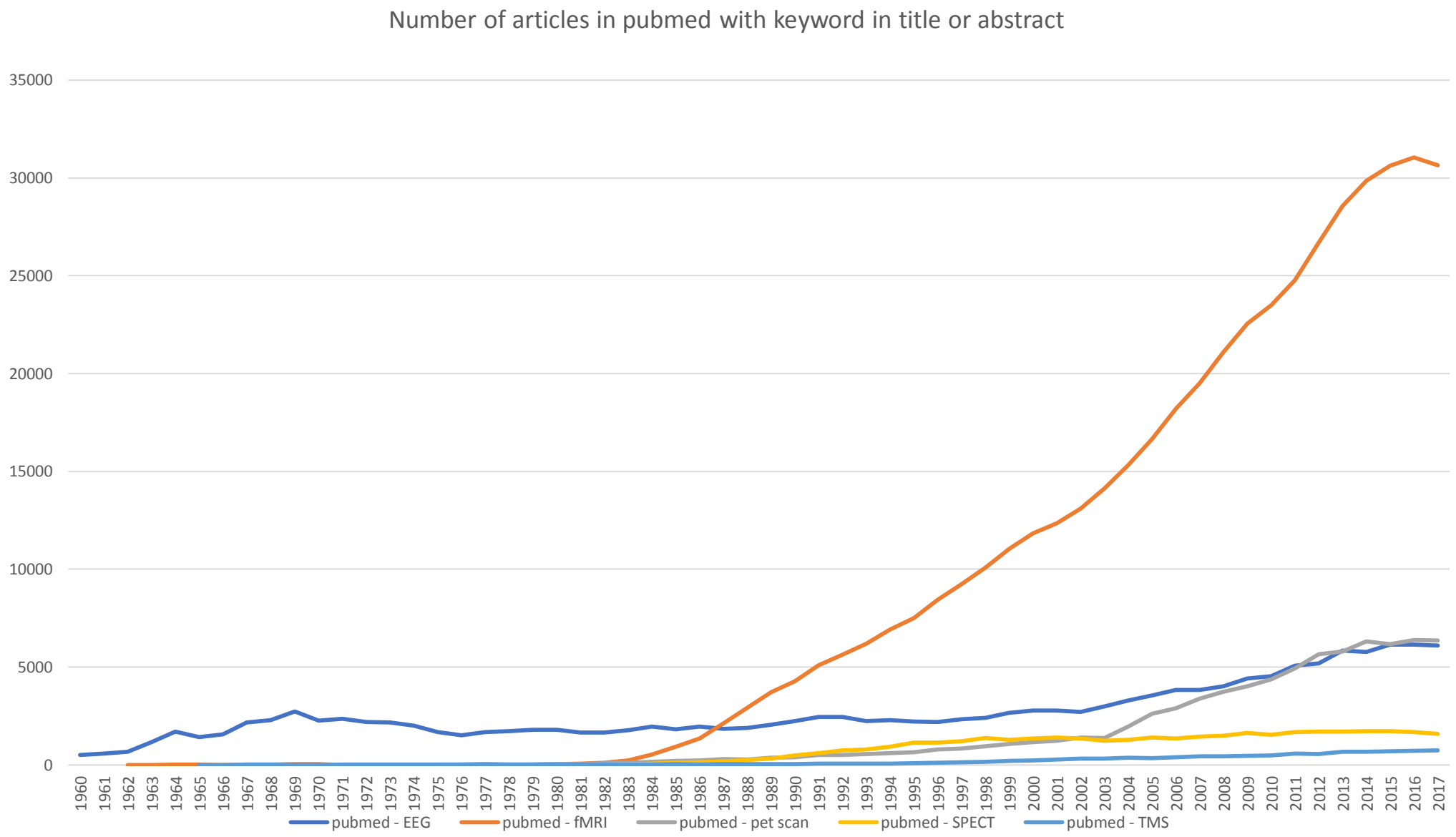


Spatial scale

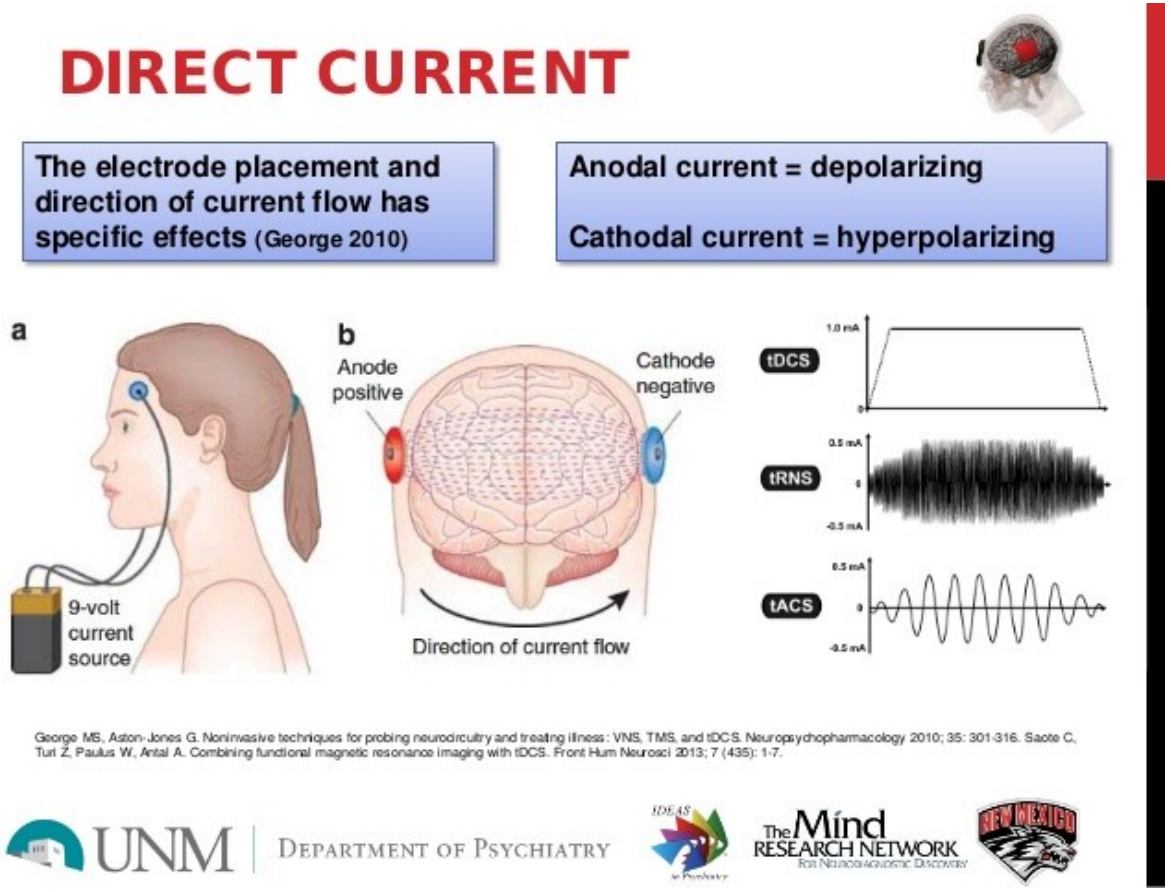
Temporal scale

Whole-brain neuroimaging methods in human cognitive neoroscience

- Electrophysiology (EEG, MEG)
- MRI (fMRI, DTI, spectroscopy),
- PET and SPECT
- Perturbation (TMS, TCS)

