Psychology & Clinical Language Sciences

University of Reading

fMRI: THE METHOD & ITS APPLICATIONS

Dr. Etienne B. Roesch

Associate Professor of Cognitive Science


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fMRI: The method & its applications


PARENTAL
ADVISORY
EXPLICIT CONTENT

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1. What is a MRI scanner? What is fMRI?
2. What is the signal that fMRI is recording?
3. How is it typically used as a research tool?

functional MRI is a special way of using Magnetic Resonance Imaging.

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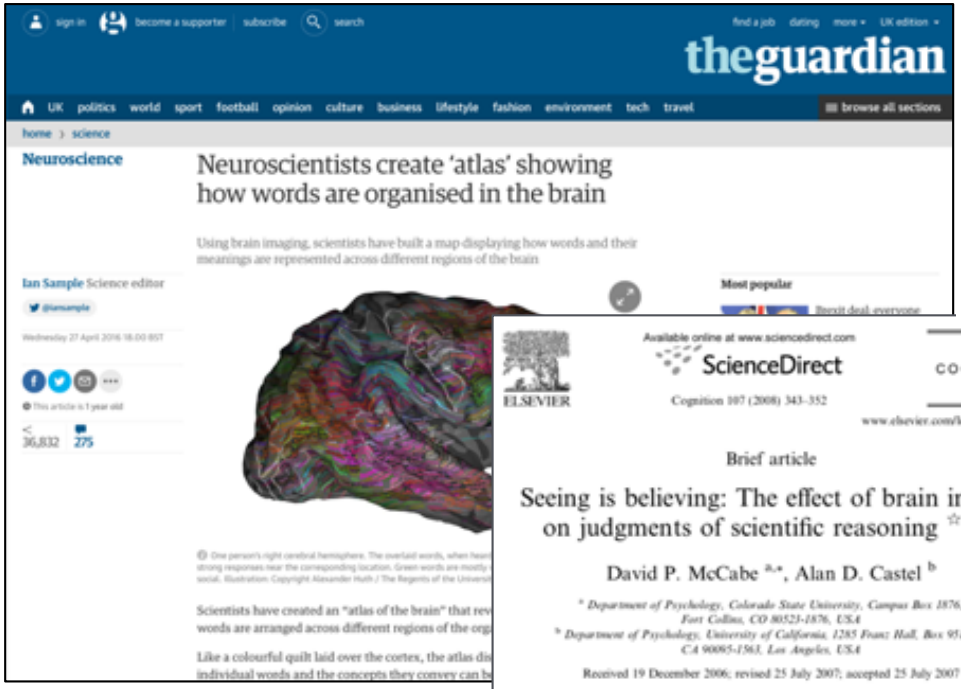
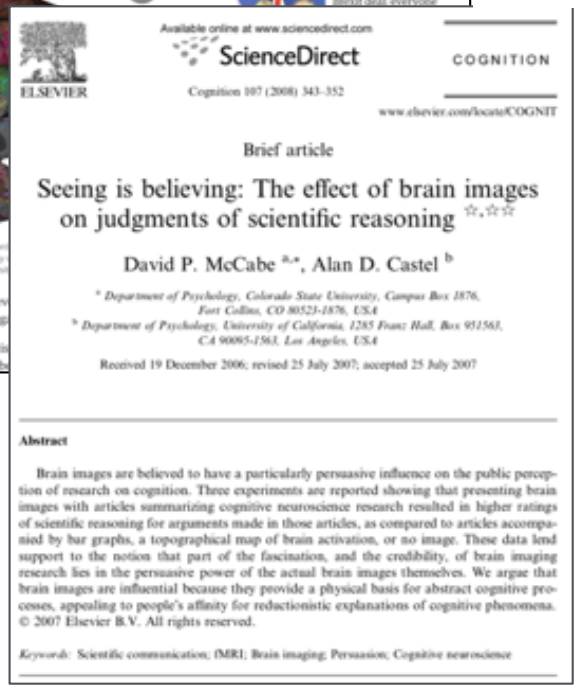
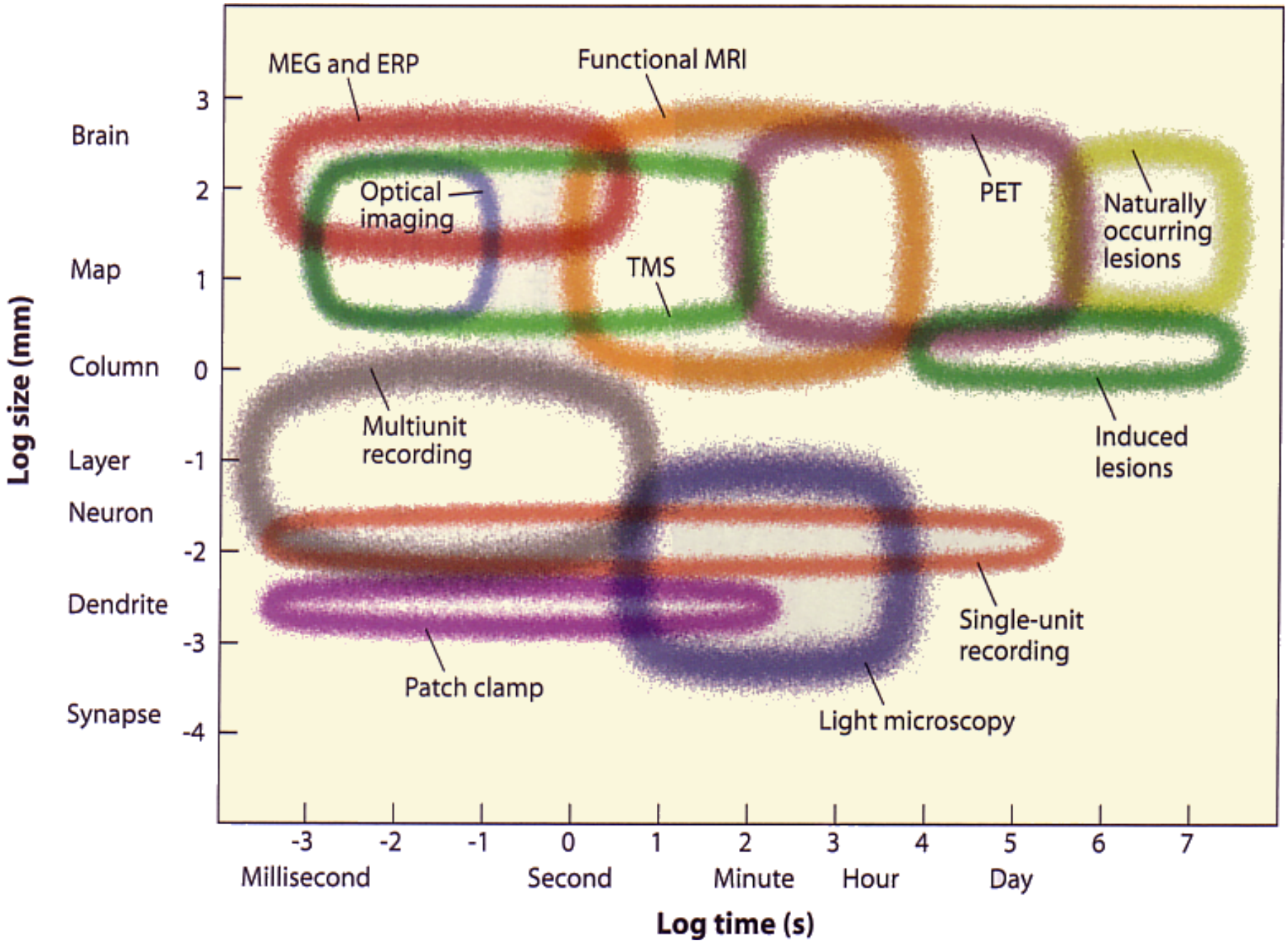


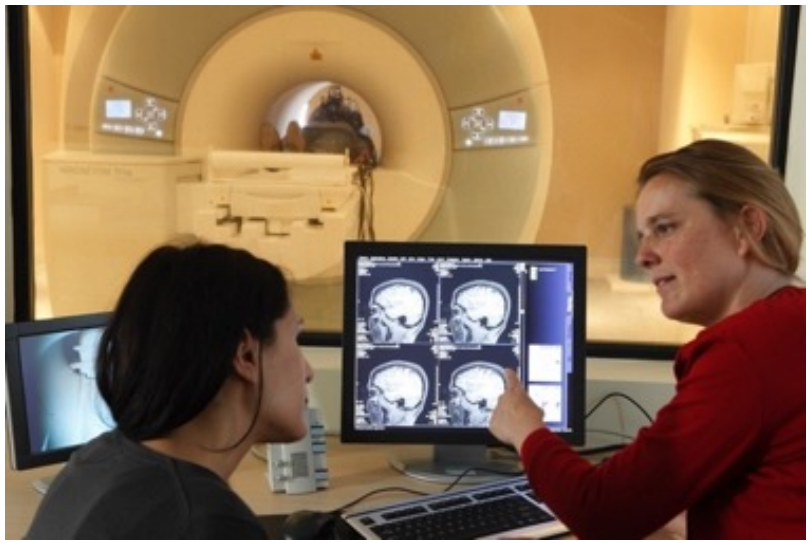




Gazzaniga, Ivry, & Mangun (1998)


MAGNETOM Prisma
A Tim+Dot System
SIEMENS

fMRI is at its infancy



1946 Block & Purcell finds that atoms absorb and re-emit RF energy (Nobel Prize laureates)

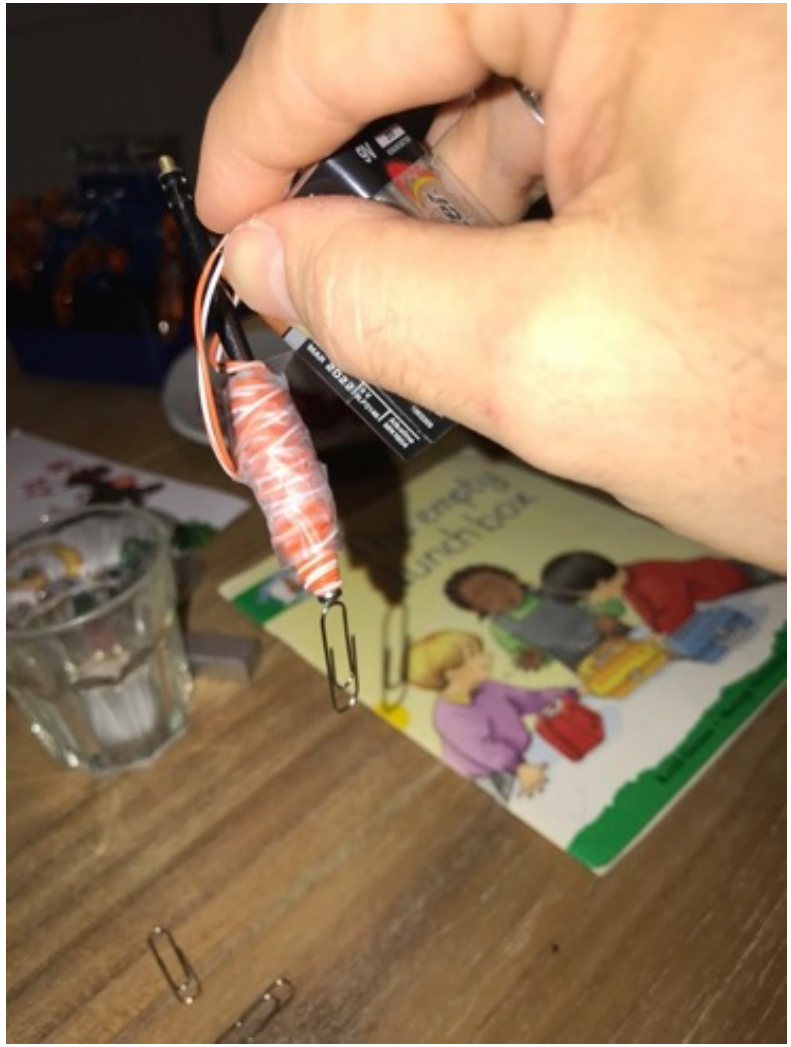
1971 MRI is used to detect tumors

1977 Clinical MRI patented + Echo-Planar Imaging (EPI)

1990 Ogawa reports Blood Oxygenation Level Dependent (BOLD) effects

1992 Ogawa et al. and Kwong et al. report first fMRI results

A coil is an electric wire wrapped up in a particular way.



