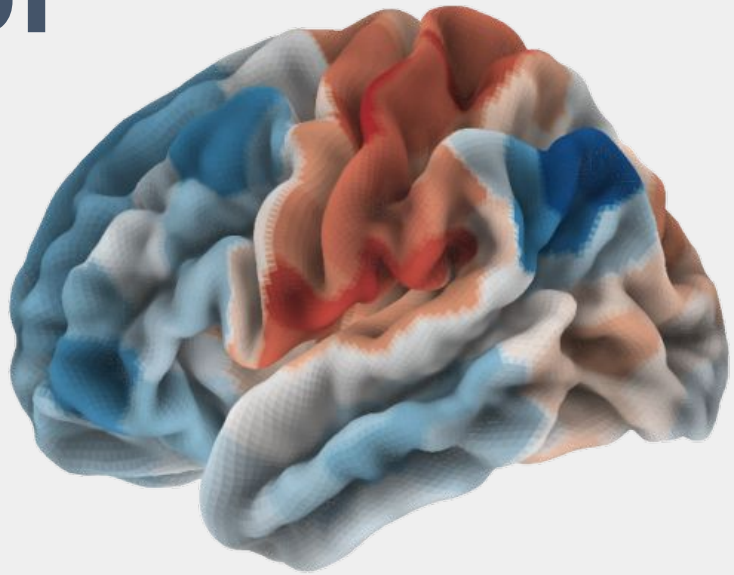
Fundamentals of fMRI data analysis



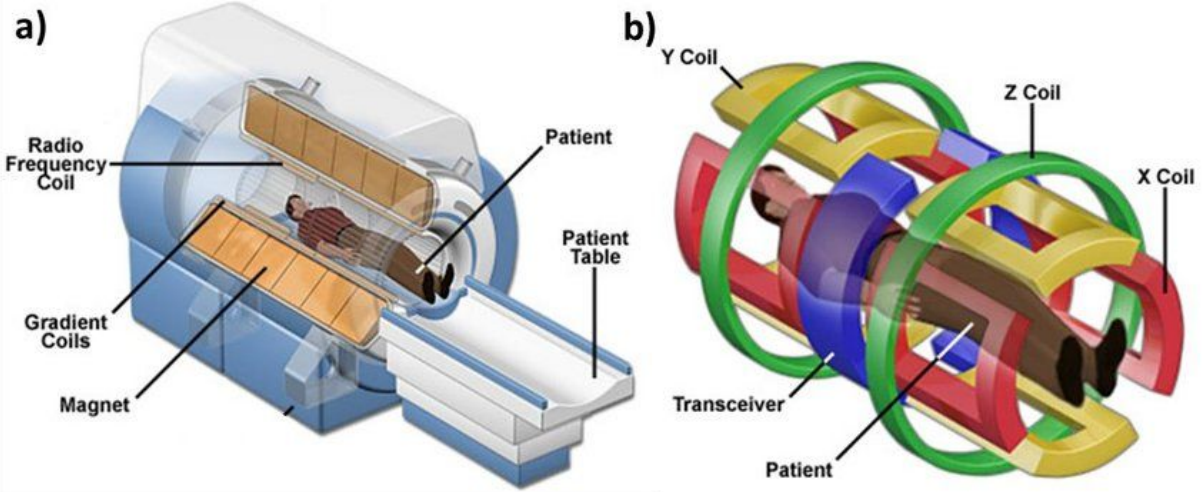
Karolina Finc

Centre for Modern Interdisciplinary Technologies

Nicolaus Copernicus University in Toruń

COURSE #00: Introduction

MRI machine

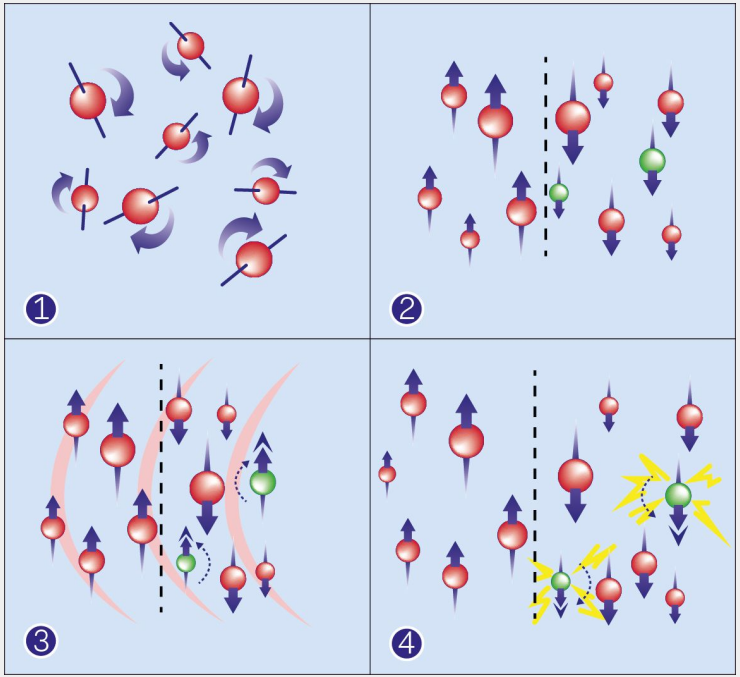


MRI machine is composed of four main components:

(1) primary magnet
(2) gradient magnets
(3) radiofrequency (RF) coils
(4) computer system