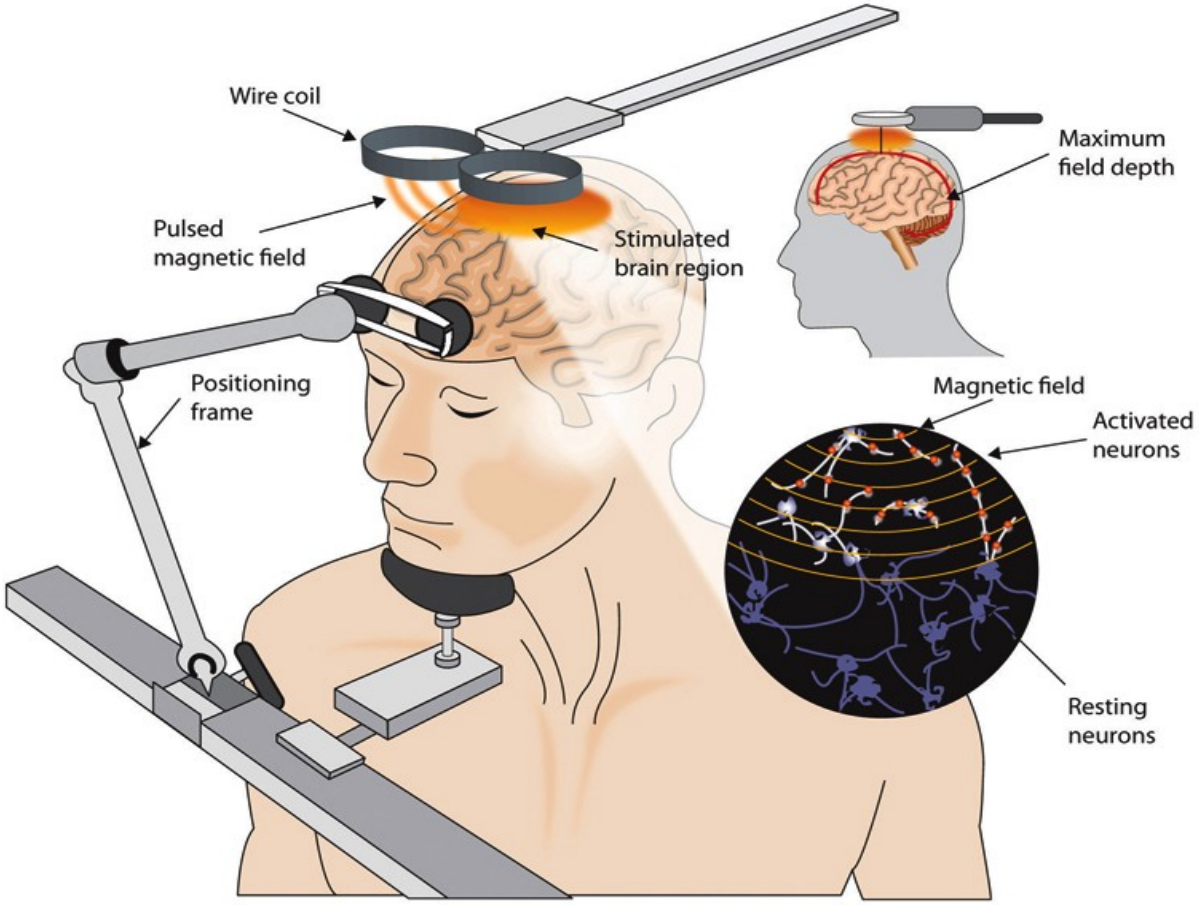

Number of articles in pubmed with keyword in title or abstract
35000
30000
25000
20000
15000
10000
5000
0
1960 1961 1962 1963 1964 1965 1966 1967 1968 1969 1970 1971 1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017
pubmed - EEG
pubmed - fMRI
pubmed - pet scan
pubmed - SPECT
pubmed - TMS

Stimulation: non-invasive



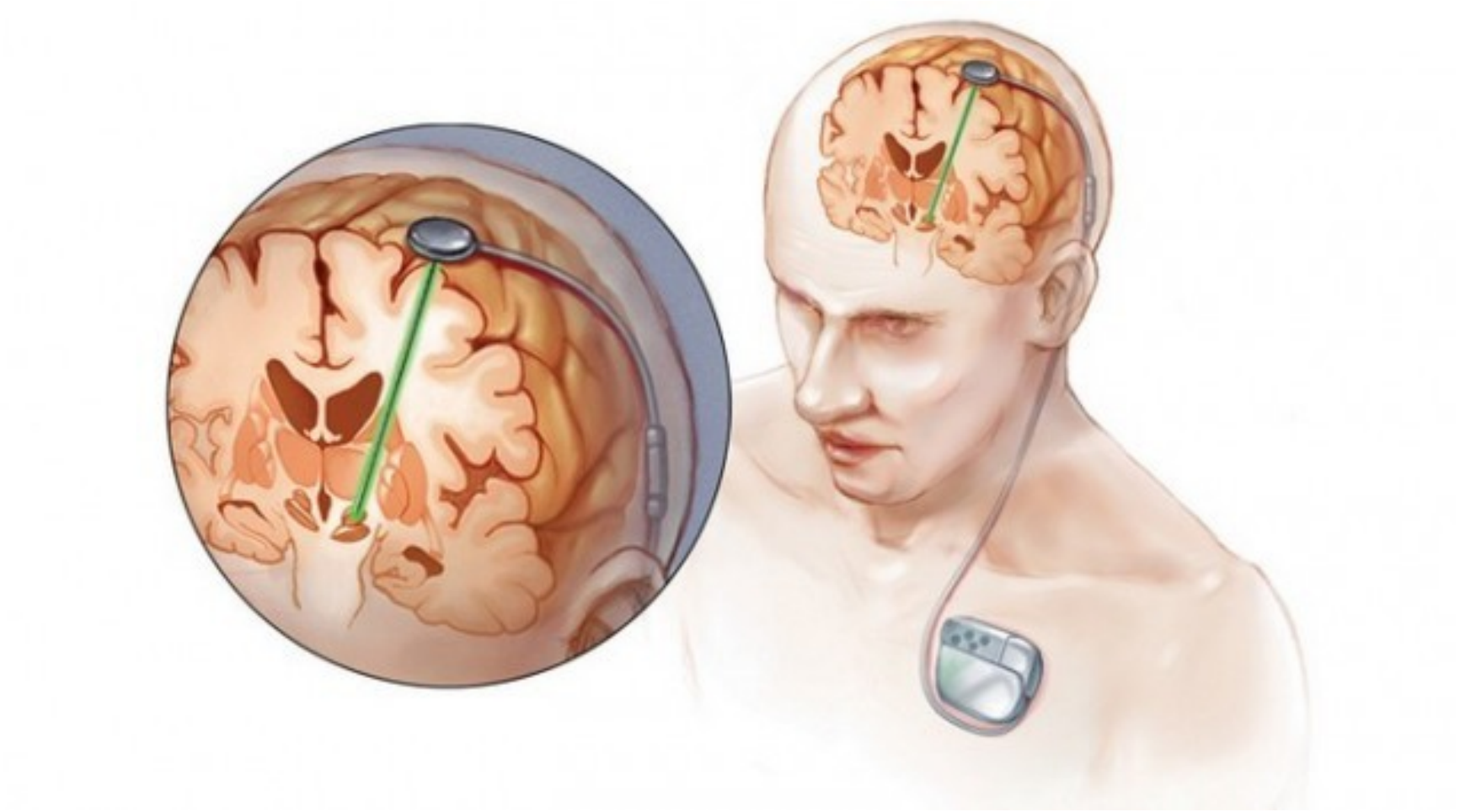
Transcranial direct current stimulation

Stimulation: non-invasive



Transcranial magnetic stimulation

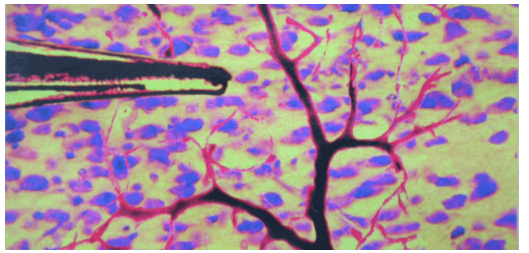
Deep brain stimulation

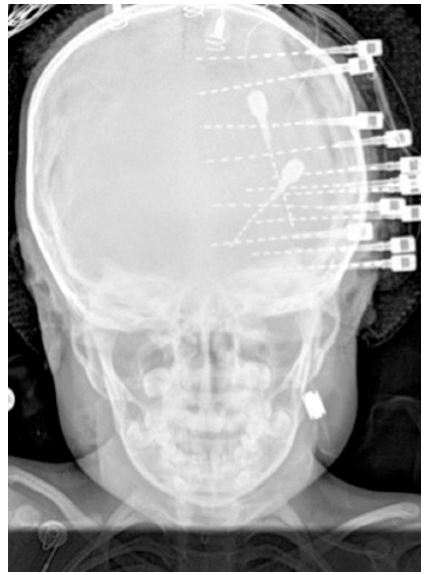


https://www.youtube.com/watch?v=wZZ4Vf3HinA

Neurophysiology methods

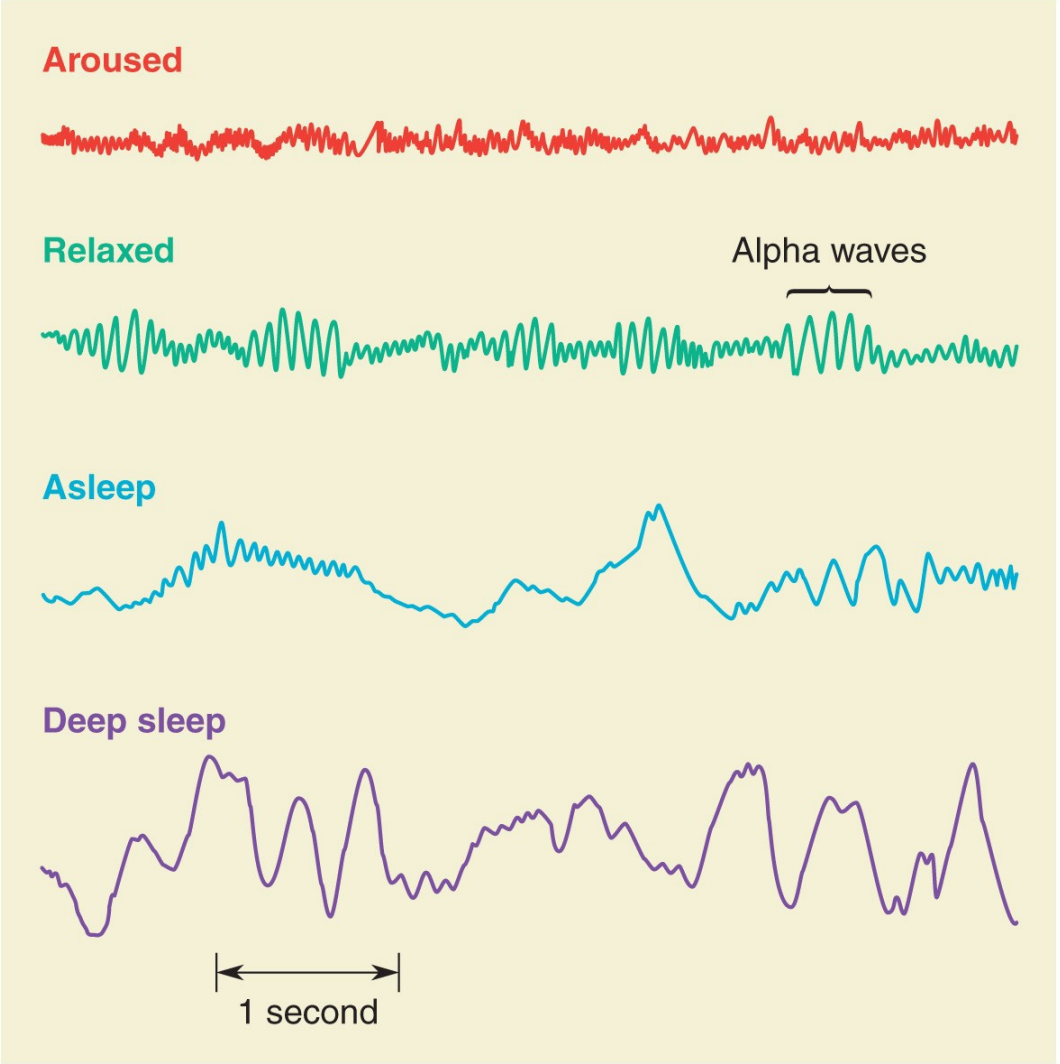
- a. Neuron (unit) activity
  - Single-unit: spike trains from single isolated neurons in the brain
  - Multi-unit: spike trains from multiple neurons in the brain
    b.Population (field potential or field) activity
- Electroencephalogram (EEG): recording of cortical electrical activity from extracranial sensors
- Magnetoencephalogram (MEG): recording of cortical magnetic activity from extracranial sensors
- Local Field Potential (LFP): recording of cortical electrical activity from microelectrodes in cortex
- Intracranial EEG (iEEG): recording of cortical electrical activity from macroelectrodes in cortex
- Electrocorticogram (ECoG): recording of cortical electrical activity from macroelectrodes on surface of cortex