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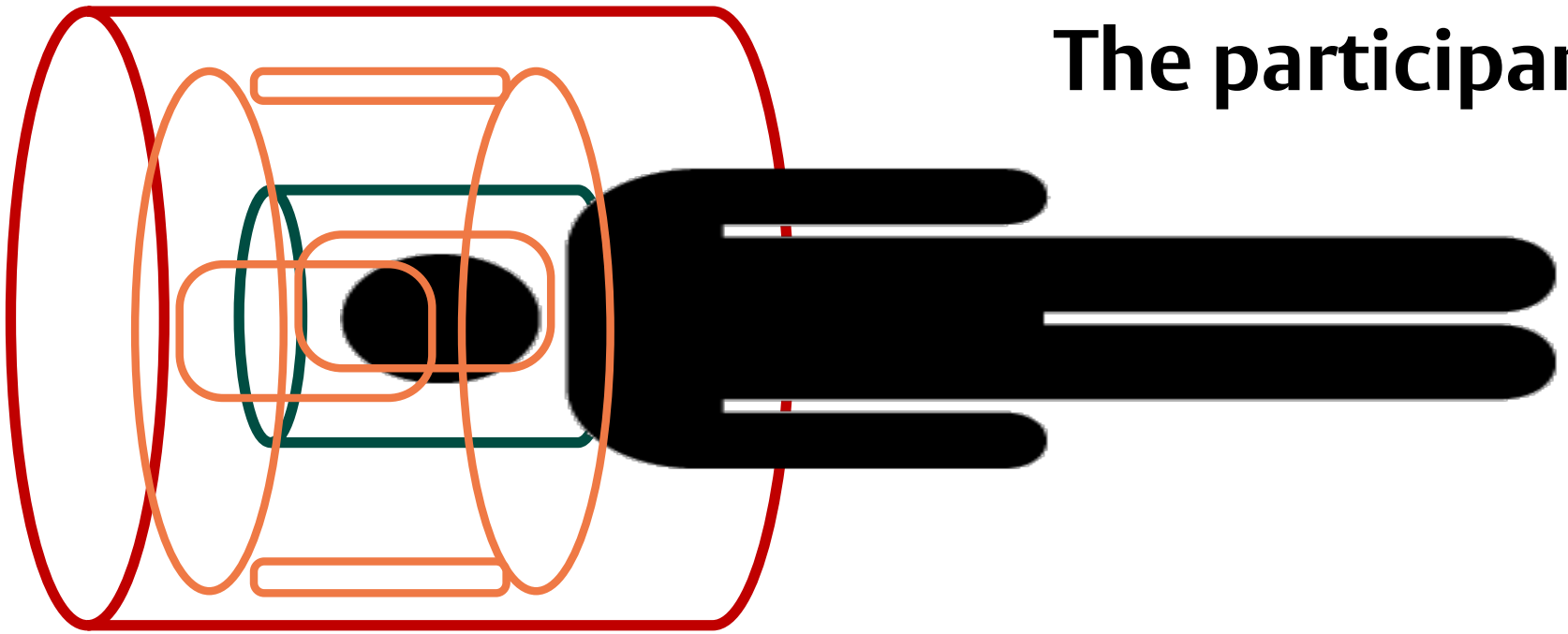
The magnet (main coil)
The gradient coils
The RF coil / antenna (1-64 channels)



A typical scanner creates a magnetic field 60,000 times stronger than that of the Earth.

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This field is referred to as the "main field", or simply "B_0"

Earth's magnetic field is 0.5 Gauss

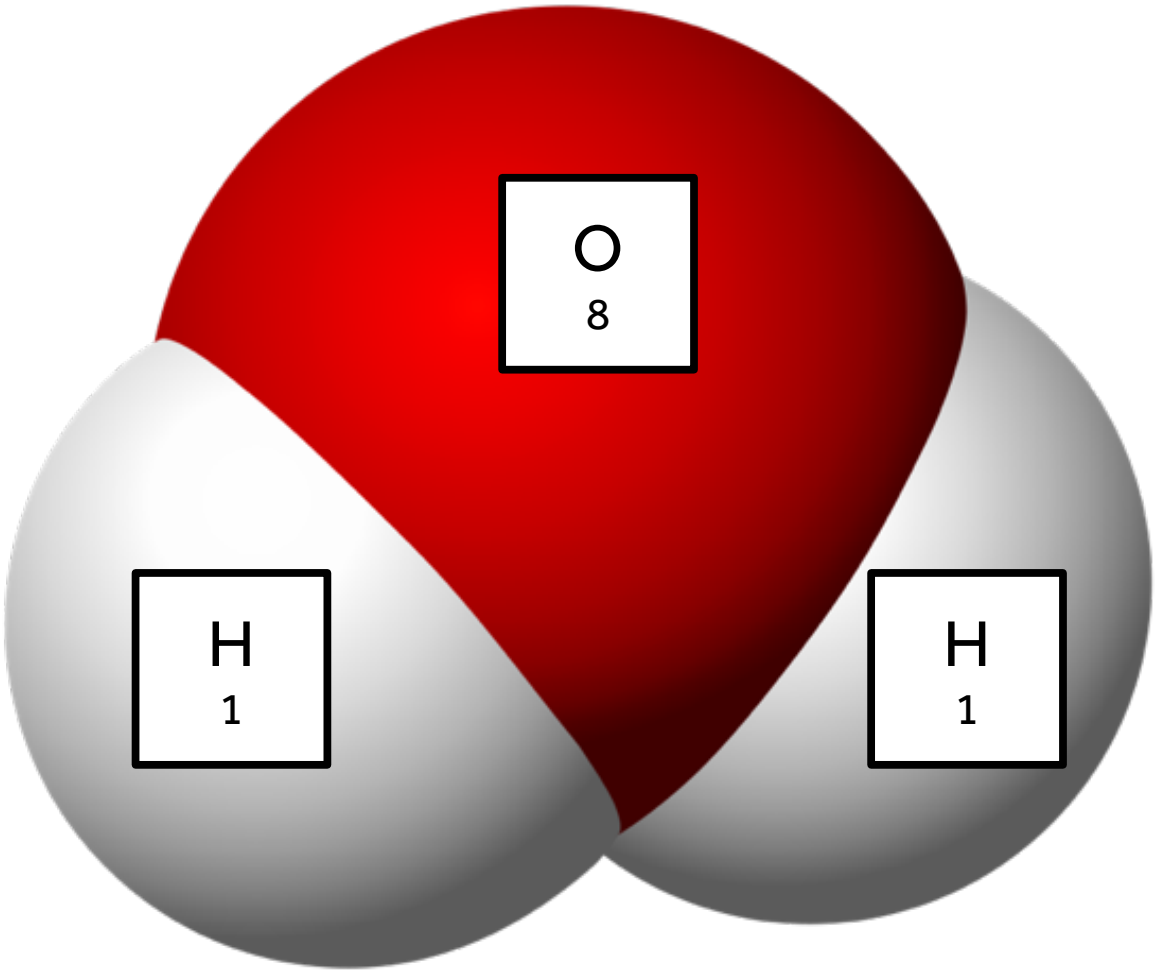
1 Tesla (T) = 10,000 Gauss

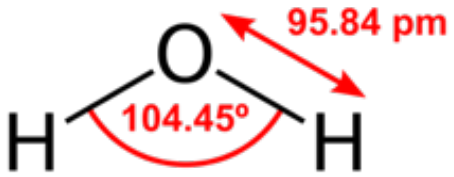
3T = 60,000 Gauss

The human brain's intrinsic magnetic field is 10^{-9} to 10^{-8} Gauss

$$\frac{1}{1{,}000{,}000{,}000} = 0{,}000000001 \text{ Gauss}$$

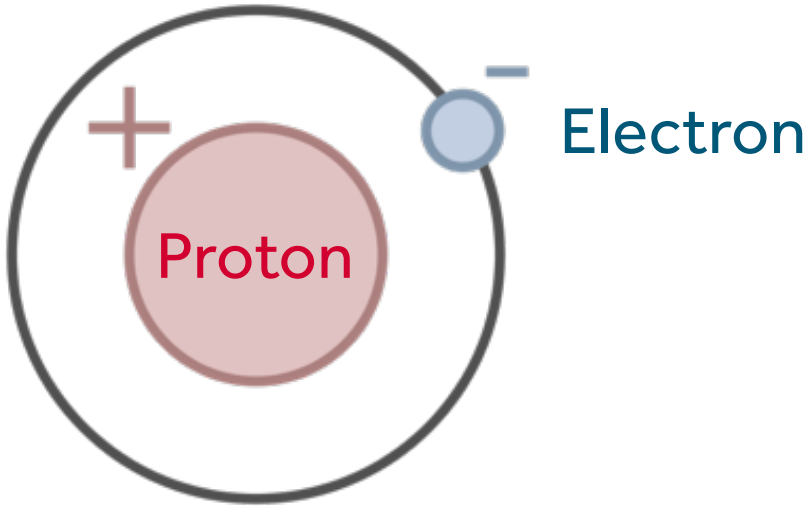
Water (H2O) has magnetic properties.





https://simple.wikipedia.org/wiki/Water_(molecule)

An atom of Hydrogen has 1 proton.