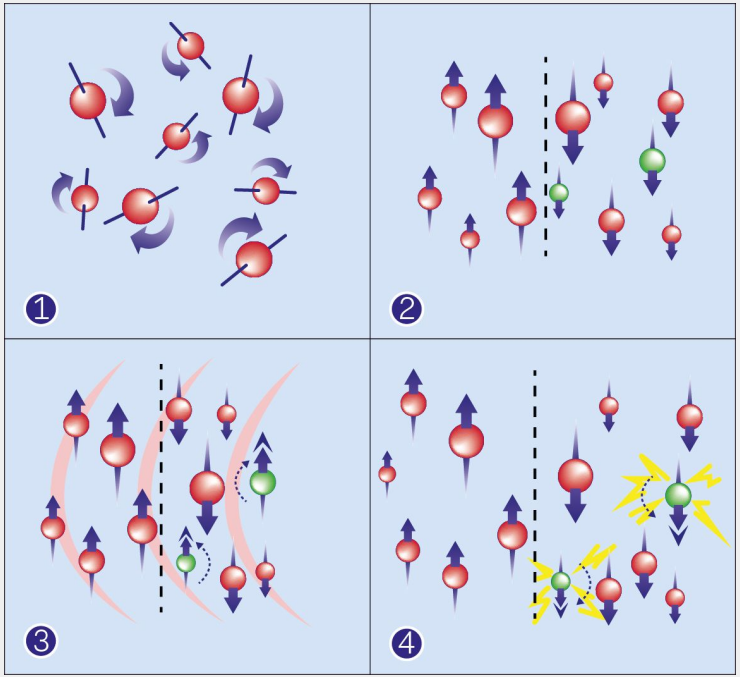
The strength of magnetic field is measured in Tesla (T).

How MRI works?



Human body - 70% of water (H_2O).

How MRI works?



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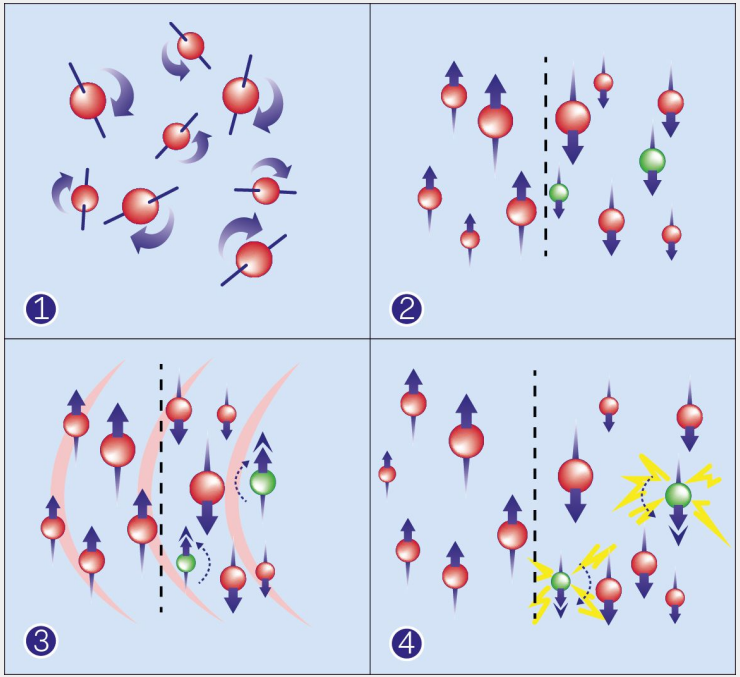

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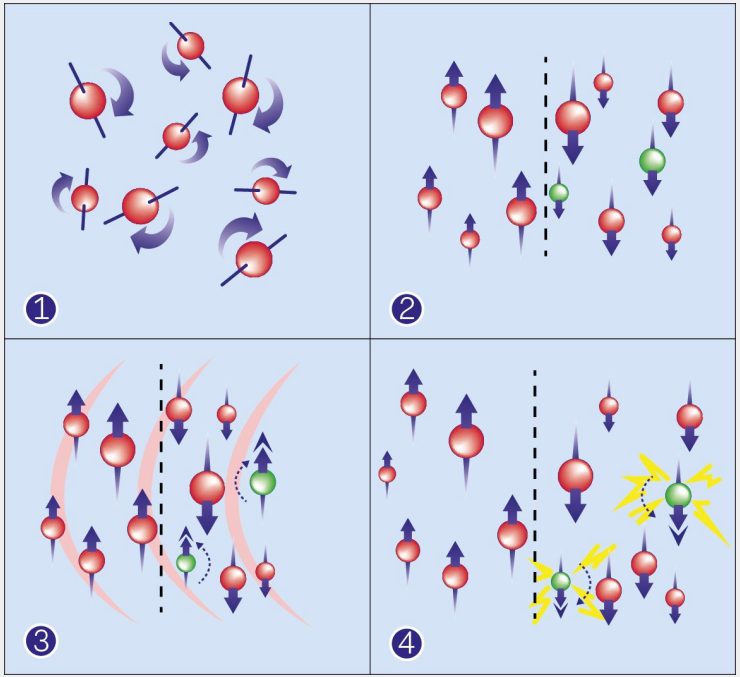

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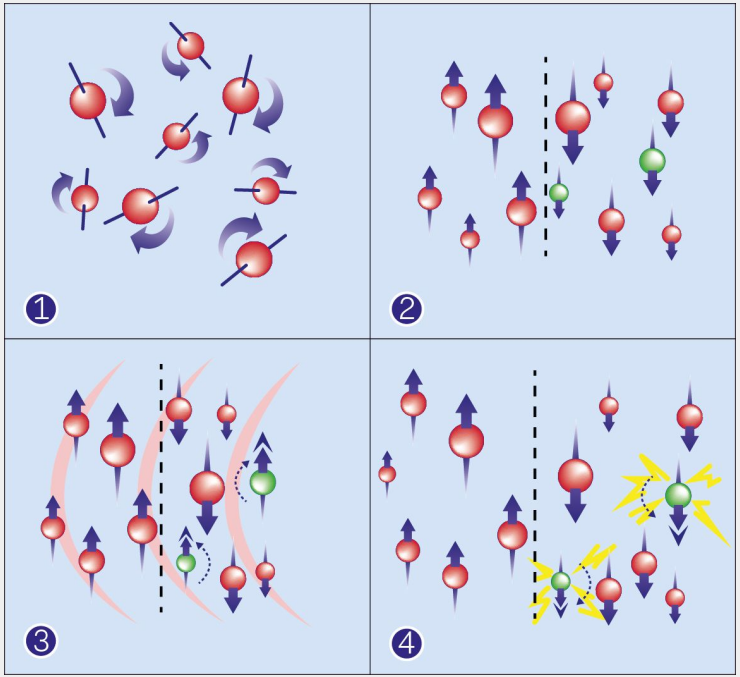

