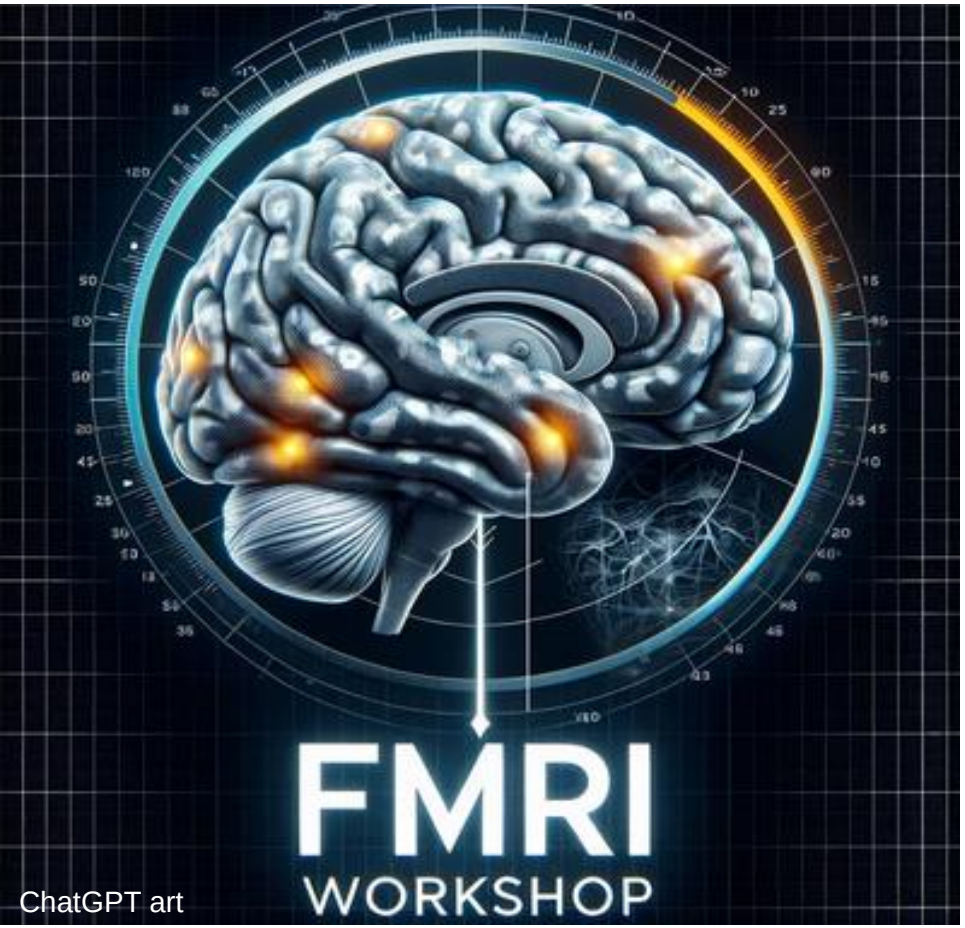
MRC Cognition and Brain Sciences Unit

UNIVERSITY OF CAMBRIDGE



ChatGPT art

Functional Magnetic Resonance Imaging

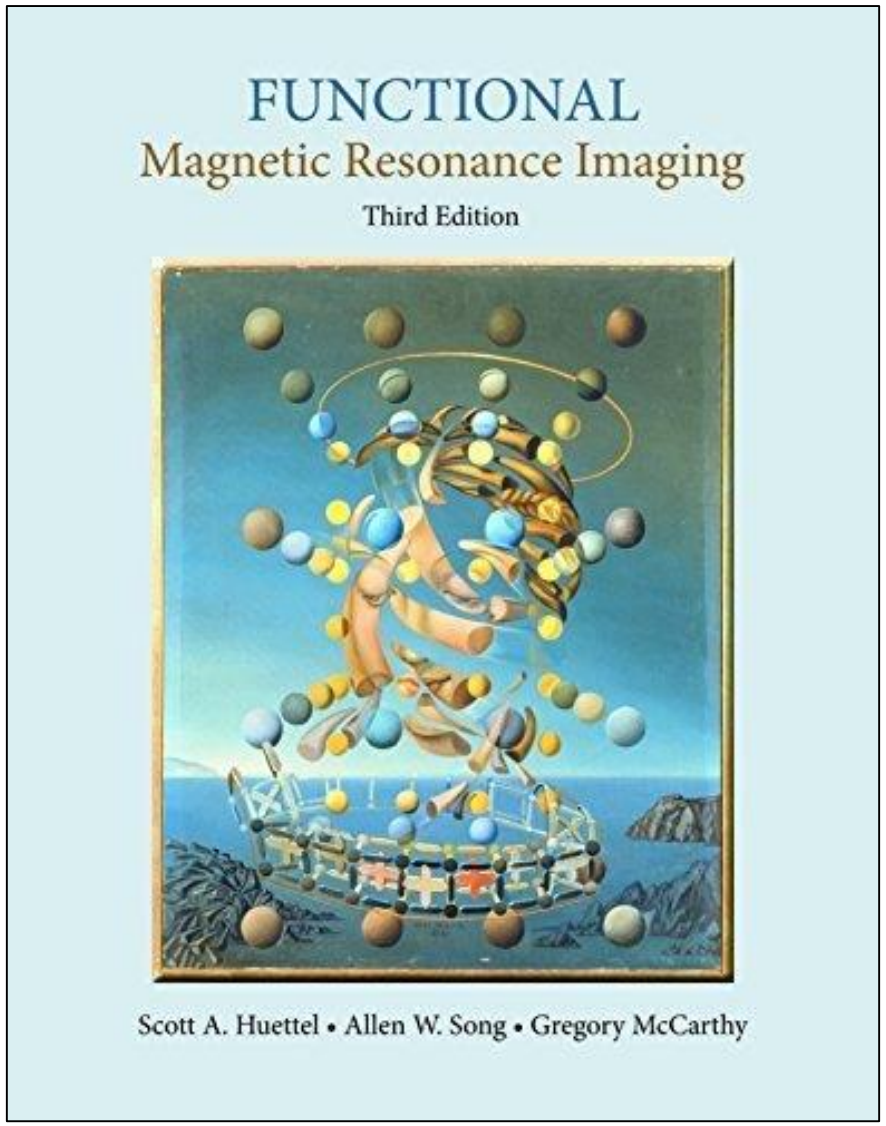
Dace Apšvalka

Winter, 2024

Outline

- Introduction
- Experimental design
- Data management