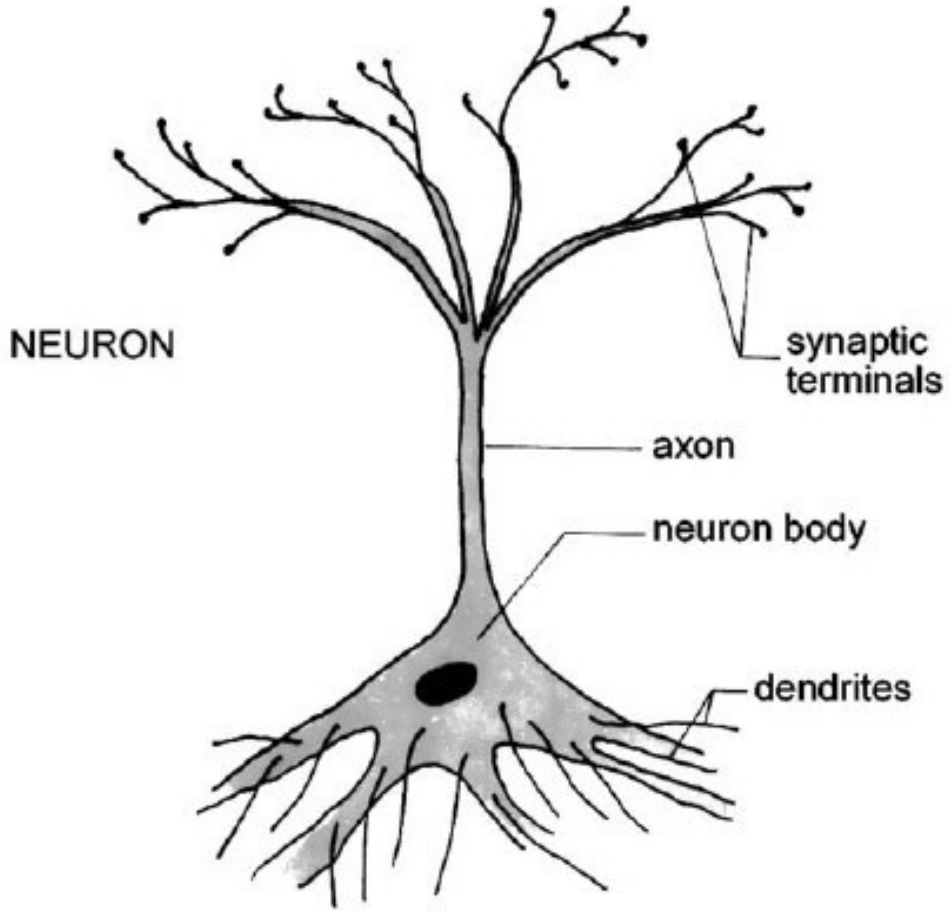


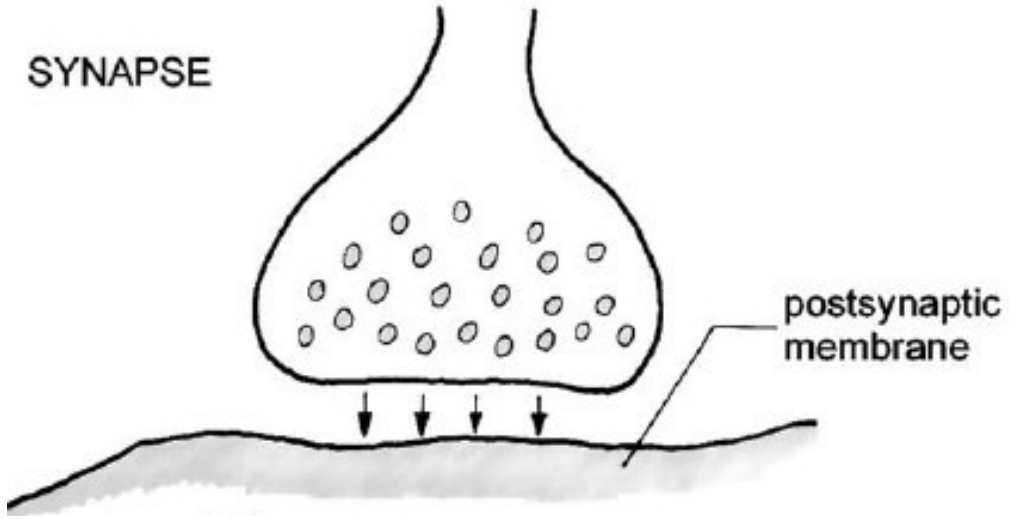
Neurophysiology: „brainvawes“

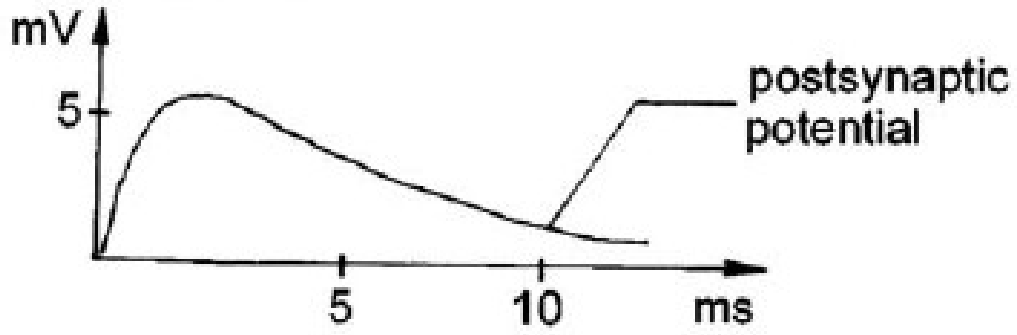
- Electrical activity recorded via electrodes (mostly)
- Excellent temporal resolution, bad spatial