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(4) After turning off the RF pulse, protons return to their initial equilibrium (relaxation) and emit energy in this process.

fMRI

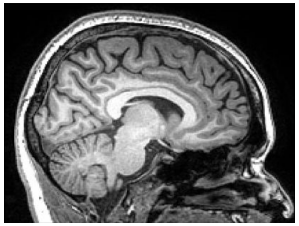
Functional Magnetic Resonance Imaging

fMRI

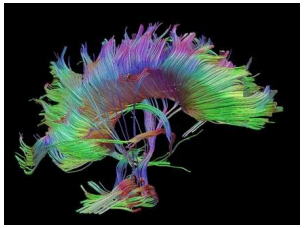
Functional Magnetic Resonance Imaging

Structural

MRI (T1)



DTI

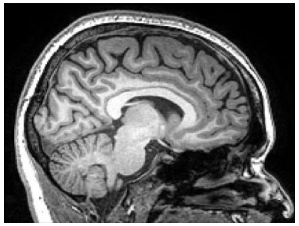


fMRI

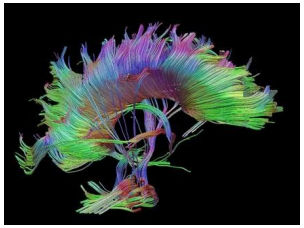
Functional Magnetic Resonance Imaging

Structural

MRI (T1)

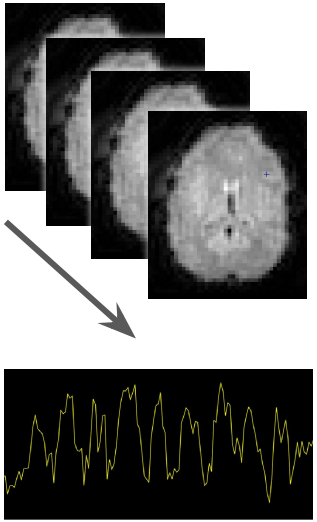


DTI



Functional

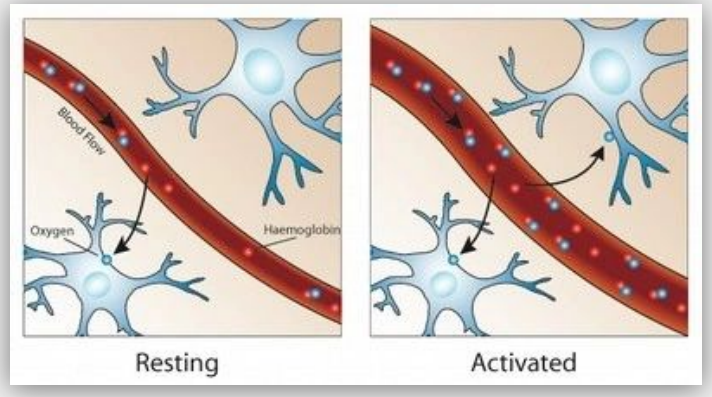
fMRI (T2*)




How to measure brain activity with fMRI?

BOLD signal

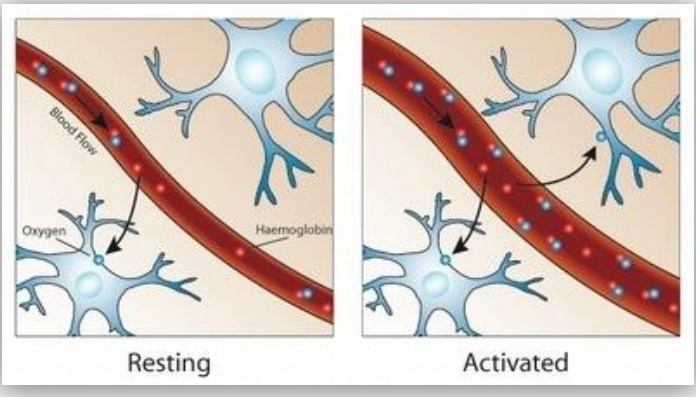
Blood Oxygenation Level Dependent



Ratio of oxygenated to deoxygenated hemoglobin in the blood.

BOLD signal

Blood Oxygenation Level Dependent



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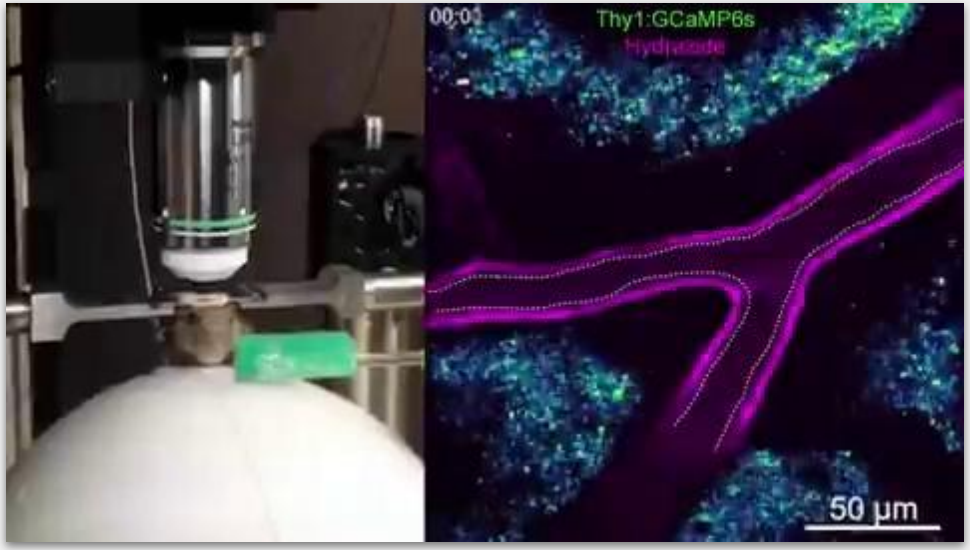
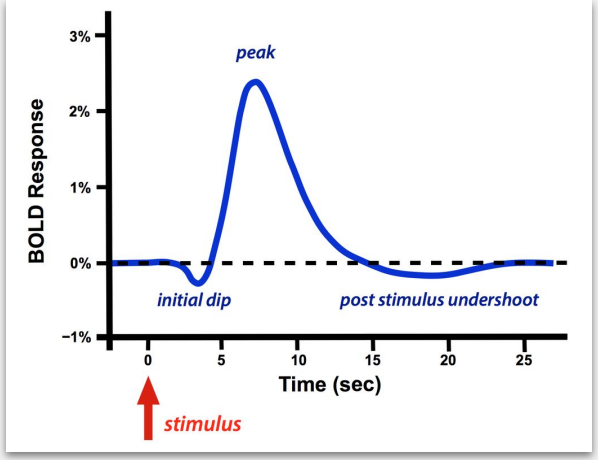


Chow et al. (2020), *Nature*.