- Pre-processing
- Statistical analysis
- Practical demo

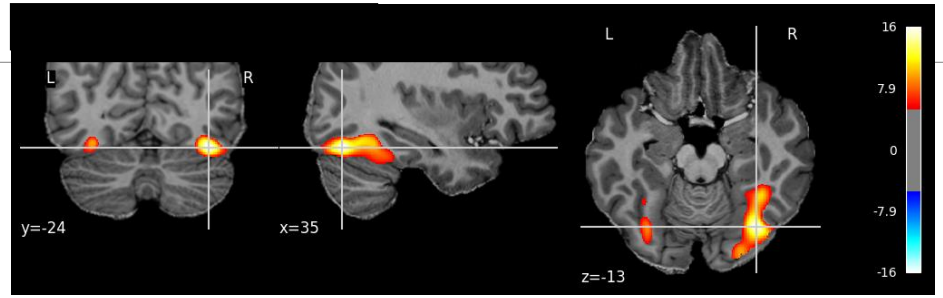
Recommended book



University of Cambridge Library link

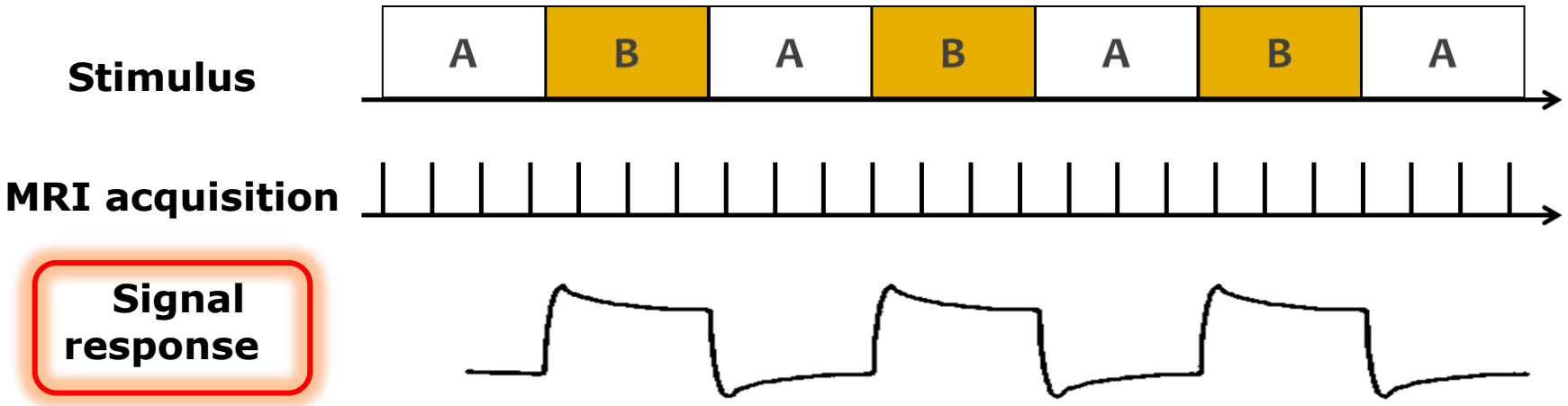
Introduction

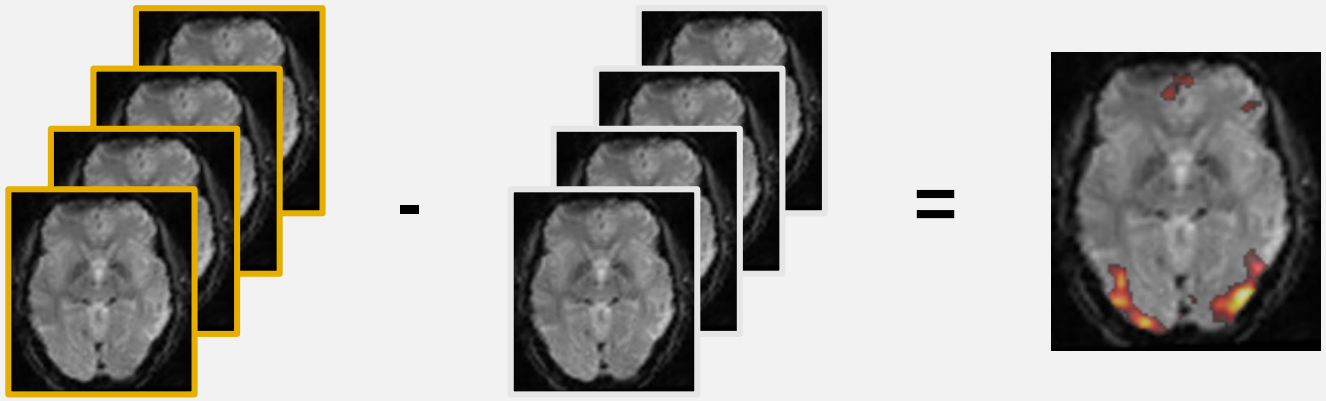
Functional MRI (fMRI)



