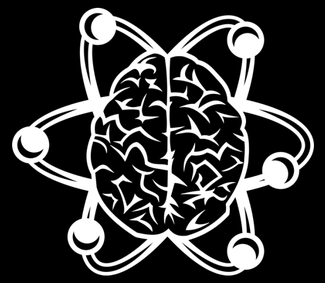


WELCOME TO THE PET NEUROIMAGING COURSE

Turku PET Centre Brain Imaging Course 2025

Lauri Nummenmaa, Turku PET Centre

STAR WARS

EPISODE IV

A NEW HOPE

COMPOSED BY JOHN WILLIAMS

Objectives

- Understand basic principles of human neuroimaging
- Know basics of PET and structural and functional MR imaging
- Grasp the basic pharmacokinetic models behind PET imaging
- Understand the nuts and bolts of (F)MRI and PET data preprocessing and modelling
- Learn the principles of statistical analysis of brain imaging data
- Total 5 ECTS credits

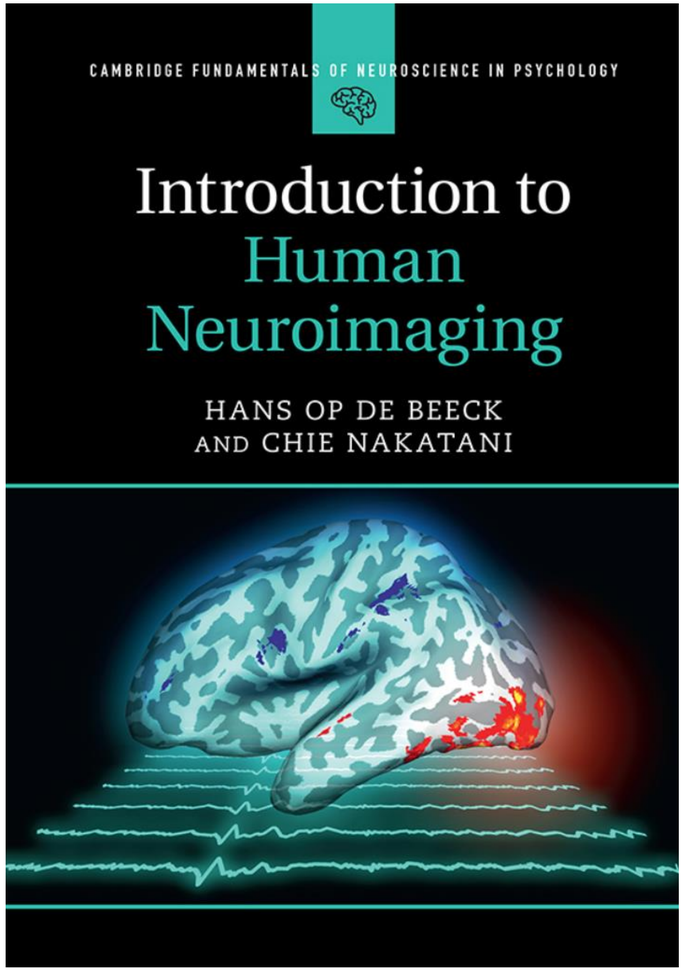
Practical stuff

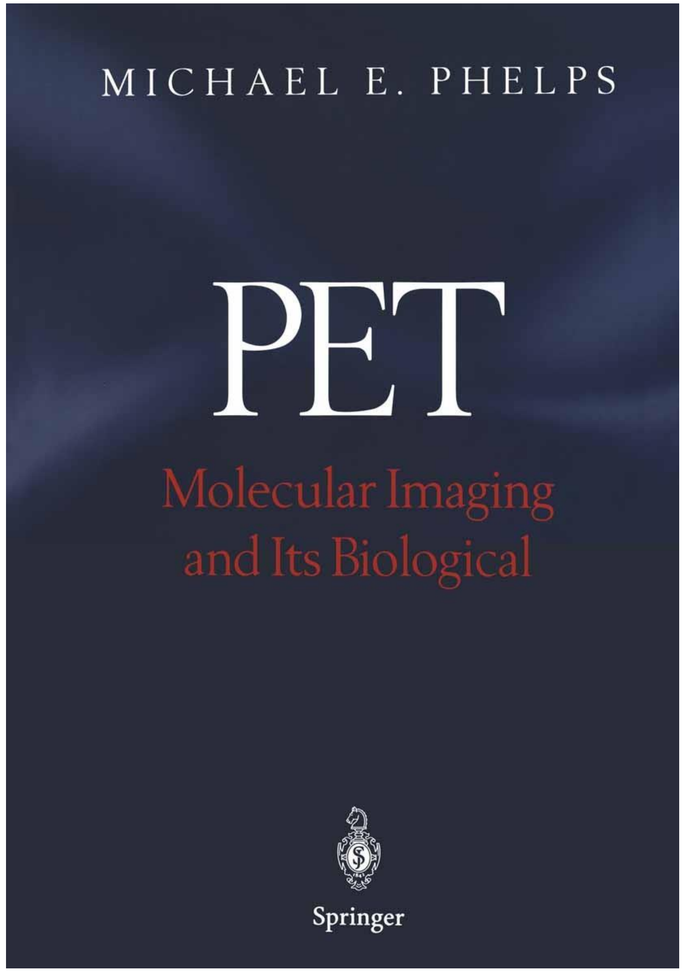
- Materials available at emotion.utu.fi/neurocourse
- Lectures streamed and stored on Echo360, Q/A session on Discord throughout the course (see webpage)
- **Day 1**: Principles of neuroimaging
- **Day 2:** Practical issues in brain imaging and data analysis
- **Day 3:** Advanced topics in brain signal analysis

Computer labs

- **Day 4**: Data preprocessing
- **Day 5**: Statistical inference
- Note – we have limited seats at the computer labs, please bring your own laptop if possible so we don't have to share the lab computers!

Examination





- **Electronic examination** on the Uni Turku Exam system
- Multiple choice questions from books and lectures
- Open from Oct 1st to Dec 31st
- NOTE: only available Uni Turku students, external attendants can get certificate for participation upon request

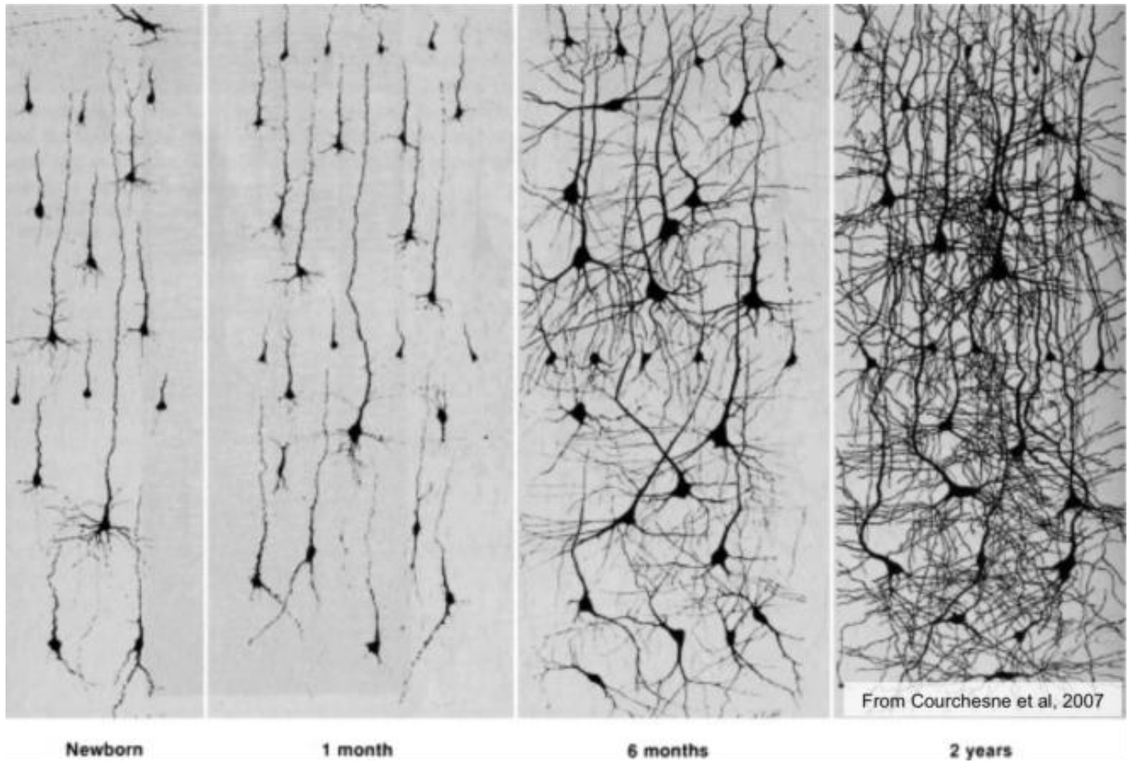
BASIC PRINCIPLES OF HUMAN NEUROIMAGING

Turku PET Centre Brain Imaging Course 2025

Lauri Nummenmaa, Turku PET Centre

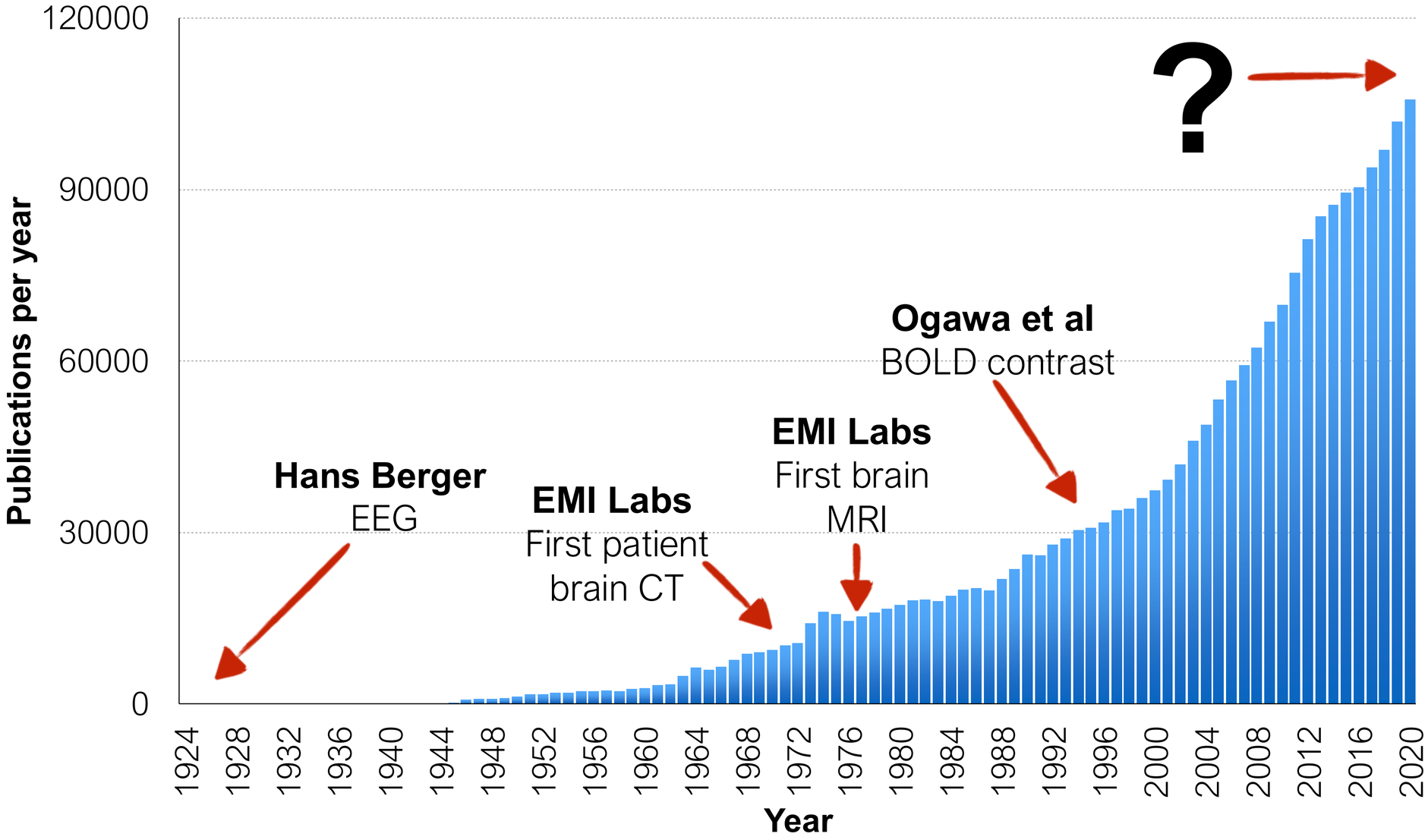
The human brain

- **Weight** 1.3 - 1.5 kg; volume ~ 1.3 l
- A total of **86 billion** neurons
- Main function: **to coordinate the human bodily functions** via spinal cord and its innervation
- Brains **receive, process and store** information gathered by the senses to **predict the future**
- Most important manifestation of brain function: **behaviour**
- **Protected** by skull, meninges and brain-blood barrier



What do we want to know about brain?