Haemodynamic response function



The change in BOLD signal that follows a brief period of neuronal activity.

Peak about 5 seconds after stimulation

Undershot (returns to baseline in for at least 15-20 seconds)

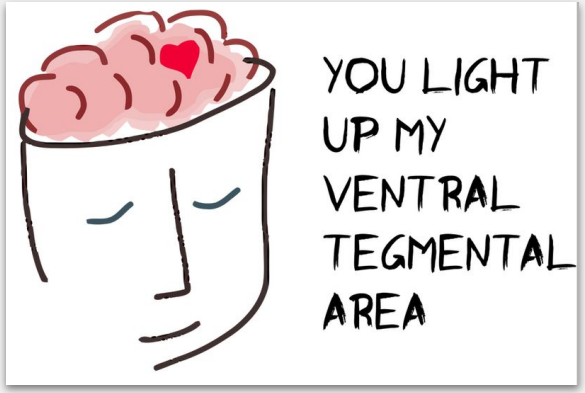
The shape of HRF may differ in different brain areas or between subjects subjects.

Cool stuff:
https://www.slideshare.net/rnja8c/fmri-study-design

Remember!

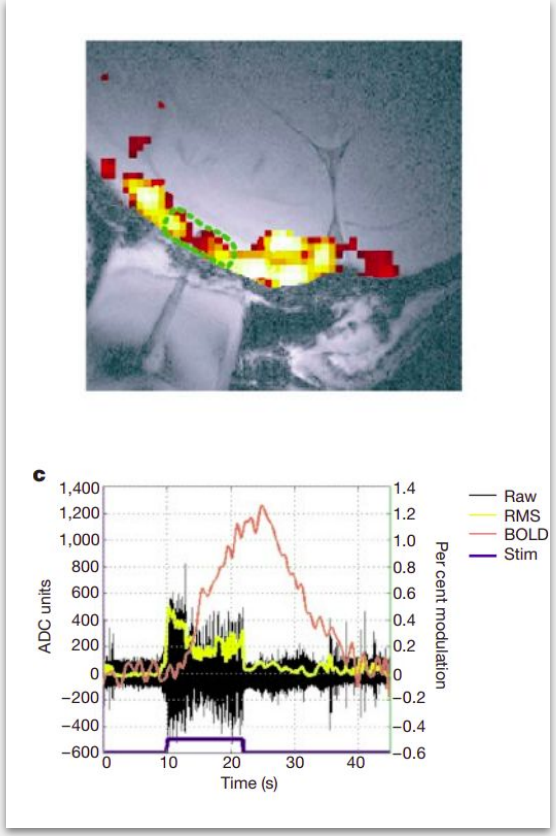
BOLD signal is not a direct measure of neuronal activity!

It measures metabolic demands of active neurons (oxygen consumption).



But...

BOLD signal corresponds closely to the local field potential - the electrical field potential surrounding group of neurons.



Logothetis et al. (2001), *Nature*.

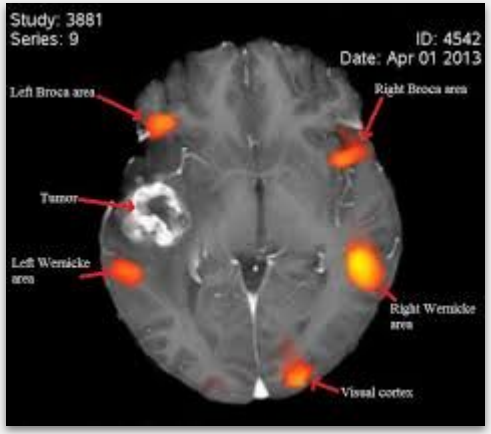
Why we may want to analyze fMRI data?

Why we may want to analyze fMRI data?

Understanding how the human brain works in health and disease.

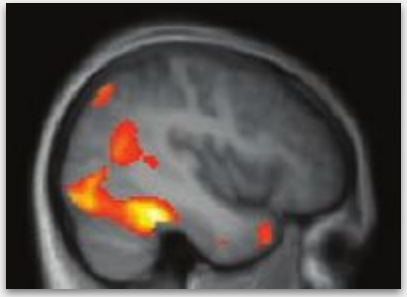
Example questions:

- How cognitive functions are organized in the human brain?
- How the human brain changes during learning?
- Can we diagnose psychiatric illness based on brain activity ?
- Can we predict neurodegenerative disorder based on brain activity?
- Can we use knowledge about how the human brain works to build more efficient artificial intelligence?



How we can look at fMRI data?

