

Brain Imaging

Introduction

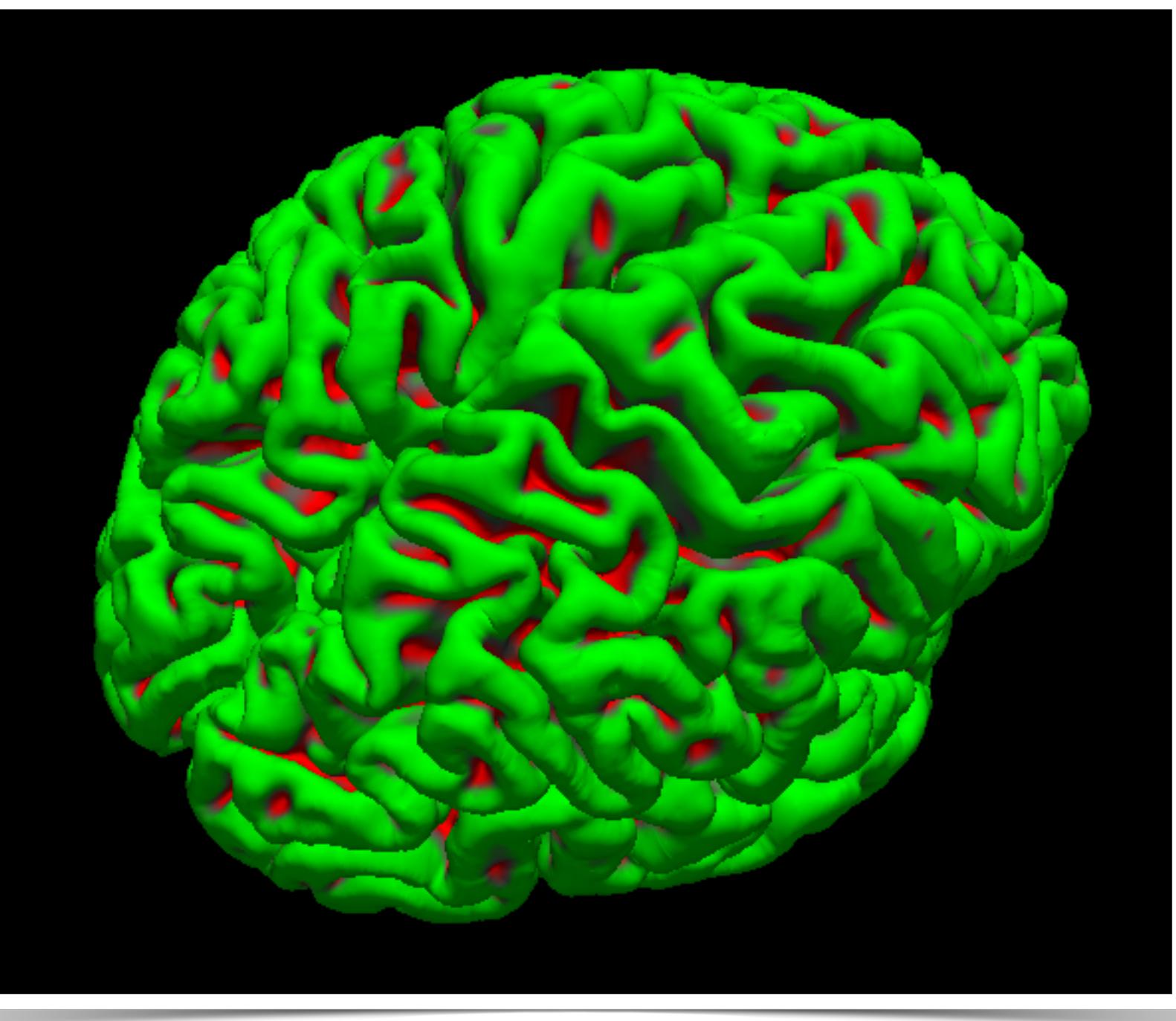
Tomas Knapen 2021

My Brain:

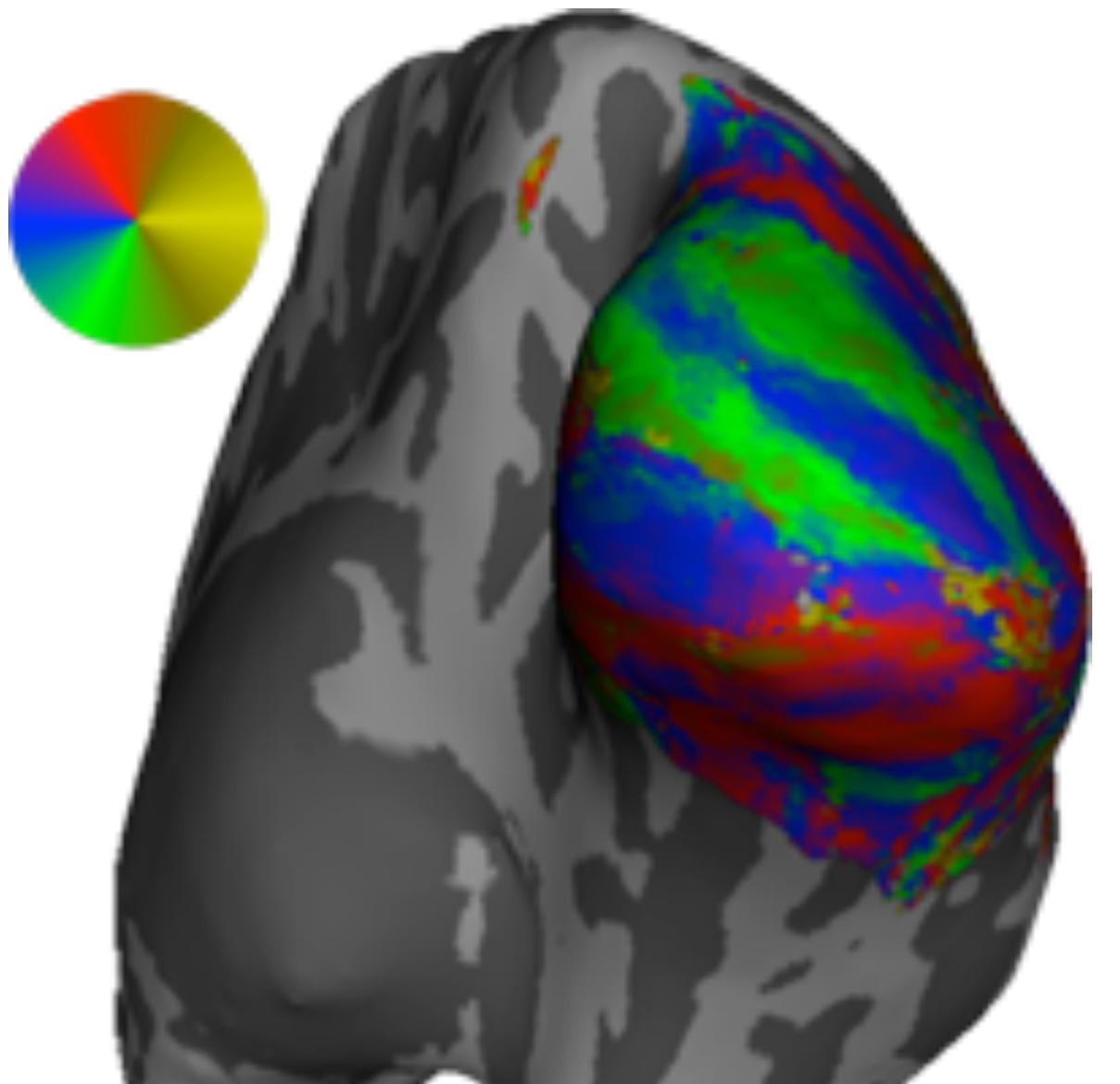
Welcome to this course!