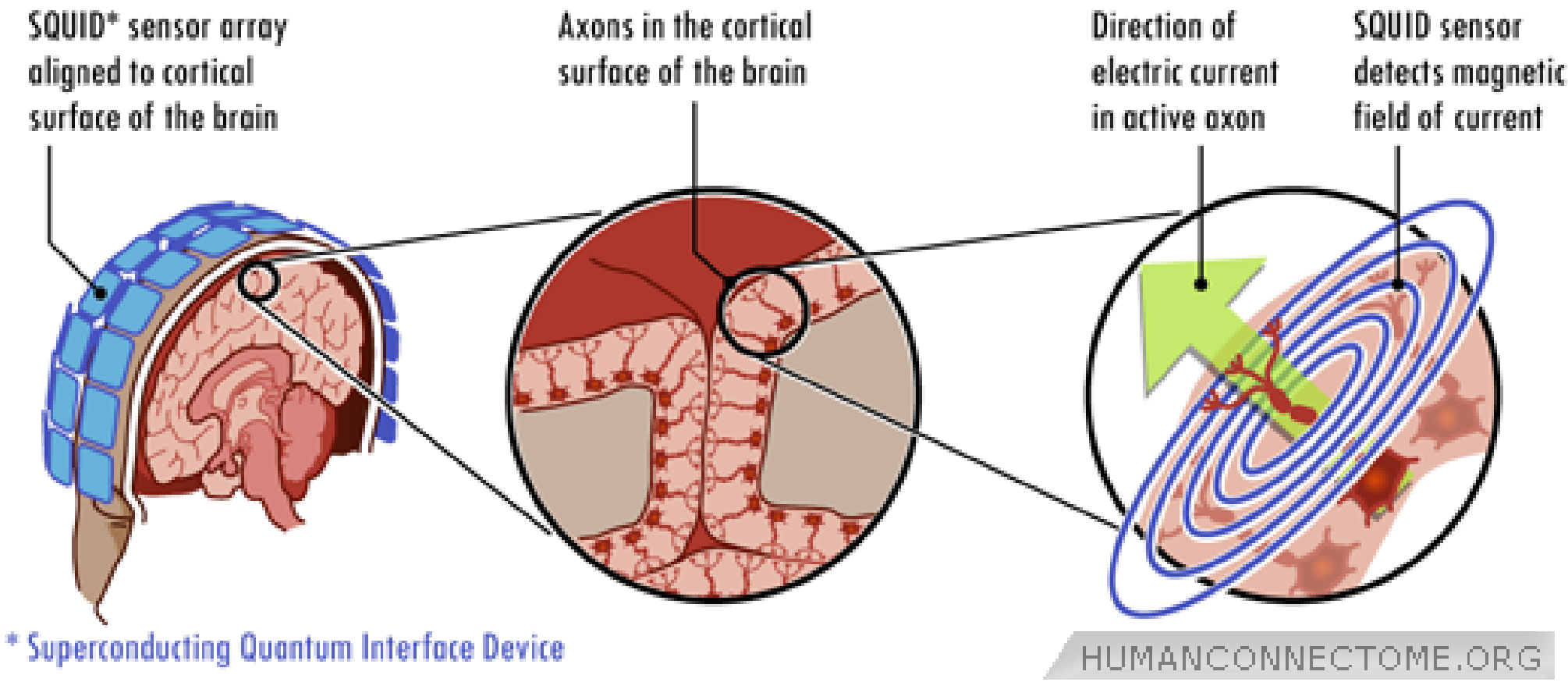
Neural basis



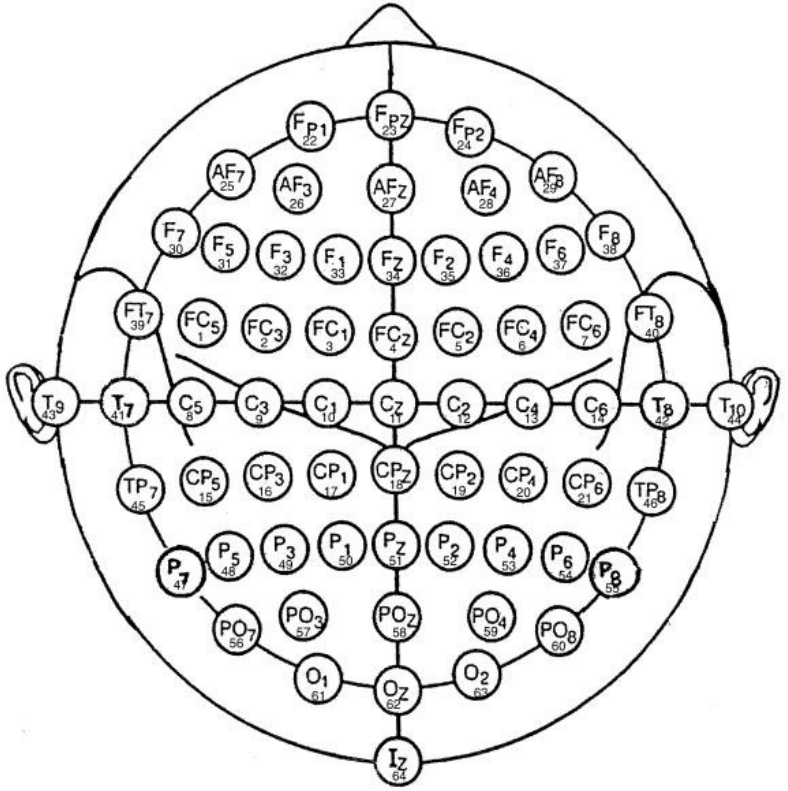




Neural basis



Recording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FPZ 23
FP2 24
AF7 25
AF3 26
AFZ 27
AF4 28
AF8 29
F7 30
F5 31
F3 32
F1 33
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F2 35
F4 36
F6 37
F8 38
FT7 39
FC5 1
FC3 2
FC1 3
FCZ 4
FC2 5
FC4 6
FC6 7
FT8 40
T9 43
T7 41
C5 8
C3 9
C1 10
CZ 11
C2 12
C4 13
C6 14
T8 42
T10 44
TP7 45
CP5 15
CP3 16
CP1 17
CPZ 18
CP2 19
CP4 20
CP6 21
TP8 46
P7 47
P5 48
P3 49
P1 50
PZ 51
P2 52
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P8 55
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POZ 58
PO4 59
PO8 60
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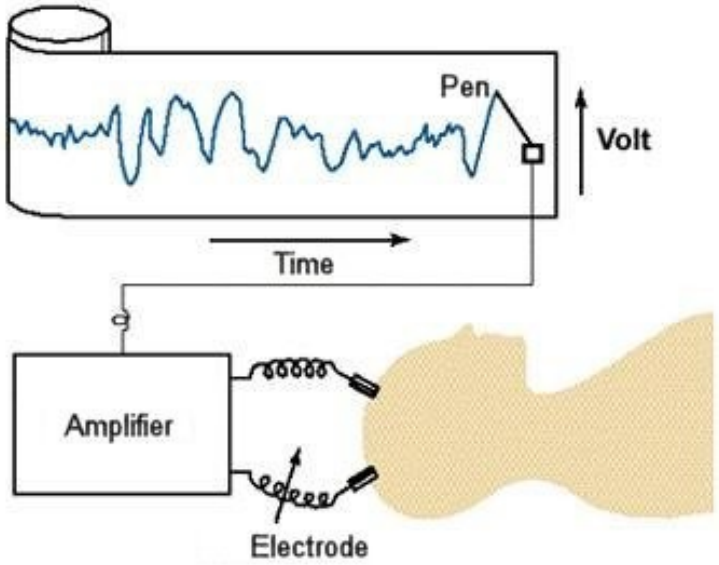
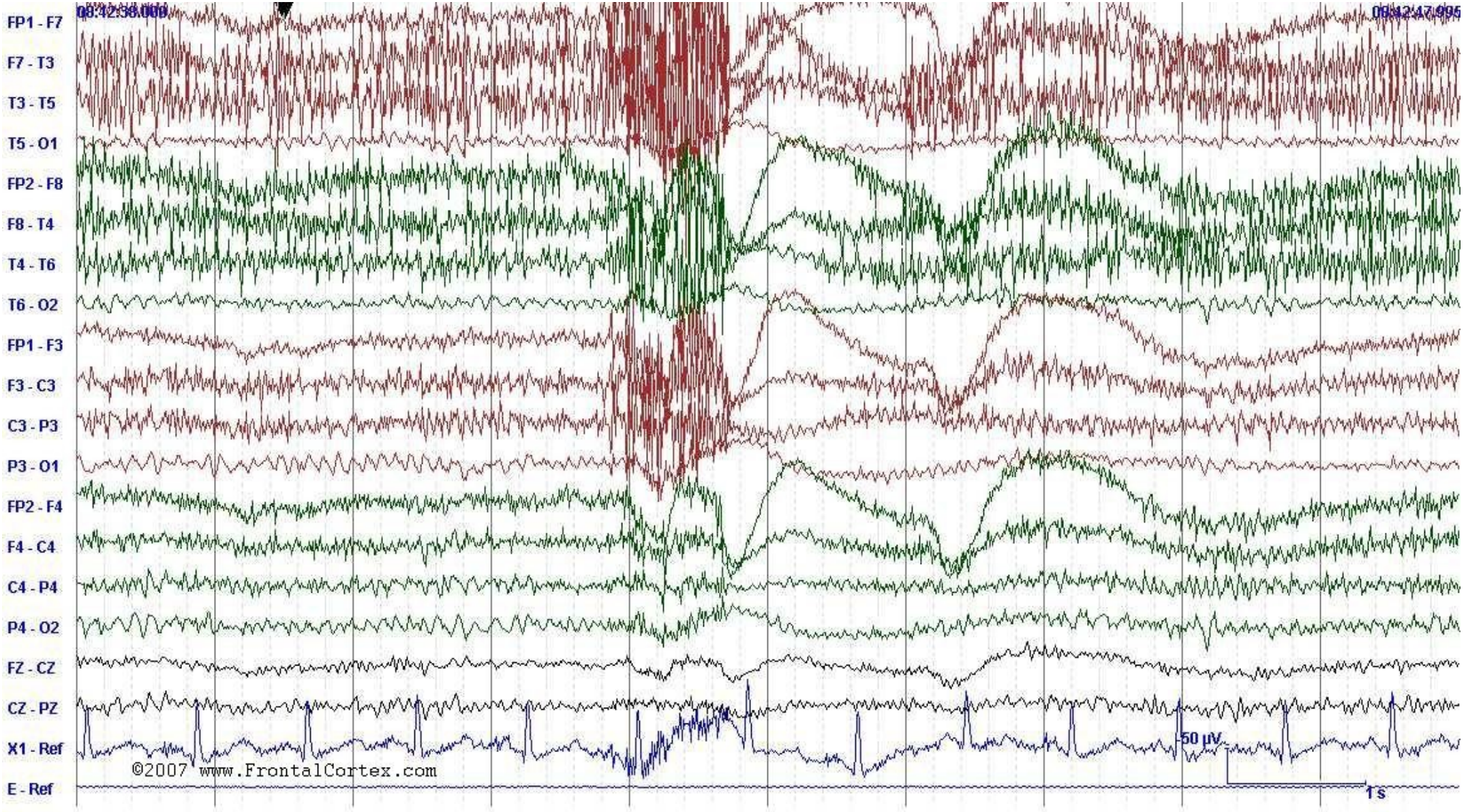
OZ 62
O2 63
IZ 64


Pen
Volt
Time
Amplifier
Electrode


1 Fp1-F3
2 F3-C3
3 C3-P3
4 P3-O1
5 Fp2-F4
6 F4-C4
7 C4-P4
8 P4-O2
9 Fp1-F7
10 F7-T7
11 T7-P7
12 P7-O1
13 Fp2-F8
14 F8-T8
15 T8-P8
16 P8-O2
17 Fz-Cz
18 Cz-Pz
19 X7-A1 EKG