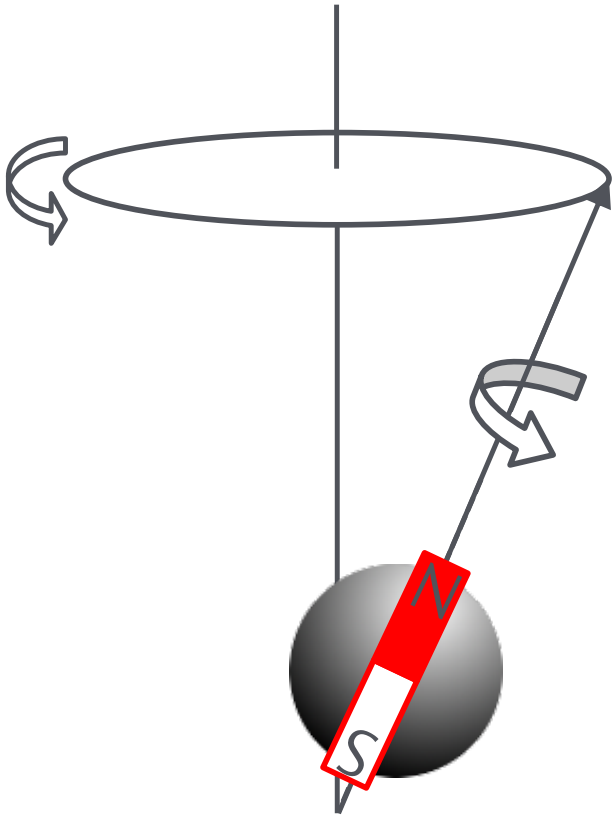


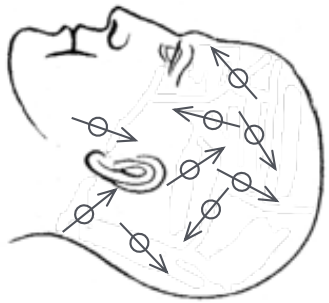
A proton is typically represented as a rotating sphere with a polarity.

By placing a proton inside an external magnetic field (B_0)...

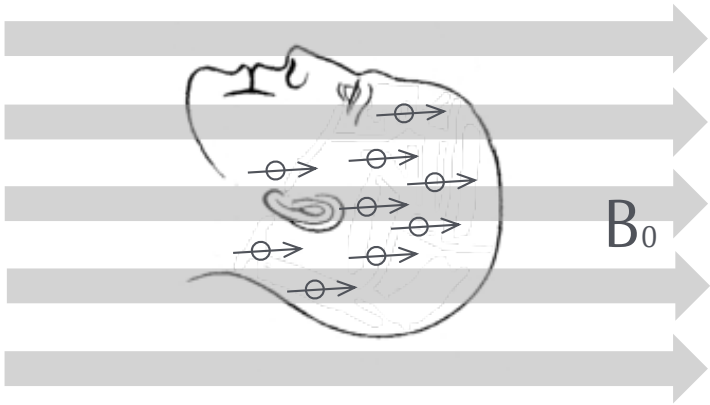
.. we can measure the energy emitted by their "spins"

... and estimate physical properties that represent the orientation, frequency of the rotations, etc



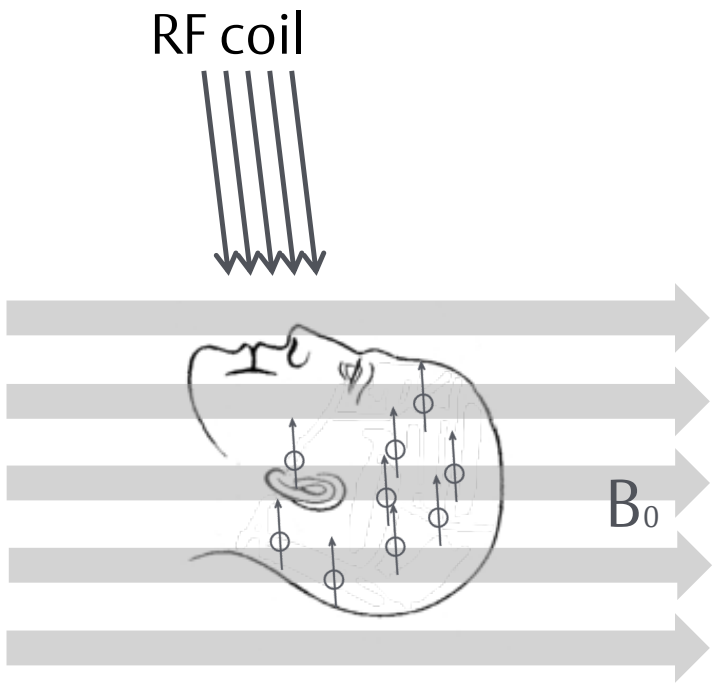


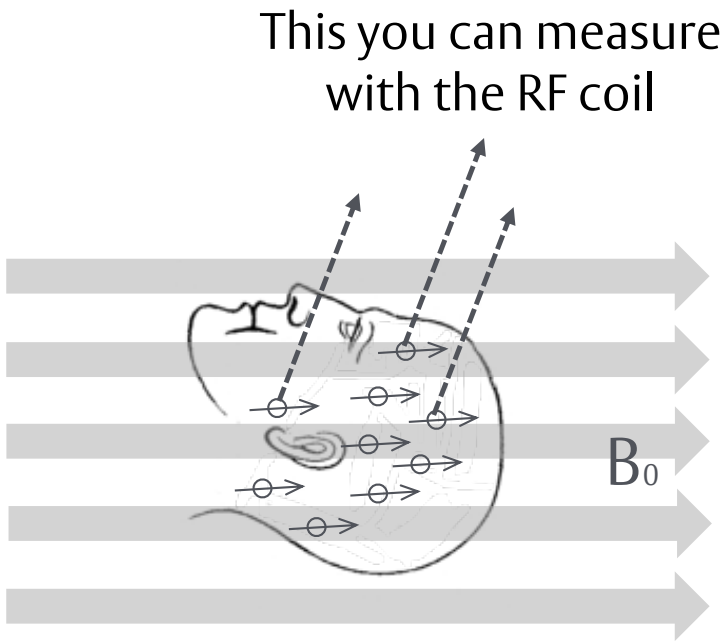
Outside a magnetic field, protons are oriented randomly



When you put a material (like a brain) in an MRI scanner, some of the protons orient themselves with the magnetic field (B_0).

The RF coil is turned on/off rapidly, and the energy emitted is measured





When you apply radio waves (RF pulse) at the appropriate frequency, you can change the orientation of the spins as the protons absorb energy.

After you turn off the radio waves, as the protons return to their original orientations, they emit energy in the form of radio waves.

The RF coil is turned on/off rapidly, and the energy emitted is measured

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"T1 weighted relaxation" (structural) refer to the period of time when spins align from B_0 to the orientation of the RF coil.

The RF coil is turned on/off rapidly, and the energy emitted is measured

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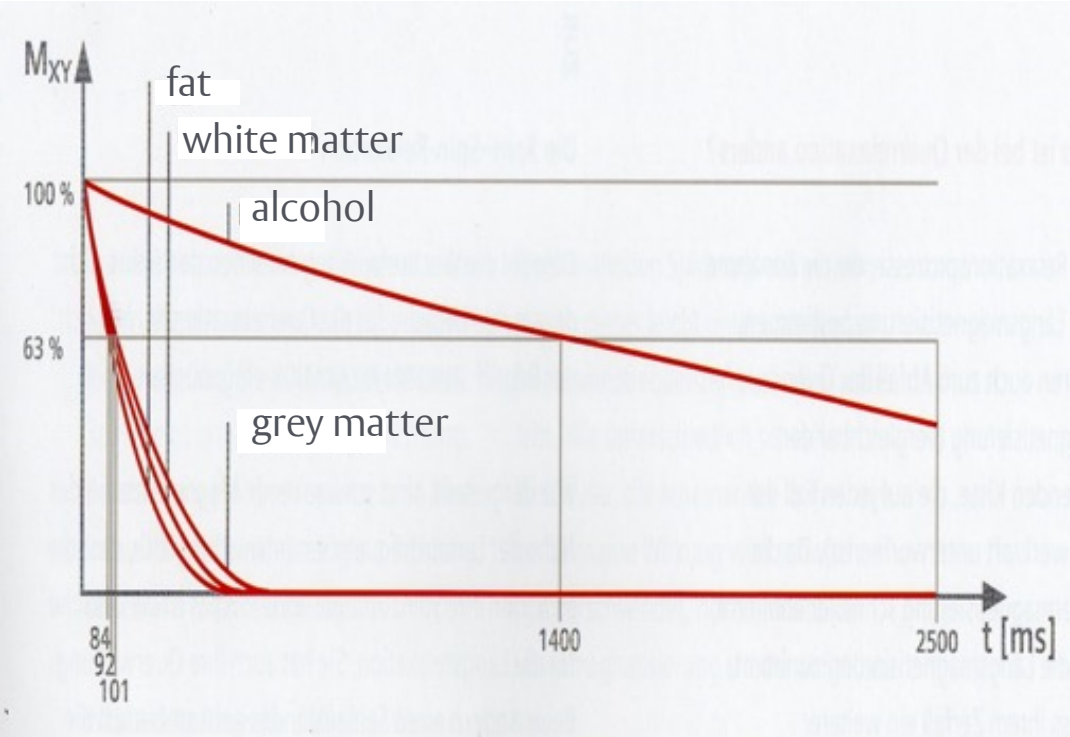
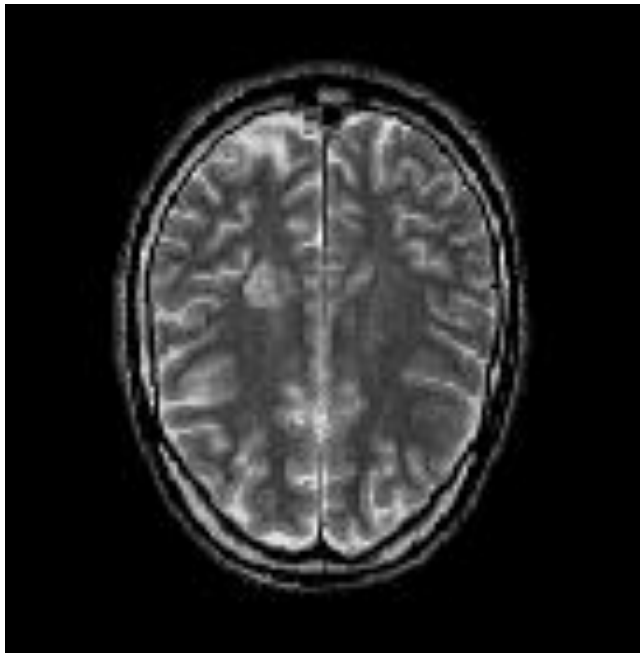
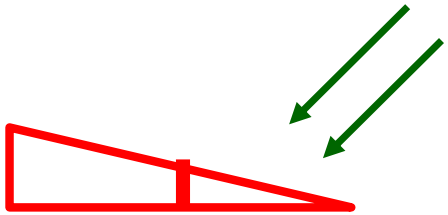
"T2 weighted relaxation" (T2*) refer to the period of time when spins go back to their natural momentum.