Who are we?

- **Teacher:** Tomas Knapen
tknapen.teaching@gmail.com
email me with **[Brain Imaging]** in the subject line
- **TAs:** Jet Lageman & Ron vd Klundert, PhD students
- We do fMRI for a living. Mainly, interested in the visual system.



My retinotopic visual maps:



My most recent publication (PNAS 2021):

Topographic connectivity reveals task-dependent retinotopic processing throughout the human brain

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Edited by Marcus E. Raichle, Washington University in St. Louis, St. Louis, MO, and approved November 19, 2020 (received for review August 11, 2020)

The Lab

Our topics & links with other labs

- We collaborate a lot, with:
 - Spinoza Centre for Neuroimaging (*fMRI, MR physics*)
 - Vrije Universiteit Cognitive Psychology (*fMRI, behavior*)
 - UvA Artificial Intelligence (*fMRI, modeling of neural computation*)
 - National Institutes of Mental Health (*fMRI, MR physics*)
 - University of Minnesota (*fMRI, modeling of neural computation*)

About the course

Mutual expectations:

What you can expect from me, and what I will expect from you....

Course outline

Corona-proofing the course

Battling corona-fatigue

- I don't know about you, but most people I know have started to get corona-fatigued.
- How to teach in this situation? Changes to the course:
 - Flexibility ++
 - Learn/Work at your own pace ++
 - Get together for discussions ++
 - Collaborative project for human-human interaction ++

What will you learn?

Knowledge and Know-how

- ***Basic fMRI knowledge:***



- What is fMRI data composed of?
- What you can and cannot learn from an fMRI experiment...
- How do you design an experiment?
- How do you interpret fMRI results?

- ***Basic fMRI know-how:***



- Work with fMRI data
- Analyze fMRI data in standard ways
- A few more advanced analyses...

Information on the course is on Canvas, and our GitHub repo:
https://github.com/tknapen/brainimaging_VU

Course Structure

What types of learning, when?

- 2 **Lectures** per week, Wed & Fri
 - Are recorded
 - Later lectures more guest lectures and discussions of relevant literature
 - Supplements and extends YouTube playlist
- 3 **Practicals**, select Wednesdays (rooster.vu.nl)
 - Jupyter notebooks on Google Colaboratory
 - Perusall reading assignments

The practicals are on the GitHub repo

Course Structure

What do you have to do?

- **Exam**, end of the course.
 - Proctored on TestVision, Multiple Choice & Open Questions
 - ***Exam materials:***
 - My lectures, and the content of the practicals
 - Articles discussed and read on Perusall
 - Selected YouTube modules Wager & Lunquist
- **Research Project**, second half of the course
 - Teams of 3, analyse a dataset (based on what you've learned in the practicals) and collaboratively write a report in Jupyter notebook.
 - Review colleagues' reports.

About fMRI

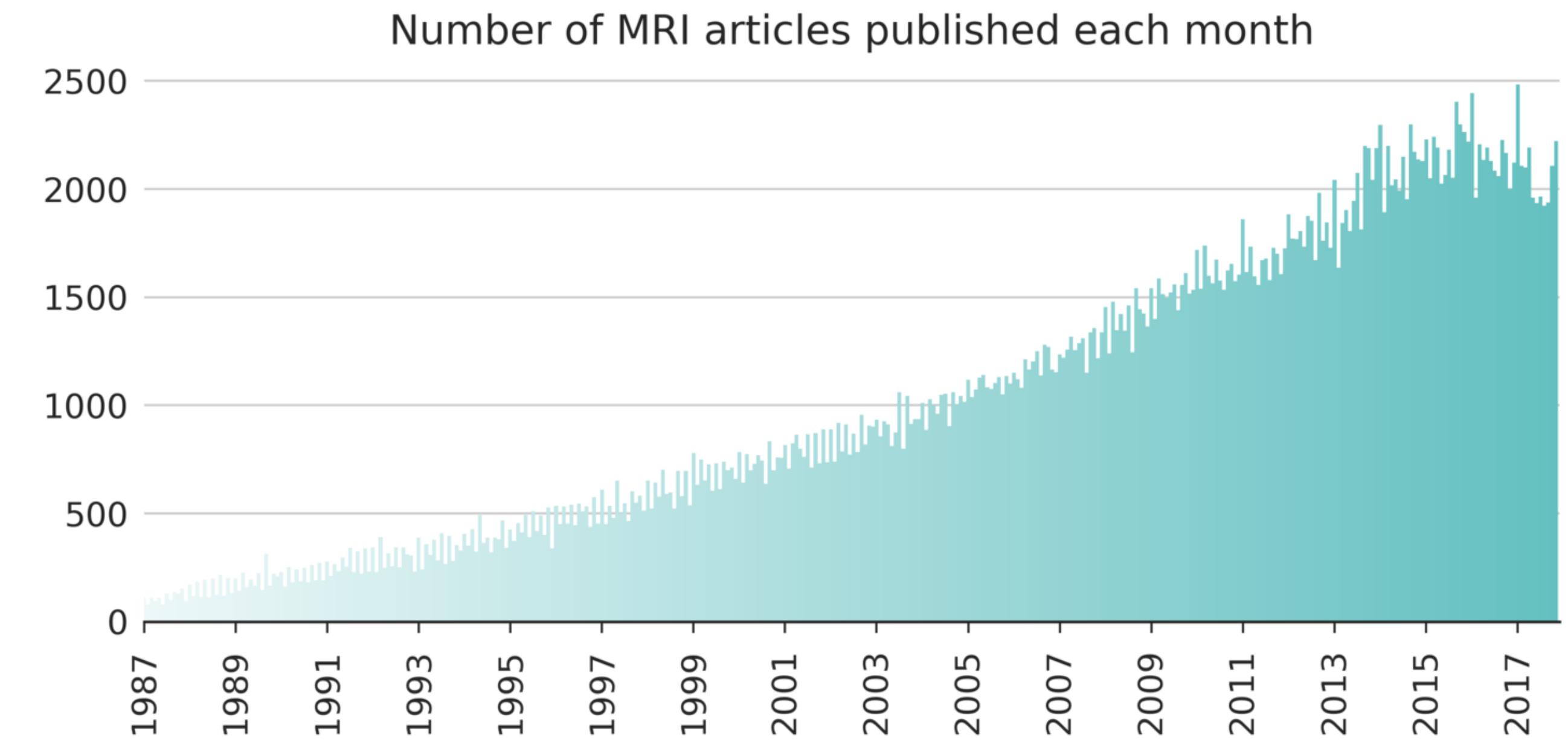
What are we going to teach you?

The awesomeness of being able to look inside people's living, behaving brains

Welcome!

What is this course about? What is fMRI, really?