- A brain imaging technique that uses an **MRI** scanner to measure and map **brain activity**
- It is **non-invasive**
- Can give **whole-brain** coverage
- It has the **highest spatial resolution** of any non-invasive imaging technique (typically 1-3 mm)
- It has a **reasonable temporal resolution** (typically 1-3 seconds)

Functional MRI (fMRI)





B state images

A state images

Contrast/**B activation** map

Diagram adapted from Glover, 2011

fMRI signal

- Blood oxygen level-dependent (BOLD) signal

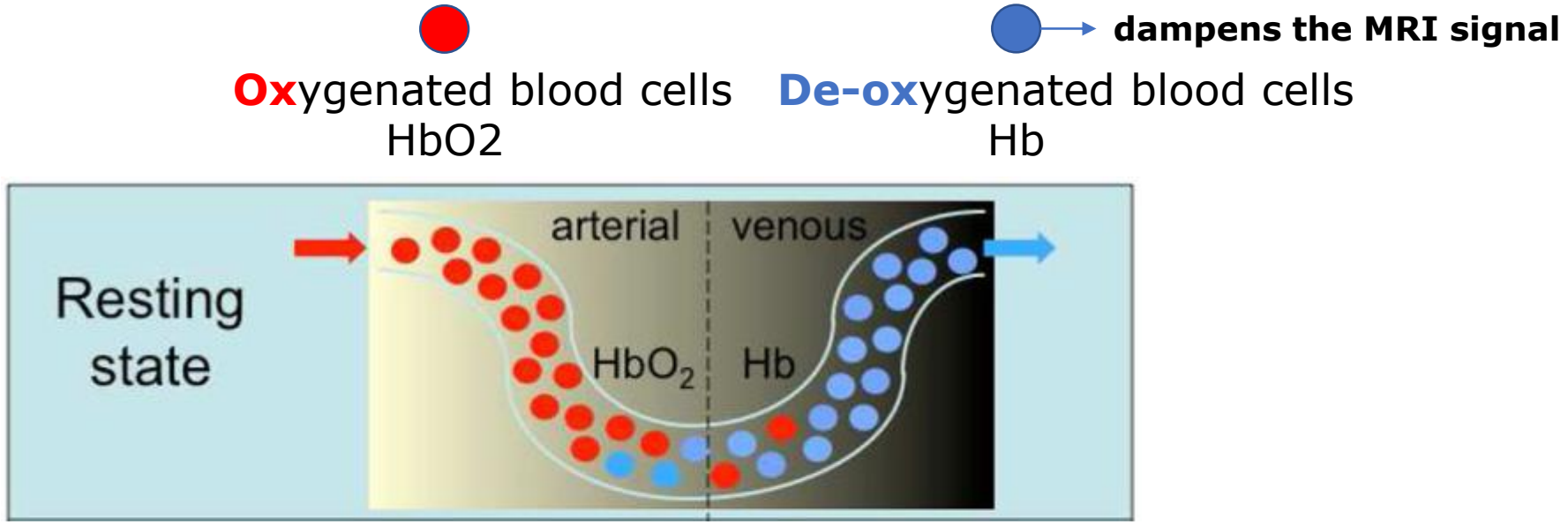


Diagram adapted from Glover, 2011

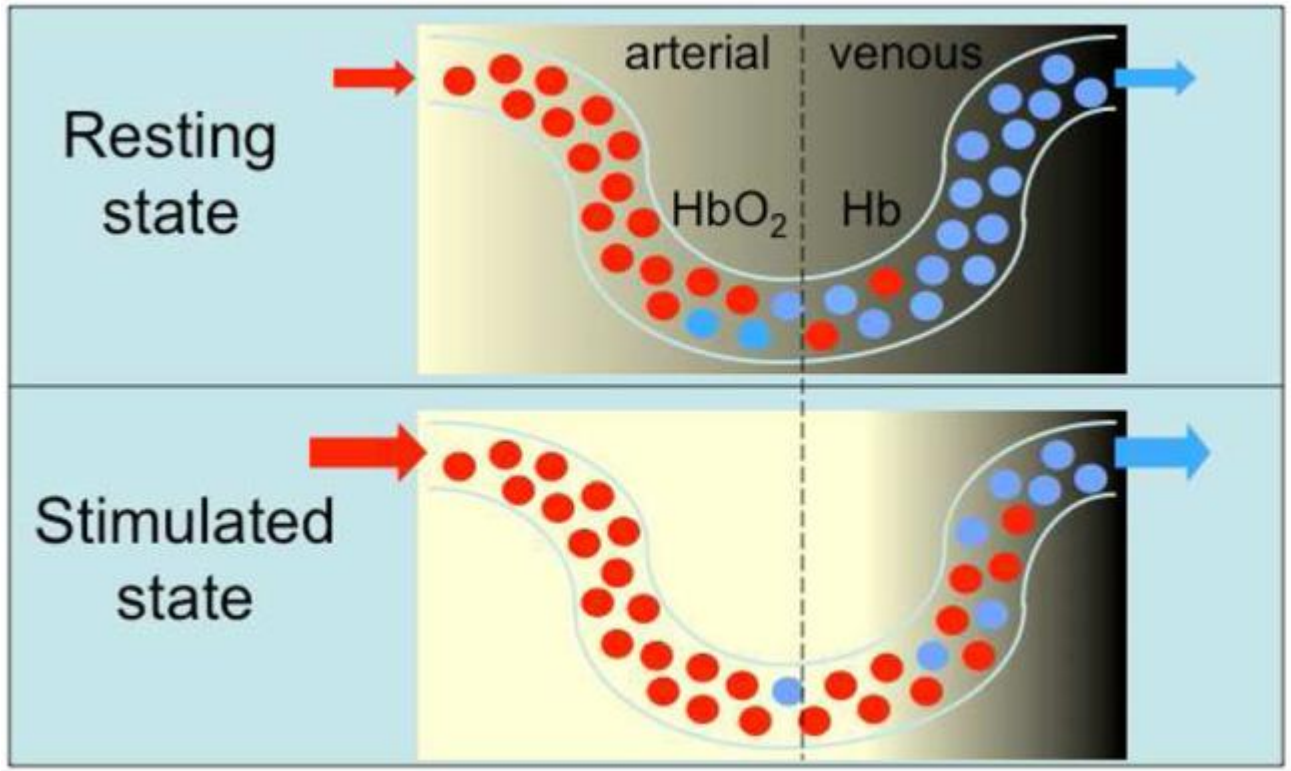
fMRI signal

- Blood oxygen level-dependent (BOLD) signal

Oxygenated blood cells
HbO2

dampens the MRI signal