- **LOCATION:** Where different processes (consciousness, emotions, memory…) happen?
- **SPEED:** When and at which time scales different processes occur in the brain?
- **MECHANISMS:** How different processes occur in the brain?
- **INDIVIDUAL DIFFERENCES:** Do different groups (patients / controls; men / women…) differ in the above?
- **CAUSALITY:** How we can influence brain function with external manipulations (learning, experience, drugs…)


120000
90000
60000
30000
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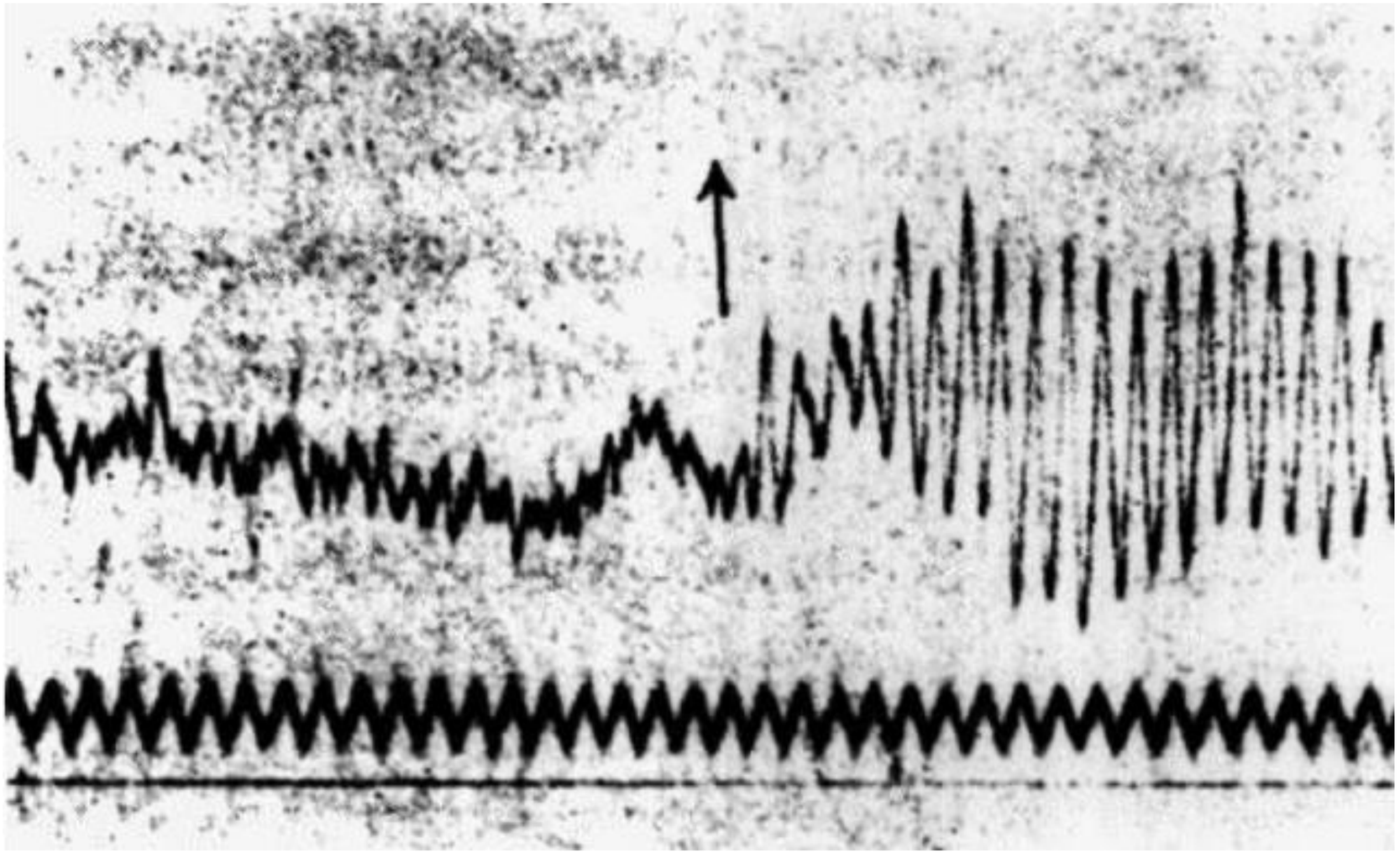
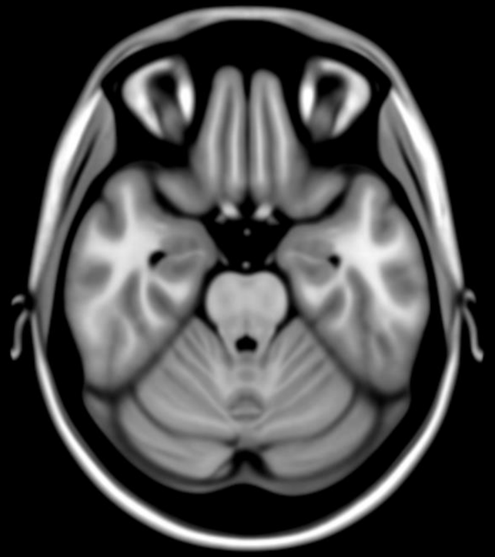
Publications per year
1924
1928
1932
1936
1940
1944
1948
1952
1956
1960
1964
1968
1972
1976
1980
1984
1988
1992
1996
2000
2004
2008
2012
2016
2020
Year
?
Ogawa et al
BOLD contrast
EMI Labs
First brain
MRI
EMI Labs
First patient
brain CT
Hans Berger
EEG

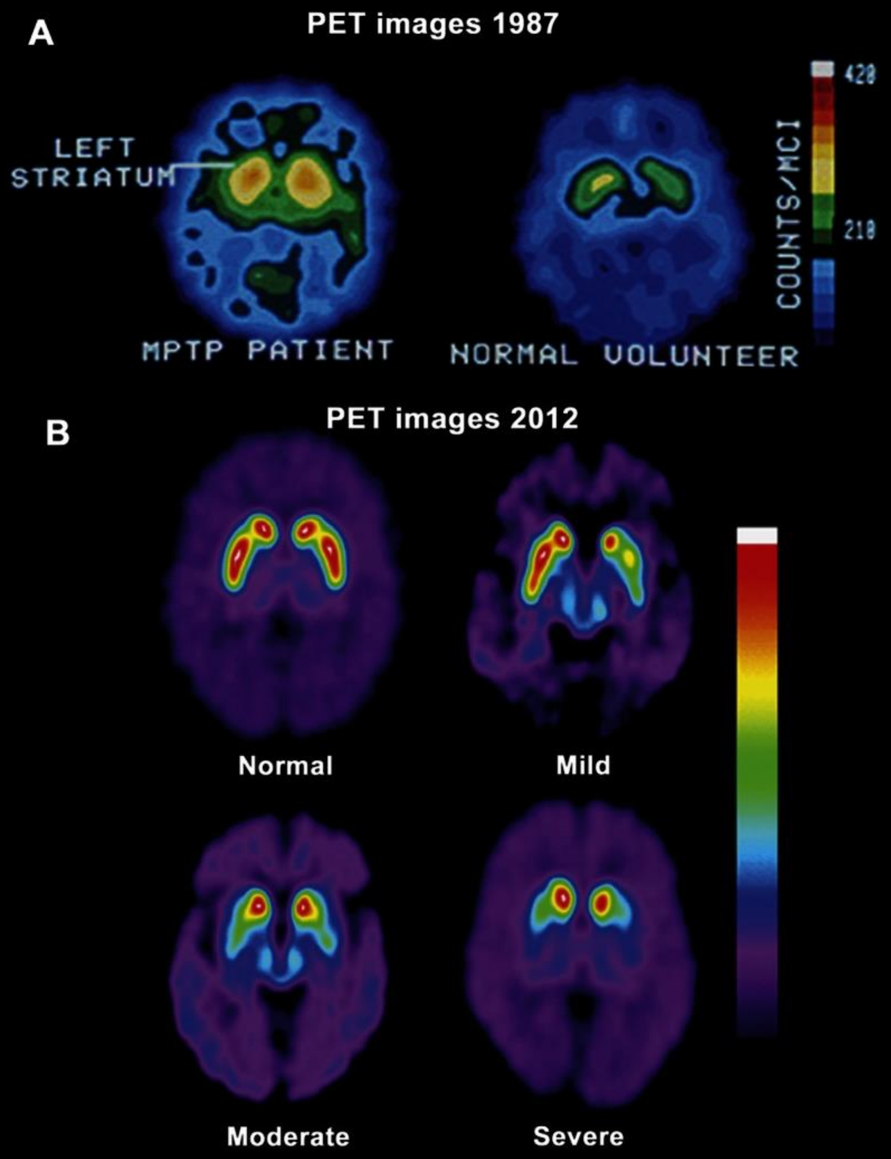
Mental arithmetic **Rest:** Alpha waves return