- Brain imaging has exploded over the last ~30 years.
- Any hospital has an MRI scanner that's also usable for cognitive neuroscience research.
- Brain imaging is changing how people think about themselves; it's placed our psyches firmly in our heads
- ***We'll teach you how to do it!***

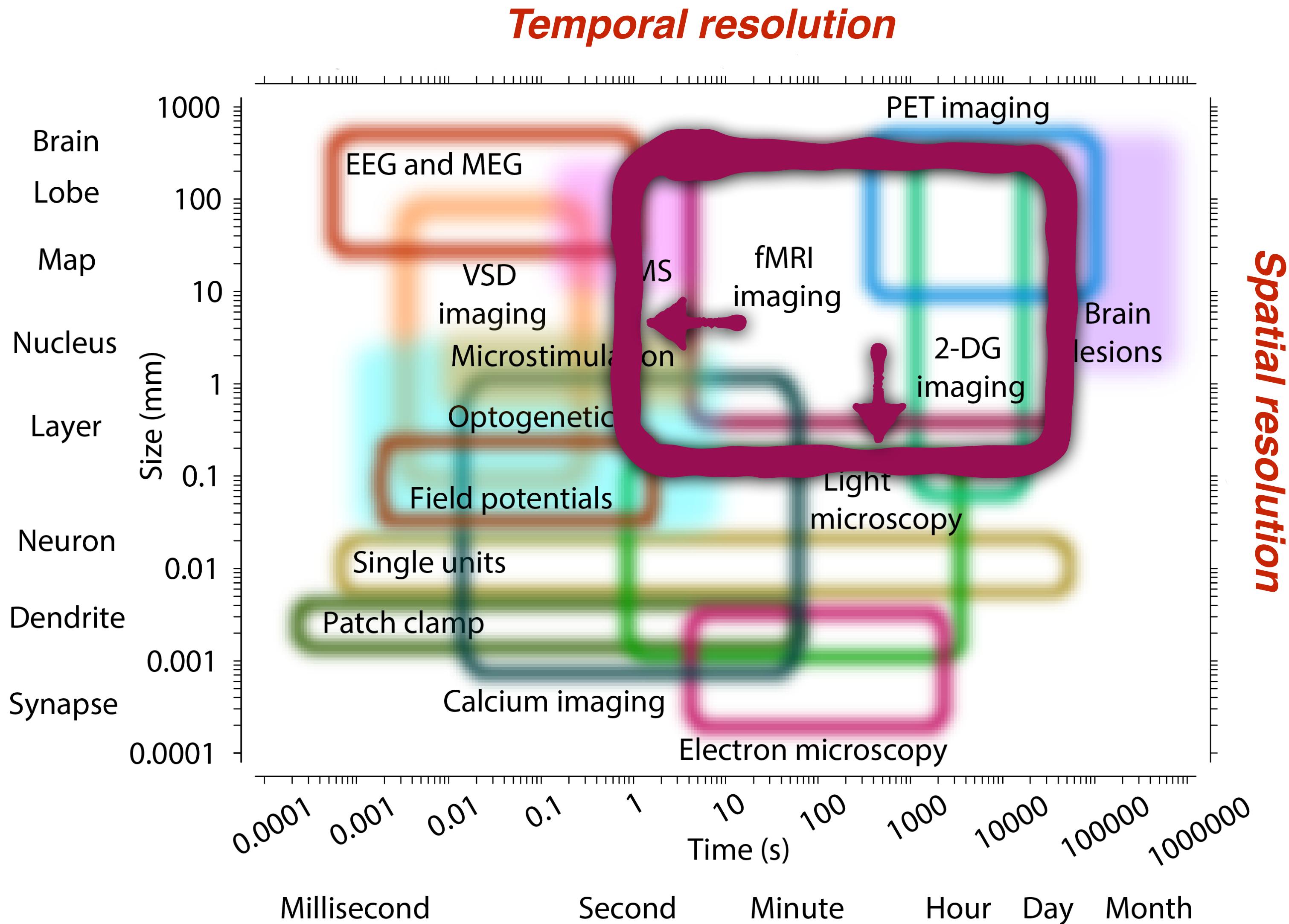


Poldrack et al, 2016 paper on Perusall

Functional Brain Imaging

fMRI is so popular because it is considered *non-invasive*, and provides an appealing balance between *temporal and spatial resolution*

fMRI is evolving: it's becoming faster and higher-resolution



functional MRI

What is our view on the brain like?

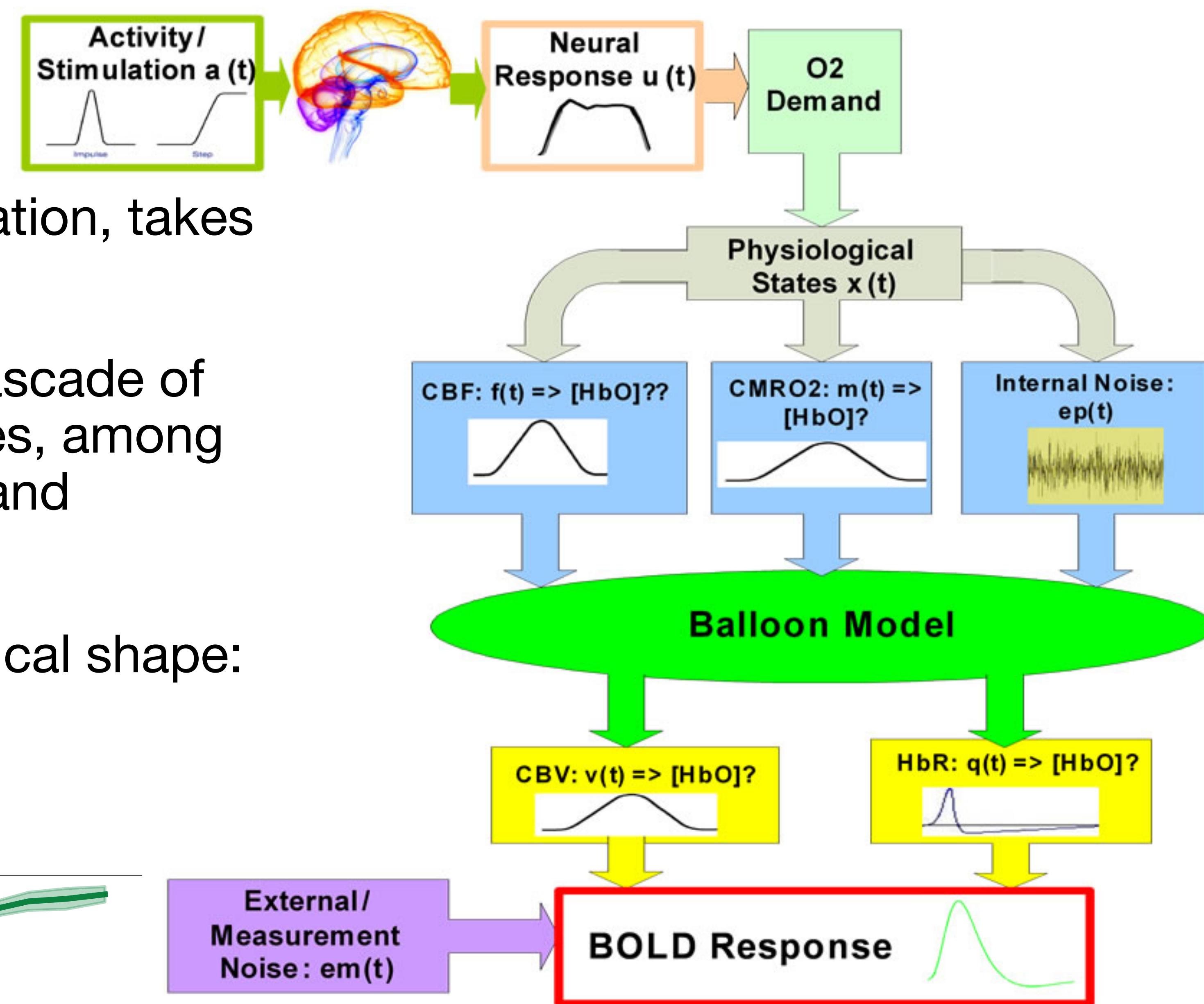
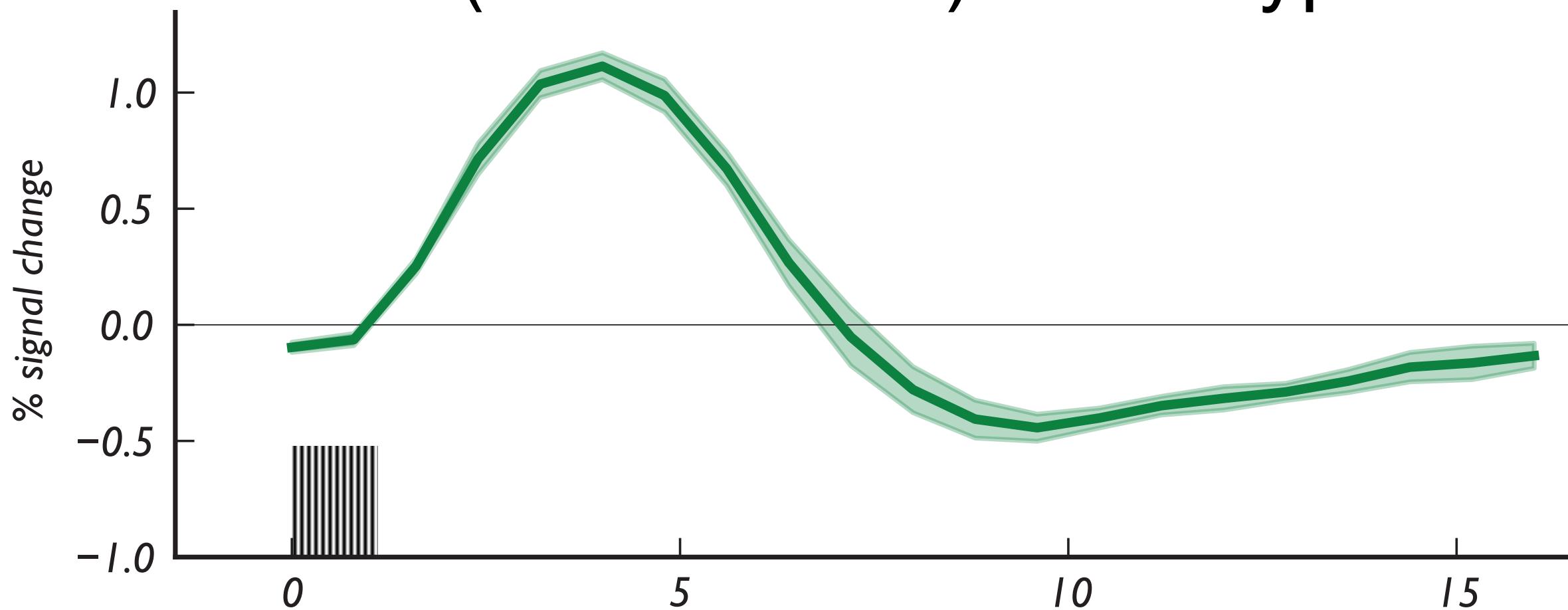
- The signals we measure with fMRI are primarily dependent on the oxygen level in the blood, they are *BOLD*, for *Blood Oxygenation Level Dependent*
- Since neural activity consumes oxygen, the level of oxygen in the blood will vary as neurons activate.
- Thus, BOLD is a *metabolic measurement*.
- *Keep in mind:* we are measuring not neural activity itself, but a derivative of it. This means BOLD provides only an indirect view on neural activity!