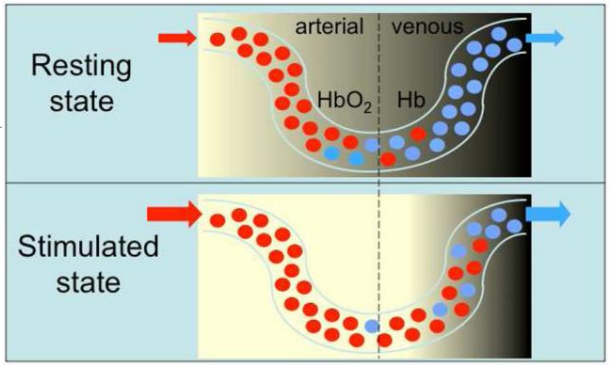
De-oxygenated blood cells
Hb



Neural activity-induced increase in blood flow **sweeps the "de-ox" away**, causing an MRI **signal increase**

Diagram adapted from Glover, 2011

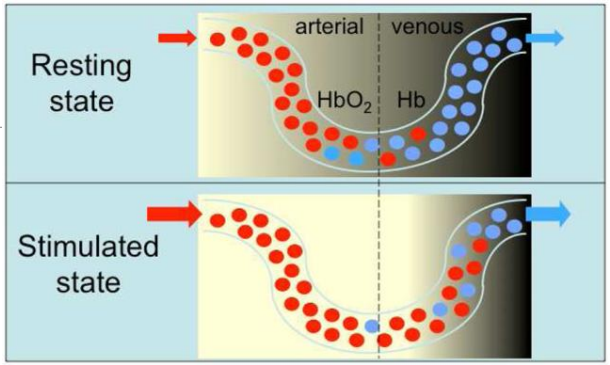
fMRI signal



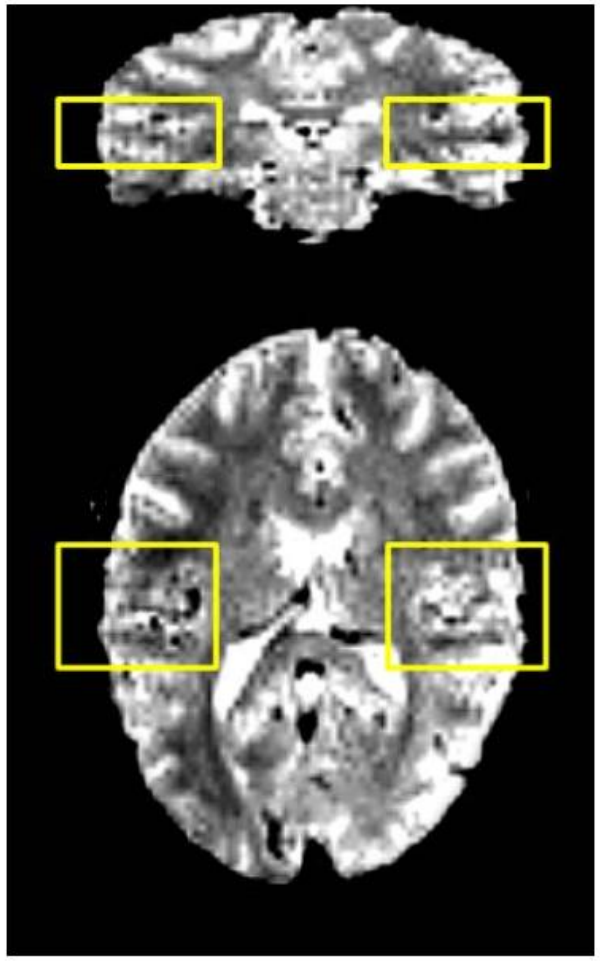
- **At rest,** the cerebral **metabolic rate of oxygen** (CMRO2) and cerebral **blood flow** (CBF) are tightly **coupled**
- During **increased neuronal activity** they become **uncoupled**, with CBF increasing relatively more than CMRO2 (Fox and Raichle, 1986)
  - 'an overcompensation'
- The uncoupling leads to an **increase in oxygenated Hb** due to an influx of fresh blood which **'flushes away' the de-oxygenated Hb** and therefore increases the BOLD signal