1924

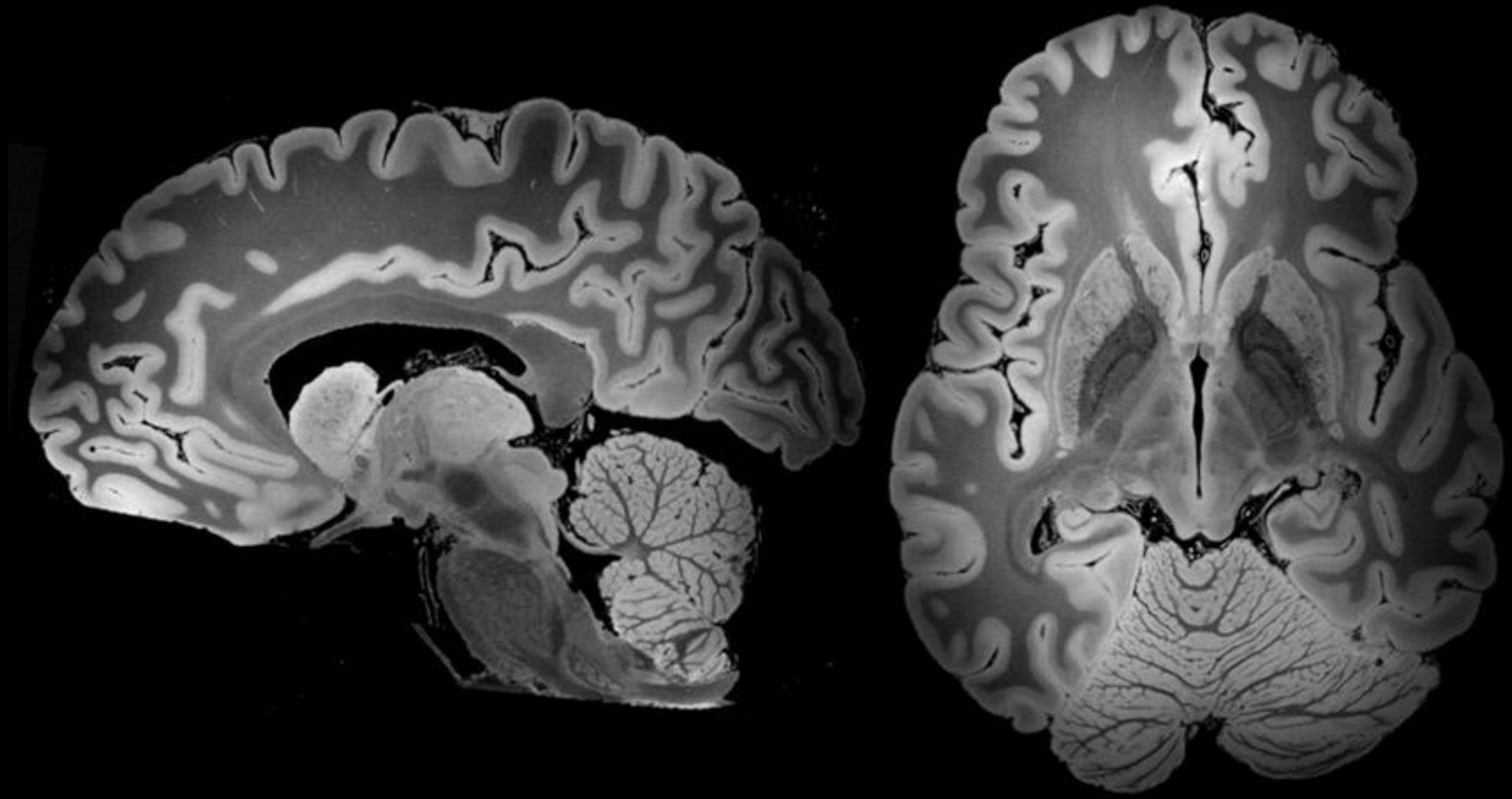




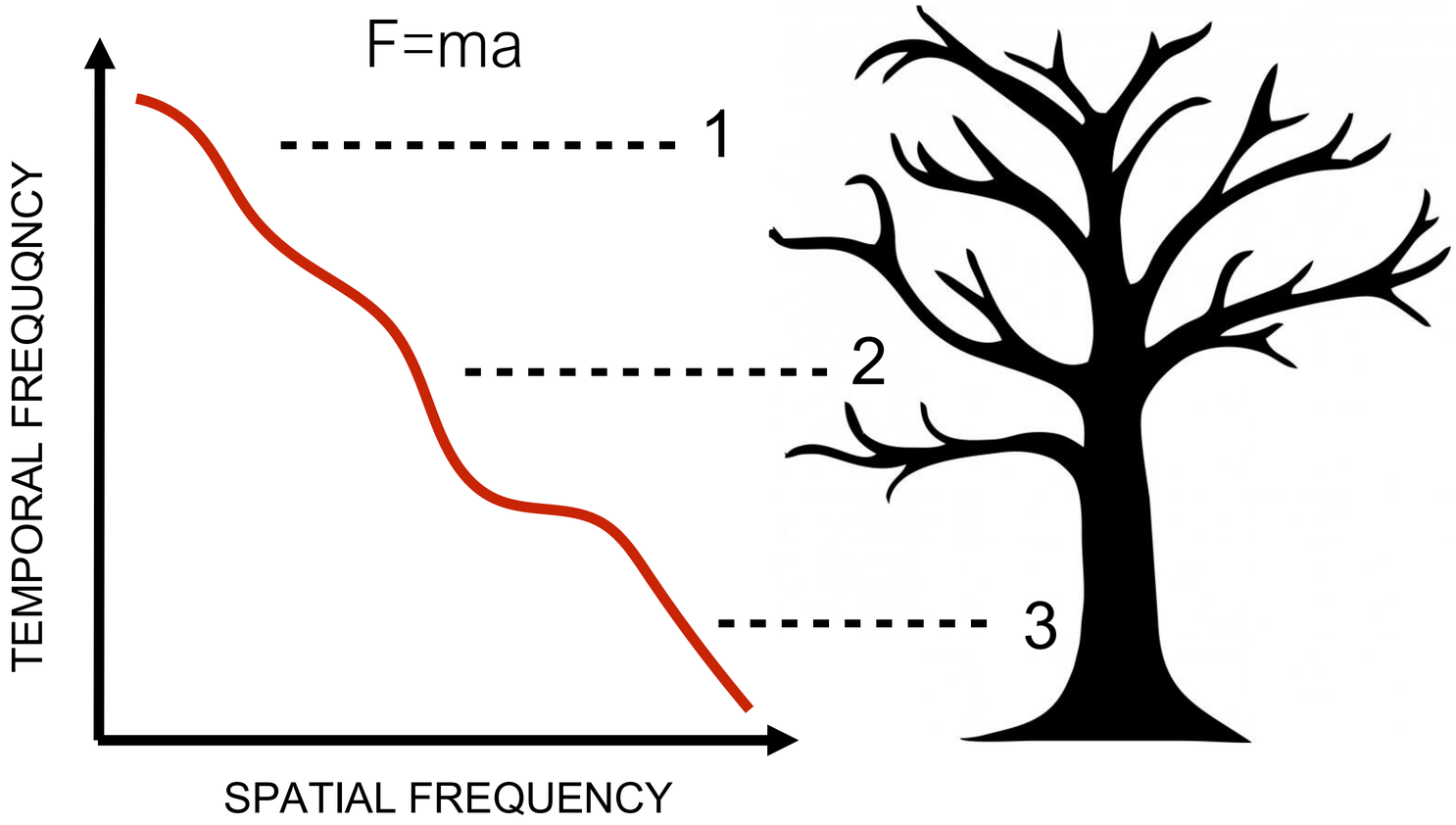
EMI central laboratories & MNI

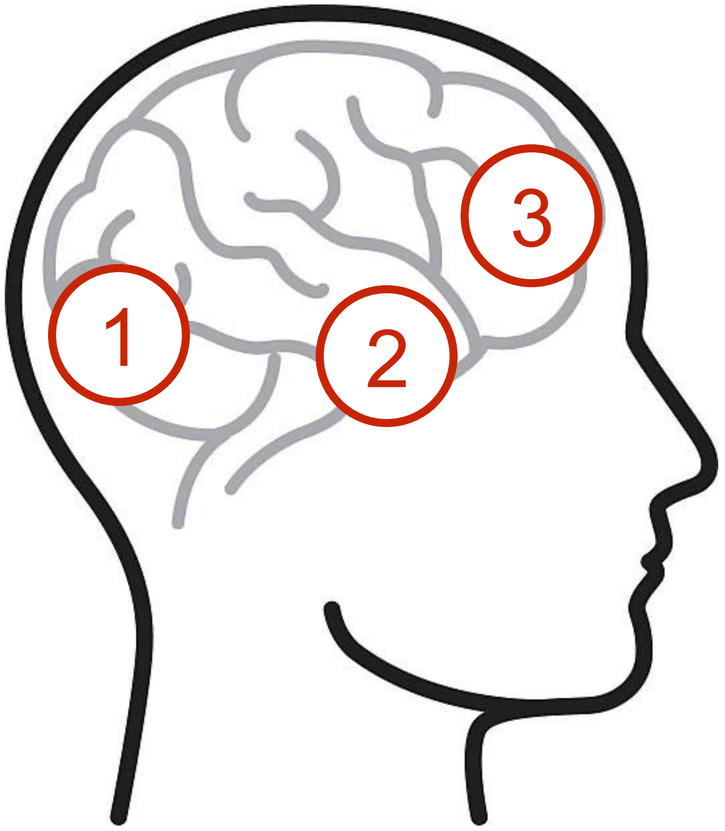


Portnow (Neurology 2013)



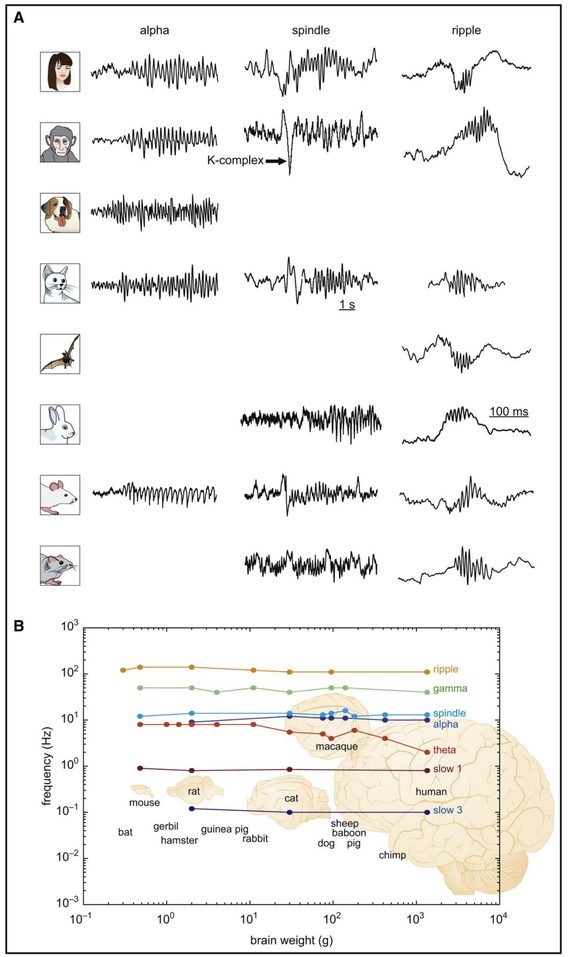
Eldow et al (2019)

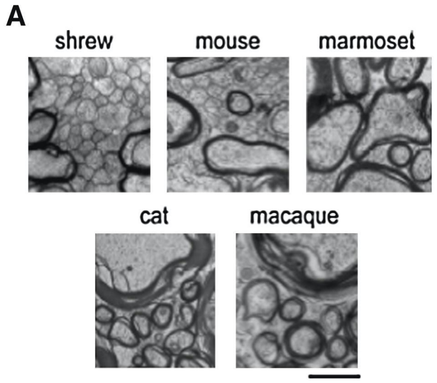


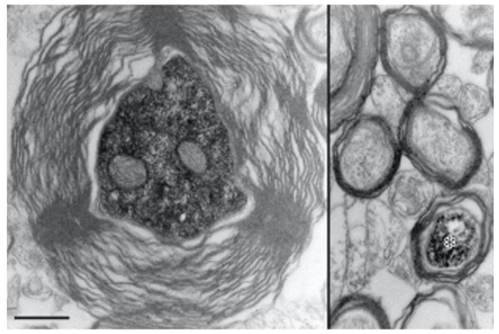


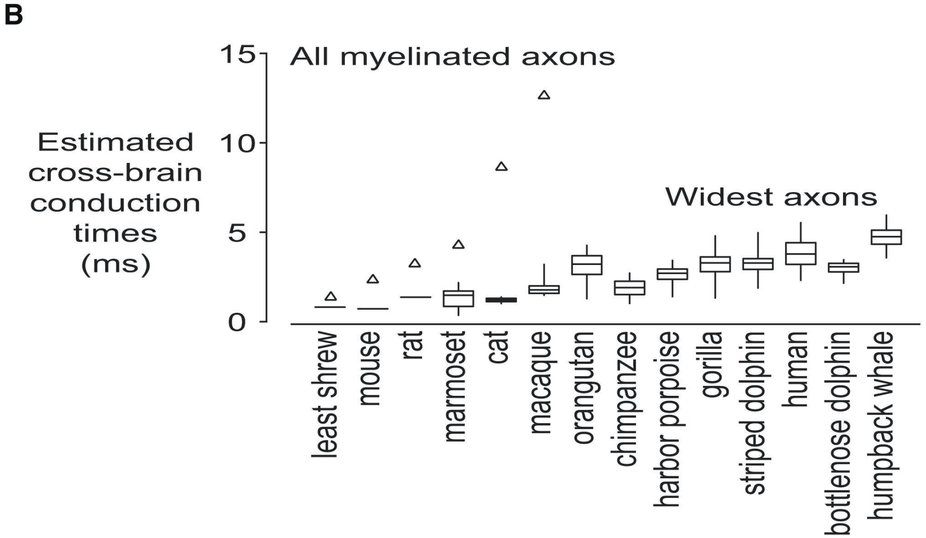
Adapted from Hari (2018)

