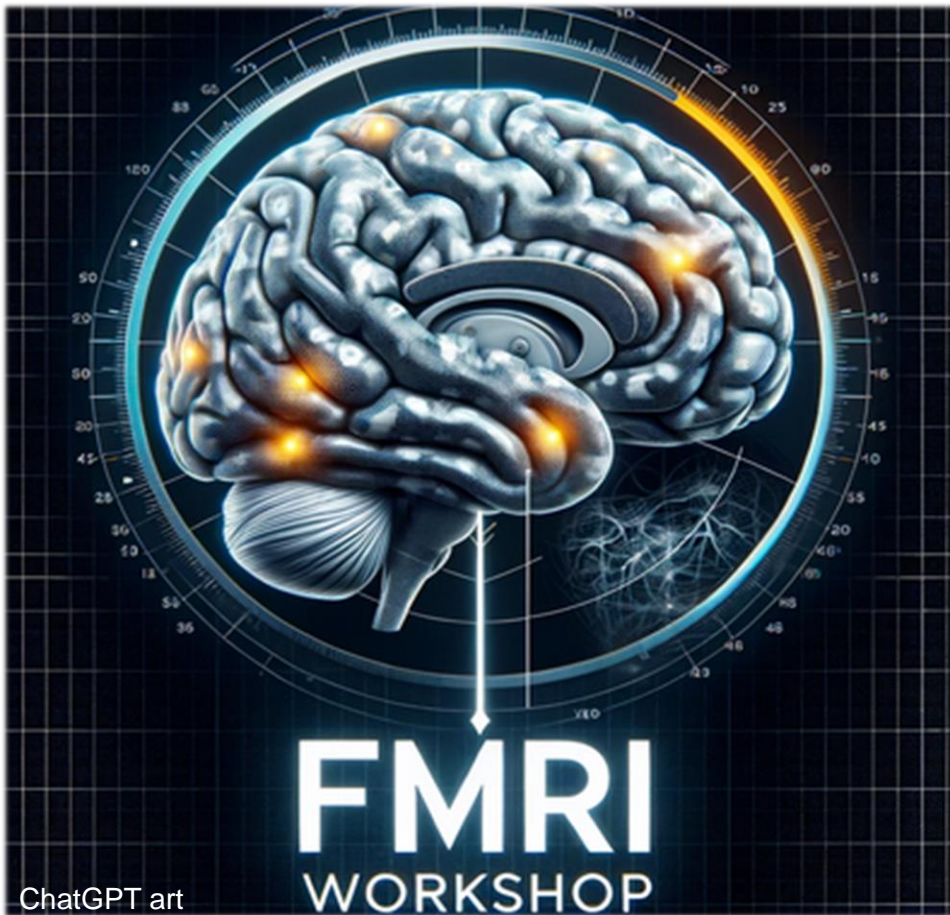




MRC Cognition
and Brain
Sciences Unit



UNIVERSITY OF
CAMBRIDGE



Functional Magnetic Resonance Imaging



GitHub

https://github.com/dcdace/fMRI_training

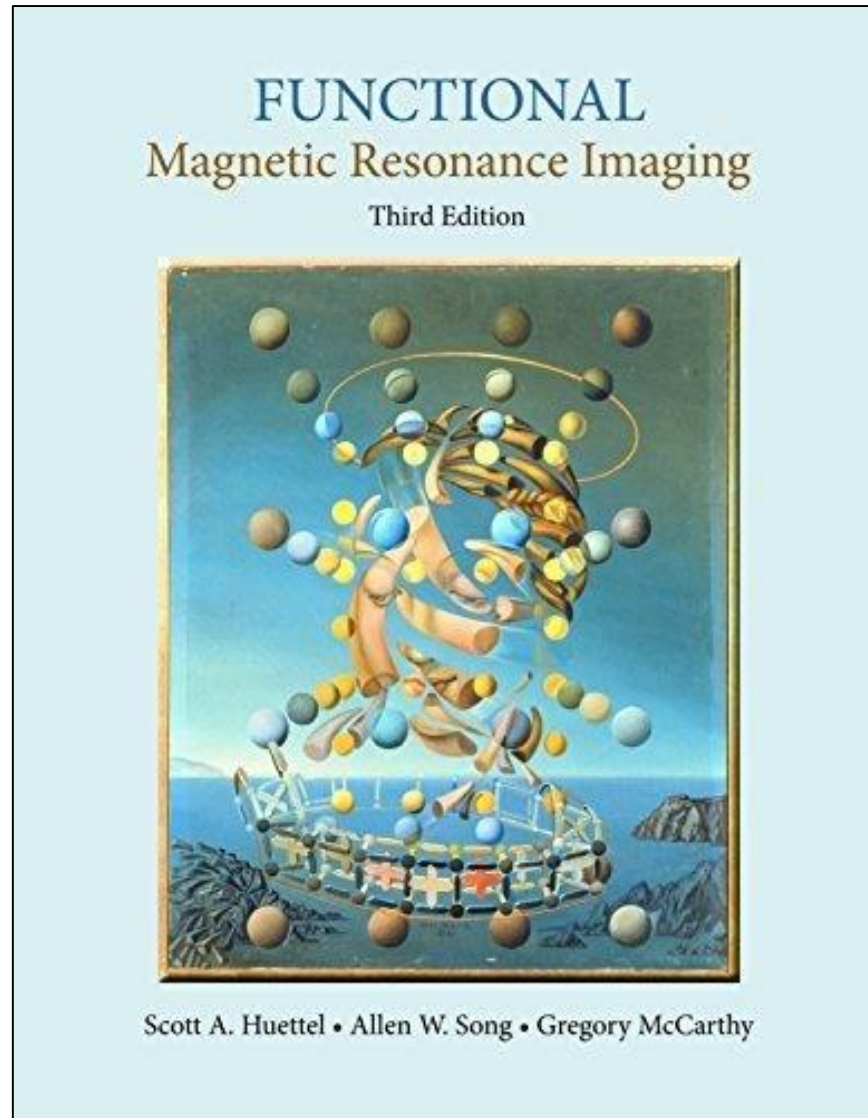
Dace Apšvalka

Winter, 2024

Outline

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

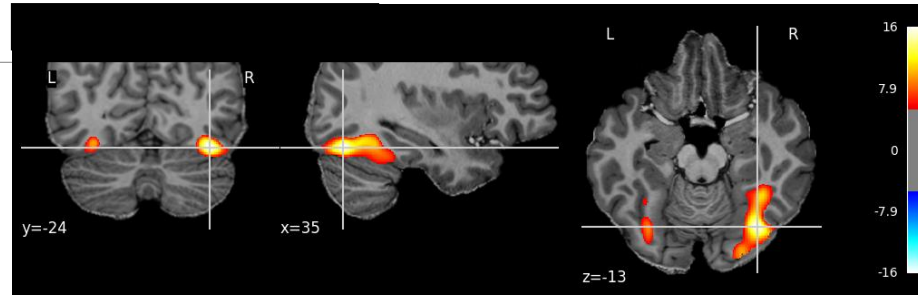
Recommended book



[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)