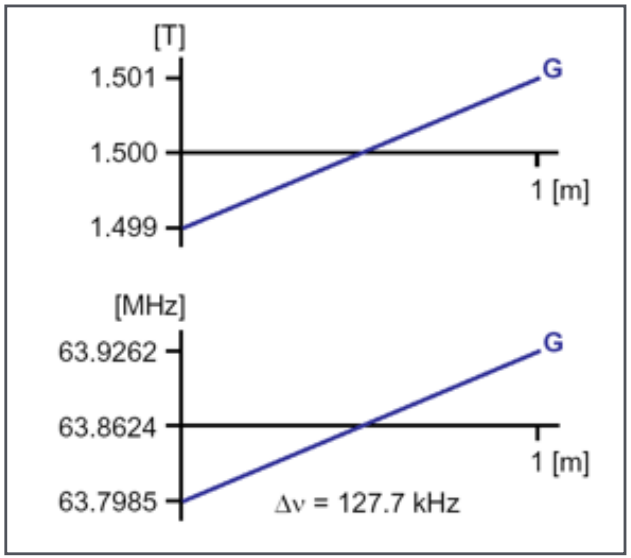


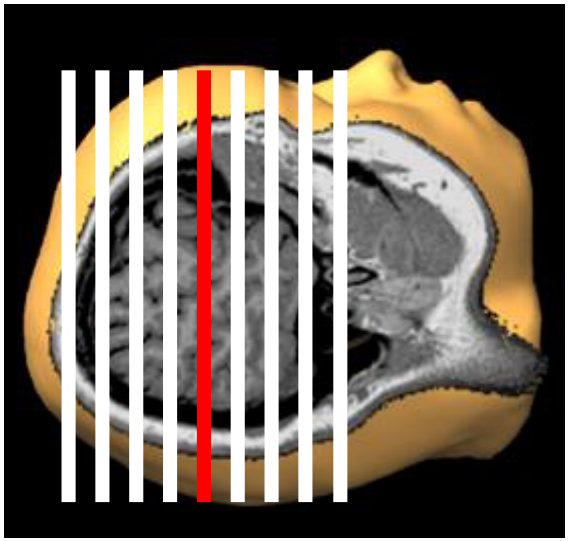


Slice selection is achieved by adding a gradient field (G_s)

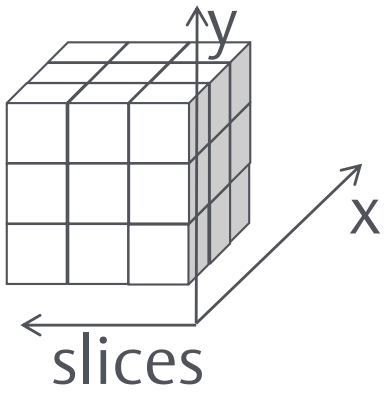


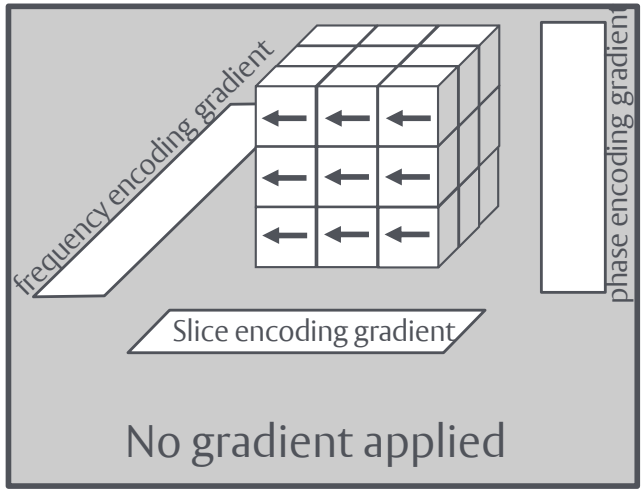
RF pulses
at Lamorfrequency

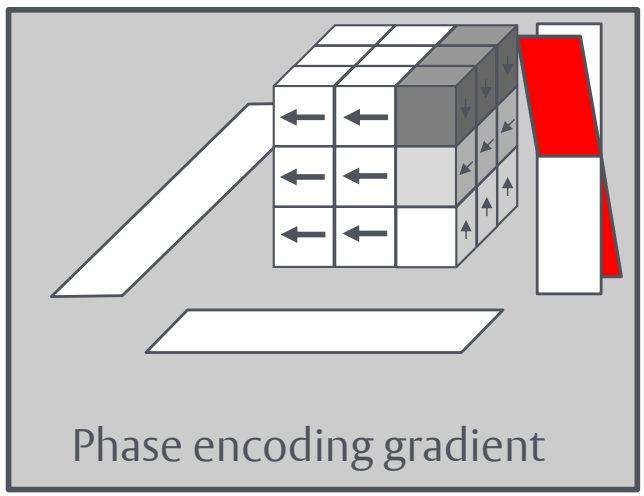


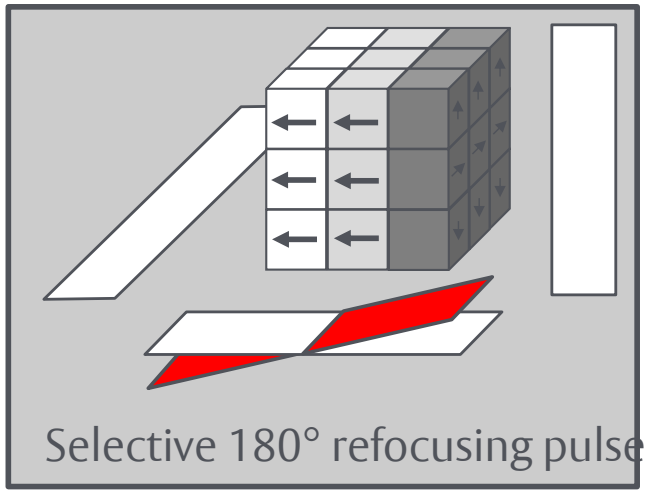


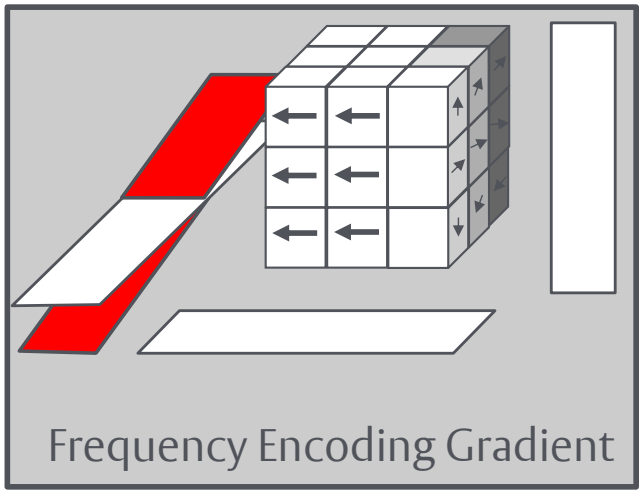
Applying several gradient fields allows the stimulation of slices and voxels











Blood Oxygenation Level Dependent is a proxy for oxygenation in the blood

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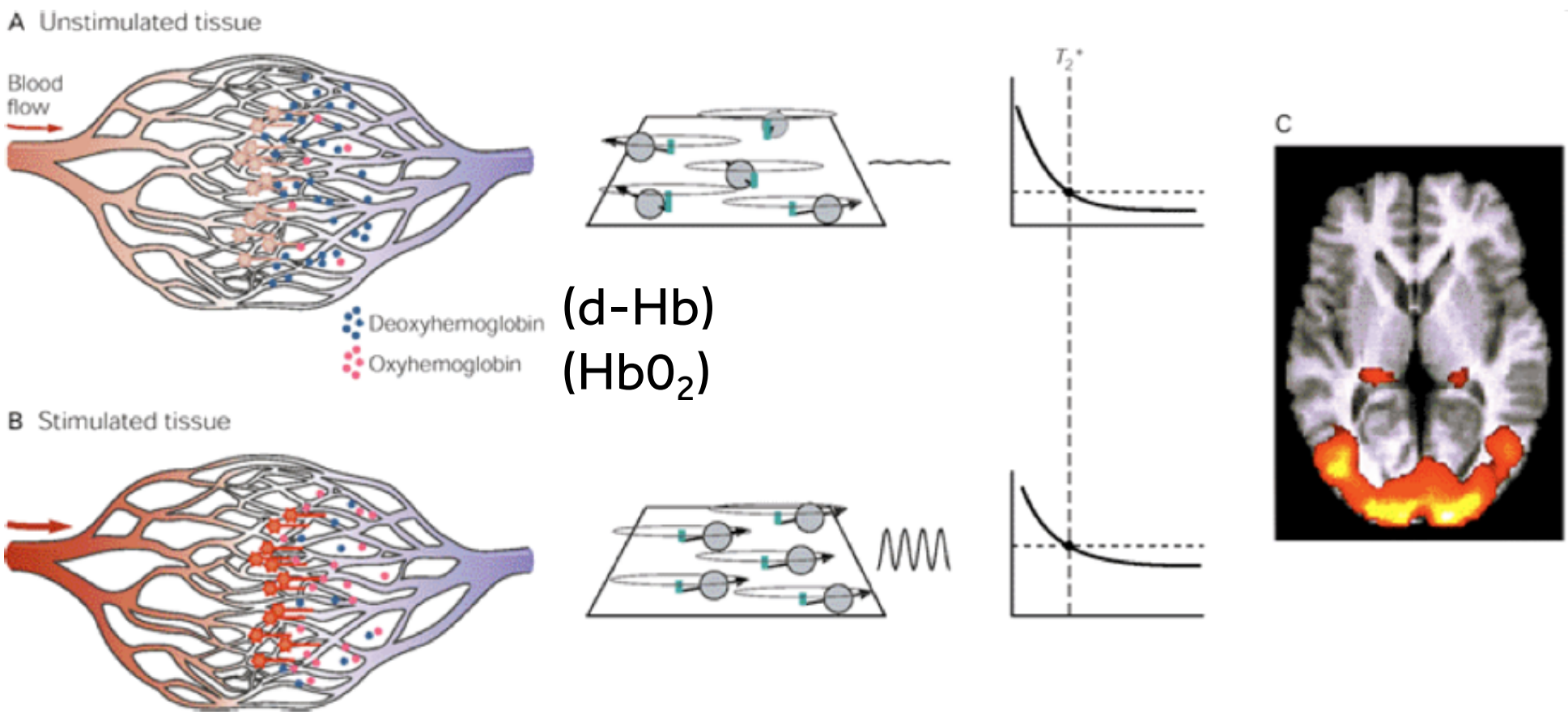
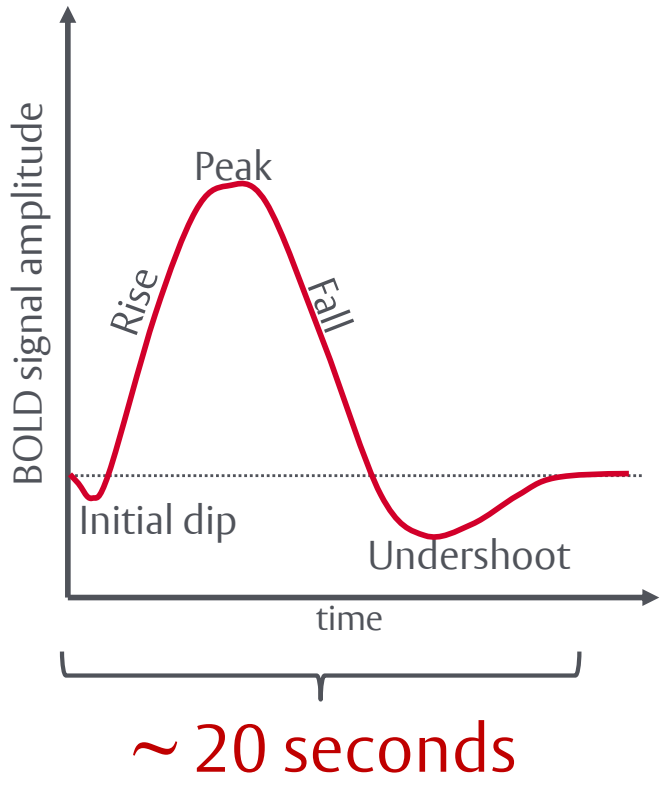