fMRI signal

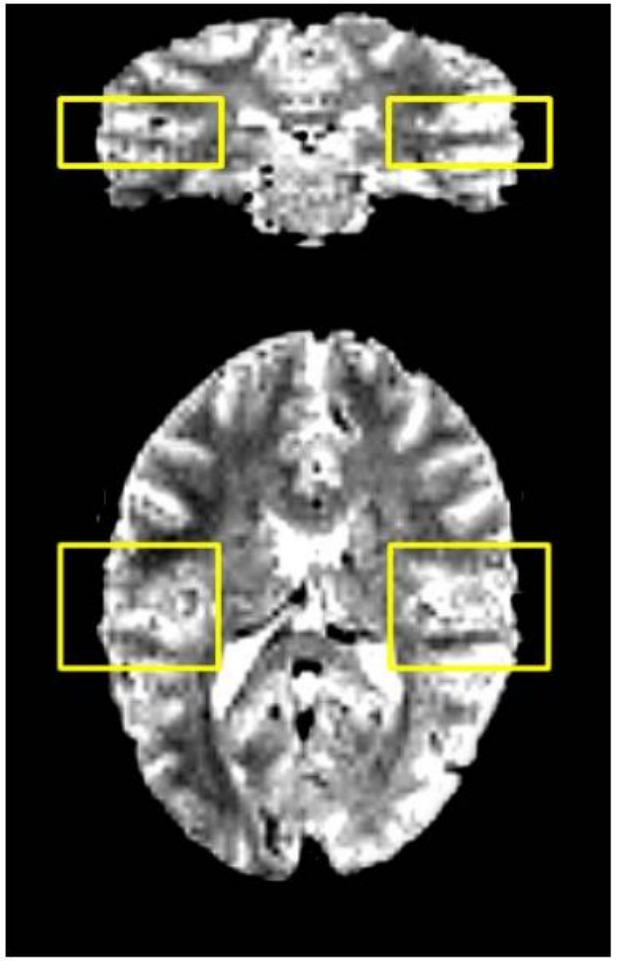
- An example of auditory cortex activation (from Marta's MRI physics slides)



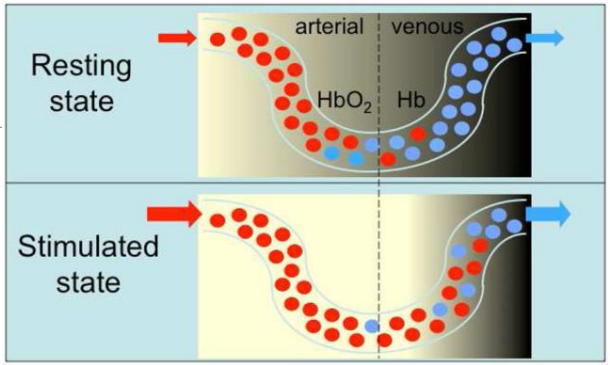
Baseline



Neural Activity



fMRI signal



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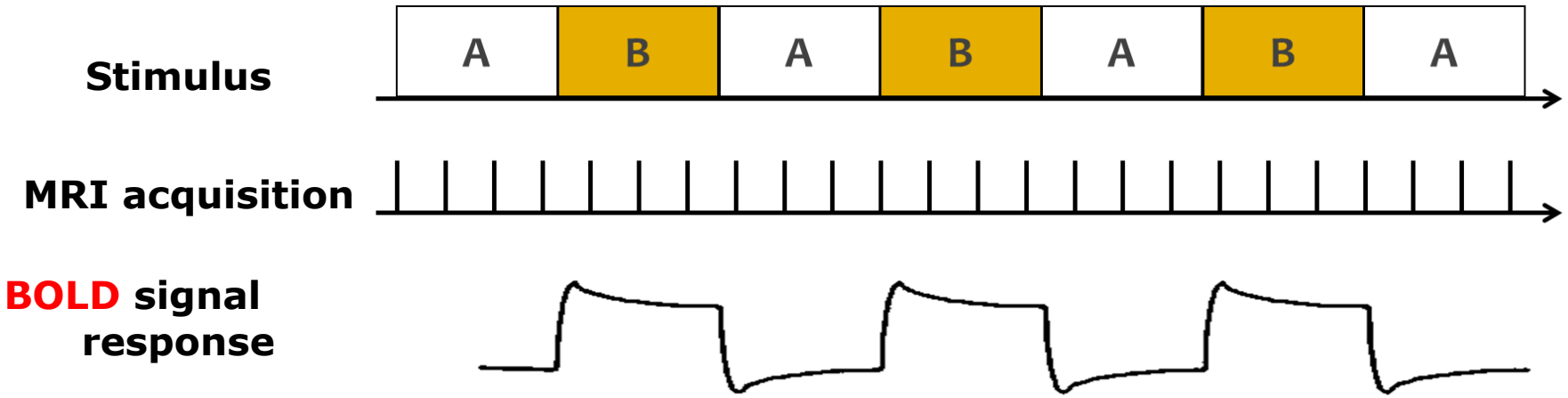
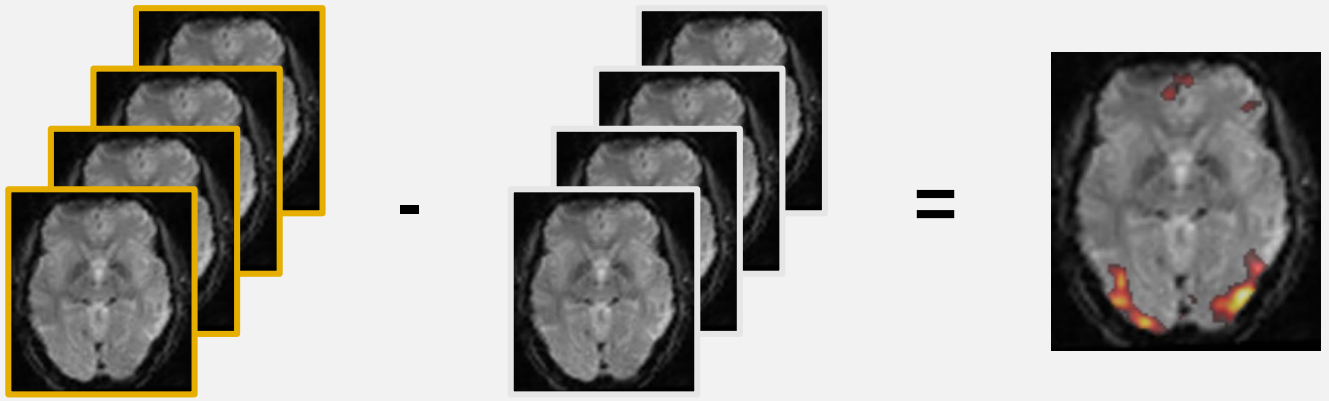
- This difference in the magnetic properties of de-oxygenated and oxygenated Hb is used in BOLD fMRI to create contrast in images – reflecting activity in different brain regions.
  - By controlling for all other factors, any observed differences in the BOLD signal are inferred to be due to differences in neuronal activity