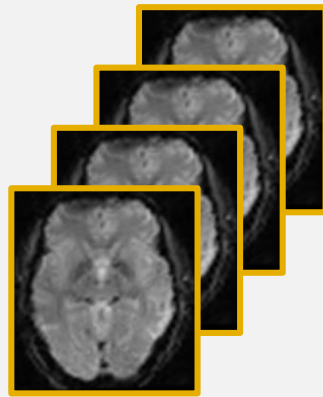
Stimulus



MRI acquisition

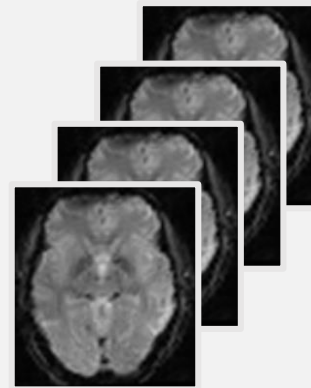


**Signal
response**



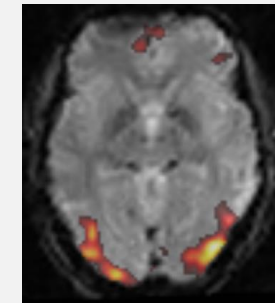
B state images

-



A state images

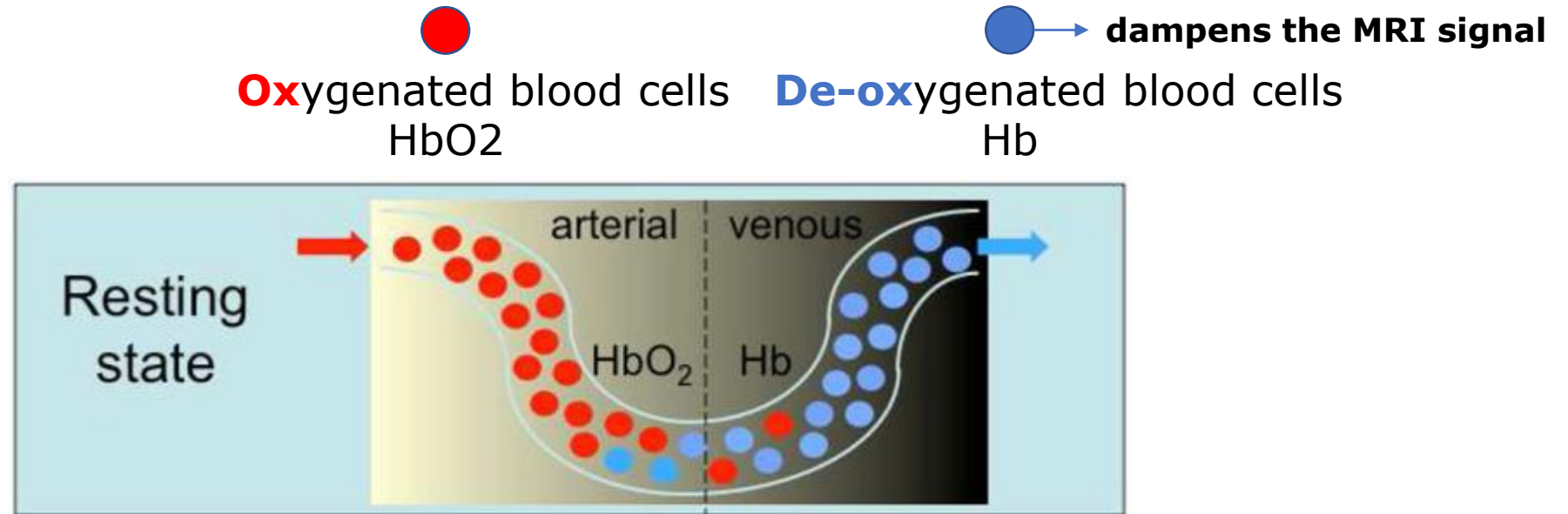
=



Contrast/**B activation** map