(d-Hb)

($Hb0_2$)

The Hemodynamic Response Function depicts a typical course of BOLD signal

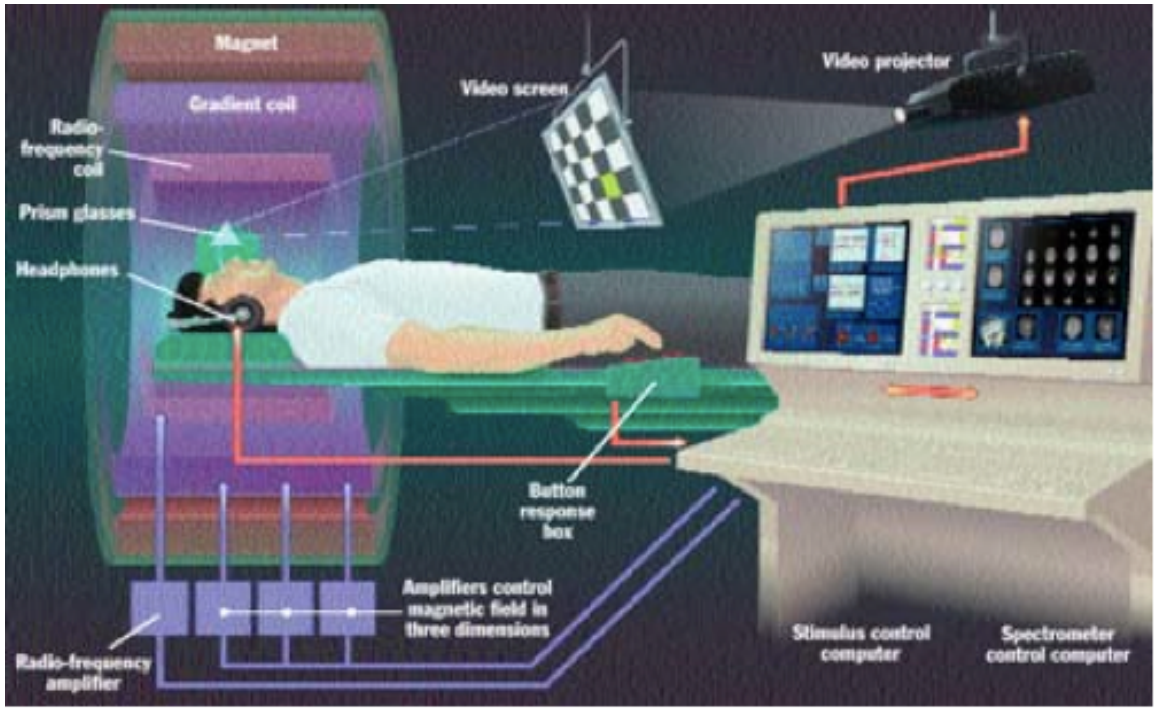


Initial dip: Transient increase in oxygen consumption, before change in blood flow

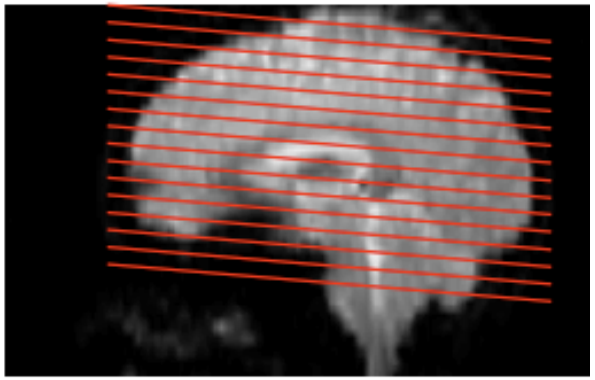
Rise: Results from vasodilation of arterioles, resulting in a large increase in cerebral blood flow

Peak: Over-compensatory response; More pronounced in BOLD signal measures than flow measures

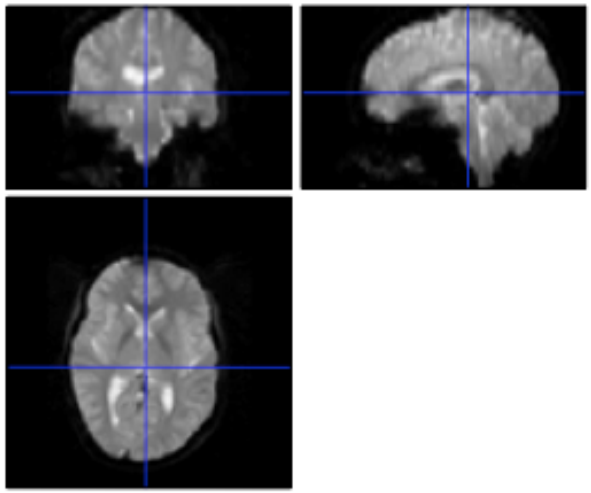
Undershoot: Slow cerebral blood flow recovery