Functional MRI (fMRI)





B state images **A state** images Contrast/**B activation** map

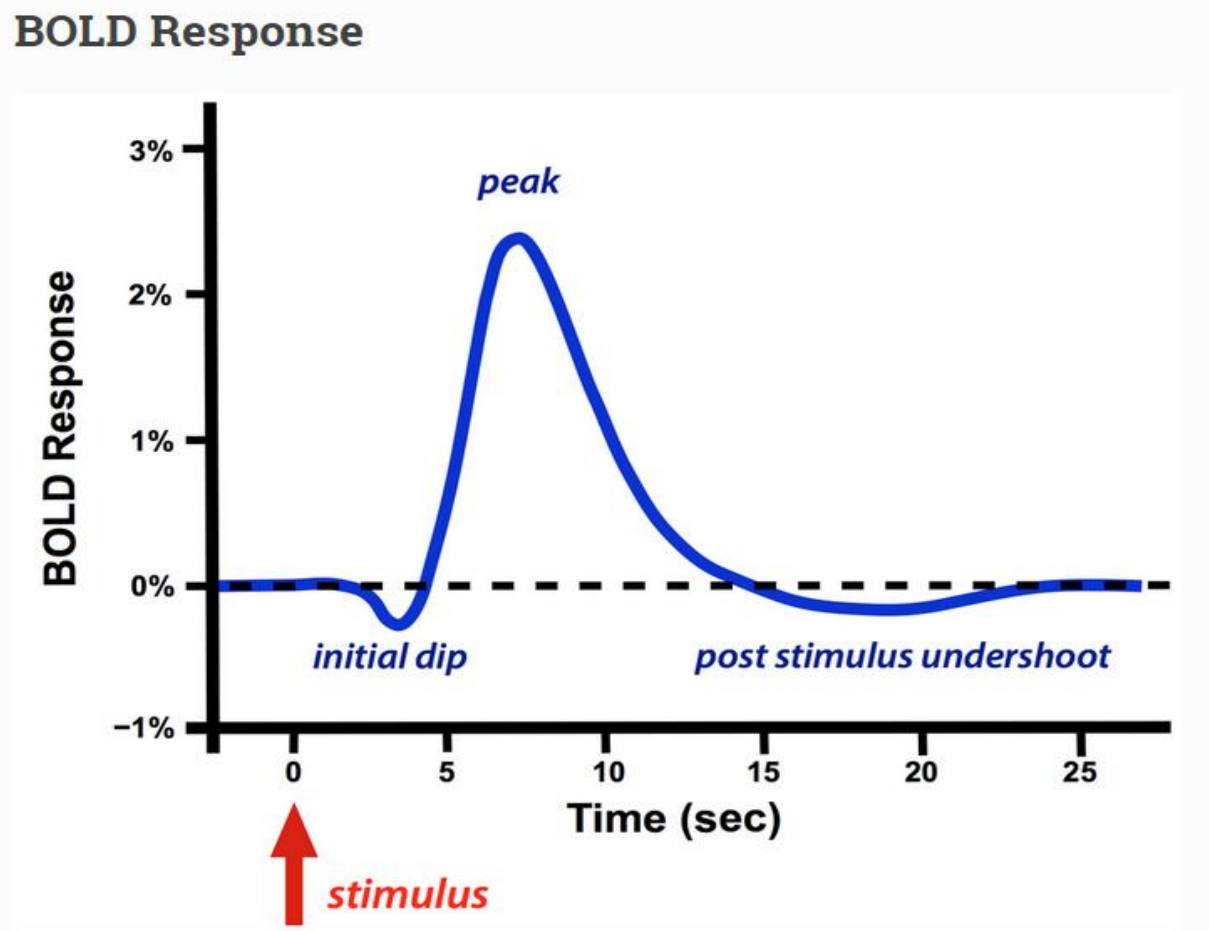
Diagram adapted from Glover, 2011

fMRI signal

- Blood oxygen level-dependent (BOLD) signal
- BOLD fMRI detects the changes in blood oxygenation that occur in response to neural activity
- The BOLD signal is well detectable with MRI
- However, BOLD is an indirect measure of neural activity
- More direct methods have failed due to poor signal

BOLD response

Hemodynamic response function (HRF)