fMRI signal

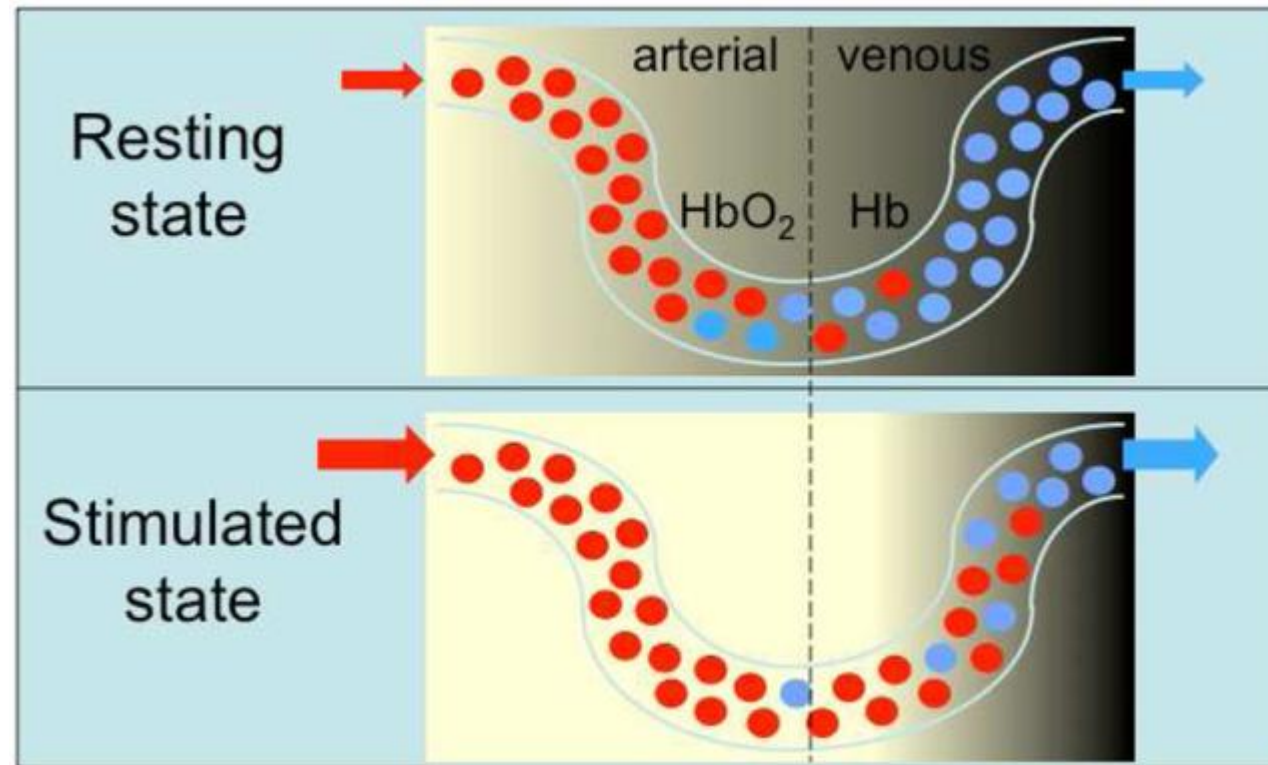
- Blood oxygen level-dependent (BOLD) signal



fMRI signal

- Blood oxygen level-dependent (BOLD) signal

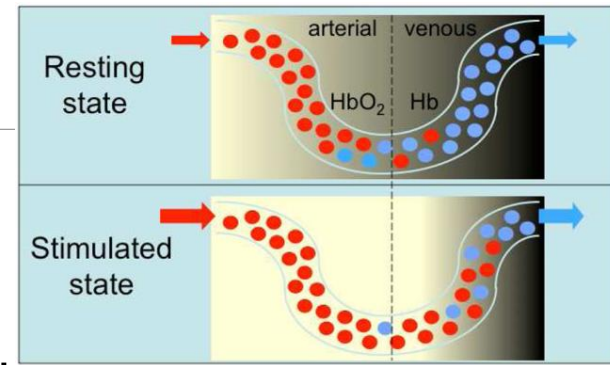
 **O**xxygenated blood cells HbO_2  **De-ox**ygenated blood cells Hb  dampens the MRI signal