Fast reactions with slow brains

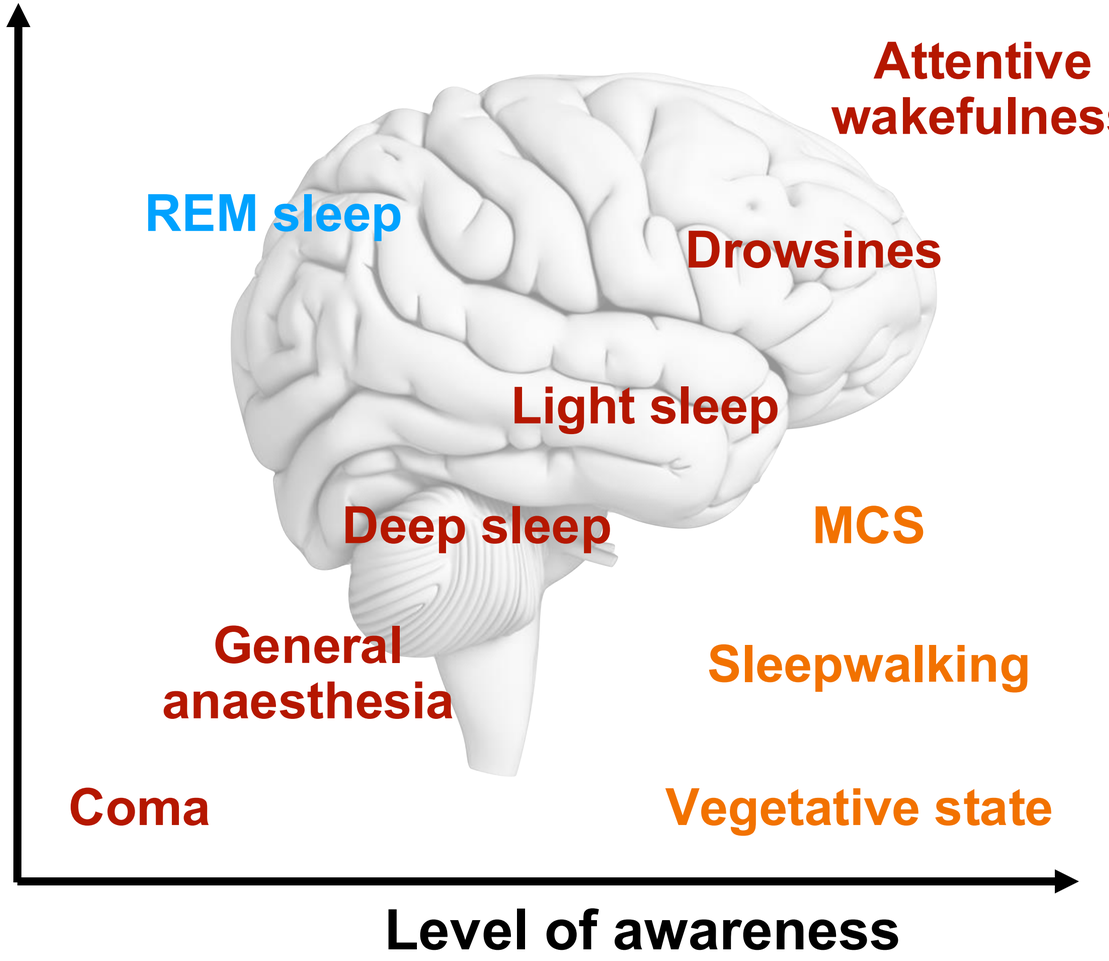


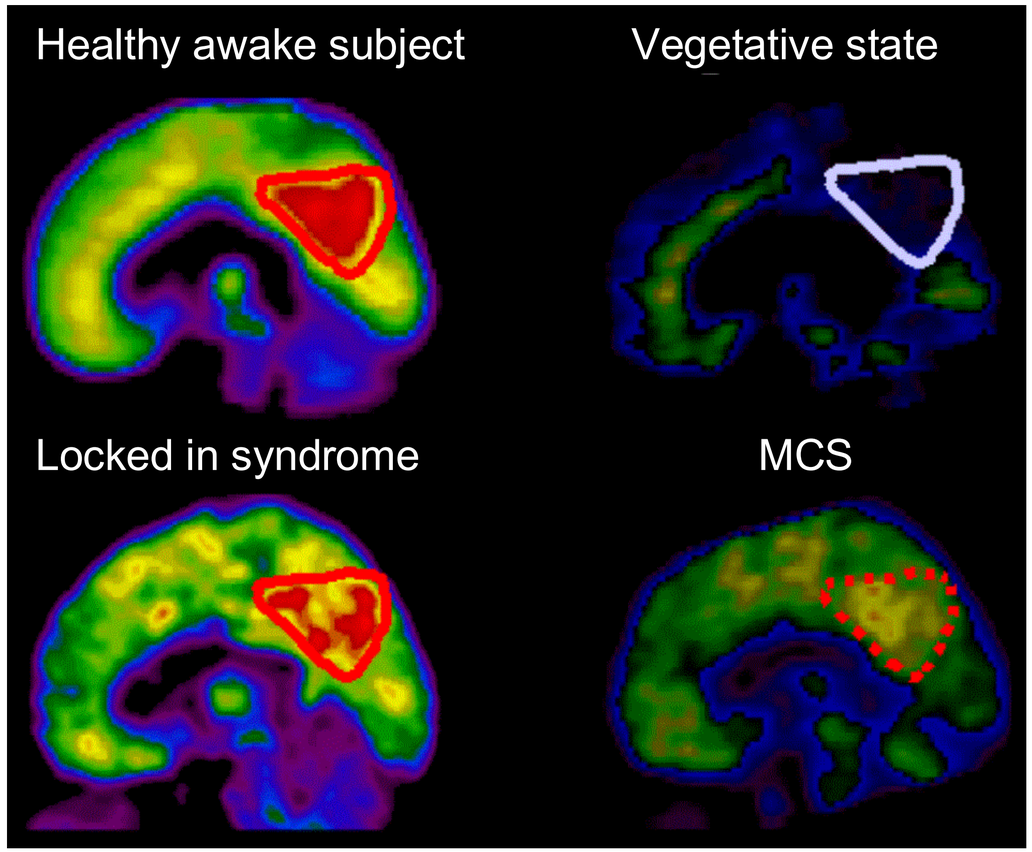




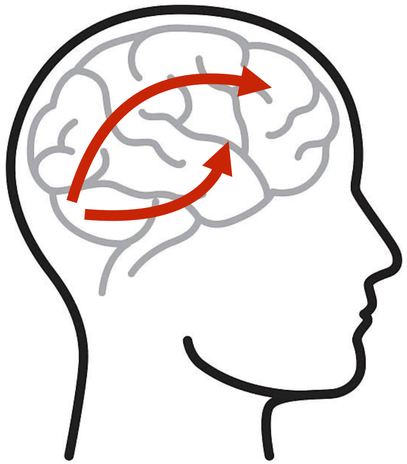


Buszaki et al (2013 Neuron)


Attentive wakefulness
REM sleep
Drowsines
Light sleep
Deep sleep
MCS
General anaesthesia
Sleepwalking
Coma
Vegetative state
Level of awareness


Healthy awake subject
Vegetative state
Locked in syndrome
MCS

Temporal windows in brain



Maturation / atrophy

Personality

Mental health

Motivation

Consciousness

Mood

Executive functions

Memory

Emotion

Attention

Perception

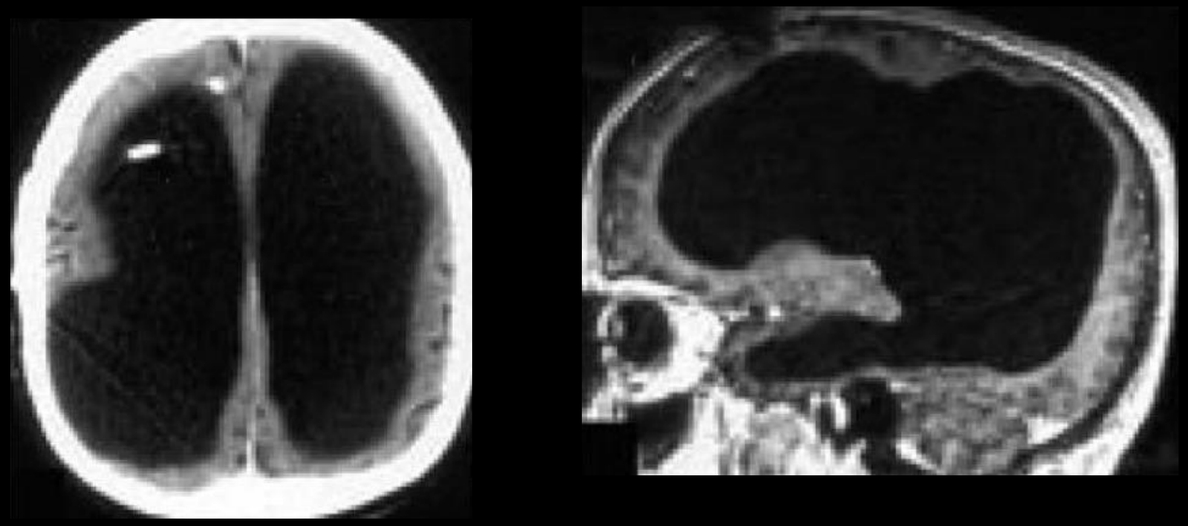
Sensation

1ms 100ms Seconds Minutes Hours Days Months Years

Gross anatomical changes occur in the absence of changes in behaviour and mental processes

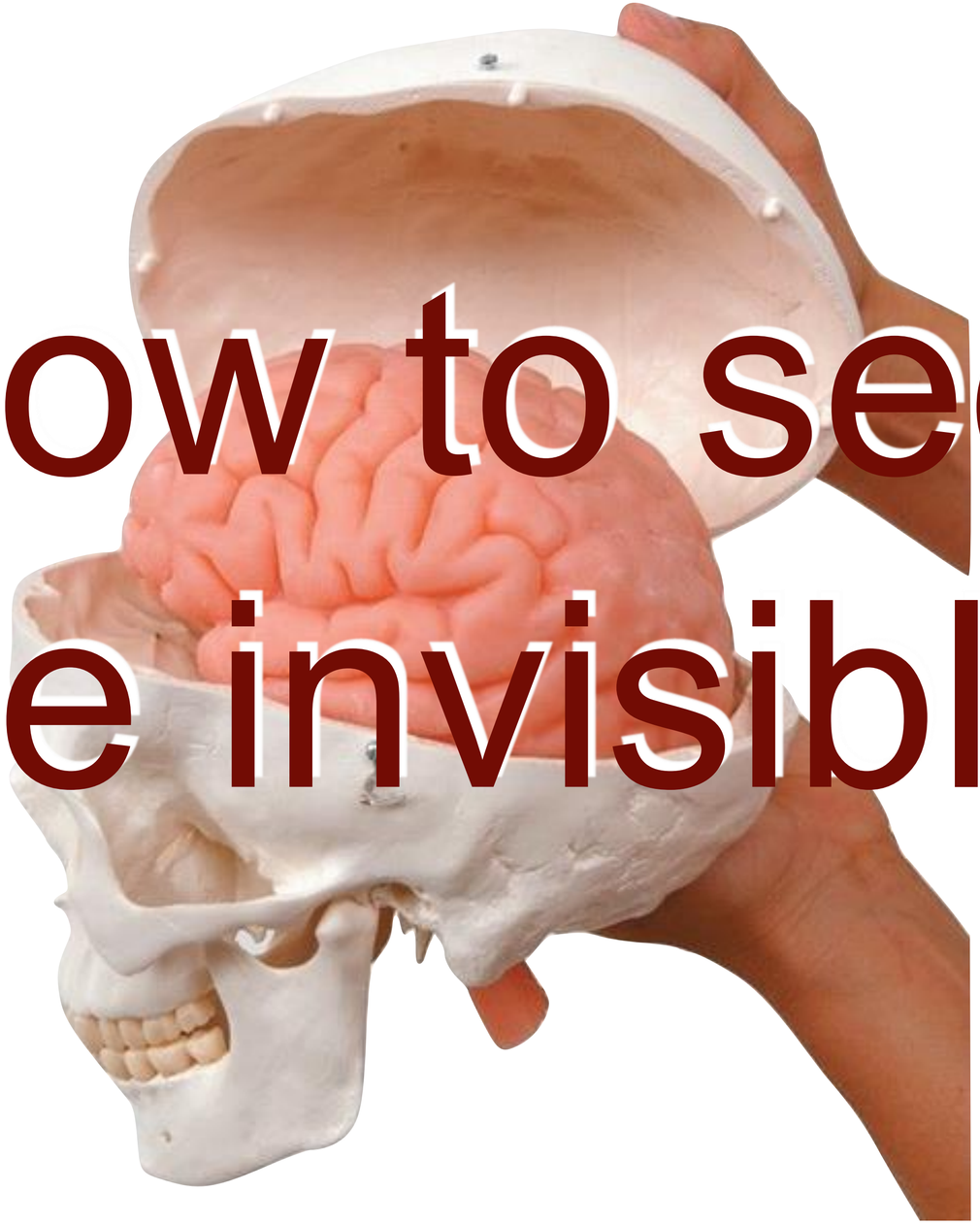
Young epilepsy patient

Extreme ventricular dilation

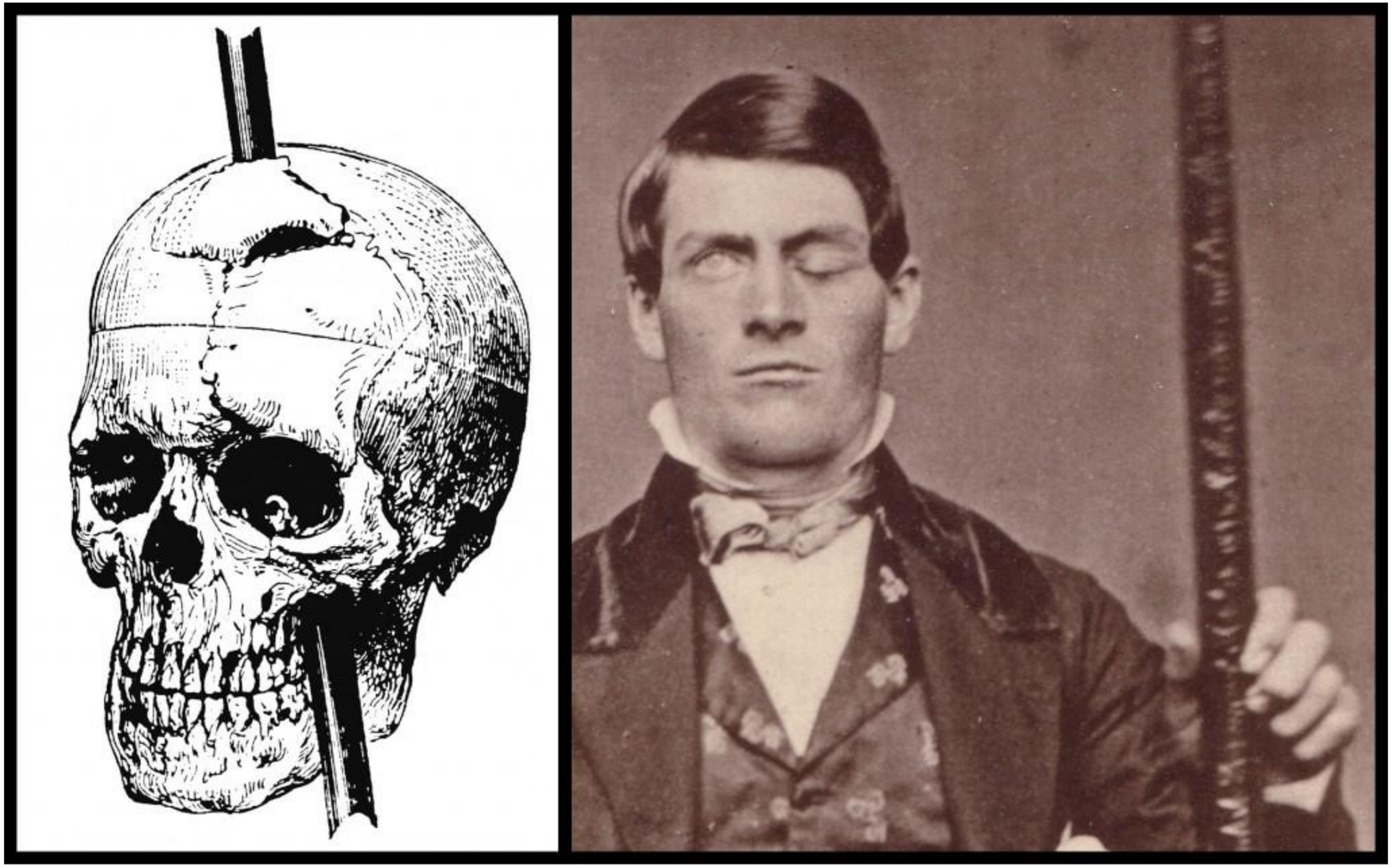


…and vice versa!