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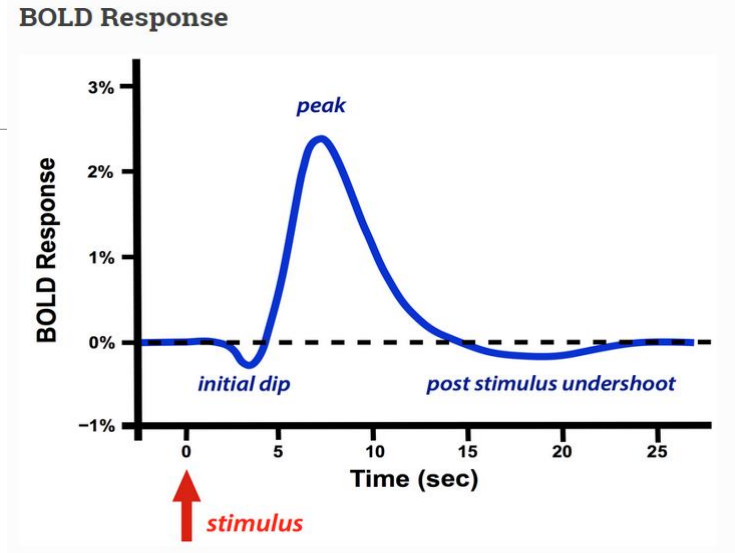
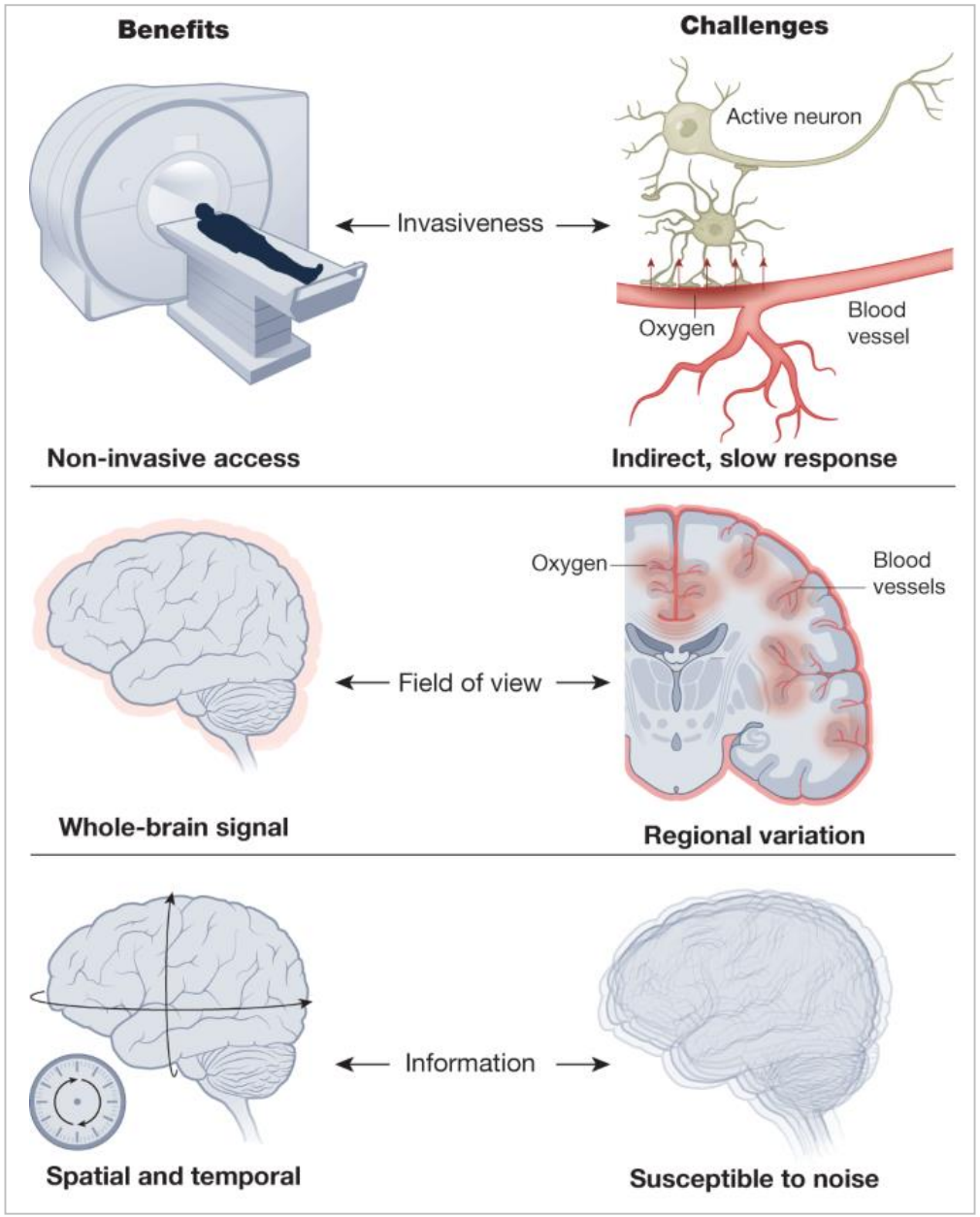
Hemodynamic response function (HRF)



- Depends on stimulus intensity and duration
- Varies across individuals
- Varies with healthy ageing and development
- Varies with common stimulants such as caffeine
- Varies across the brain, both at a distant and local scale

- The most common solution to HRF variability is to pretend it doesn’t exist and use a generic model for all participants

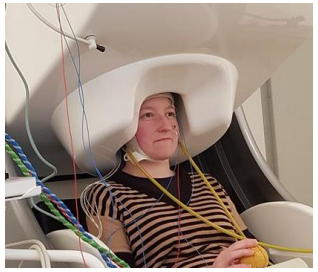
Benefits and challenges of fMRI



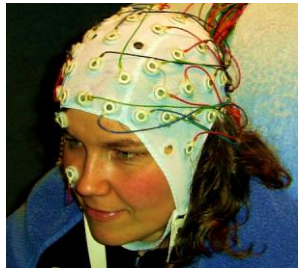
Finn, E.S., Poldrack, R.A. & Shine, J.M. *Nature*, 2023. https://doi.org/10.1038/s41586-023-06670-9