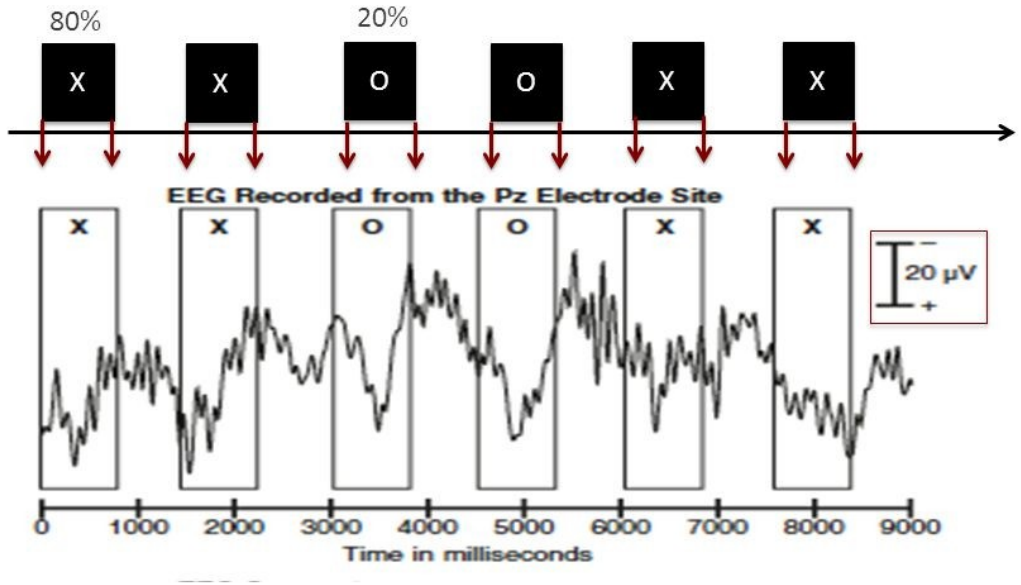
EEG data



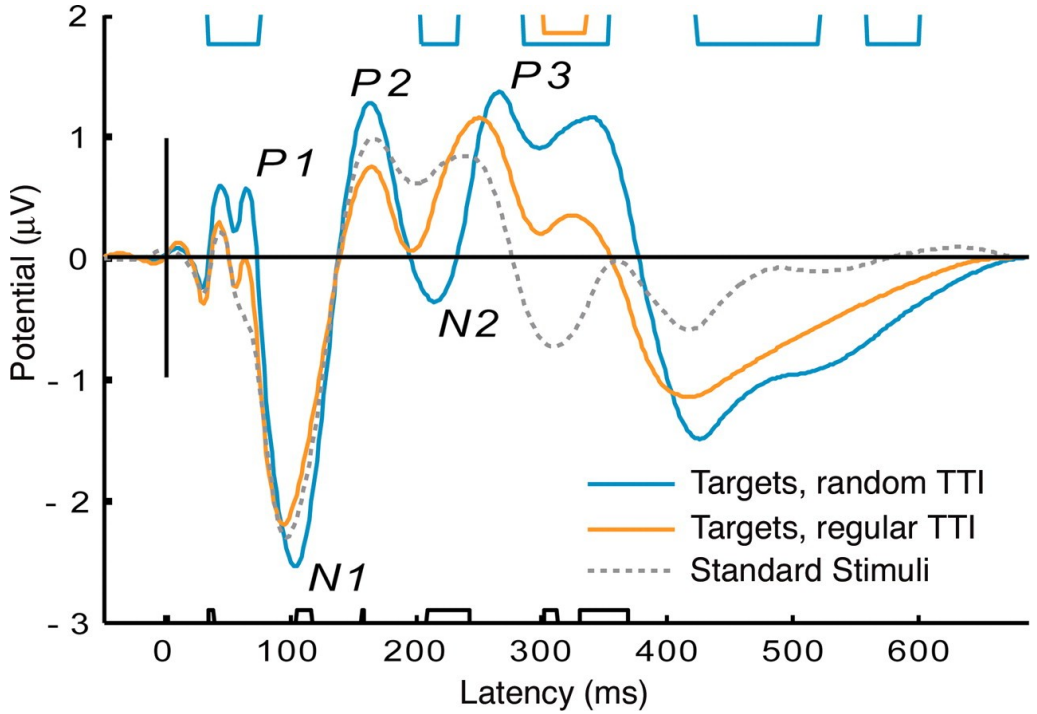
- Nothing beats clean data

Event-related potentials

Simple experiment

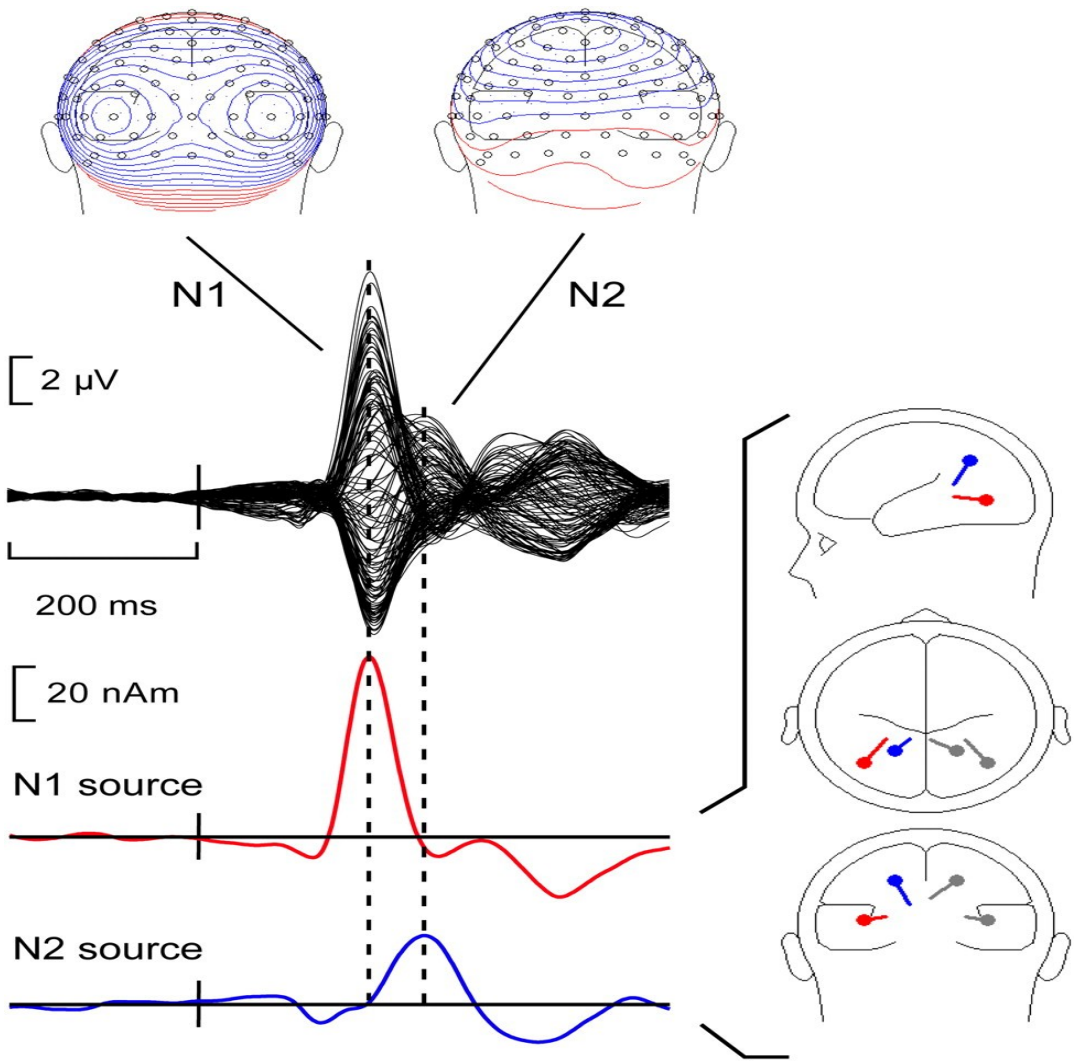


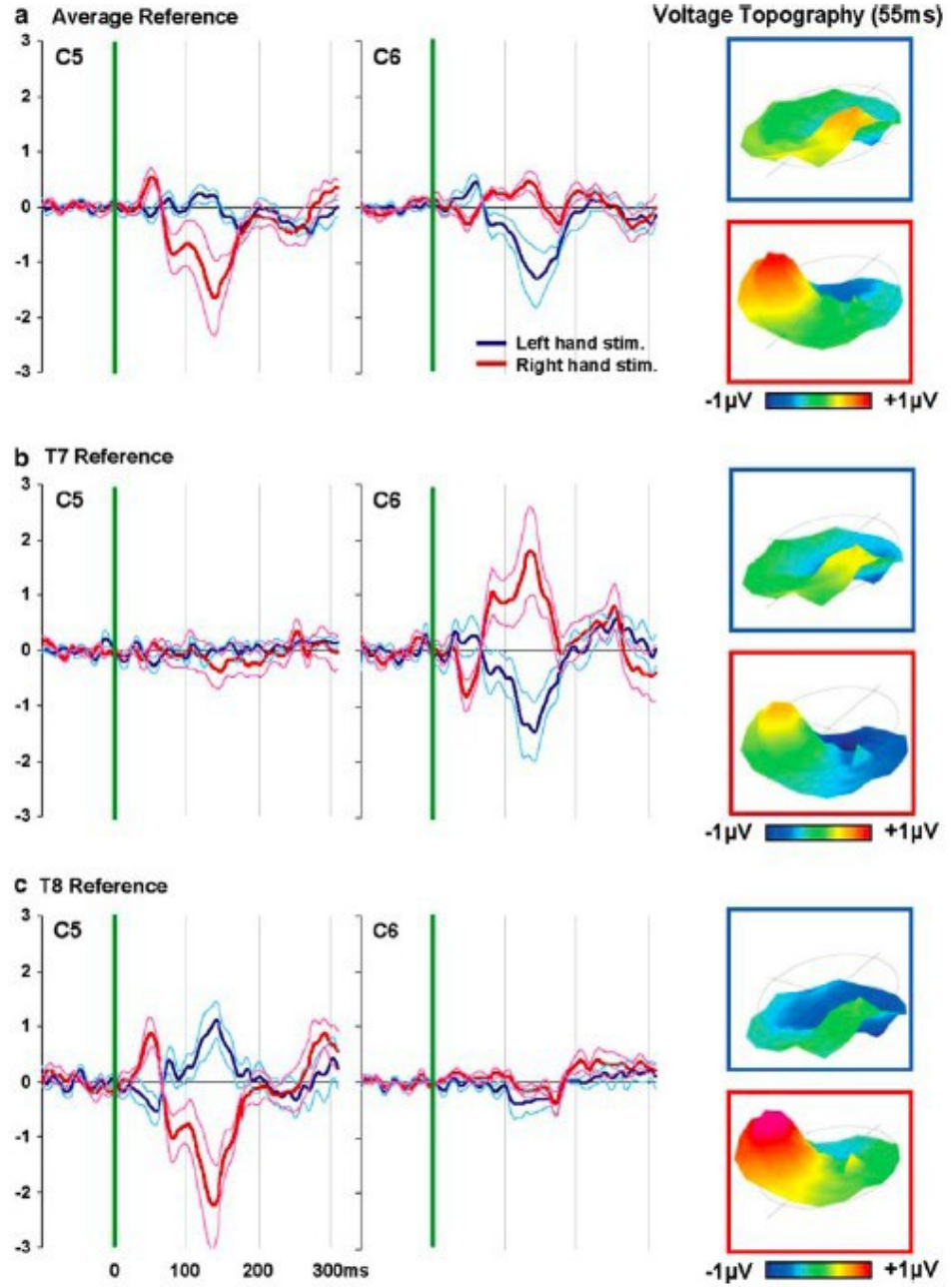
EEG from one electrode site midline over parietal lobes