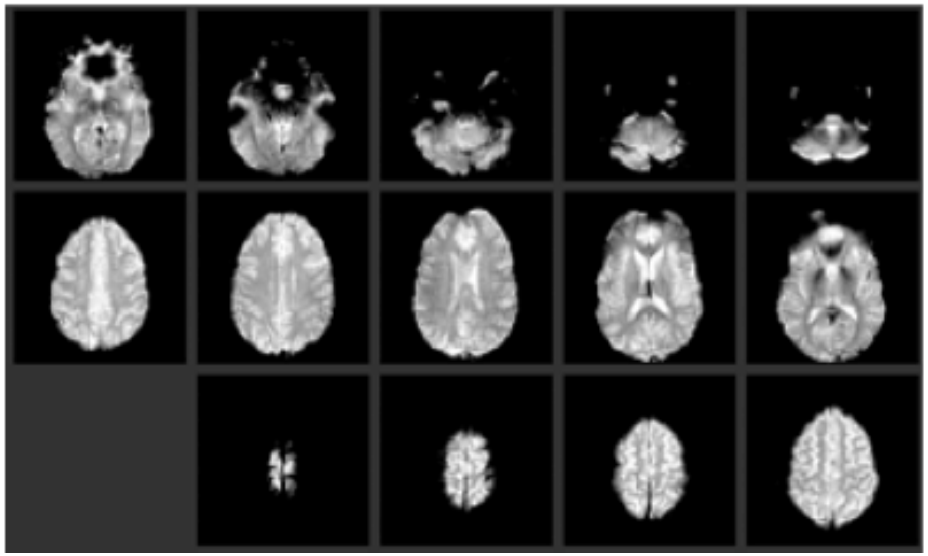


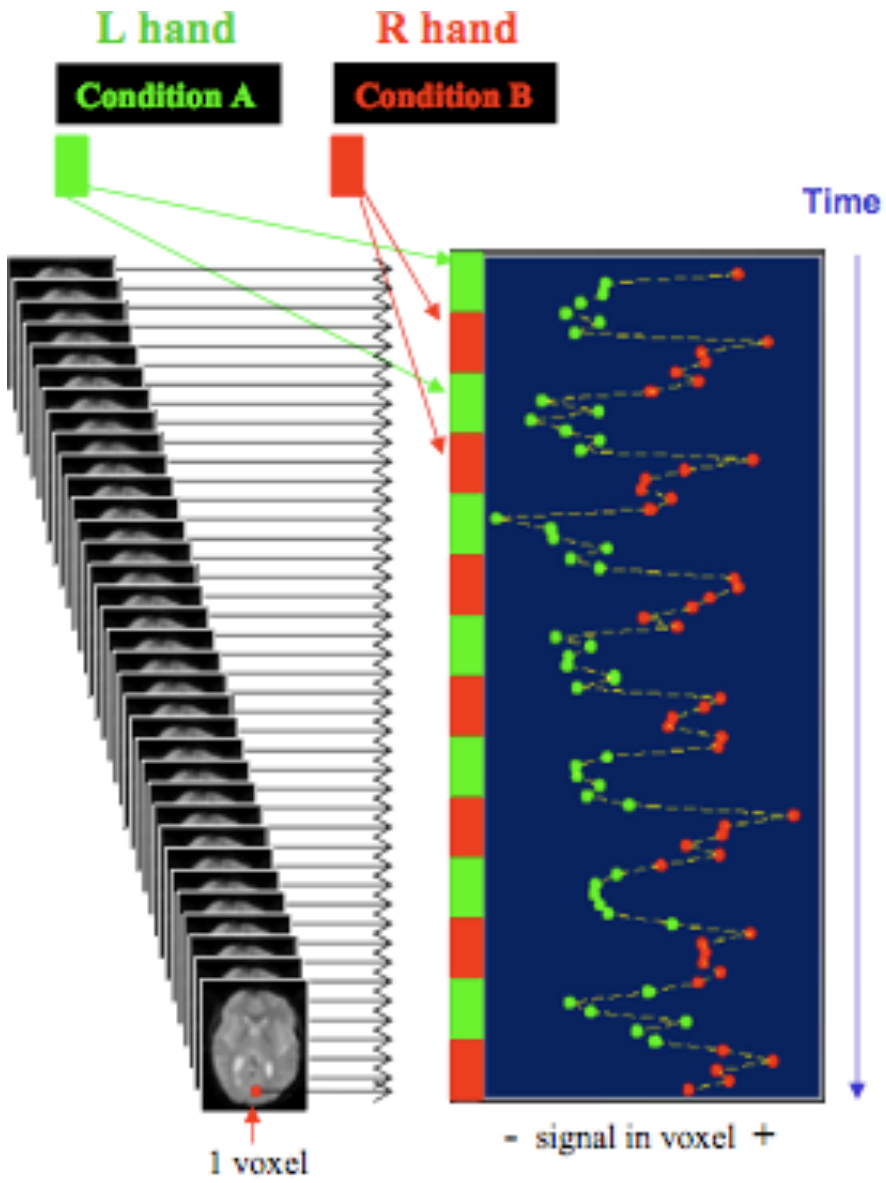
EPI, T2*

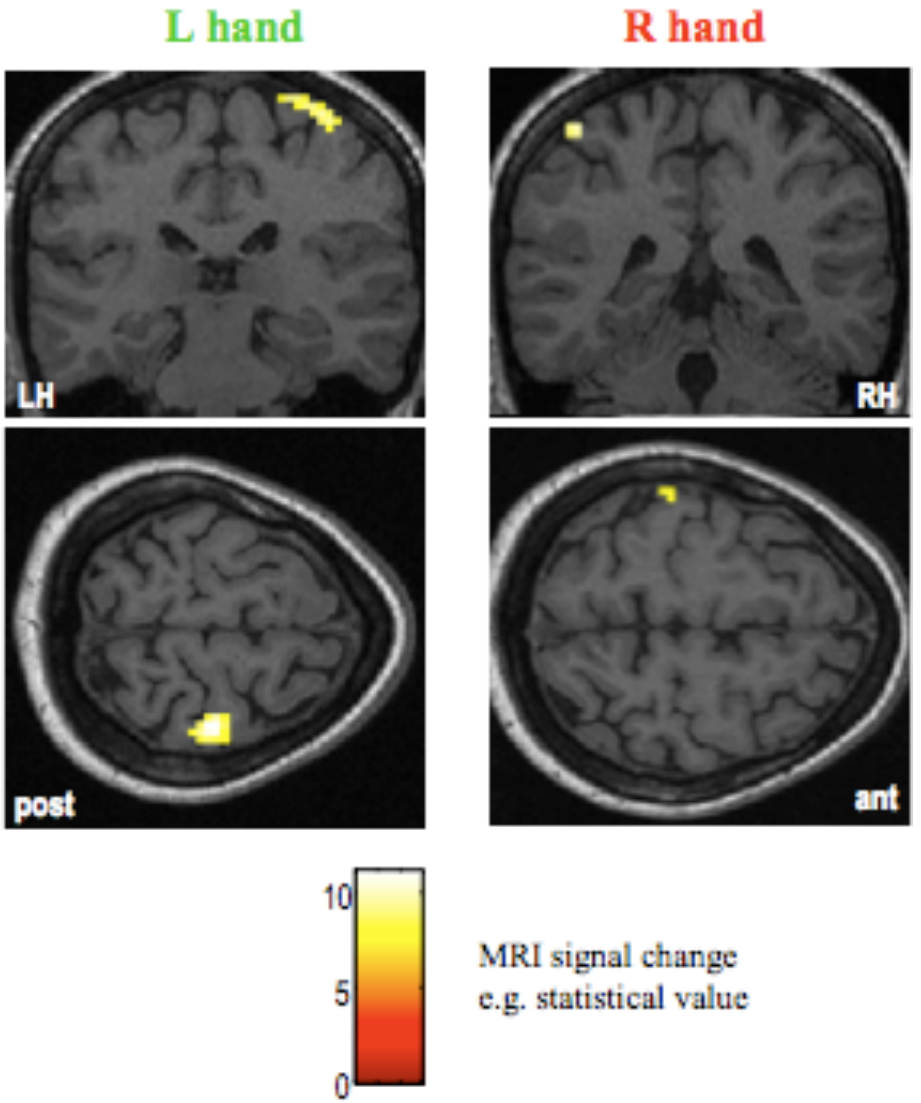


1 volume = 1 TR
(repetition time, ~2 sec)
= 20-40 slices









What I would like you to remember (1/2)

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- fMRI offers a unique opportunity to glance at what's happening inside the brain.
- It is as complex as academic research can be, but **no more**.
- To make good use of fMRI as a research tool you must free yourself from the anxiety that comes from glancing at something awesome.

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fMRI: The method & its applications


PARENTAL
ADVISORY
EXPLICIT CONTENT


Attention
Memory
Motivation
Reasoning
Self
Event
Relevance
Implication
Coping
Normative Significance
Appraisal processes
Novelty (Suddenness, Familiarity, Predictability)
Intrinsic Pleasantness
Goal/need relevance
Causality: agent
Causality: motive
Outcome probability
Discrepancy from expectation
Conduciveness
Urgency
Control
Power
Adjustment
Internal standards compatibility
External standards compatibility
Autonomic physiology
Action tendencies
Motor expression
Subjective Feeling
Time
20-16 =4
C=80
9=√4=2
x18 12 36
12:x=3:y x=8
43659

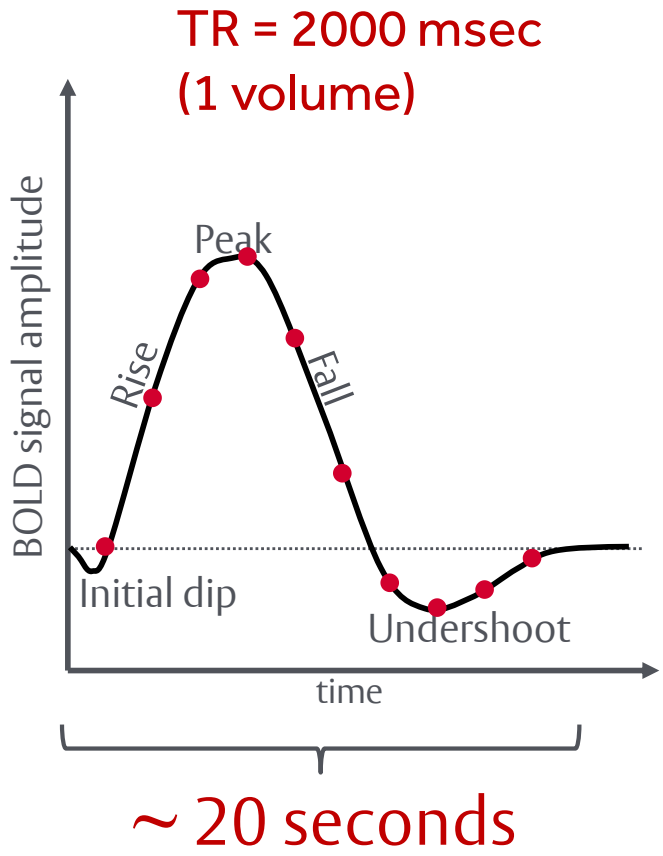
1. What are some of the limits of the method?
   - Hardware/workflow limits
   - Philosophical limits
   - Logical limits
   - Mathematical/Statistical limits
   - Human limits
   - …

2. Is this…. good for us? Hell yeah!

First, I am assuming that we can study the mind-brain problem with fMRI

The Hemodynamic Response Function depicts a typical course of BOLD signal

(notwithstanding we don't know if it signals the cause or the consequence of brain activation)



Initial dip: Transient increase in oxygen consumption, before change in blood flow

Rise: Results from vasodilation of arterioles, resulting in a large increase in cerebral blood flow

Peak: Over-compensatory response; More pronounced in BOLD signal measures than flow measures

Undershoot: Slow cerebral blood flow recovery

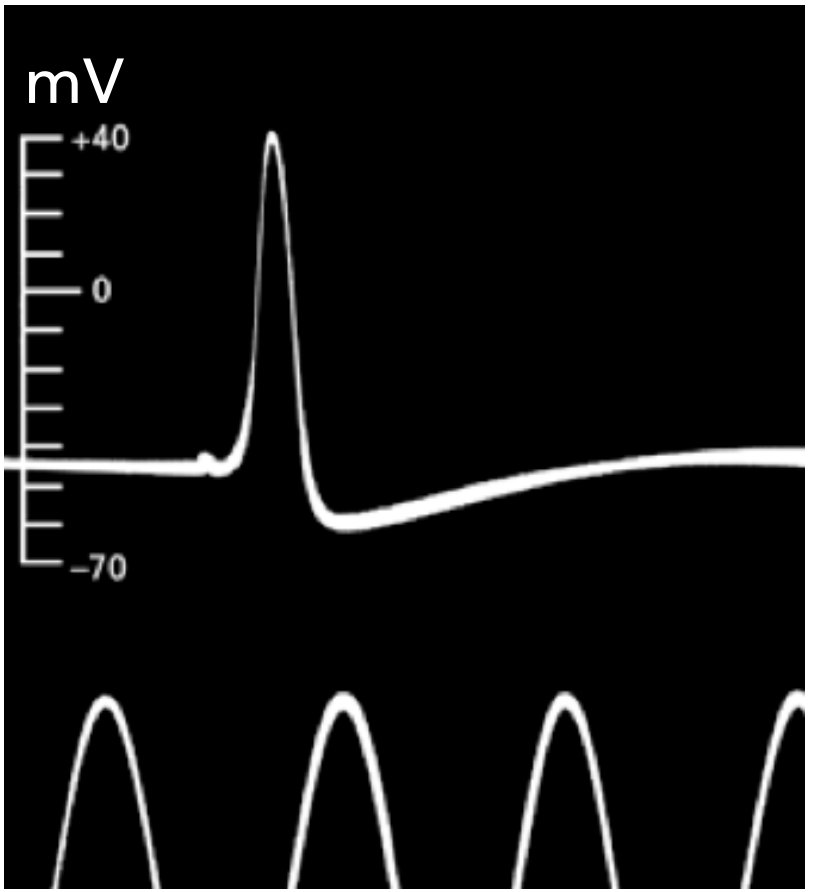
Is BOLD the whole story?