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

fMRI signal

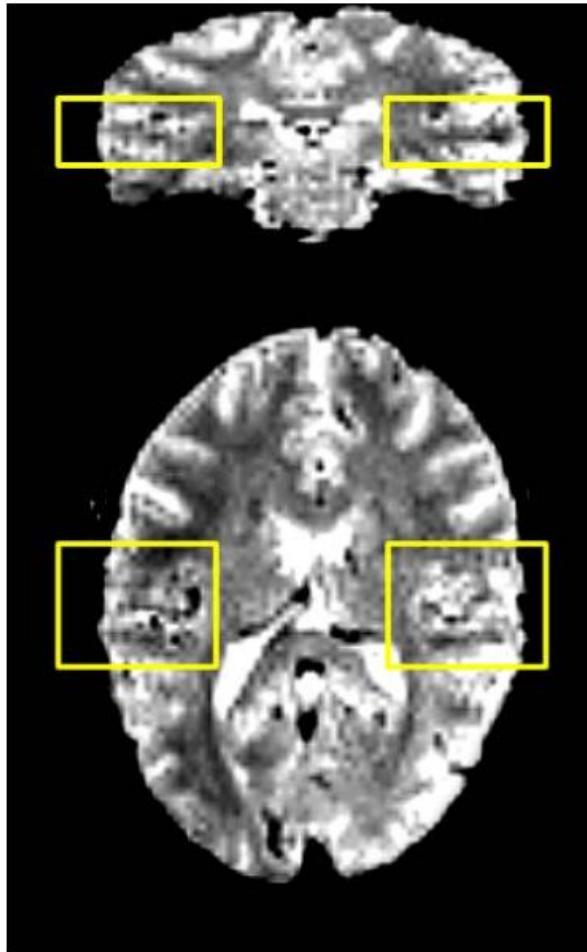
- **At rest**, the cerebral **metabolic rate of oxygen** (CMRO₂) and cerebral **blood flow** (CBF) are tightly **coupled**
- During **increased neuronal activity** they become **uncoupled**, with CBF increasing relatively more than CMRO₂ (Fox and Raichle, 1986)
 - 'an overcompensation'
- The uncoupling 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



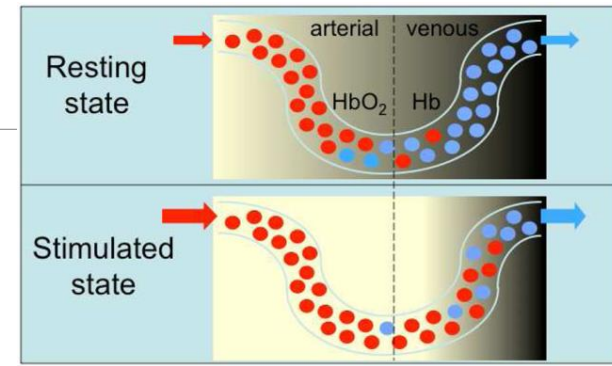
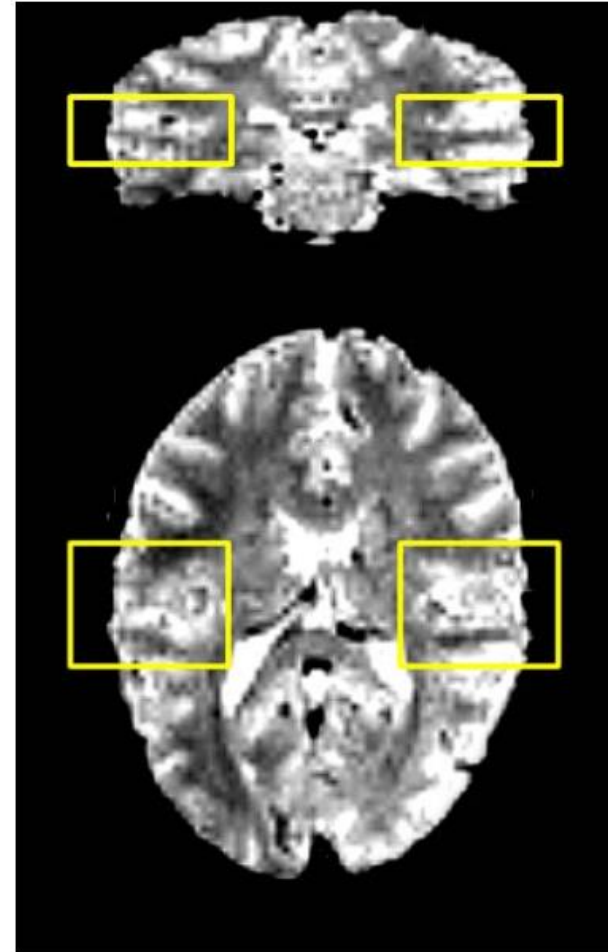
fMRI signal