Blood response

Haemodynamic response

- Slow response to neural activation, takes over 20s to unfold
- Is dependent on a complex cascade of biological, metabolic responses, among which **Cerebral Blood Flow**, and **Oxygenation**
- Has a (more or less) stereotypical shape:



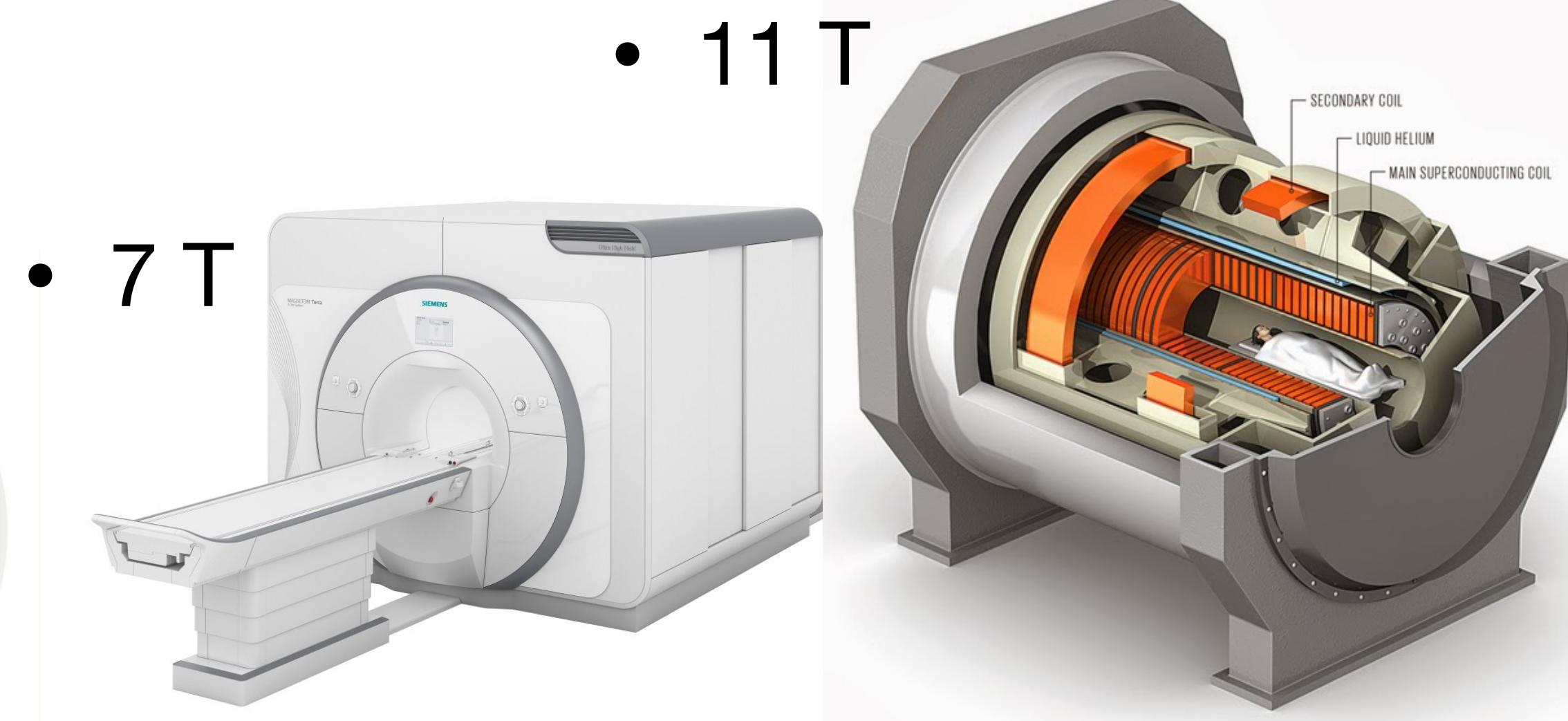
MRI scanner

A “standard” clinical device, repurposed for cognitive science

- Won the 2003 Nobel prize
- Used to create ***many different types of images of the living brain*** for diagnosis, both different types of ***anatomical*** images and different types of ***functional*** images
- Different images are created by running different programs, called ***sequences***
- Different field strengths, measured in Tesla
(Earth magnetic field: 3.2×10^{-5} T)