Neurons are connected in networks

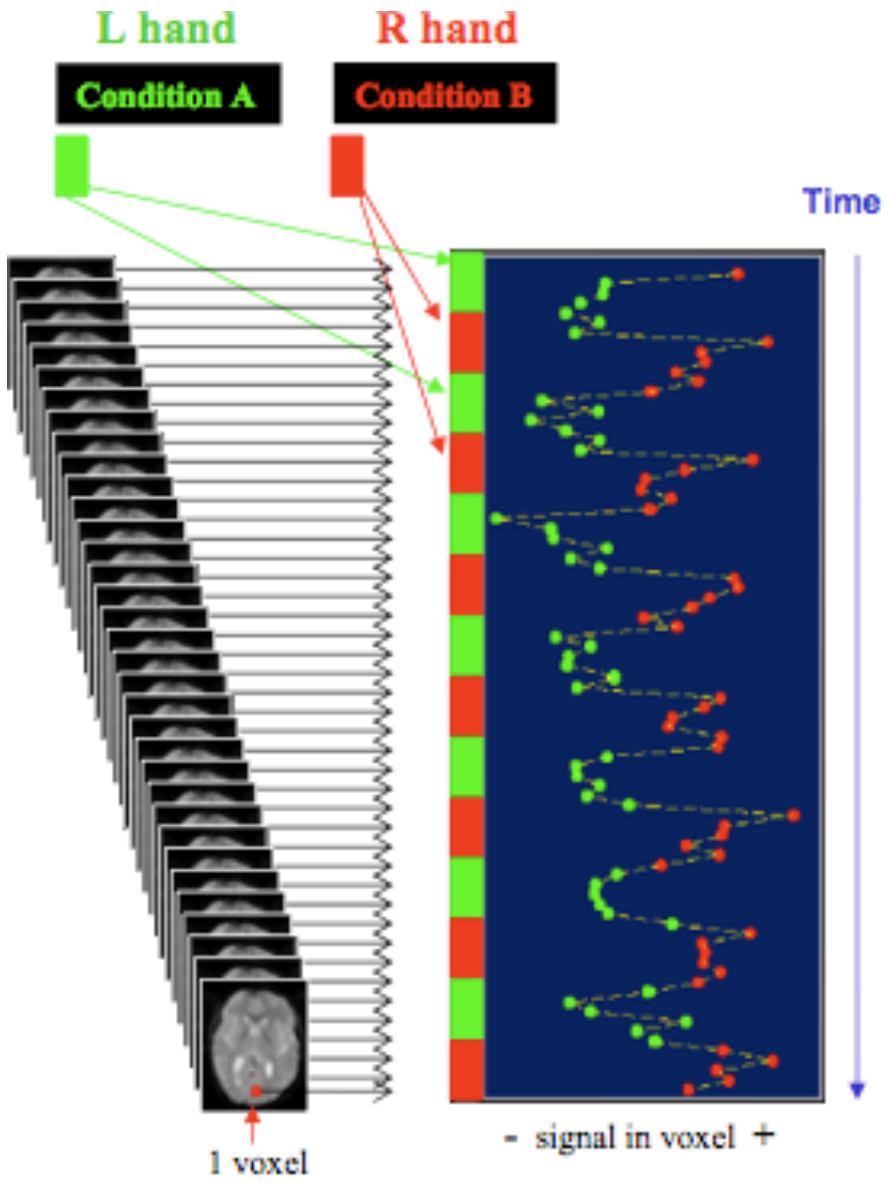
Neurons often communicate by creating bursts of electrical potential

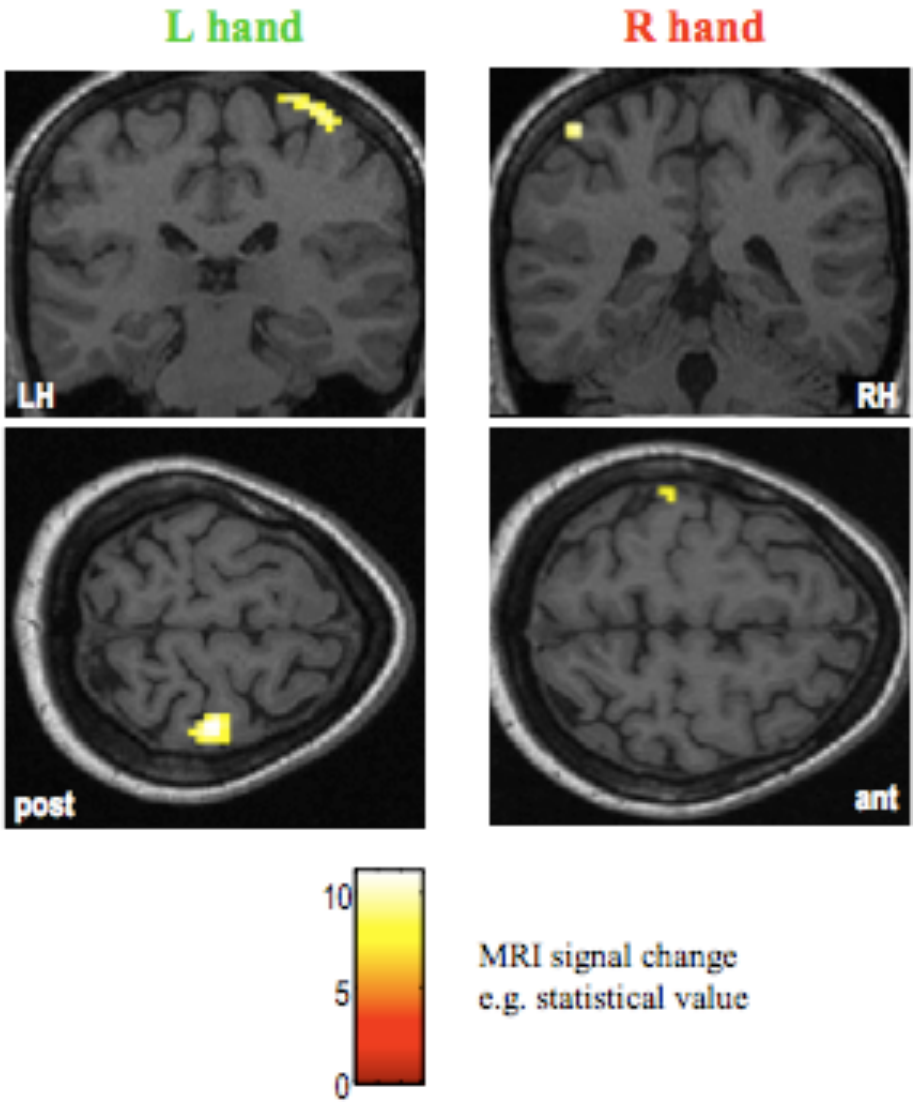
An Action Potential lasts 1 msec

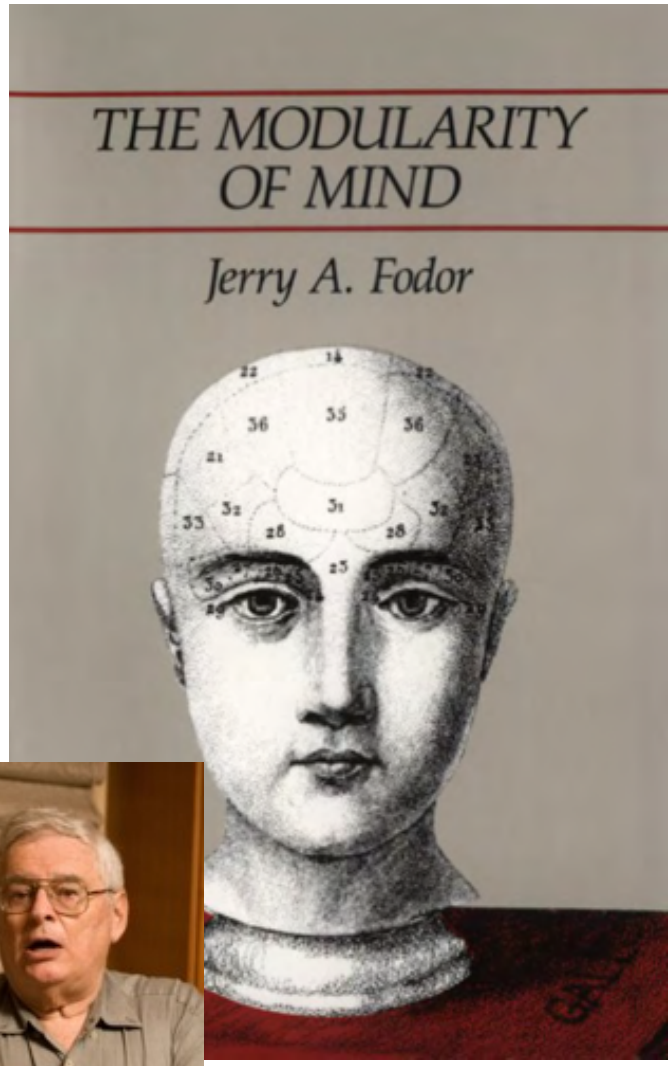
- 20,000x shorter than HRF cycle
- 2,000x shorter than 1 volume (TR)

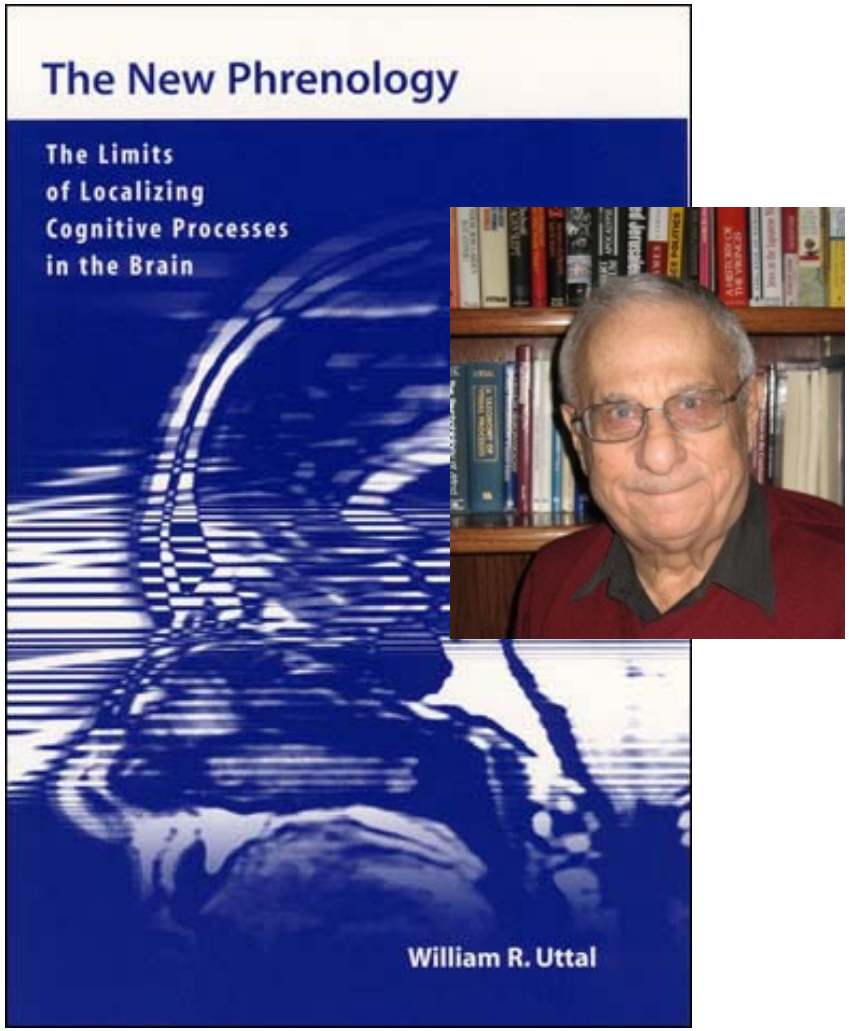


Hodgkin & Huxley (1952). J. Physiology.