Non-invasive functional brain imaging techniques

fMRI
Functional magnetic resonance imaging
1992



MEG
Magnetoencephalography
1968



EEG
Electroencephalography
1929

maturity level

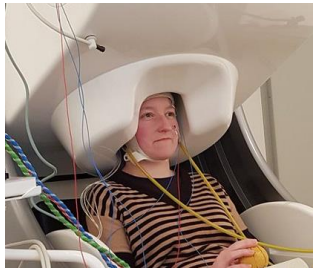
Non-invasive functional brain imaging techniques

fMRI
Functional magnetic resonance imaging
1992

Indirect
increased metabolic
demands of active neurons

Spatial resolution
Excellent
~1-3 mm
whole-brain

Temporal resolution
Not-so-good
~1-4 seconds

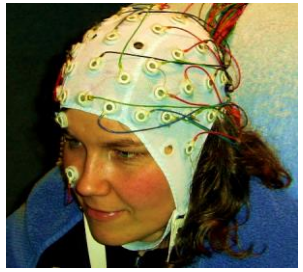


MEG
Magnetoencephalography
1968

Direct
the magnetic field generated by
the electrical activity of neurons

Spatial resolution
Not-so-good
~5 mm
limited for deep structures

Temporal resolution
Excellent
~1 millisecond



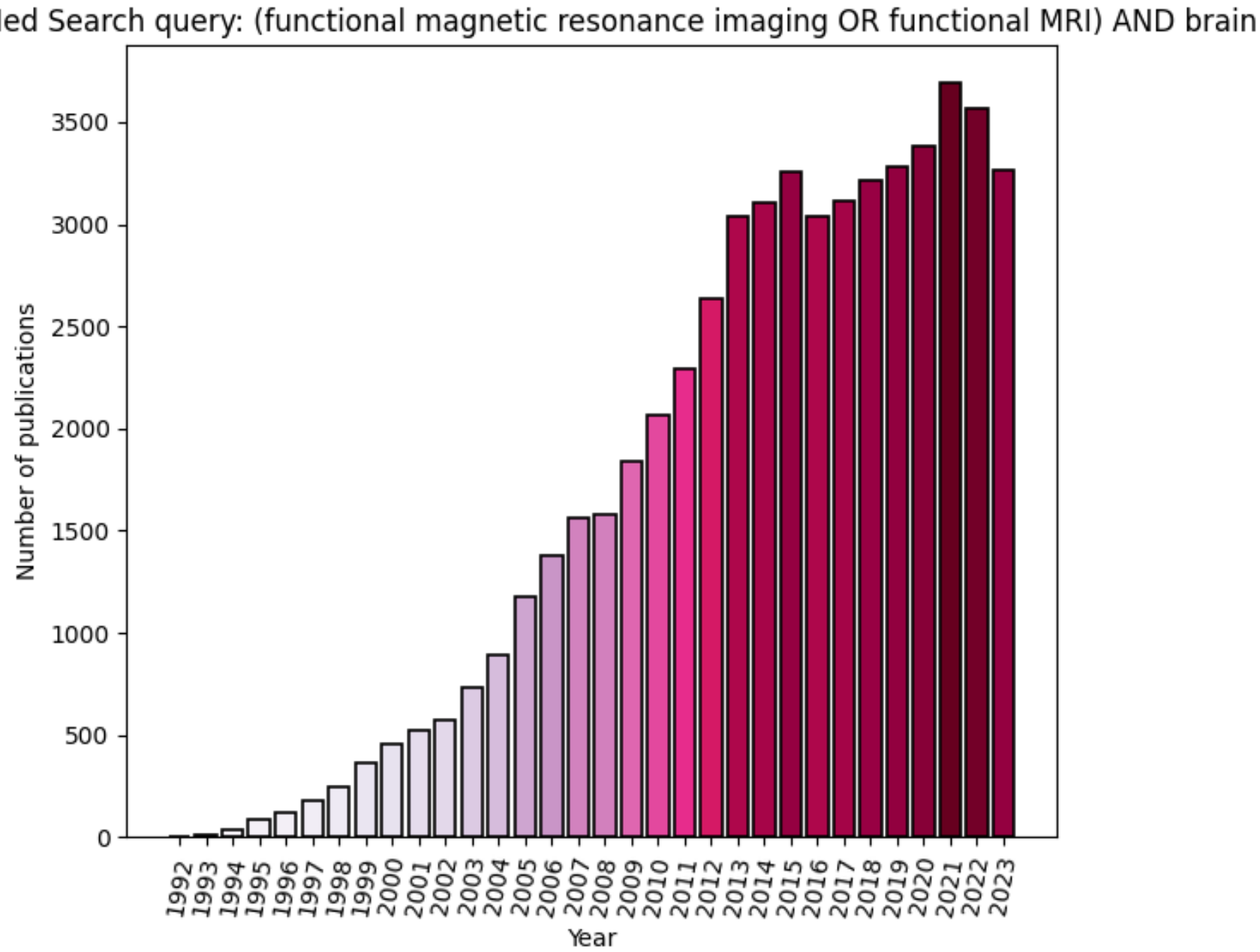
EEG
Electroencephalography
1929

Direct
the electrical activity
of the brain

Spatial resolution
Poor
~10 mm
cortical surface

Temporal resolution
Excellent
~1-10 milliseconds

fMRI popularity



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