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

Baseline

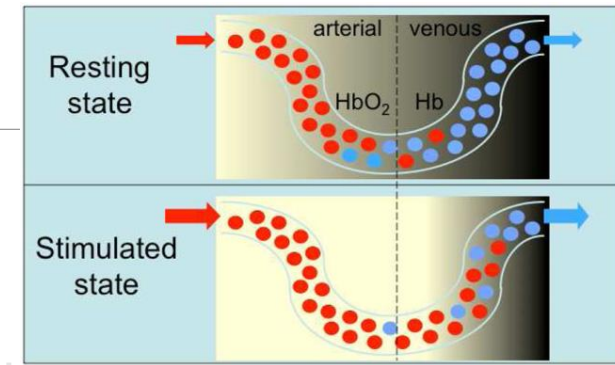


Neural Activity

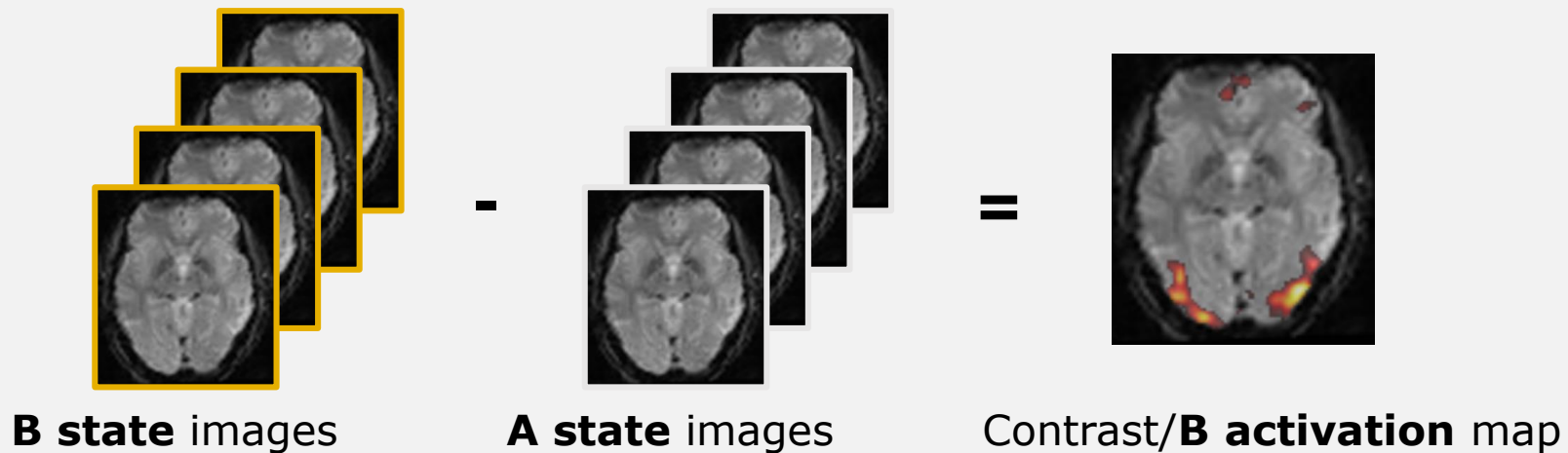
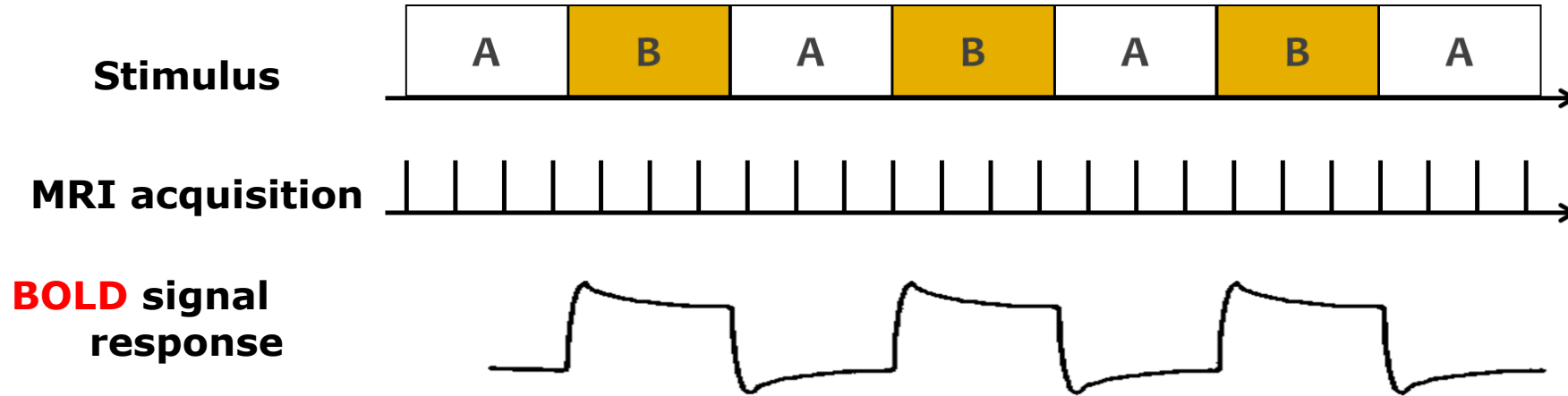