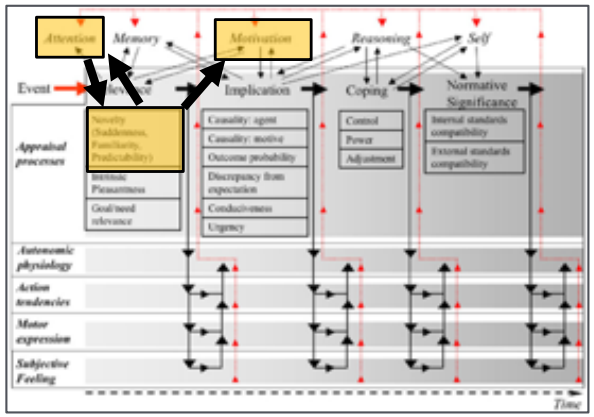





THE MODULARITY OF MIND
Jerry A. Fodor


The New Phrenology
The Limits of Localizing Cognitive Processes in the Brain
William R. Uttal

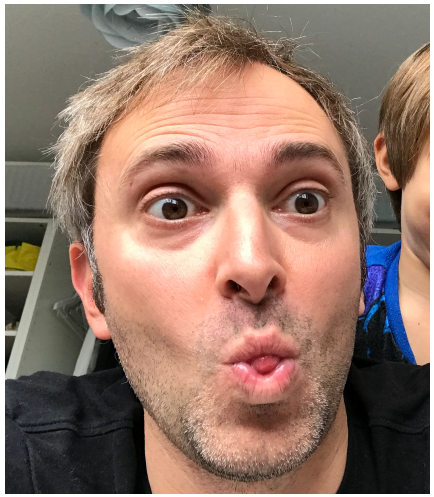
The typical inference considers that a cognitive process → brain activation



therefore...

We are doing exactly the reverse..
brain activation → cognitive process?

Poldrack (2006). Trends in Cognitive Sciences.



Physicists were excited to poke the limits of physics. Let's embrace the limits of cognitive neuroscience.

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- Intrinsic limits of the workflow
- Reverse inference

- Misuse of statistics (not necessarily maliciously)
  - Voodoo correlations (spurious correlations)
  - Data dredging (p-hacking and such)
  - Confirmation bias
  - ...

- Under-determination of the data
  - One-to-Many: One psychological process can be explained by a very large number of brain mechanisms.
  - Many-to-One: Many different parts of the brain may yield the same behaviour.

- Lack of replication – The literature is terribly inconsistent.


W e?

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What it?

What else?

How?

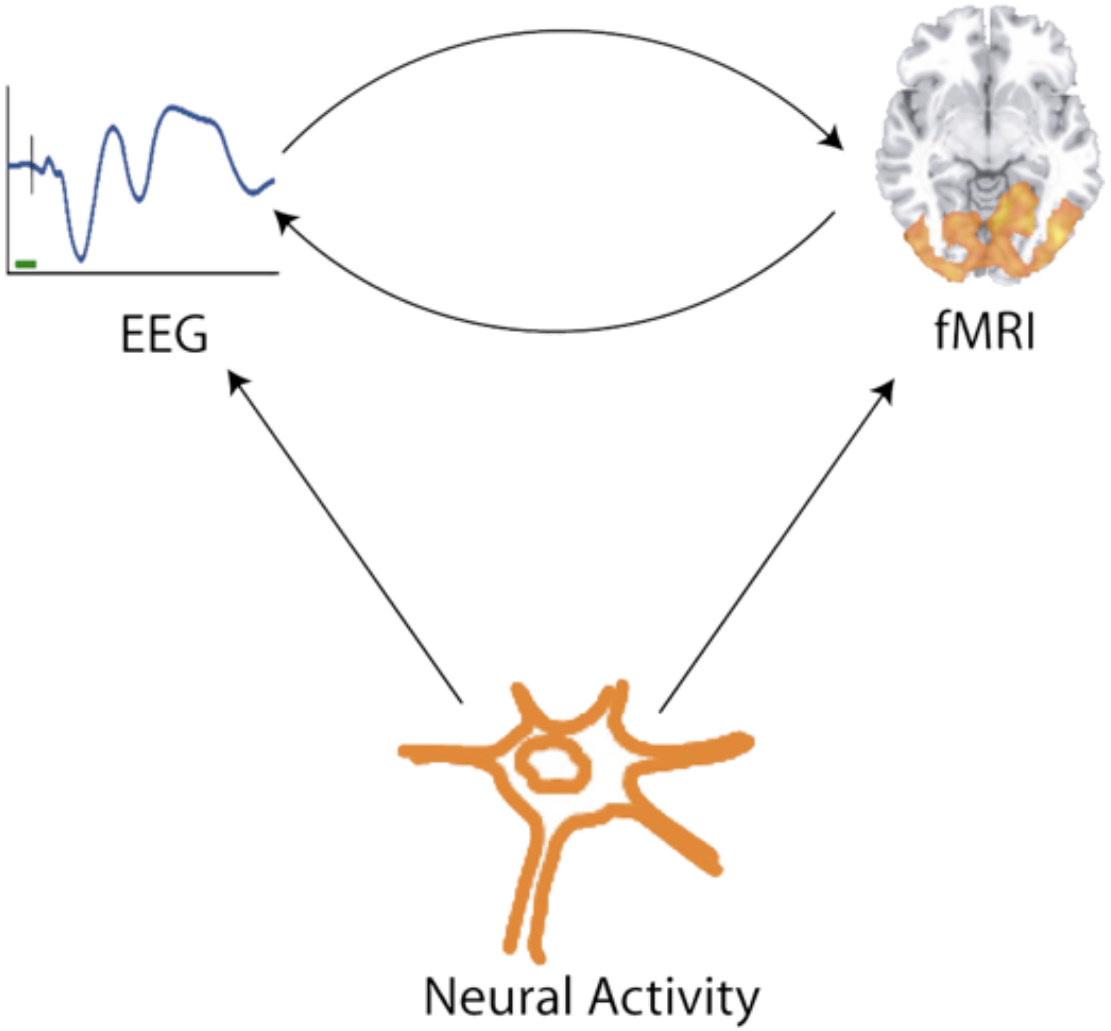
<fill in the blank>

How come?

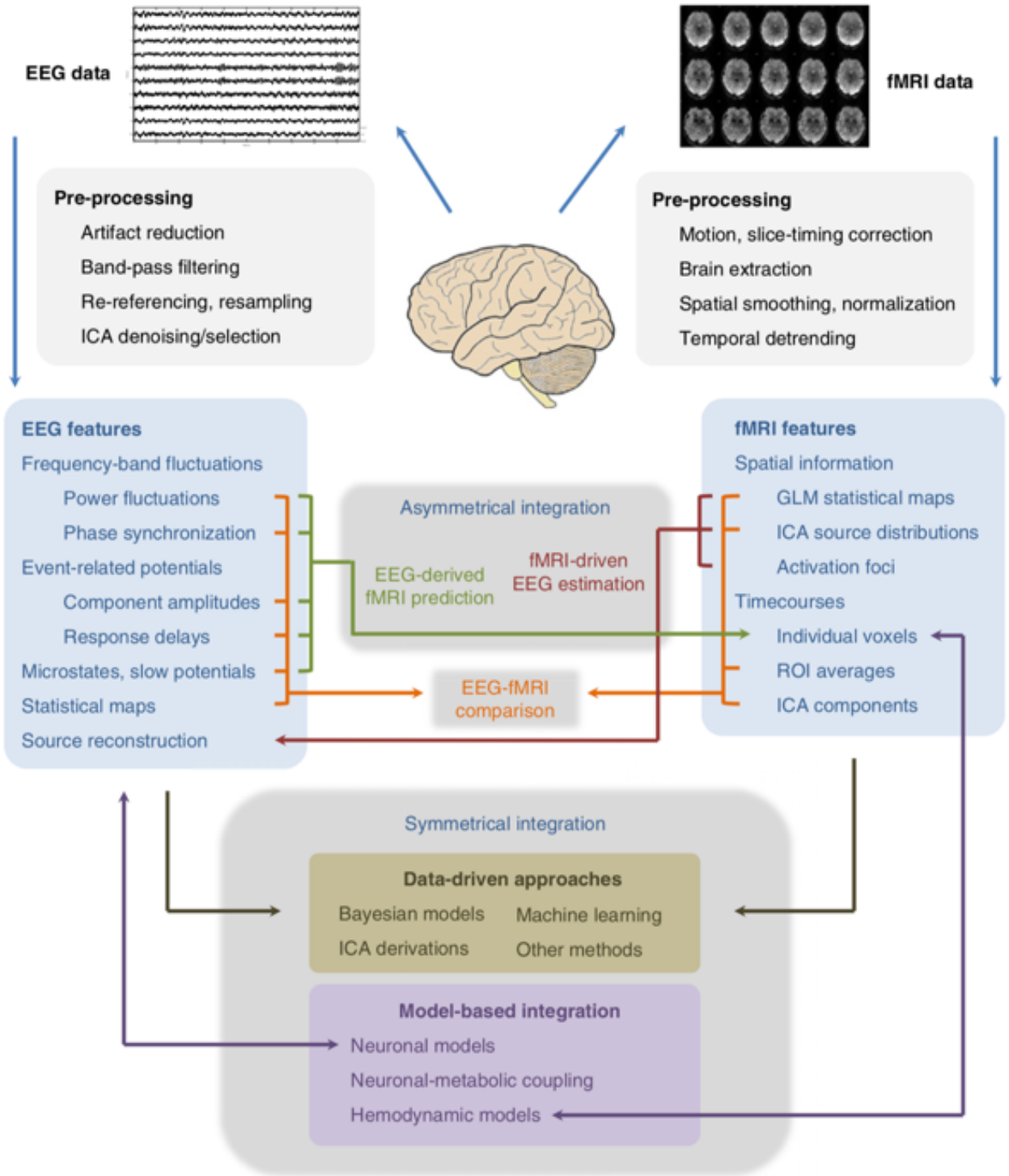
Why?

How much?

Joint EEG-fMRI is more than simultaneous recordings.



Jorge, van der Zwaag, & Figueiredo (2014). Neuroimage.



What I would like you to remember (2/2)

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- fMRI offers a unique opportunity to glance at what's happening inside the brain.
- It is as complex as academic research can be, but **no more**.
- To make good use of fMRI as a research tool you must free yourself from the anxiety that comes from glancing at something awesome.

- fMRI is young, and has limits, like any other tool. Embrace them.
- This is a good thing:
  - Rekindle with your curious inner scientist.
  - Think outside the box (and arrow), preregister hypotheses.
  - Make new friends. Learn new things. Build new ways.
  - Be critical. Don't take **anything** for granted.
  - Don't be impatient. Reproduce what you like.


Thank you for your attention!
Please keep in touch!
http://etienneroes.ch