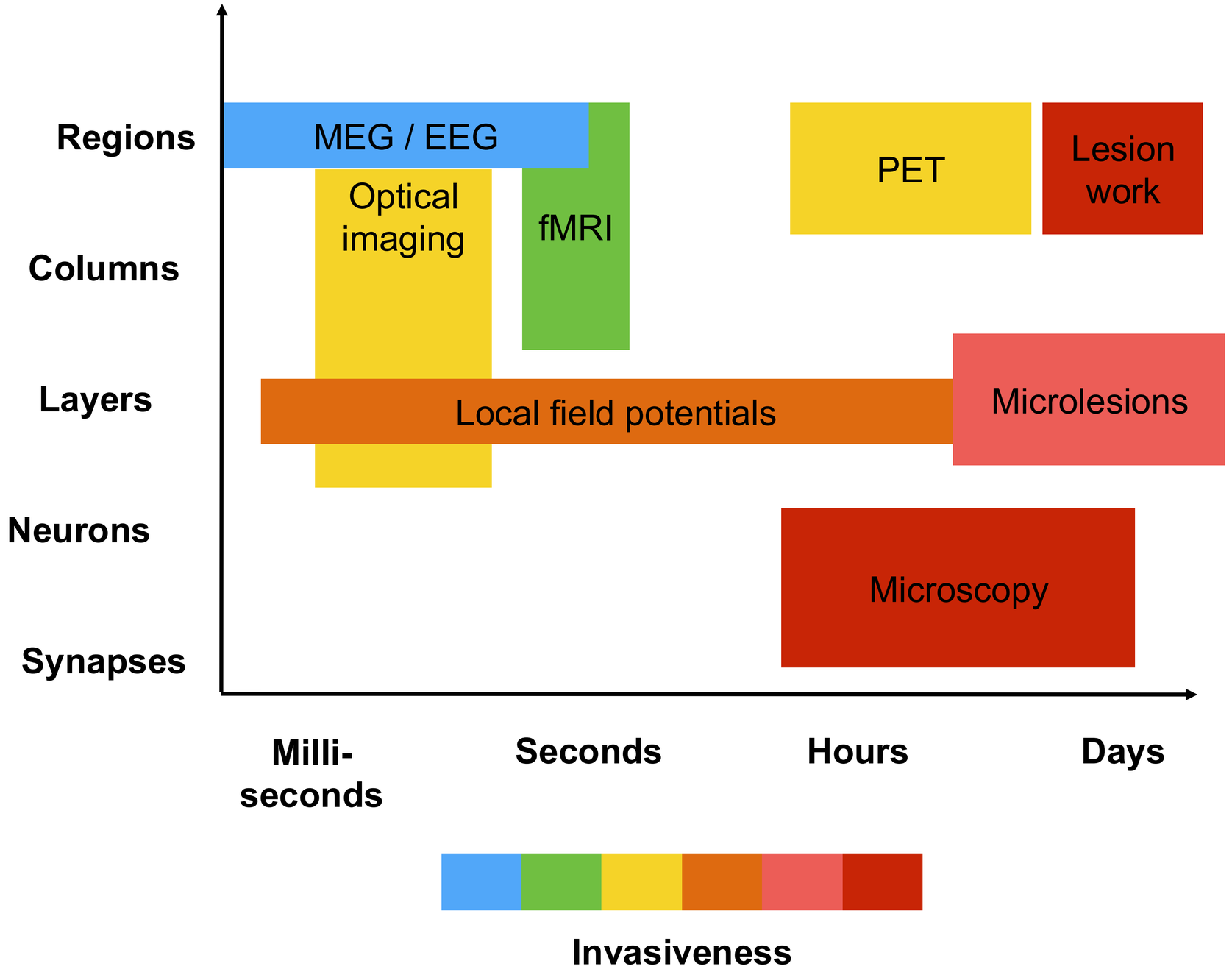
How to see the invisible



Old school cognitive neuroscience

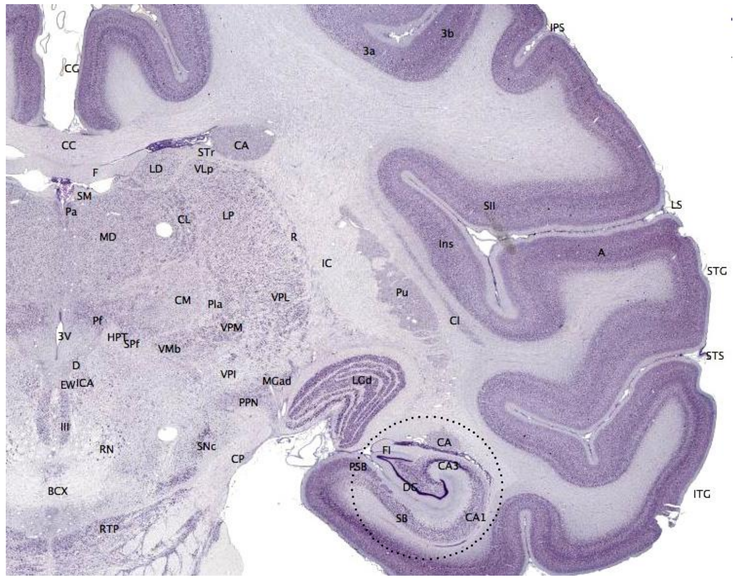


Video courtesy
of prof. Pirjo Nuutila

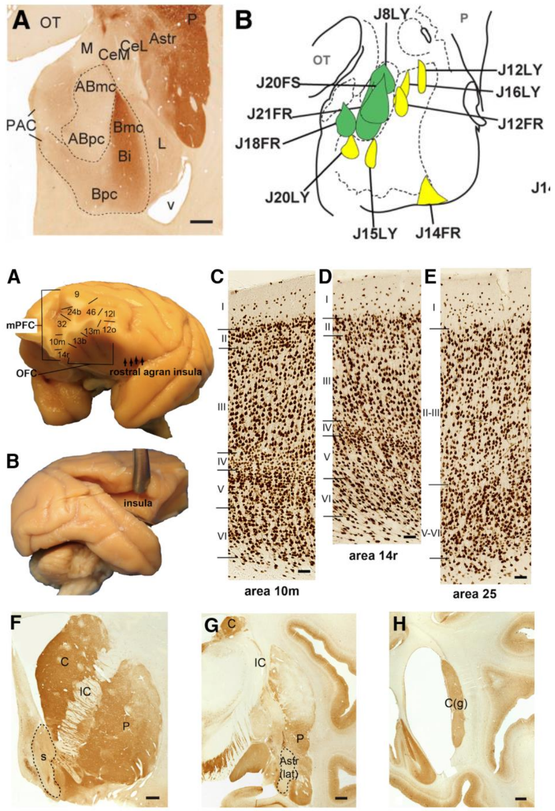

Regions
Columns
Layers
Neurons
Synapses
MEG / EEG
Optical imaging
fMRI
PET
Lesion work
Local field potentials
Microlesions
Microscopy
Milli-seconds
Seconds
Hours
Days
Invasiveness

Sturcture

Histology

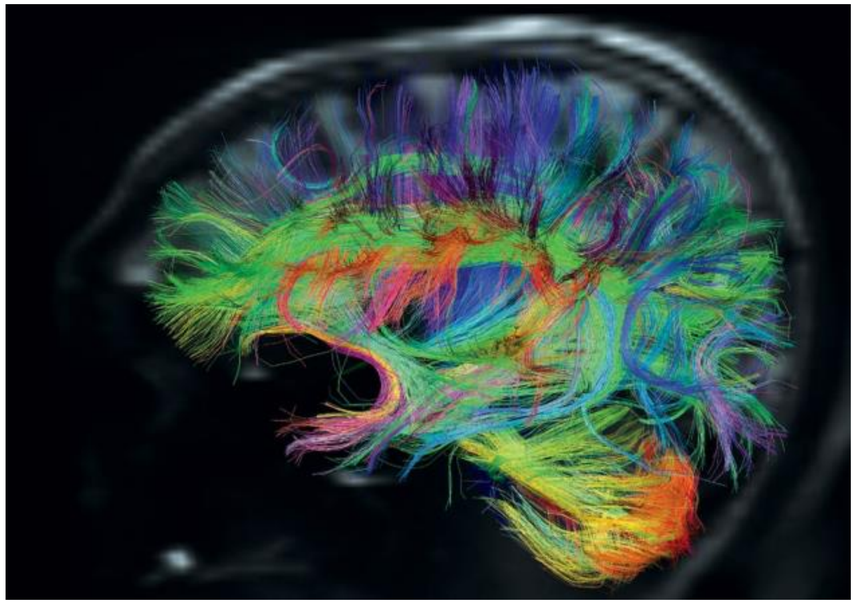


Tracing



Youngsun et al (2013 J Neurosci)