• 1.5 T



• 11 T

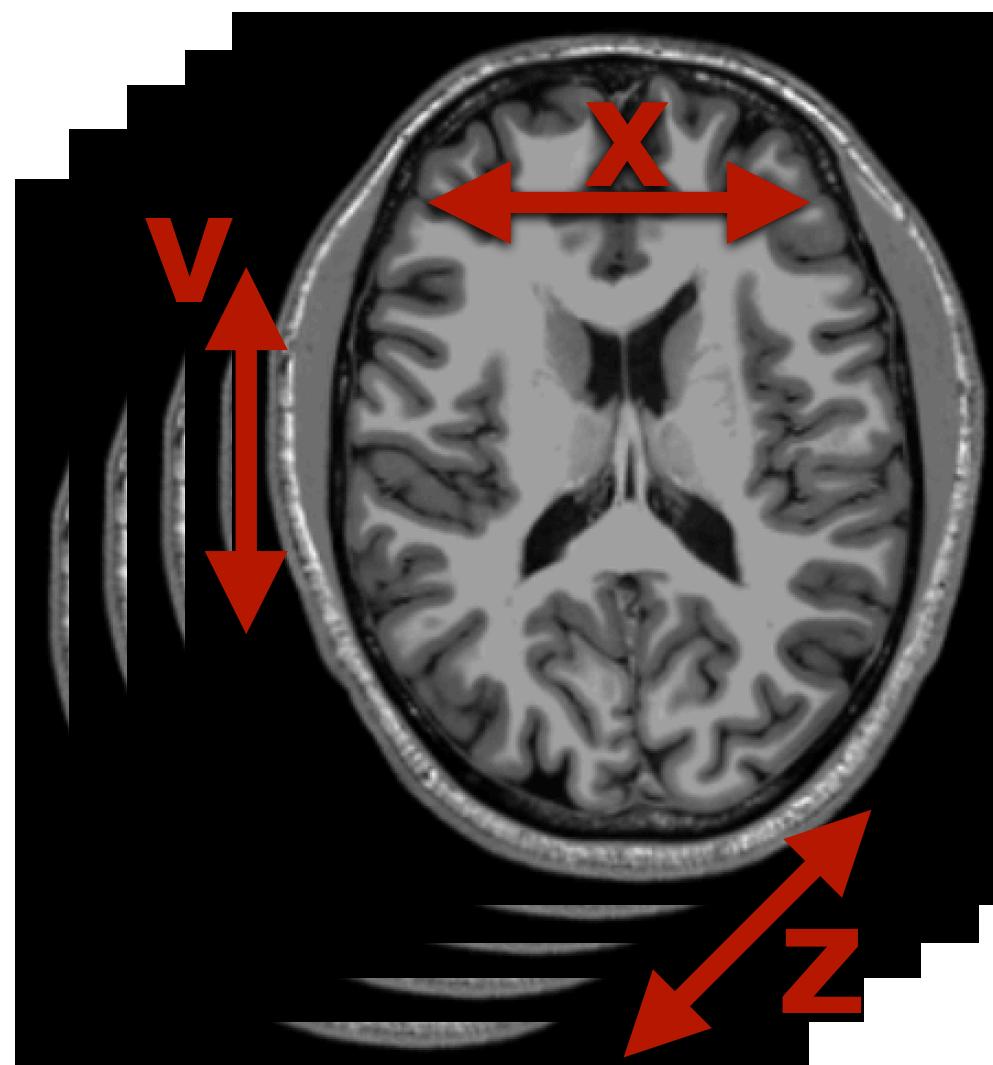


• 7 T

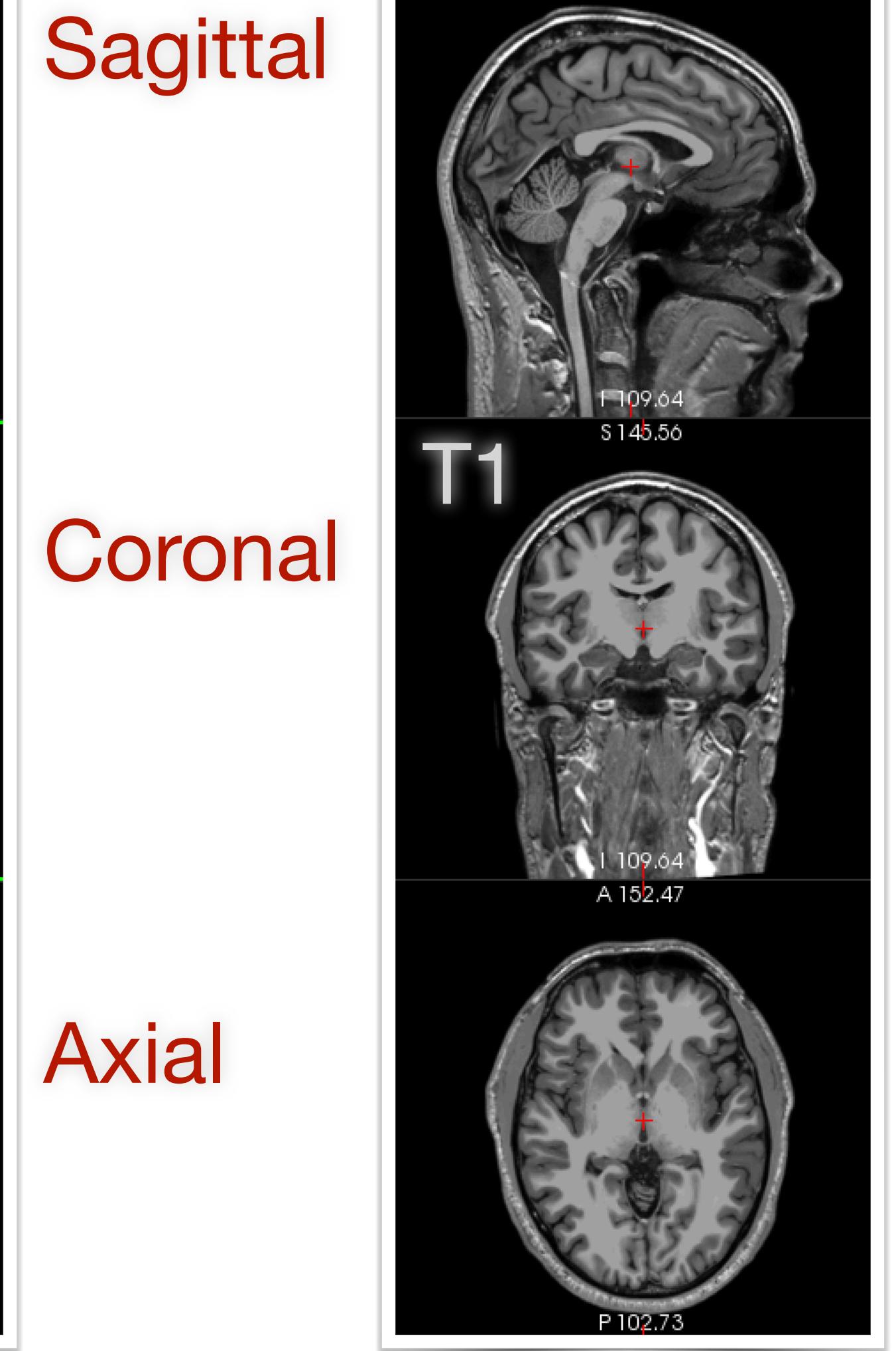
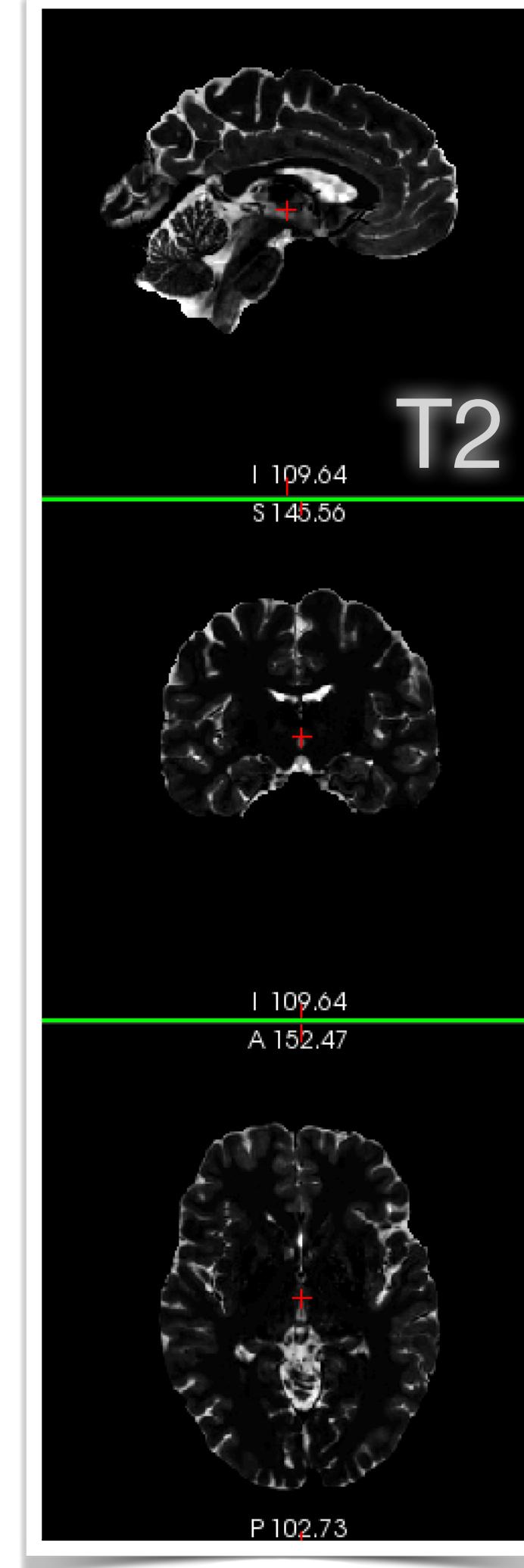
MRI data