fMRI signal

- **At rest**, the cerebral **metabolic rate of oxygen** (CMRO₂) and cerebral **blood flow** (CBF) are tightly **coupled**
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 - '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
- 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)



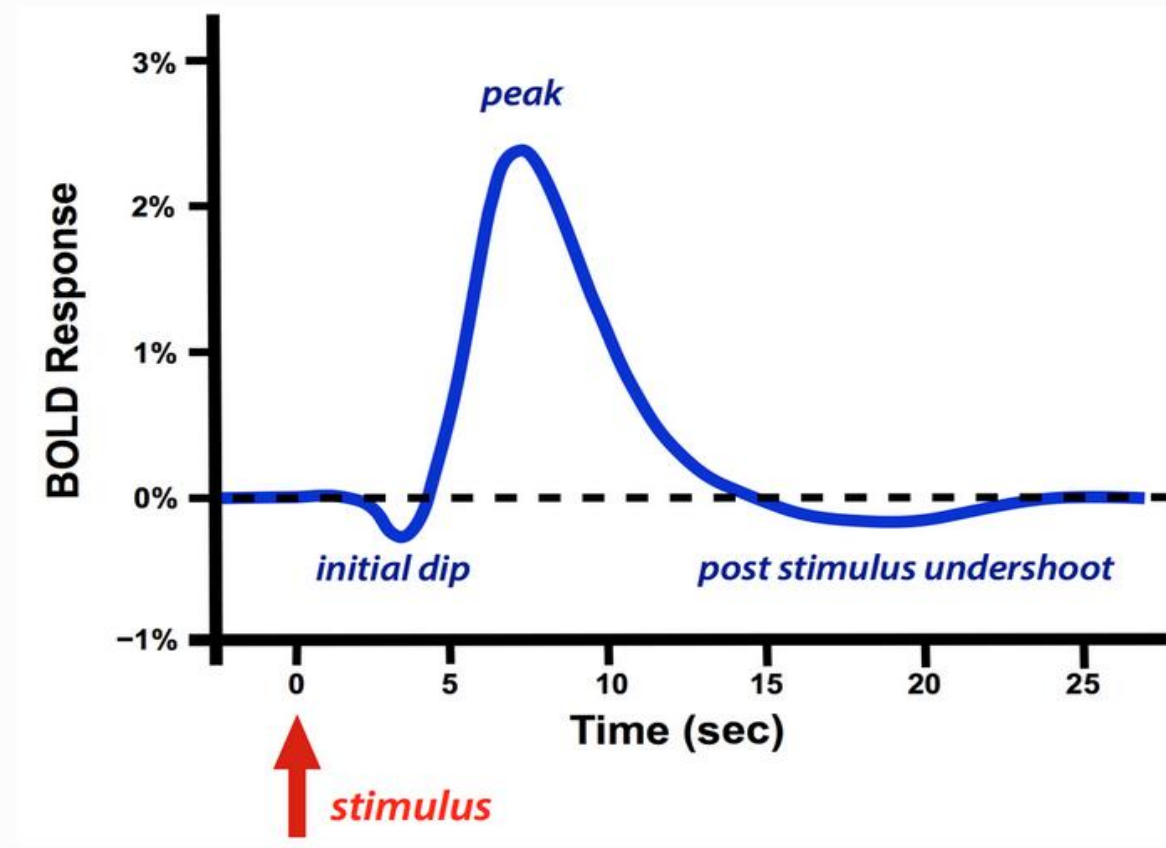
fMRI signal

- 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)