Brain activation



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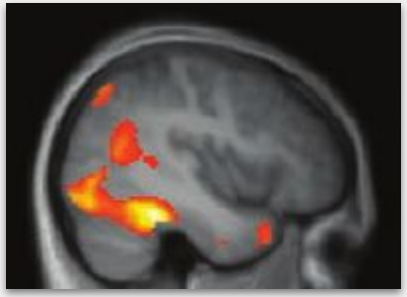
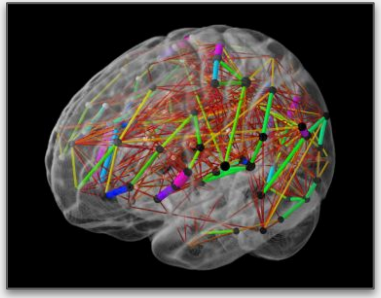


Functional connectivity



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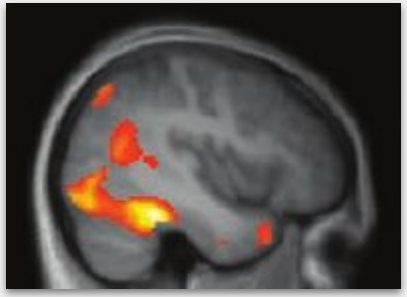

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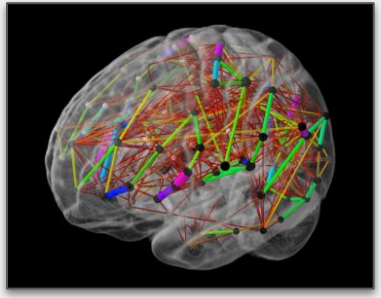
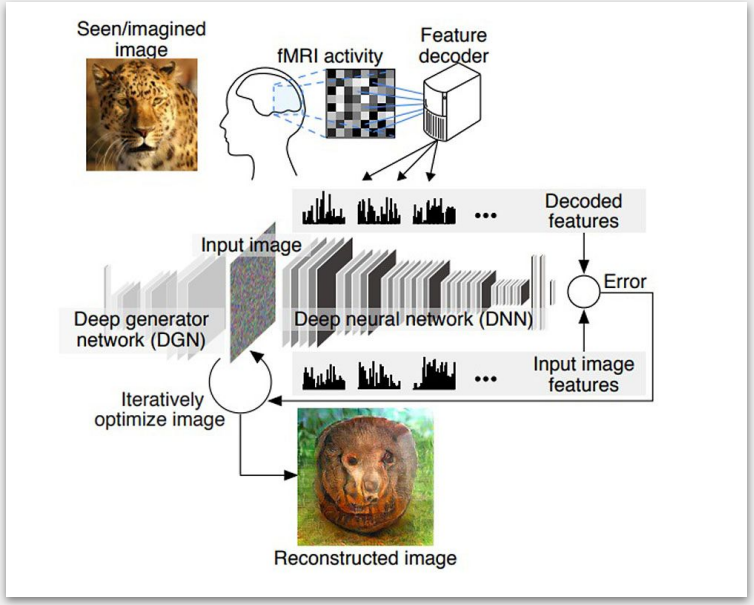


Machine learning



How does fMRI study look like?

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Question & hypothesis

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Designing experiment

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Question & hypothesis

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Collecting data

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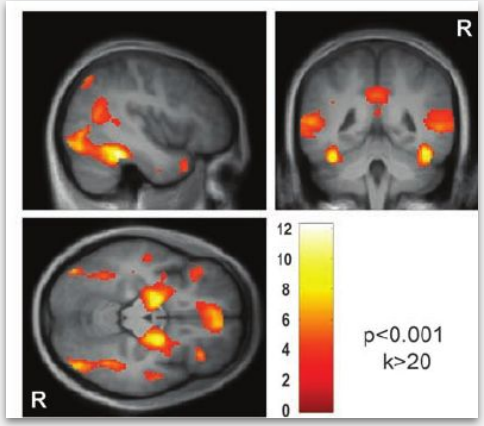
Data analysis



How does fMRI study look like?

Question & hypothesis

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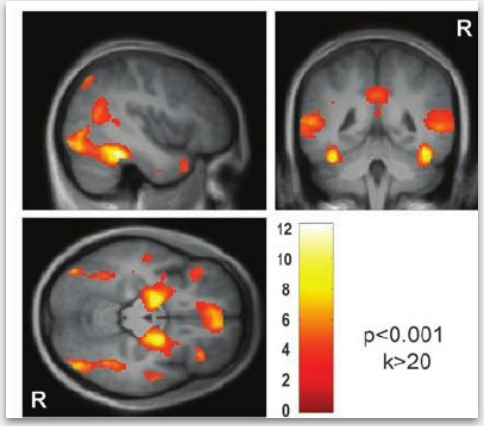
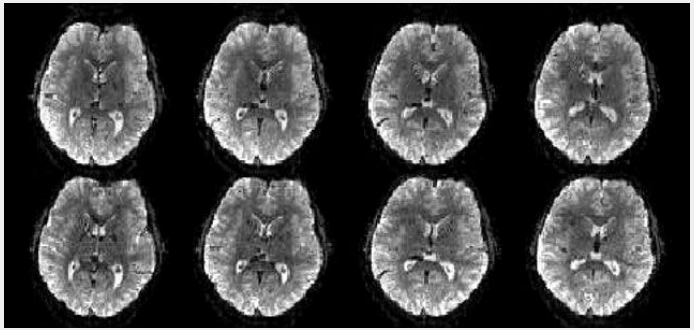
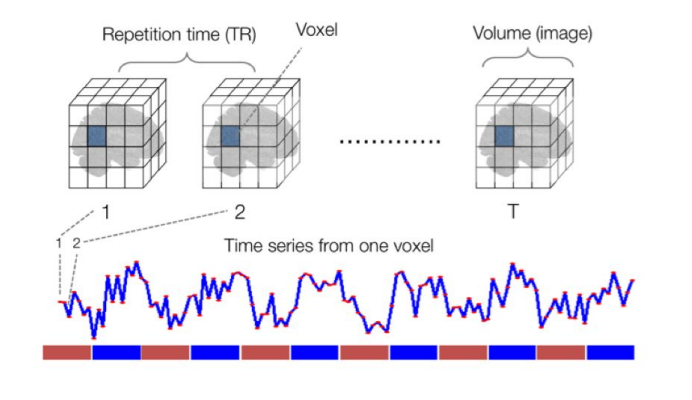


Reporting & interpretation

How does fMRI data look like?