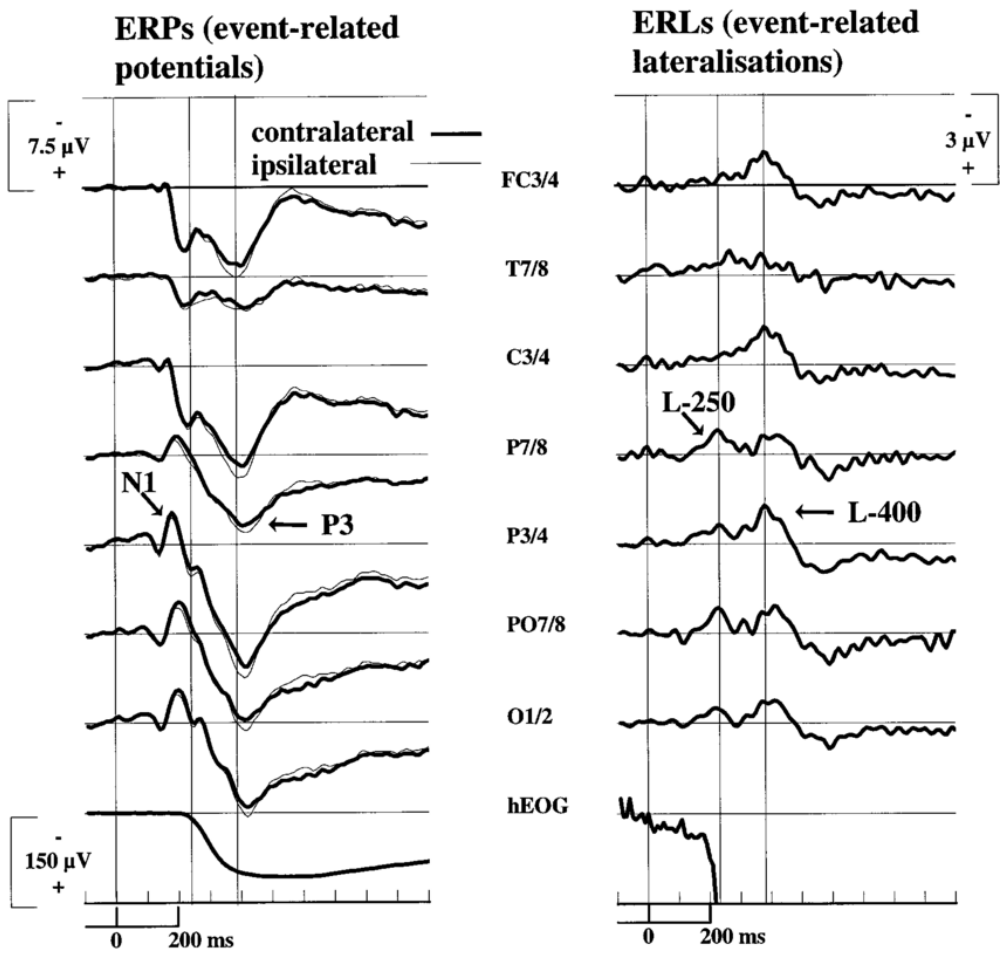
Luck, 2005

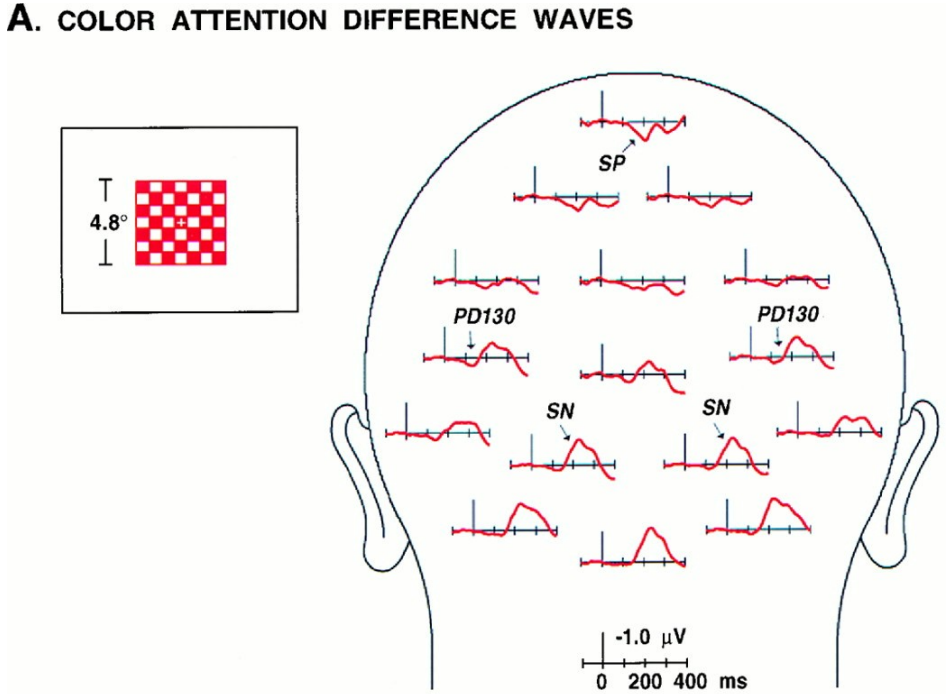
Event-related potentials

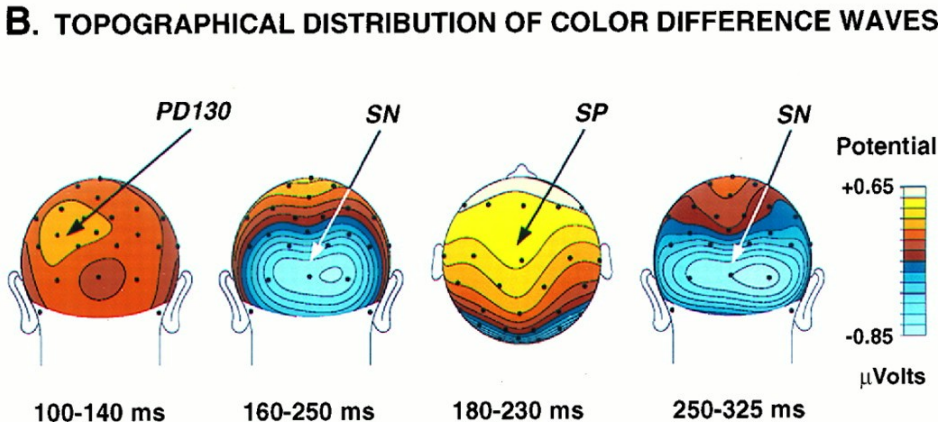




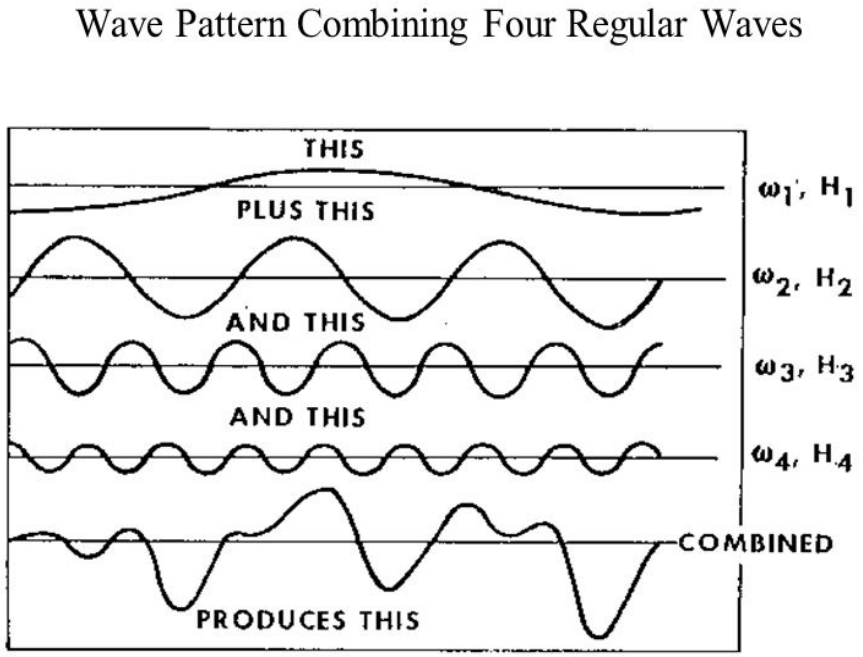
Topography



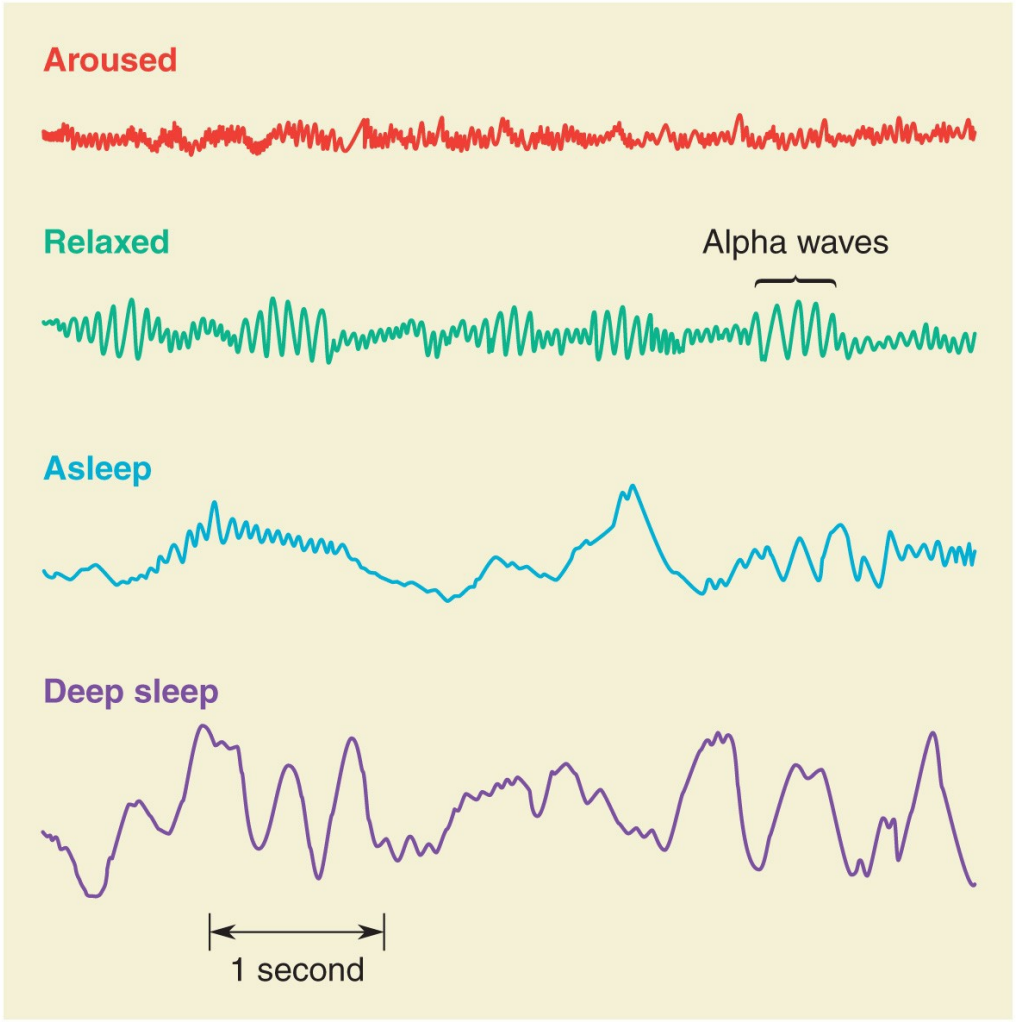




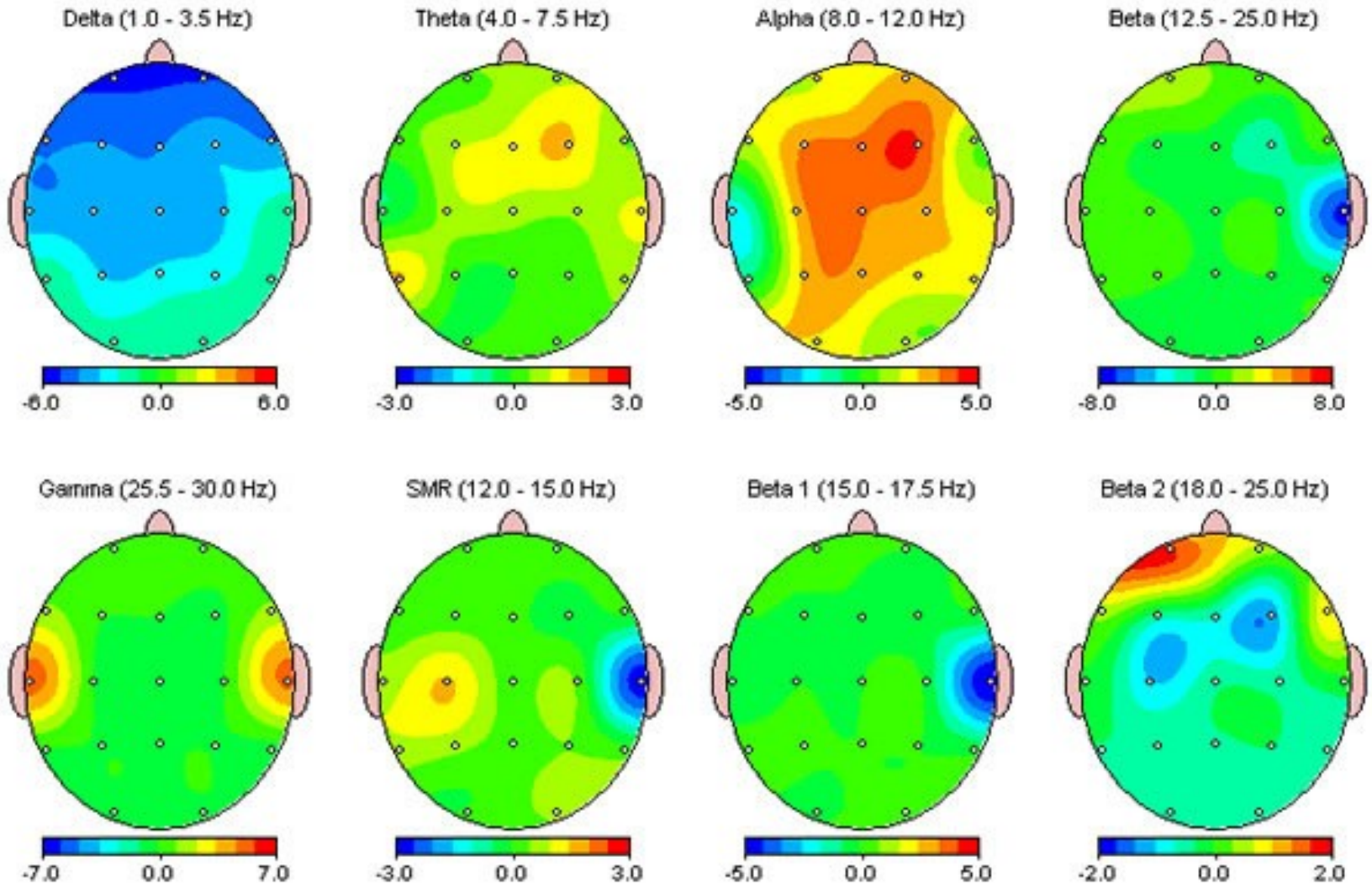
Power spectrum analysis