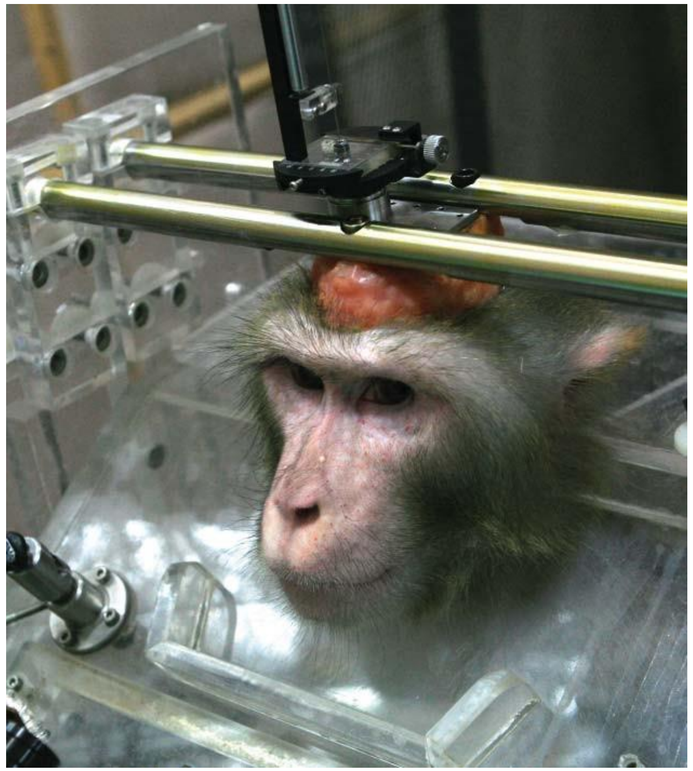
Diffusion imaging



A.G. Martinos Center

Brain states

Single cells



Cellular resolution

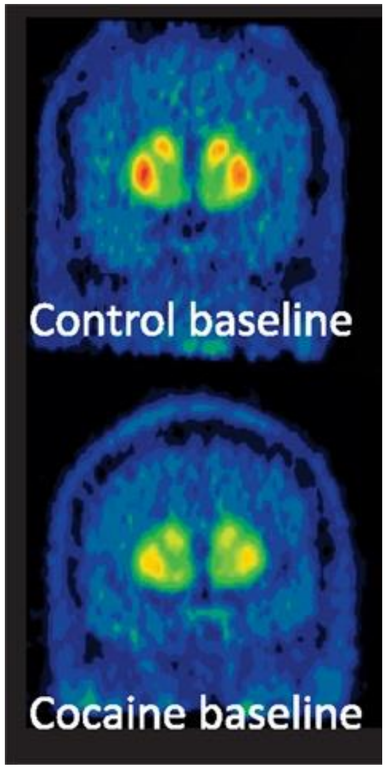
MEG

Temporal resolution

fMRI

Spatial resolution

PET

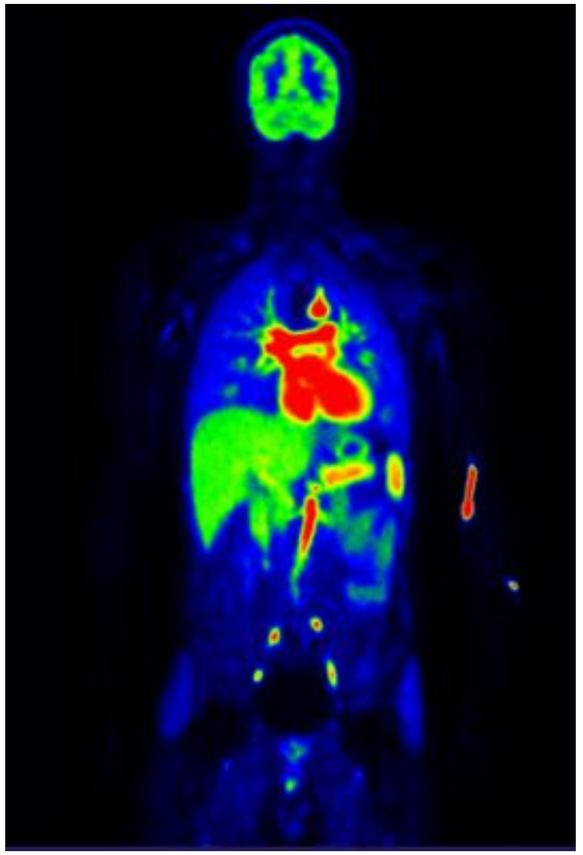


Molecular resolution

Whole-body biological circuits

CT

PET



PET-CT

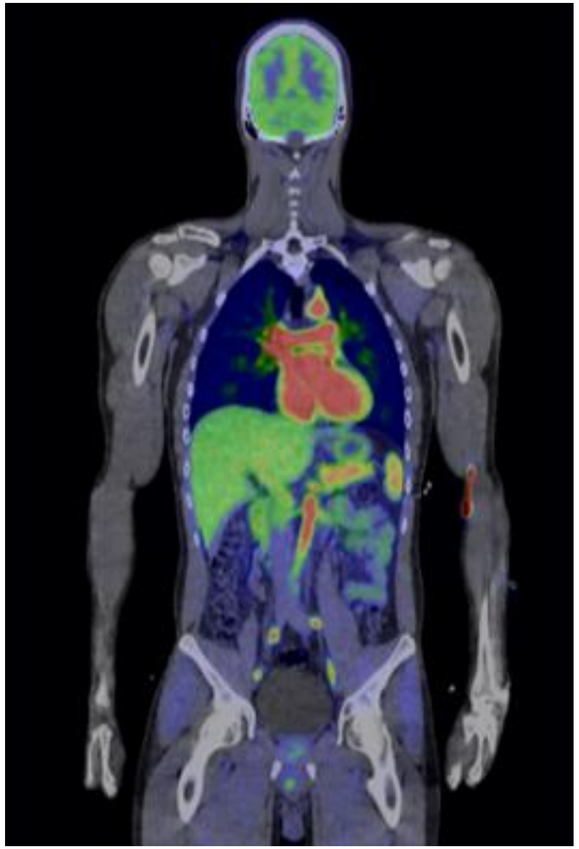
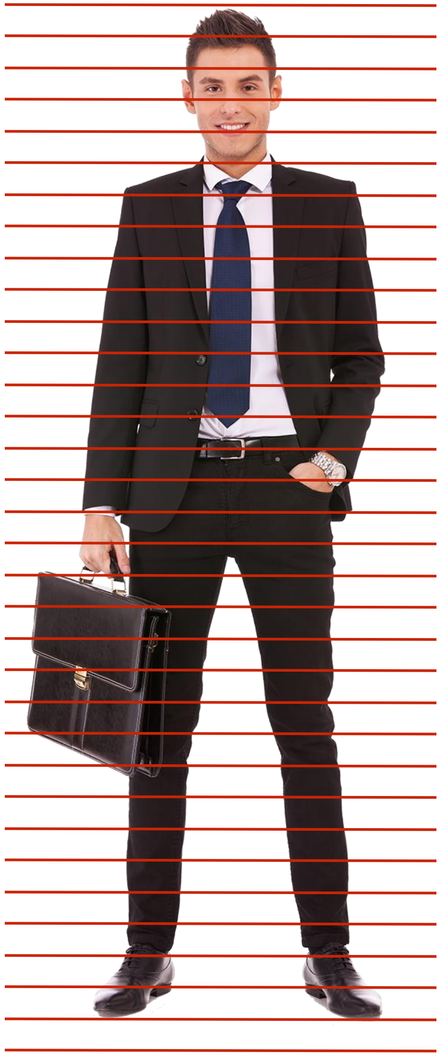
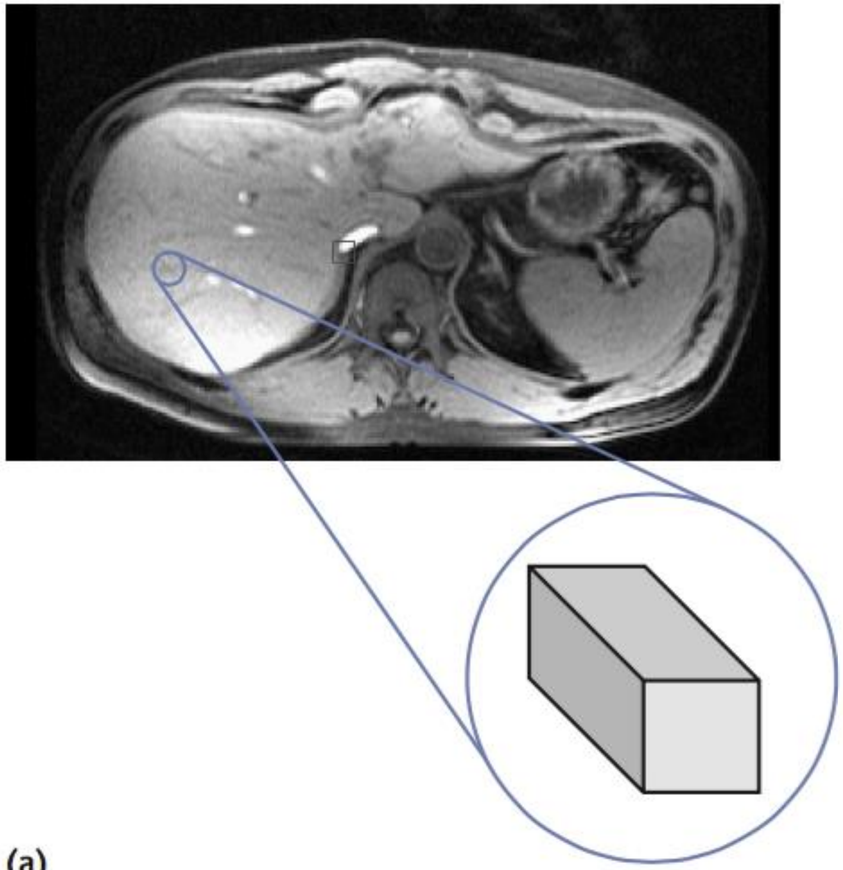


Image courtesy of Mueez U-Din 7 Turku PET Centre

Imaging: seeing the invisible

Tomographic imaging

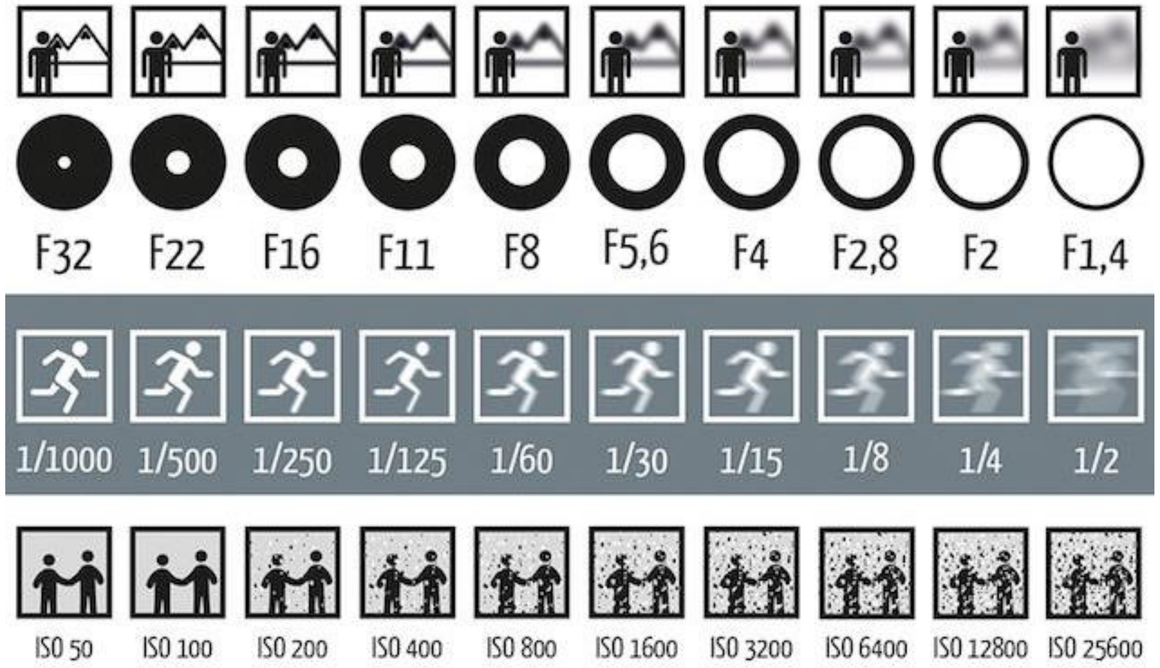


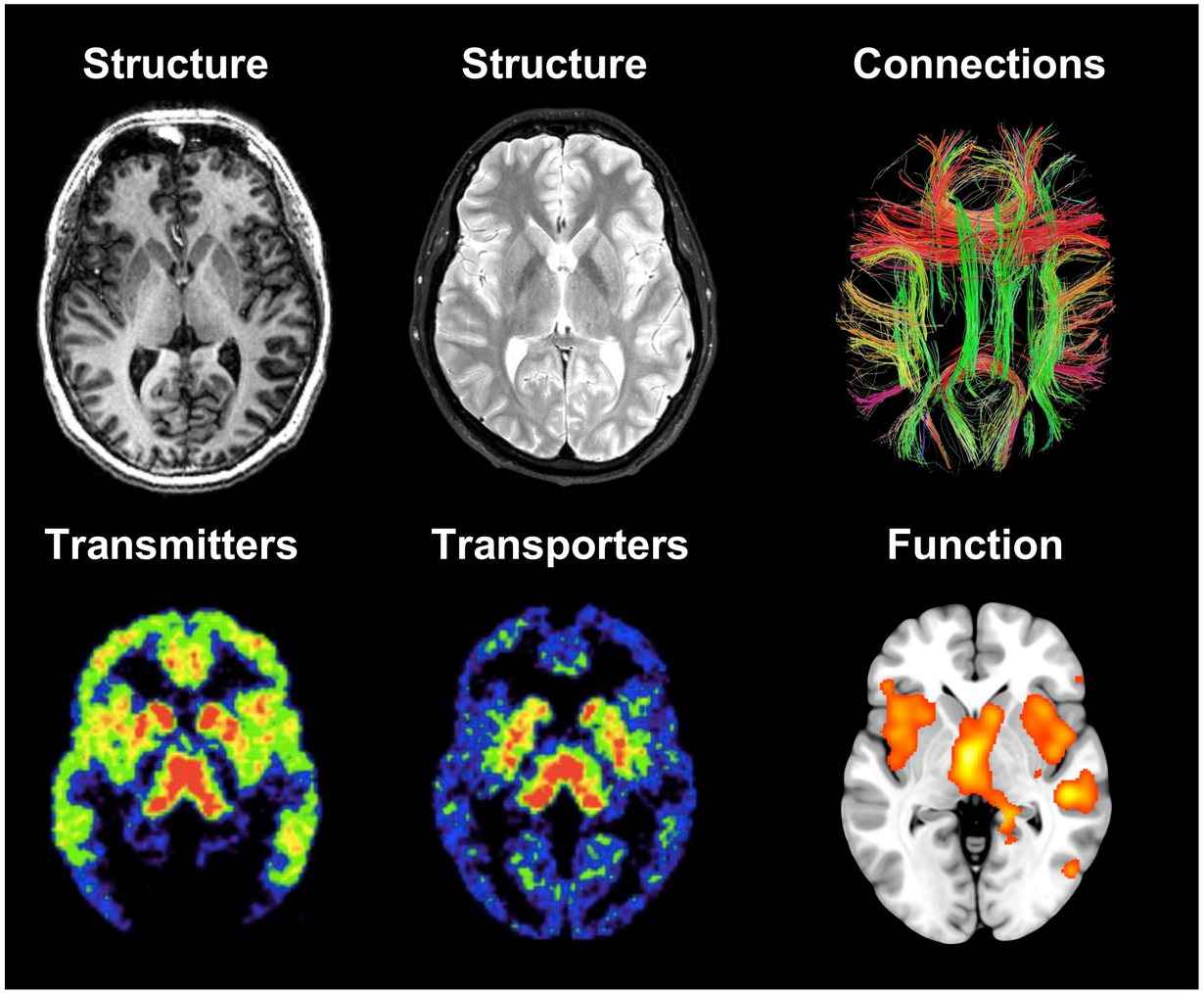


(a)