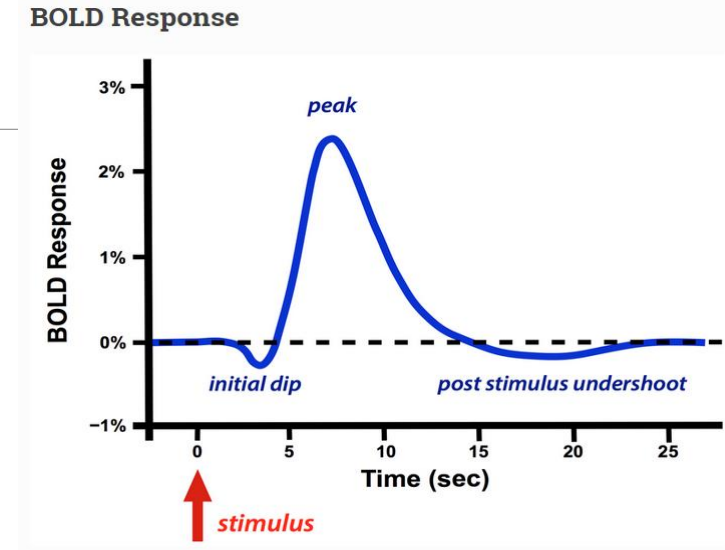
BOLD Response



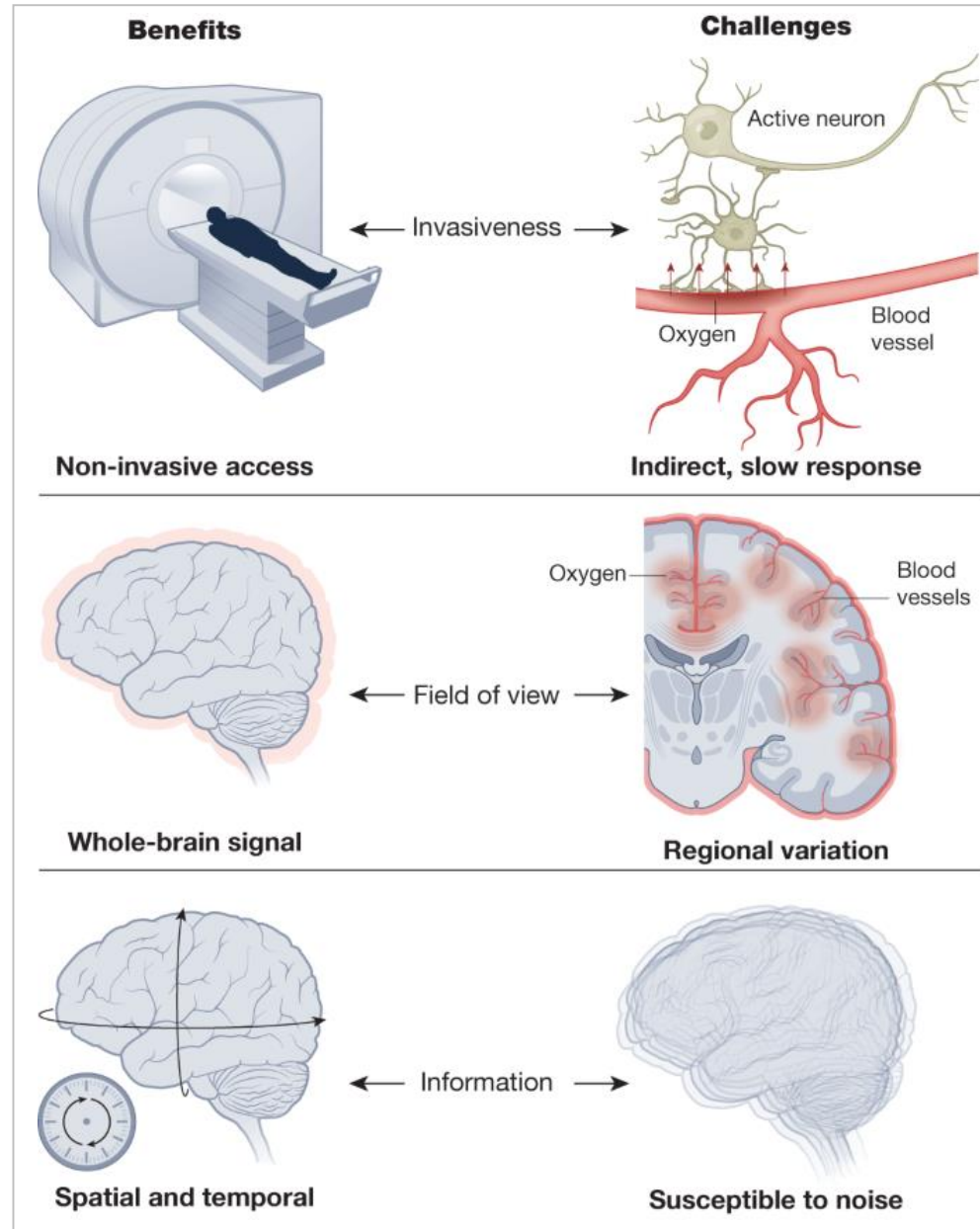
©Andy Jahn

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

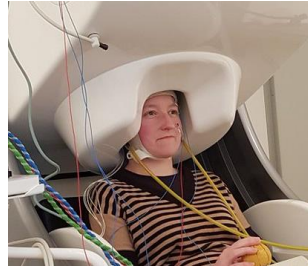


Non-invasive functional brain imaging techniques



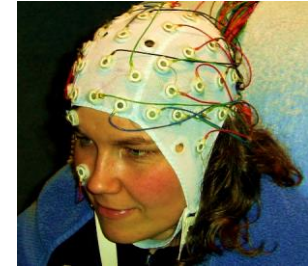
fMRI

Functional magnetic resonance imaging
1992



MEG

Magnetoencephalography
1968



EEG

Electroencephalography
1929

maturity
level



32

young adult



56

middle-aged



95

senior

Non-invasive functional brain imaging techniques



fMRI

Functional magnetic resonance imaging