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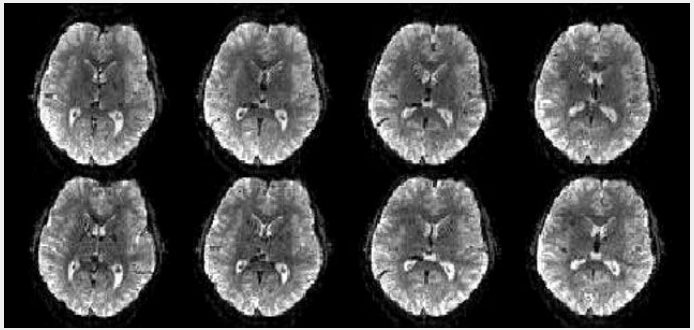

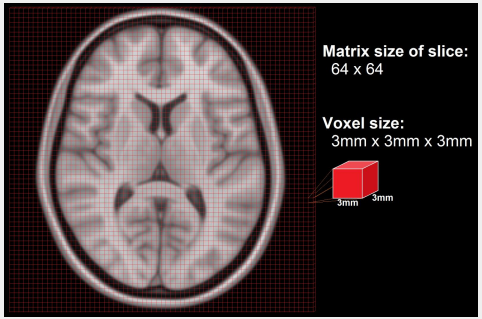

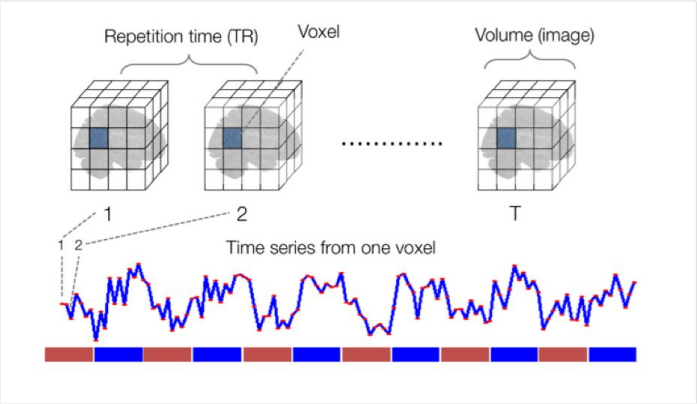

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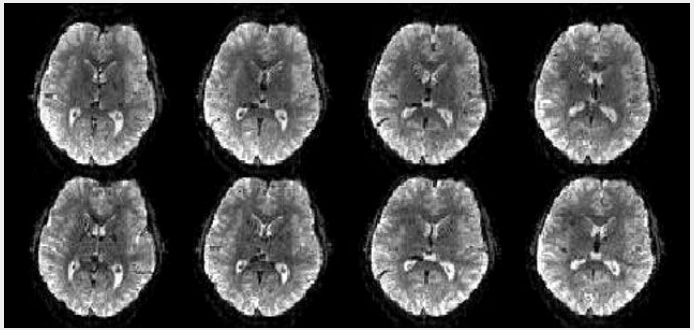
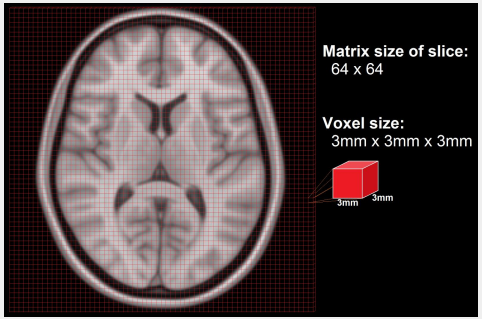
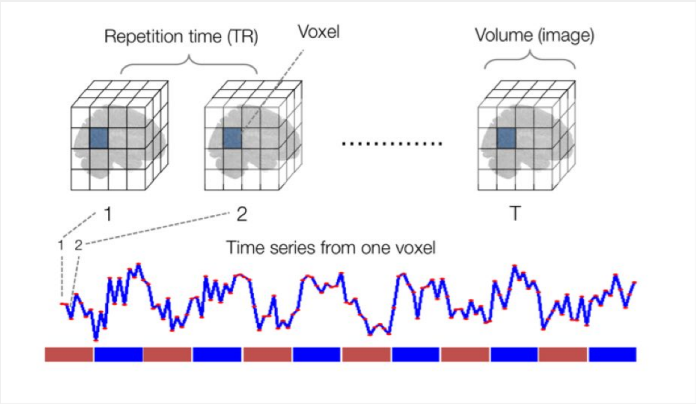






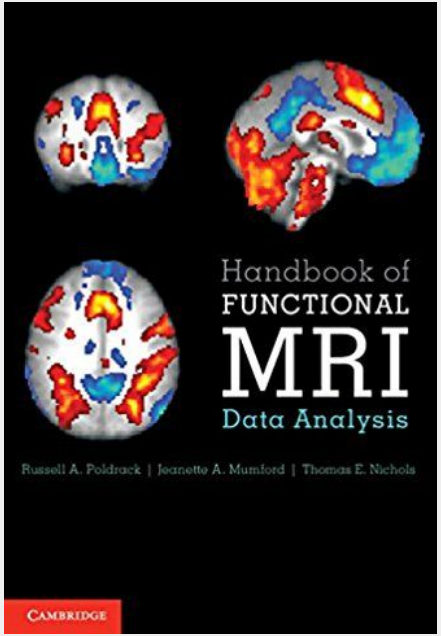
Challenges:

- Magnitude of signal changes is quite small - 0.5 - 5%
- Number of artifacts, head movement
- Variability within and between individuals
- High dimensionality of data

How to become an fMRI data analysis master?

1. Probability and statistics
2. Computer programming (Python/MATLAB)
3. Linear algebra
4. Magnetic resonance imaging
5. Neurophysiology and biophysics
6. Signal and image processing

… it can take many years!

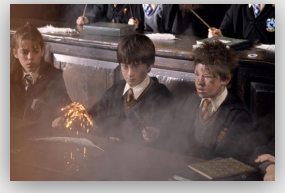



I HAVE NO IDEA
WHAT I'M DOING
quickmeme.com

How to become neuro(i)magician?