What does MRI data look like?

- It's 3D: values at $\{x, y, z\}$ represents the anatomy
- Elements are called **voxels**, for *volume element*, like *picture element* for **pixels**



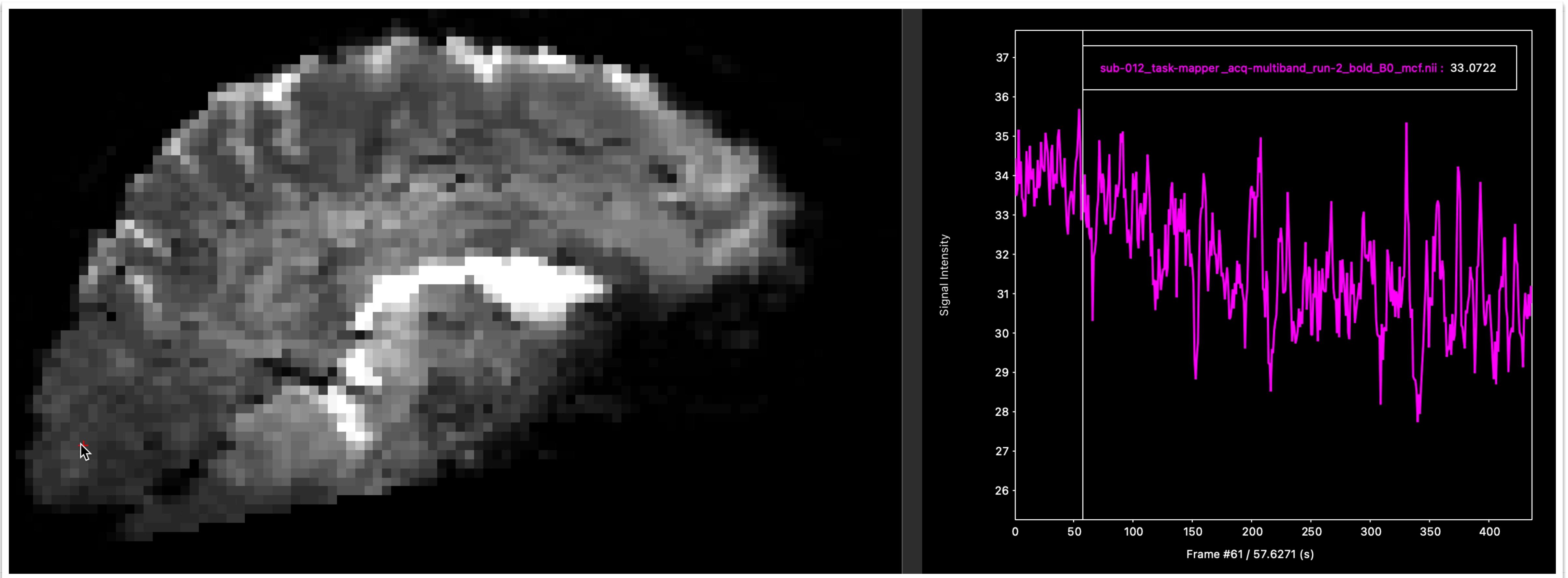
- Standard anatomy has a resolution of 1mm
- At 7T, the resolution goes to $\sim 0.3\text{mm}$
(27 times smaller, because cubic relation between voxel size and volume!)



fMRI data

What does fMRI data look like?