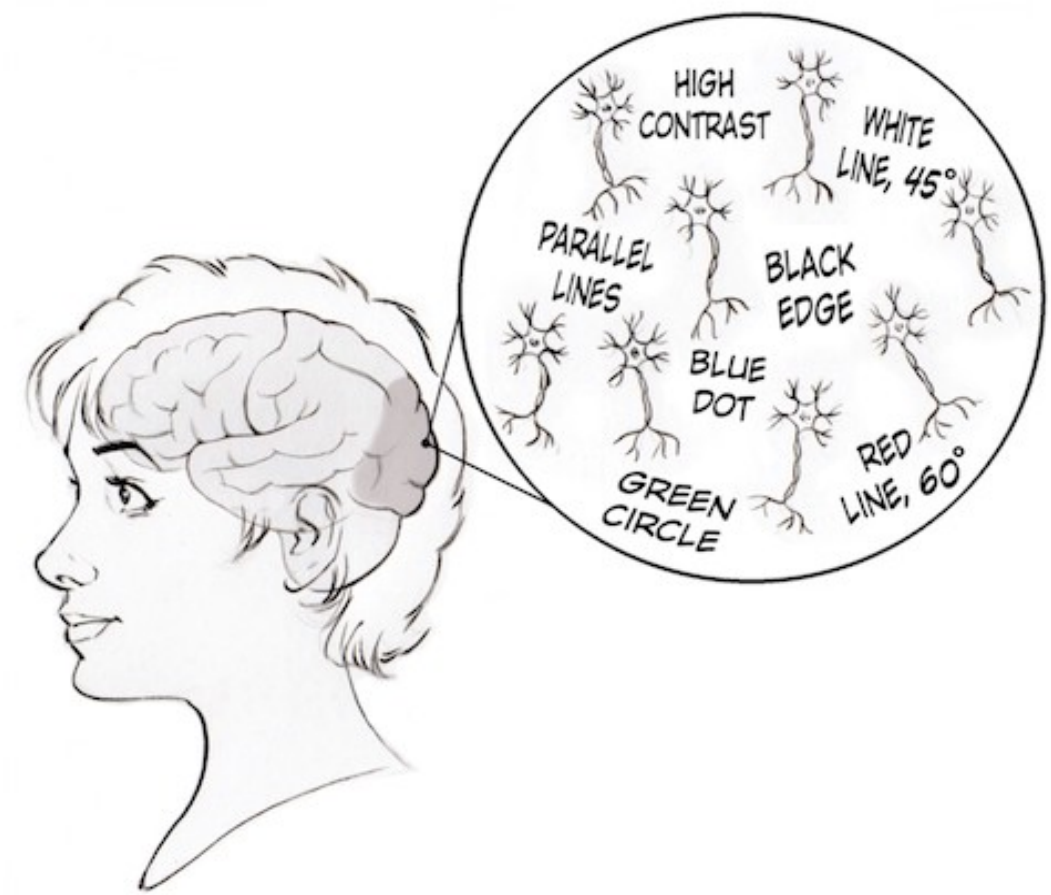
FFT & IFFT – (Inverse) Fast Fourier Transform.
Irregular wave ⟶ Regular Waves (Frequency Domain Analysis)



FFT Relative Power Difference (%)

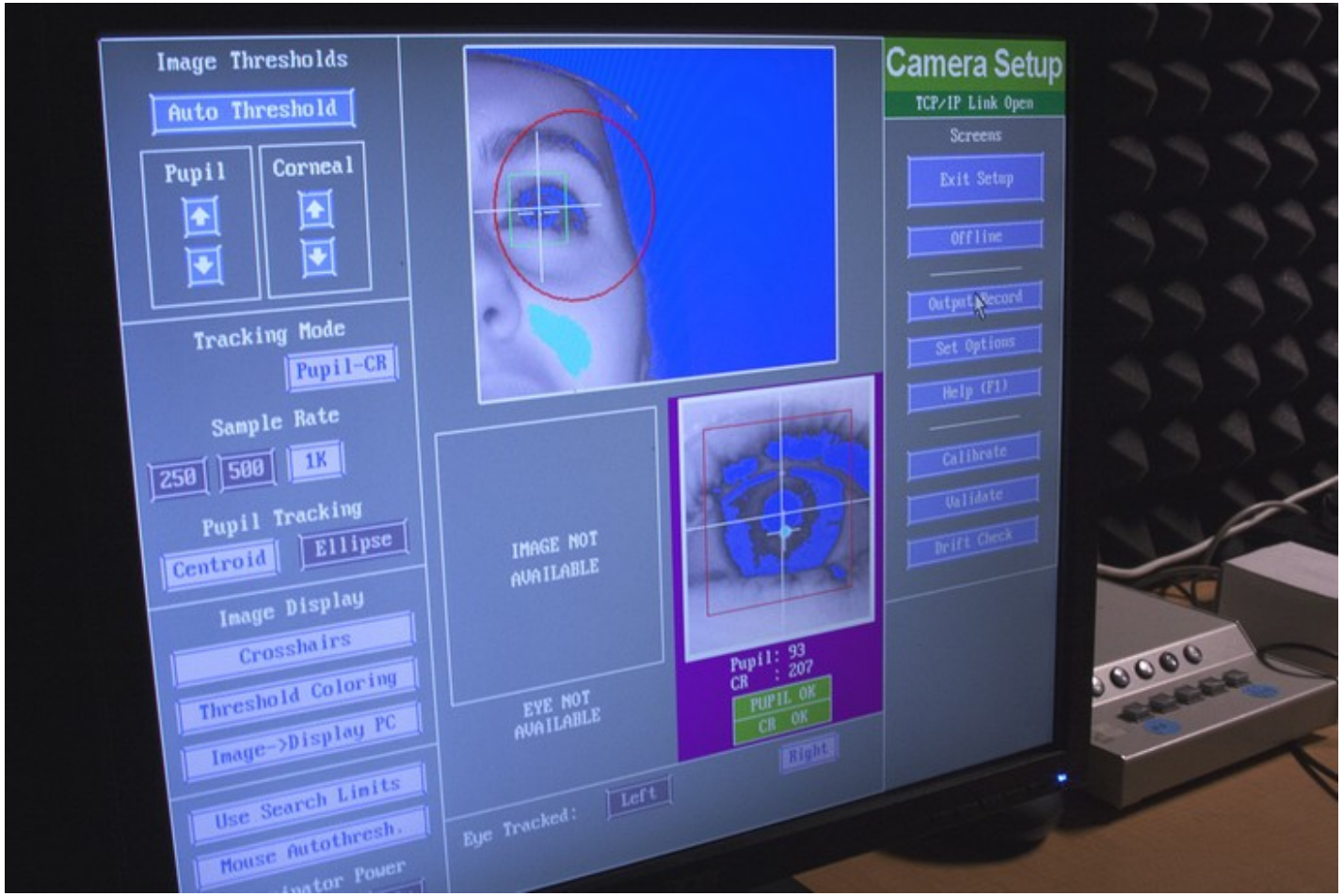


Contrast problem



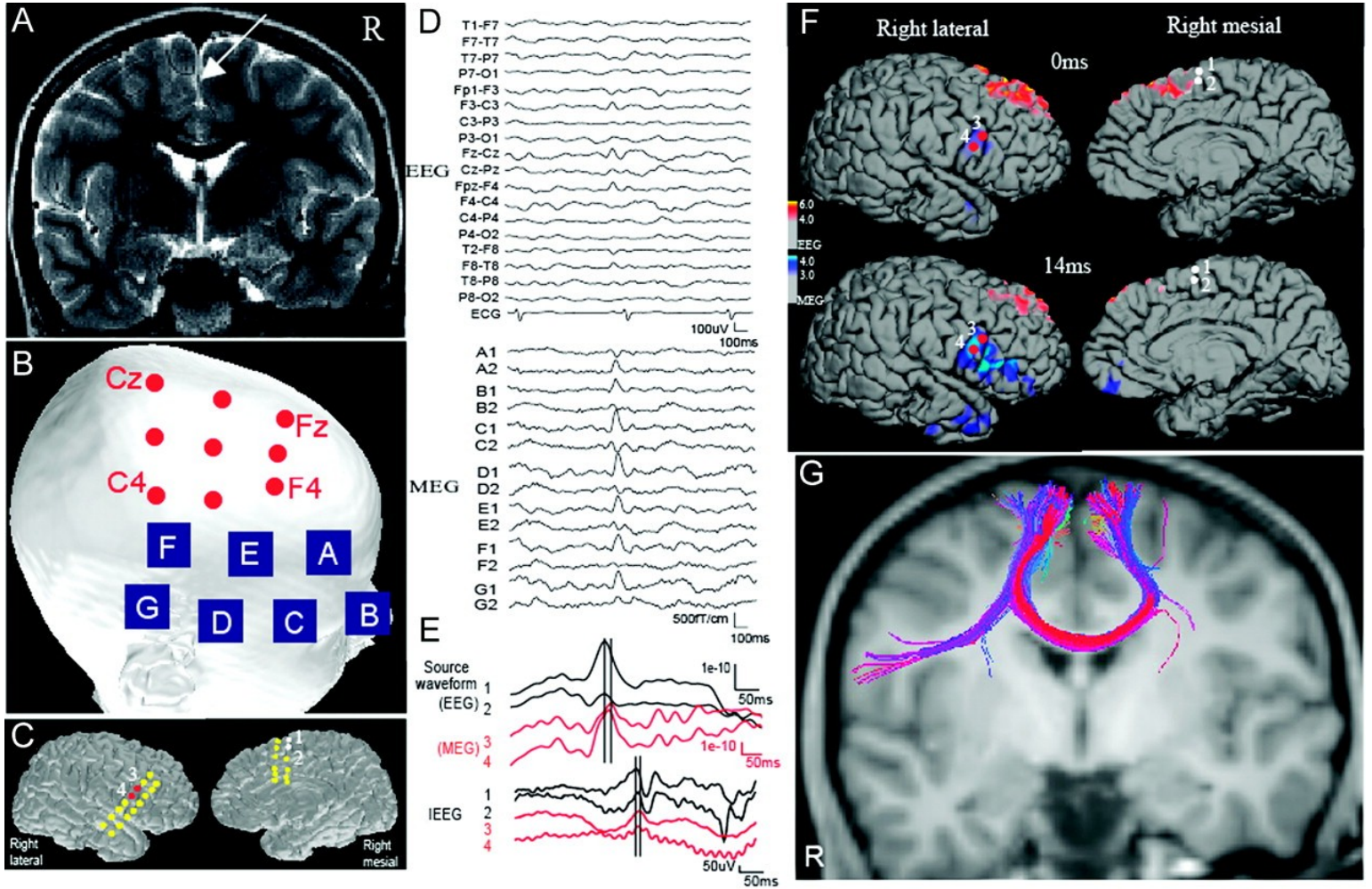
Not-so-much-neuro neuroimaging

- Heart rate
- Respiratory rate
- Skin conductance
- Eyetracking



Solution to limitations…

- Multimodal approach



Most important things:

- Great question
- Well-selected measurement method(s)
- Meticulous experiment administration
- Clean data
- Honest and robust statistics
- Reasonable interpretation