Hogwarts approach

Study plan



BEFORE

Study plan

BEFORE

AFTER

Study plan

AFTER

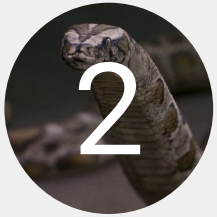
Open science &
neuroimaging

BEFORE

Study plan

BEFORE

Open science & neuroimaging

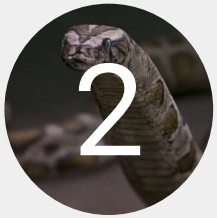


Python language for neuroimaging

AFTER

Study plan

BEFORE



Python language for neuroimaging

Open science & neuroimaging

fMRI data preprocessing

AFTER

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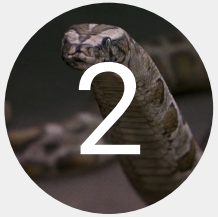


Python language for
neuroimaging

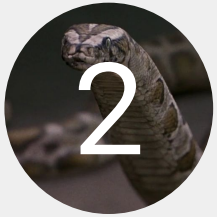
fMRI data
preprocessing

General
Linear Model

AFTER

Study plan

BEFORE



Python language for neuroimaging

Open science & neuroimaging

fMRI data preprocessing

General Linear Model

Functional connectivity

AFTER

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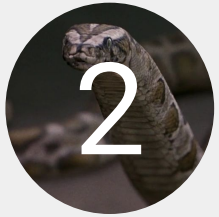
Open science & neuroimaging



Python language for neuroimaging

fMRI data preprocessing

General Linear Model

Functional connectivity

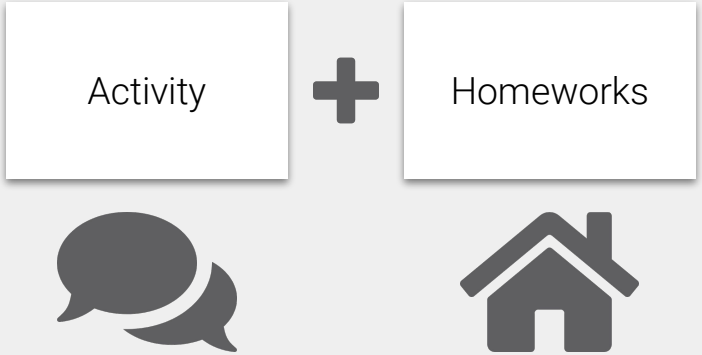
AFTER

Machine Learning on fMRI data

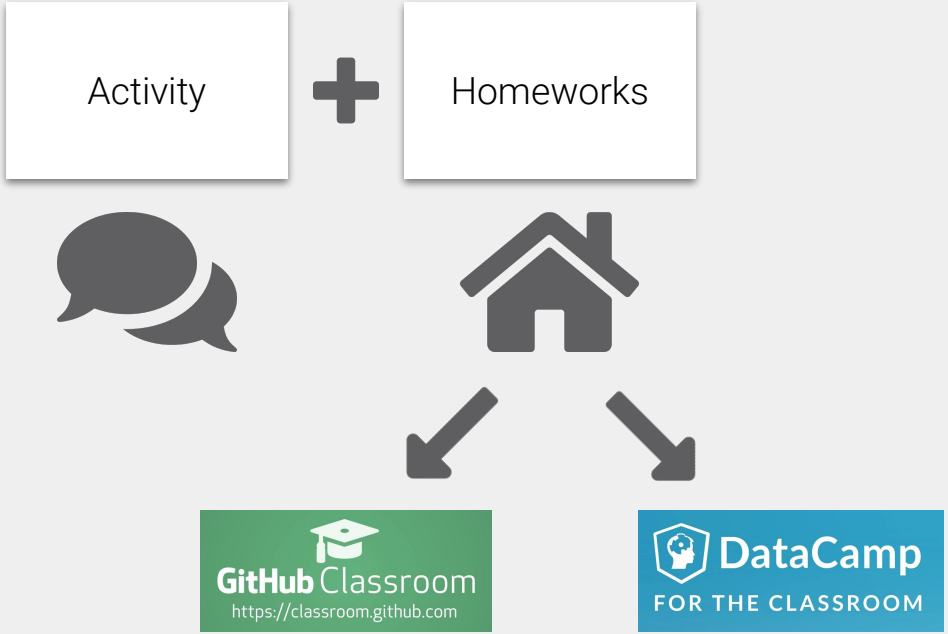
Grading

Activity

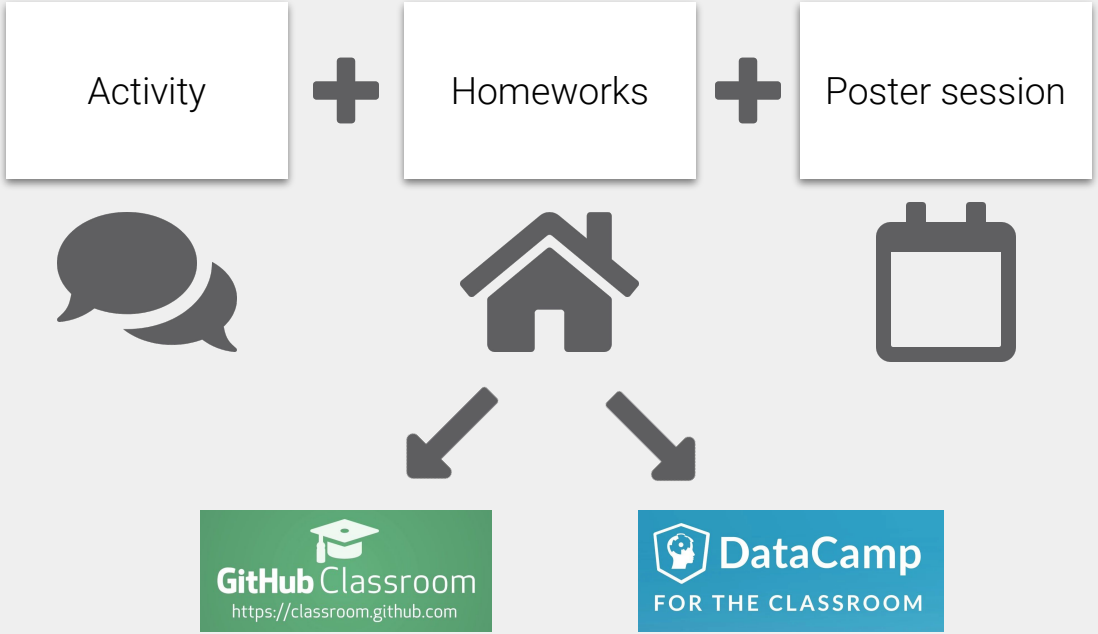
Grading



Grading


Activity
Homeworks
GitHub Classroom
https://classroom.github.com
DataCamp
FOR THE CLASSROOM