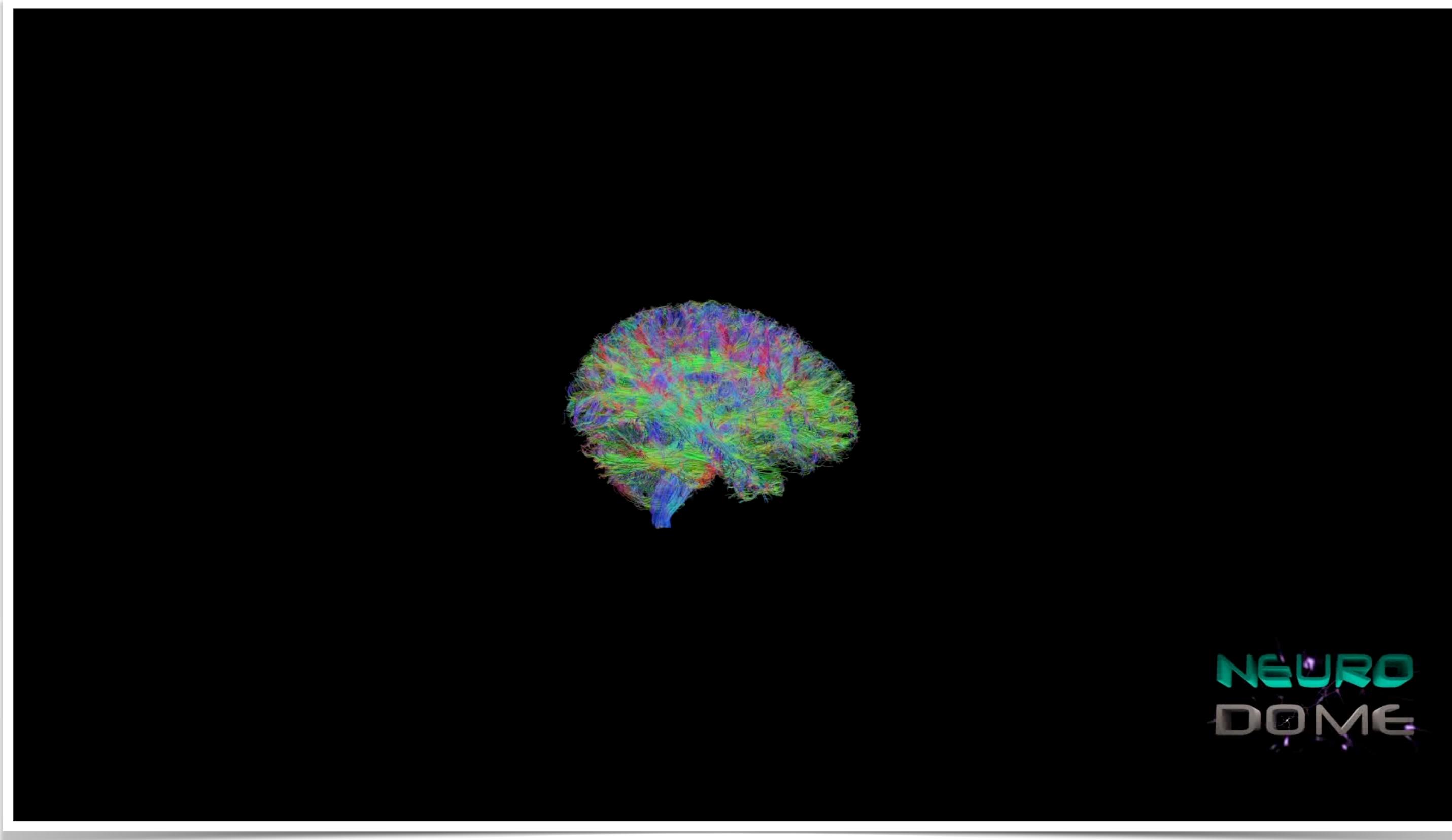
- It's 4D: a time sequence of BOLD-sensitive anatomical images, usually with lower resolution than anatomies (from 4mm @ 1.5T to 0.7mm @ 7T)



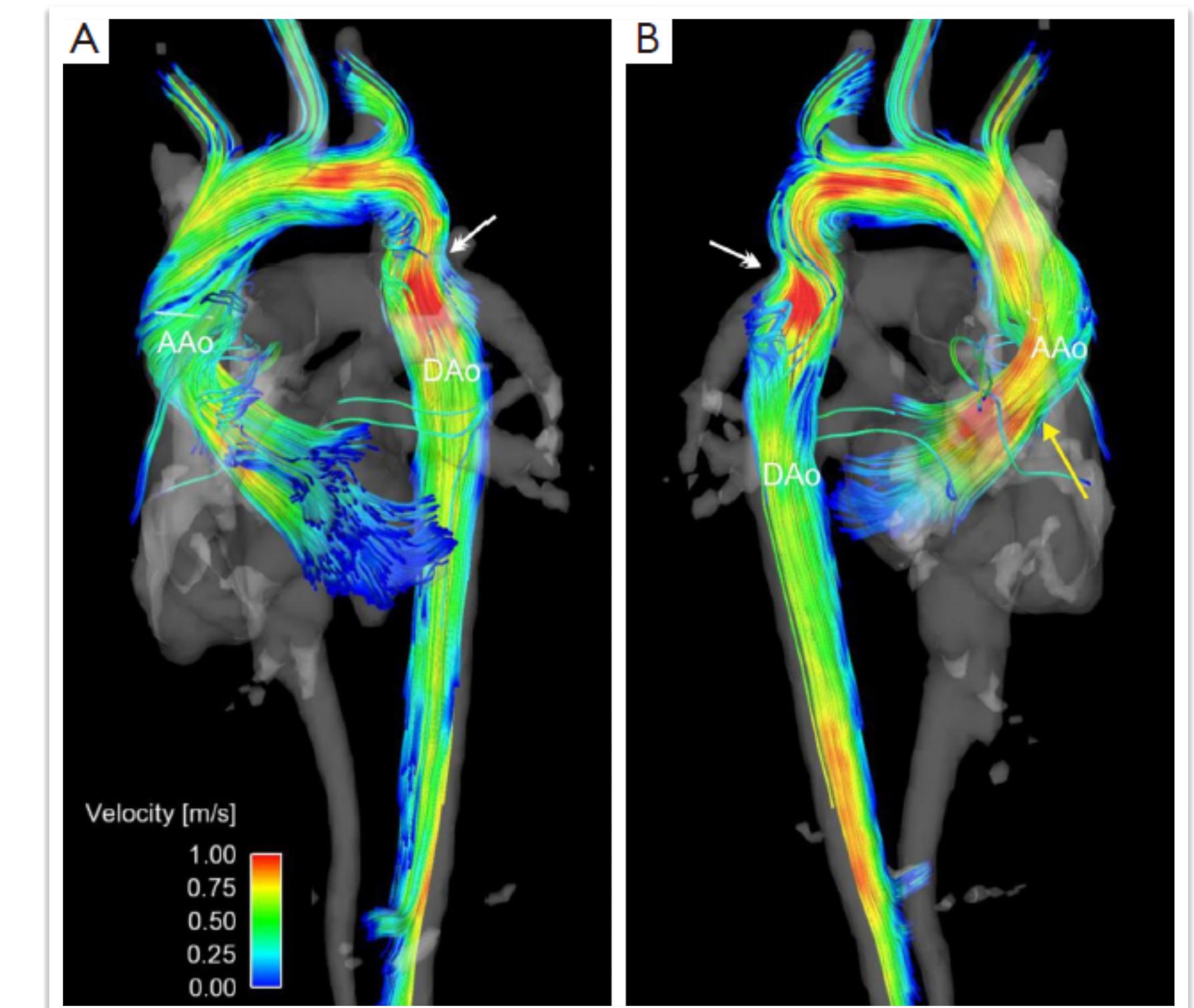
Other MRI data

What a versatile machine!