1992

Indirect

increased metabolic
demands of active neurons

Spatial resolution

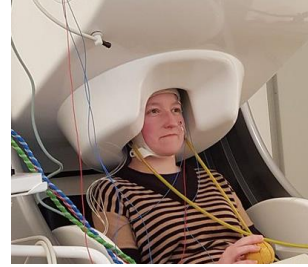
Excellent

~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

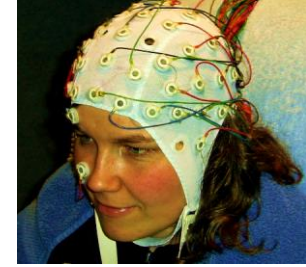
Not-so-good

~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

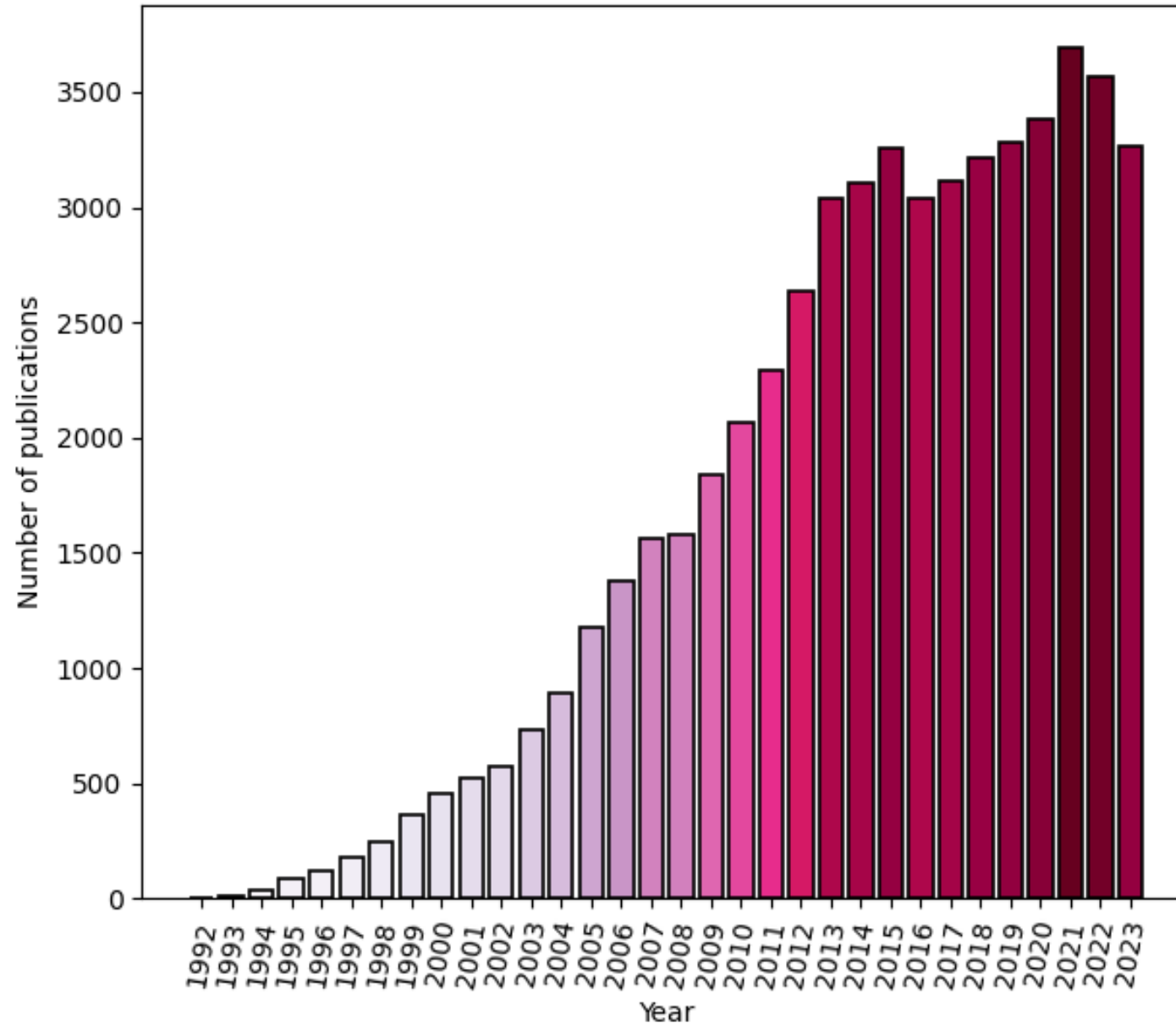
Temporal resolution

Excellent

~1-10 milliseconds

fMRI popularity

PubMed Search query: (functional magnetic resonance imaging OR functional MRI) AND brain



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