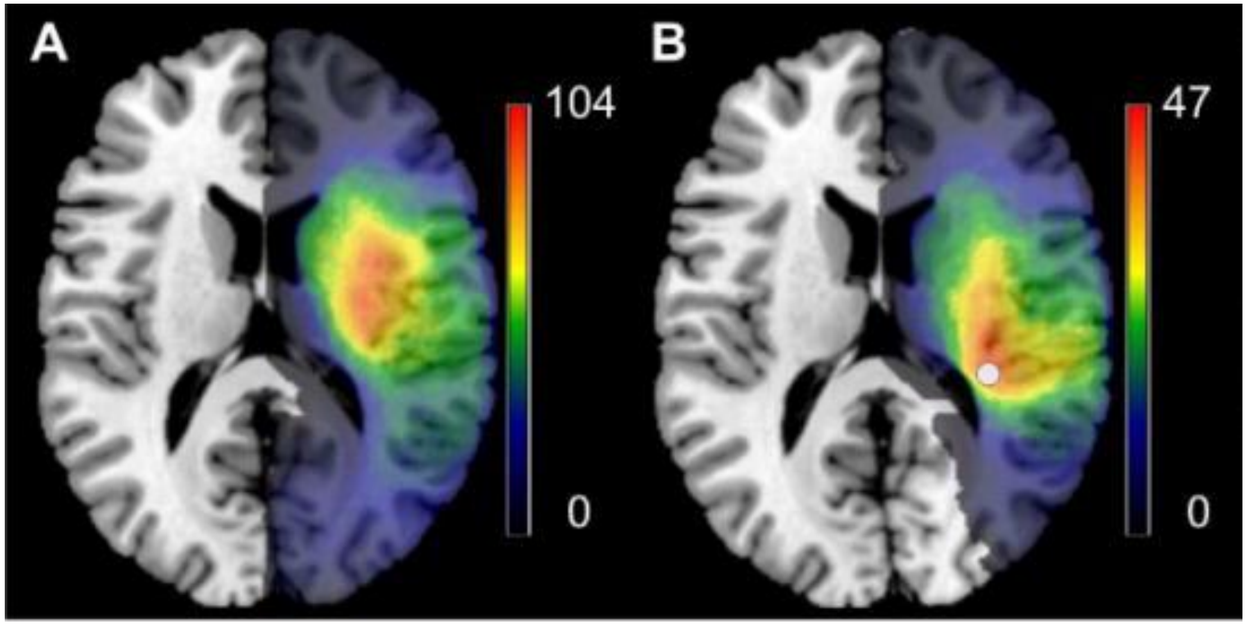
(b)

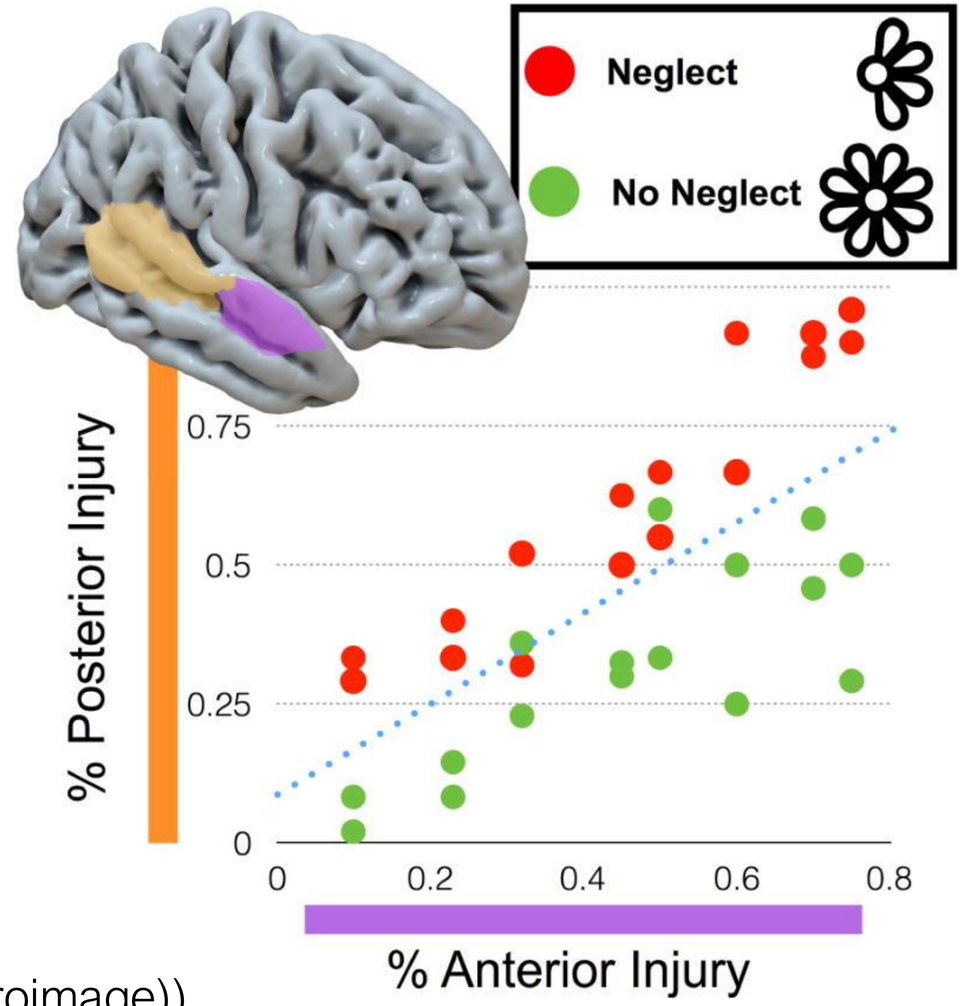
Same target - multiple contrasts





Lesion mapping

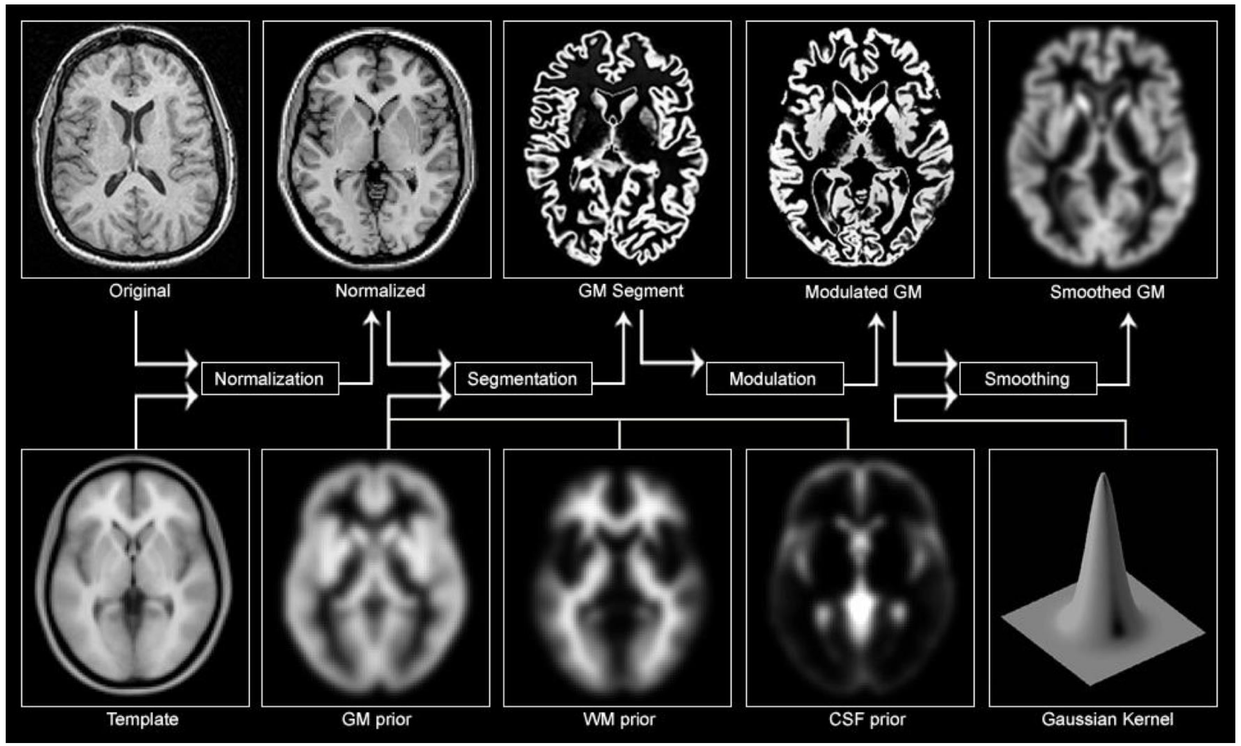




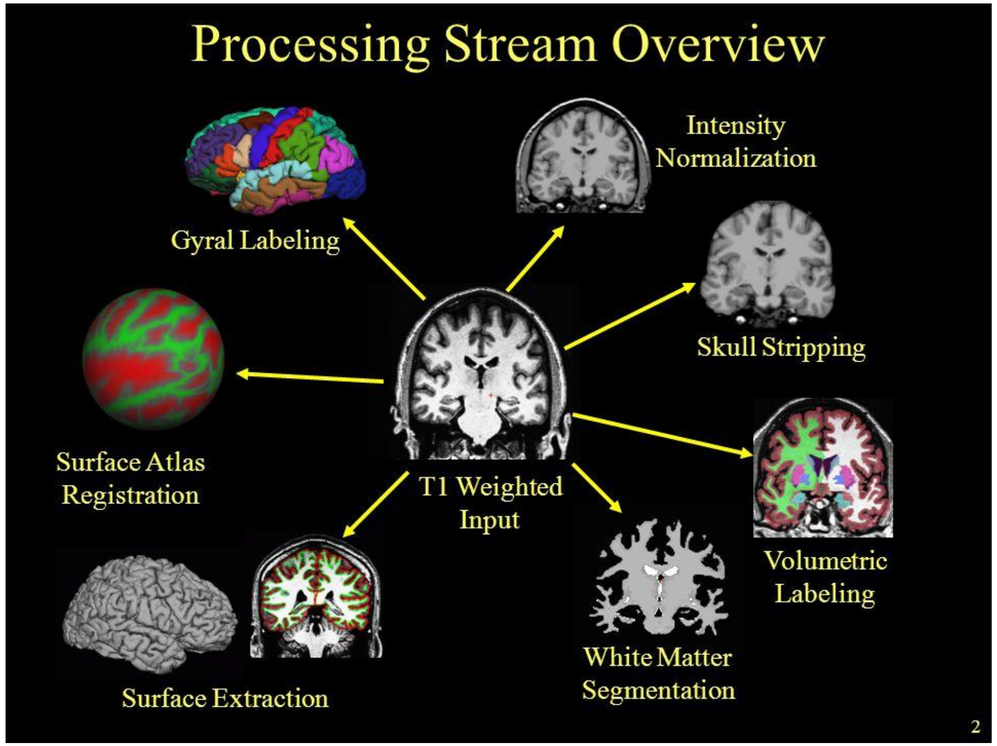
Karnath et al (2018 Neuroimage))

Morphometric analysis

Voxel-based morphometry (VBM)

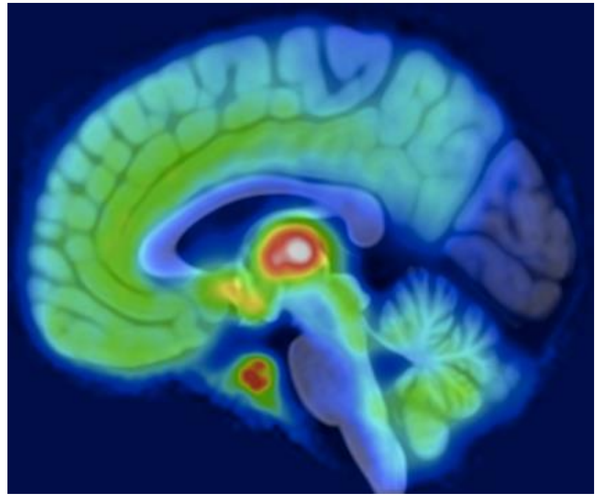


Surface analysis (FreeSurfer)