Grading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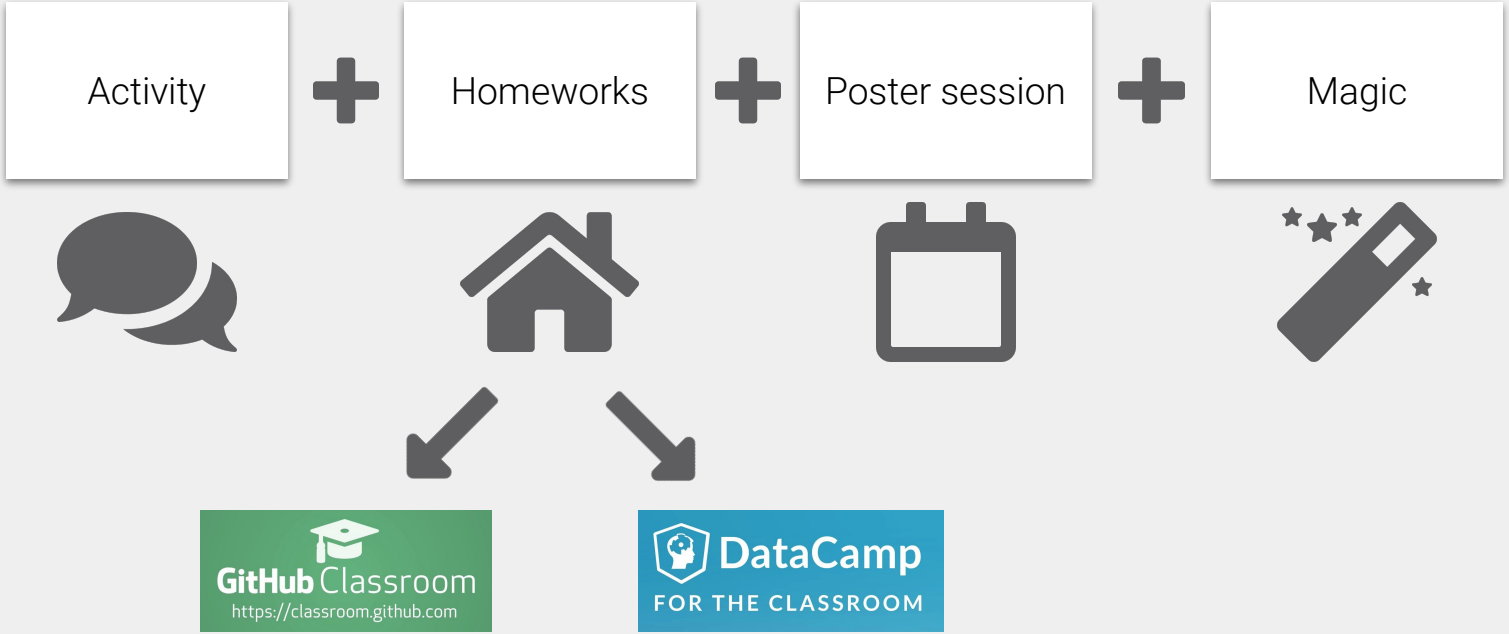
Activity
Homeworks
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Magic
GitHub Classroom
https://classroom.github.com
DataCamp
FOR THE CLASSROOM

Rules & consultations

2 allowed absence

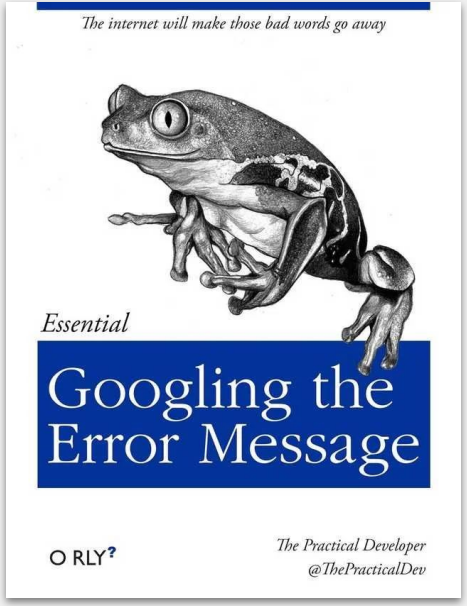
1 allowed missed homework

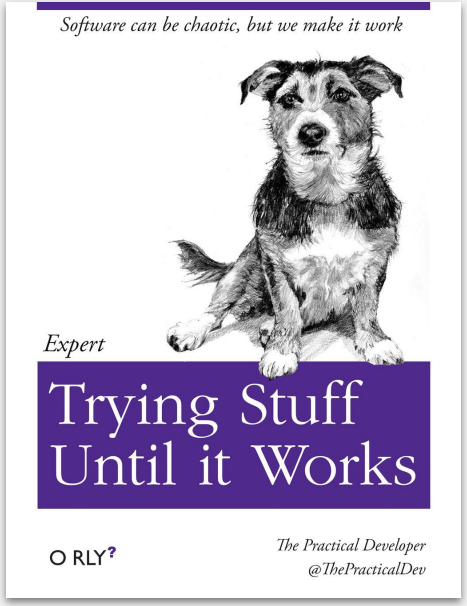
Consultations:

ICNT, Wednesdays (text me about time)

Email:

`finc@umk.pl`





Homework

1. **Data Camp Classroom**

   `https://www.datacamp.com/enterprise/advanced-fmri-data-analysis/assignments`

   Introduction to Python

Next

Reproducible neuroimaging and open science