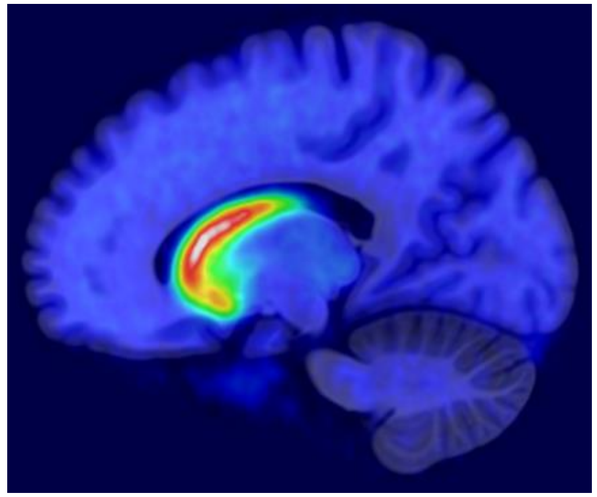
Positron emission tomography

Mu-opioid receptors



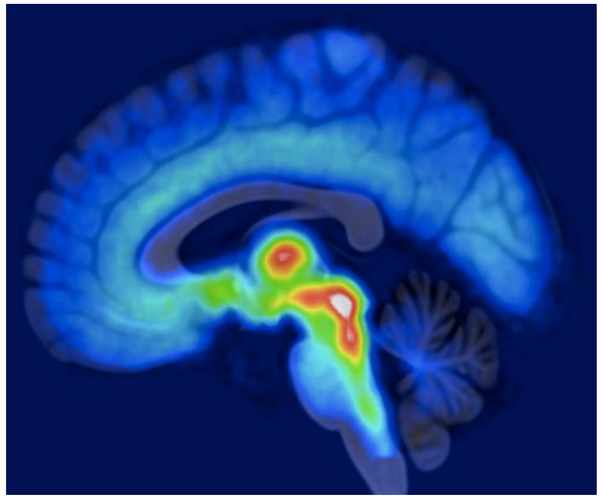
[^{11}C]carfentanil

Type 2 dopamine receptors



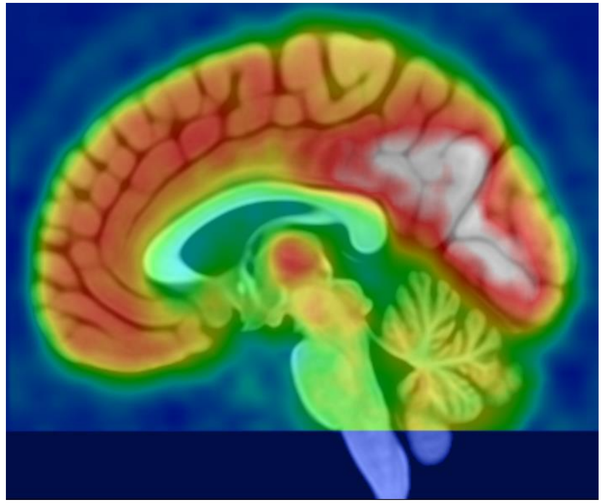
[^{11}C]raclopride

Serotonin transporters



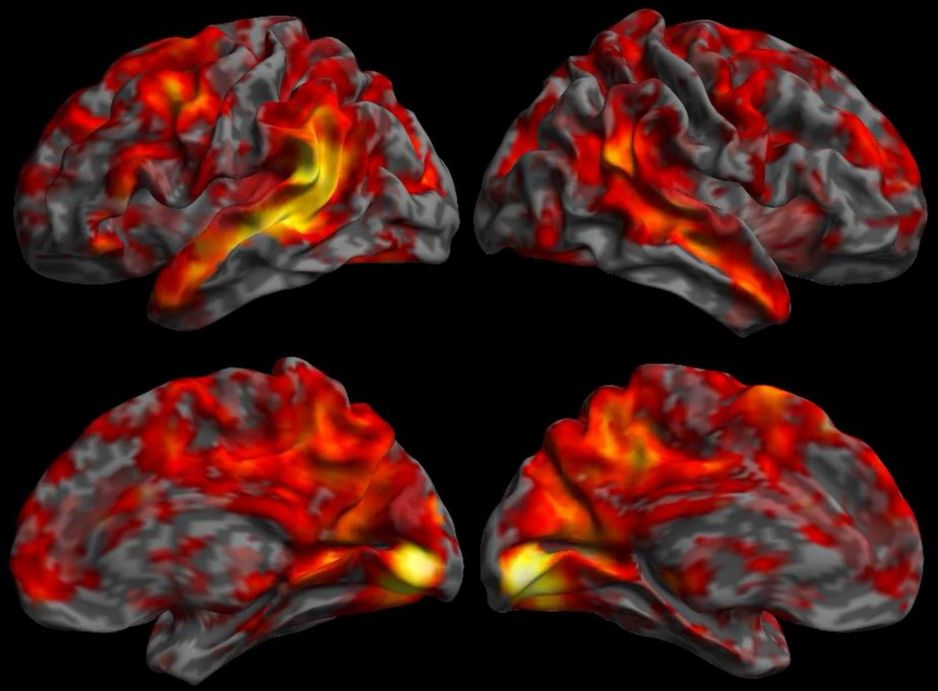
[^{11}C]MADAM

Glucose metabolism

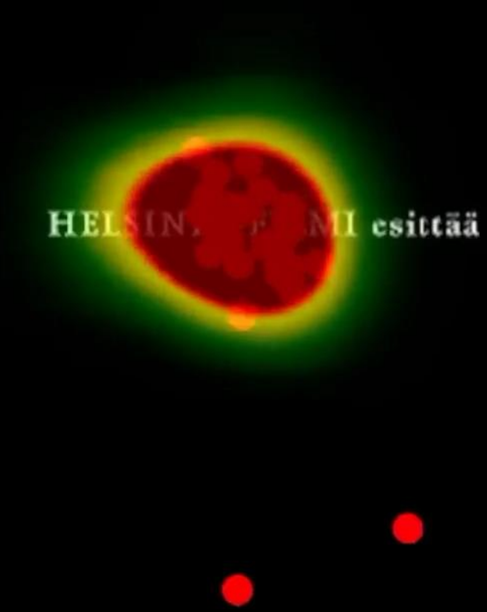


[^{18}F]FDG

Brain activity and attention during natural vision

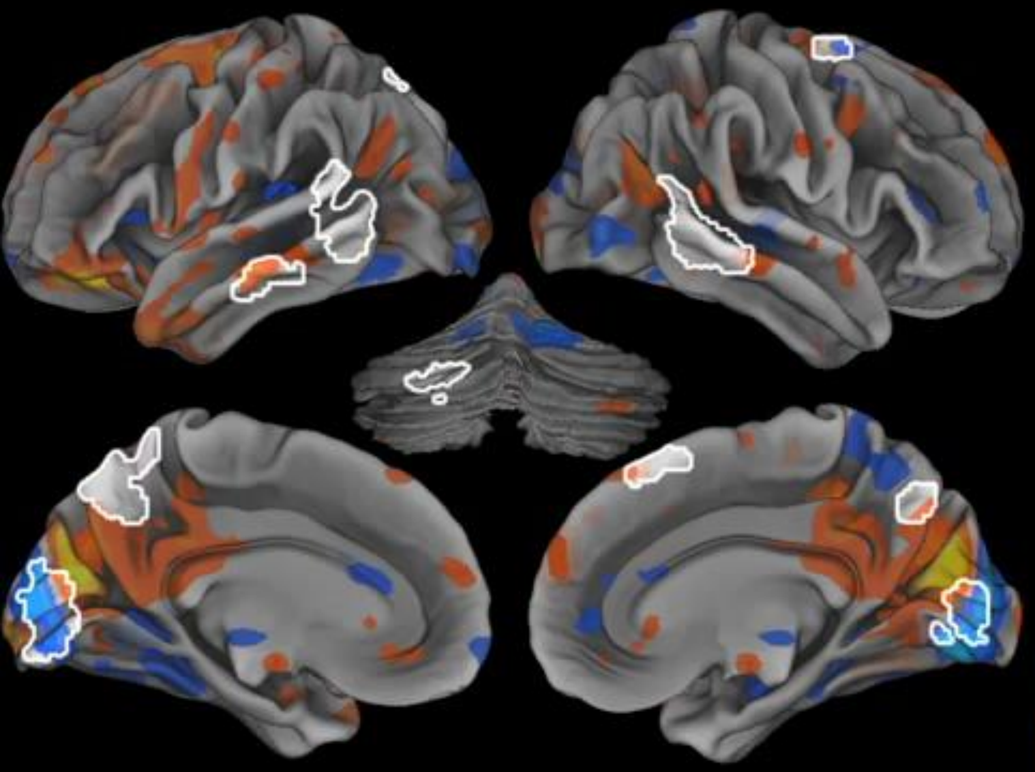


Mean brain activity (n=104)

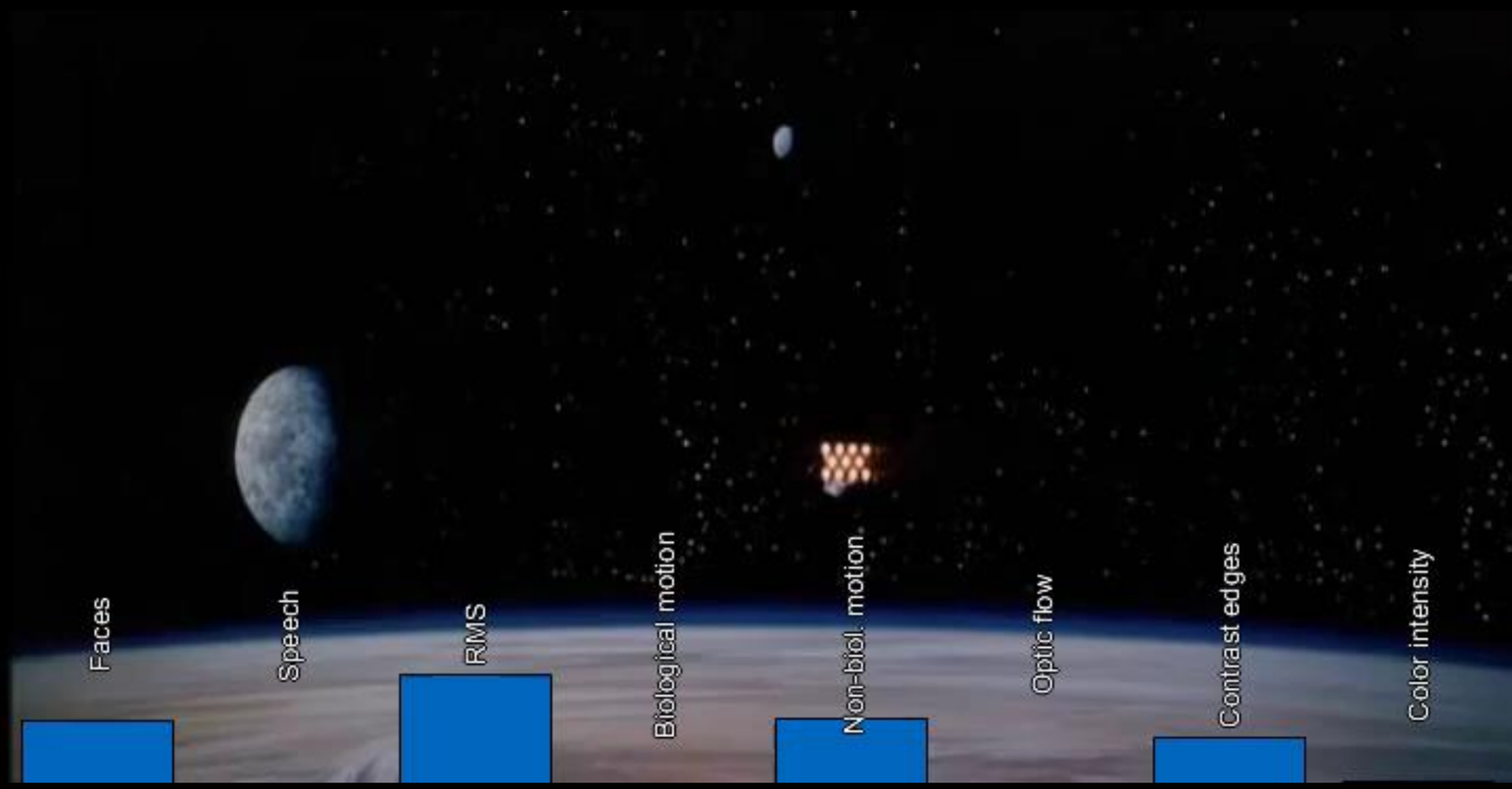


Individual (●) and mean (heatmap) gaze position

Brain activity



Sensory stimulus (Star Wars Episode IV)



Activation

Deactivation

Movie features

Lahnakoski et al (2017 Hum Brain Mapp)