- Examples of 4D or higher-D images - store not a time-course for each voxel, but more complex information



- Diffusion Tensor Imaging (DTI)

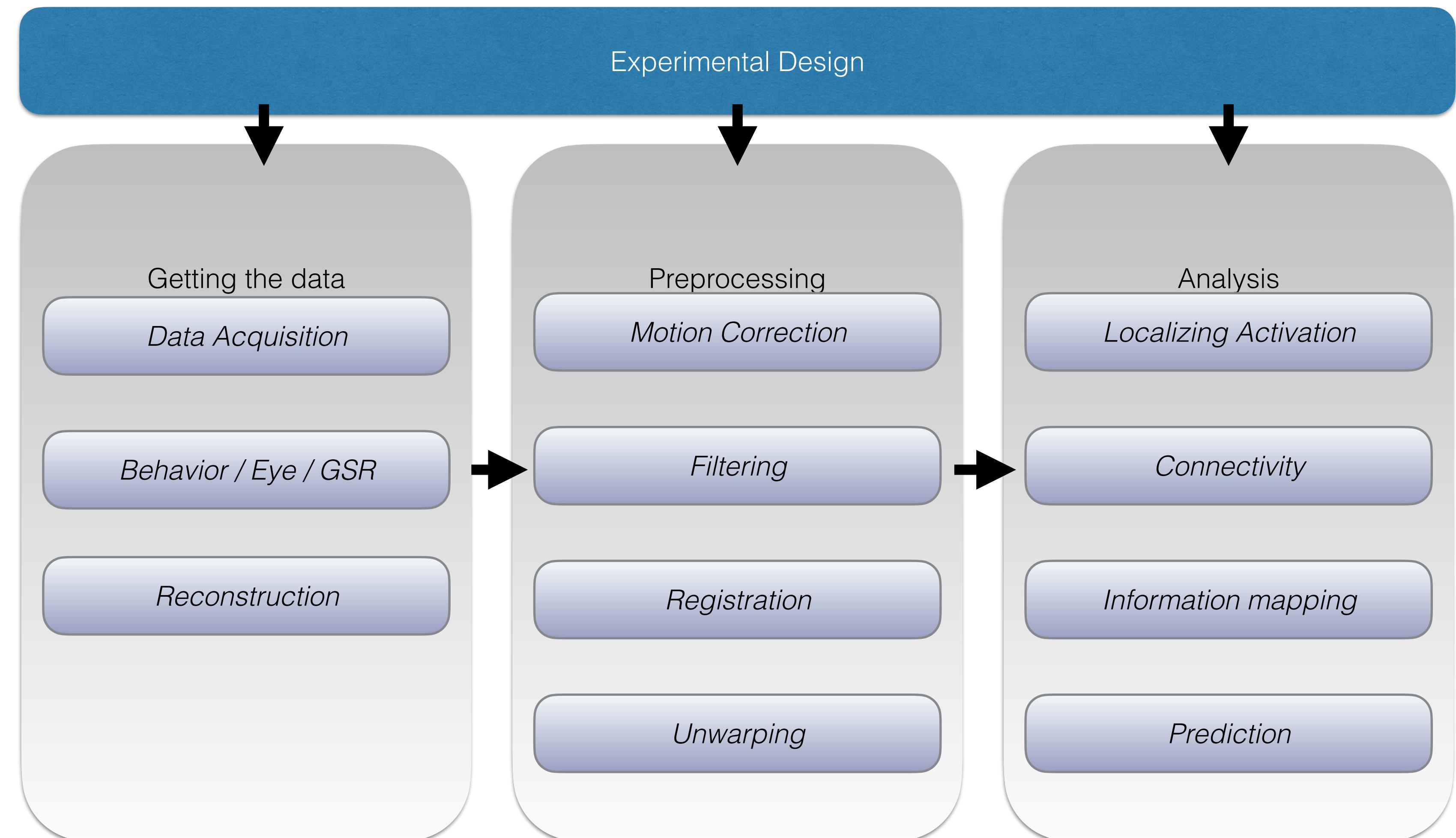


- Flow Imaging

fMRI analysis

How do you get to results?

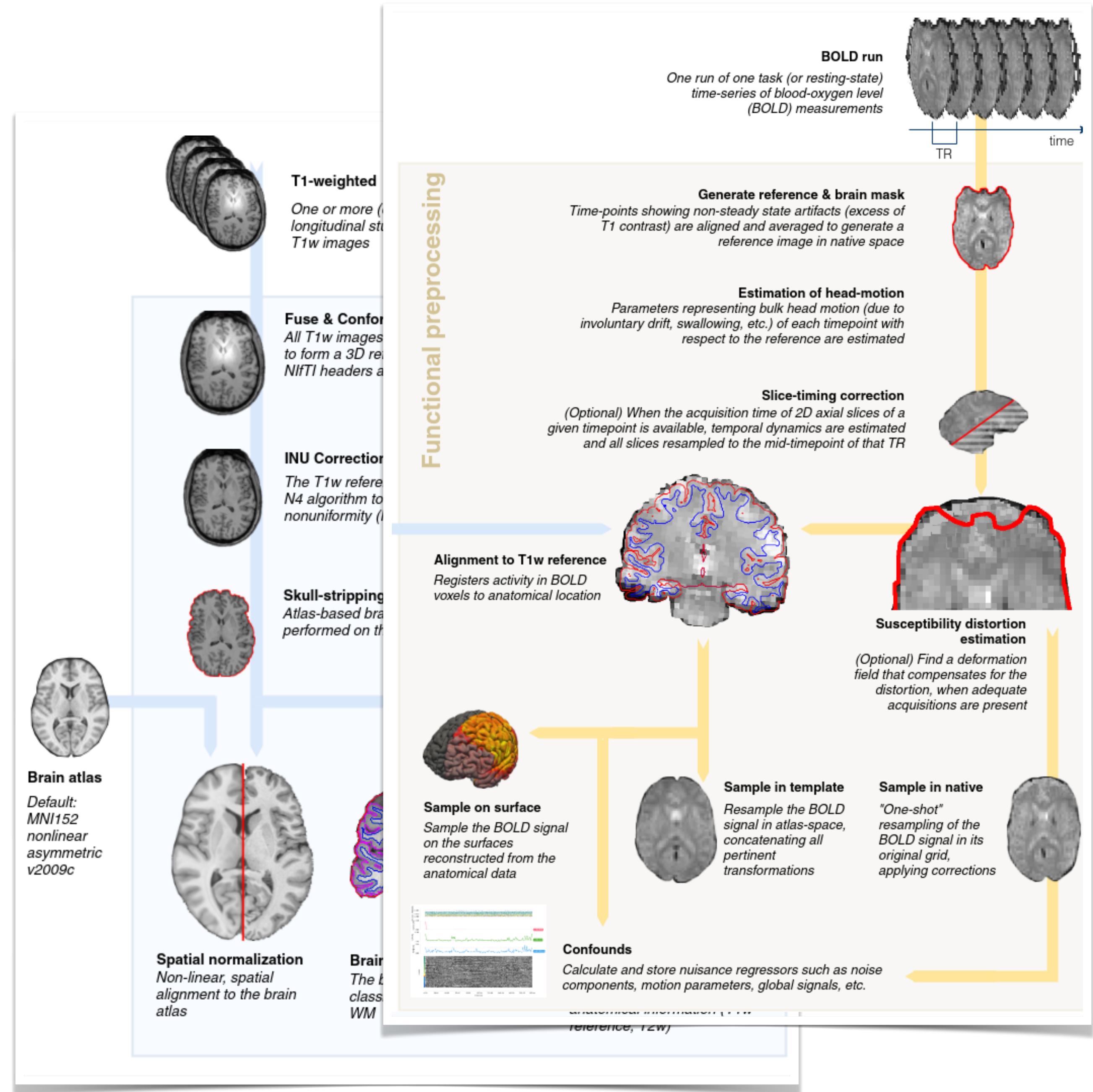
- Much more than just a single step
- Experimental design is paramount:
- ***What is your goal?***
- Many ways of going wrong



Replication Crisis

Many ways of going wrong?

- With such complex analyses, room for 1. 'Tinkering', or 2. Sloppiness
- We will teach you the newest approaches to reproducible neuroscience:
 - How to save your data
 - How to preprocess your data
 - How to program your data analyses
 - How to report your results
 - How to open-source your data and analyses

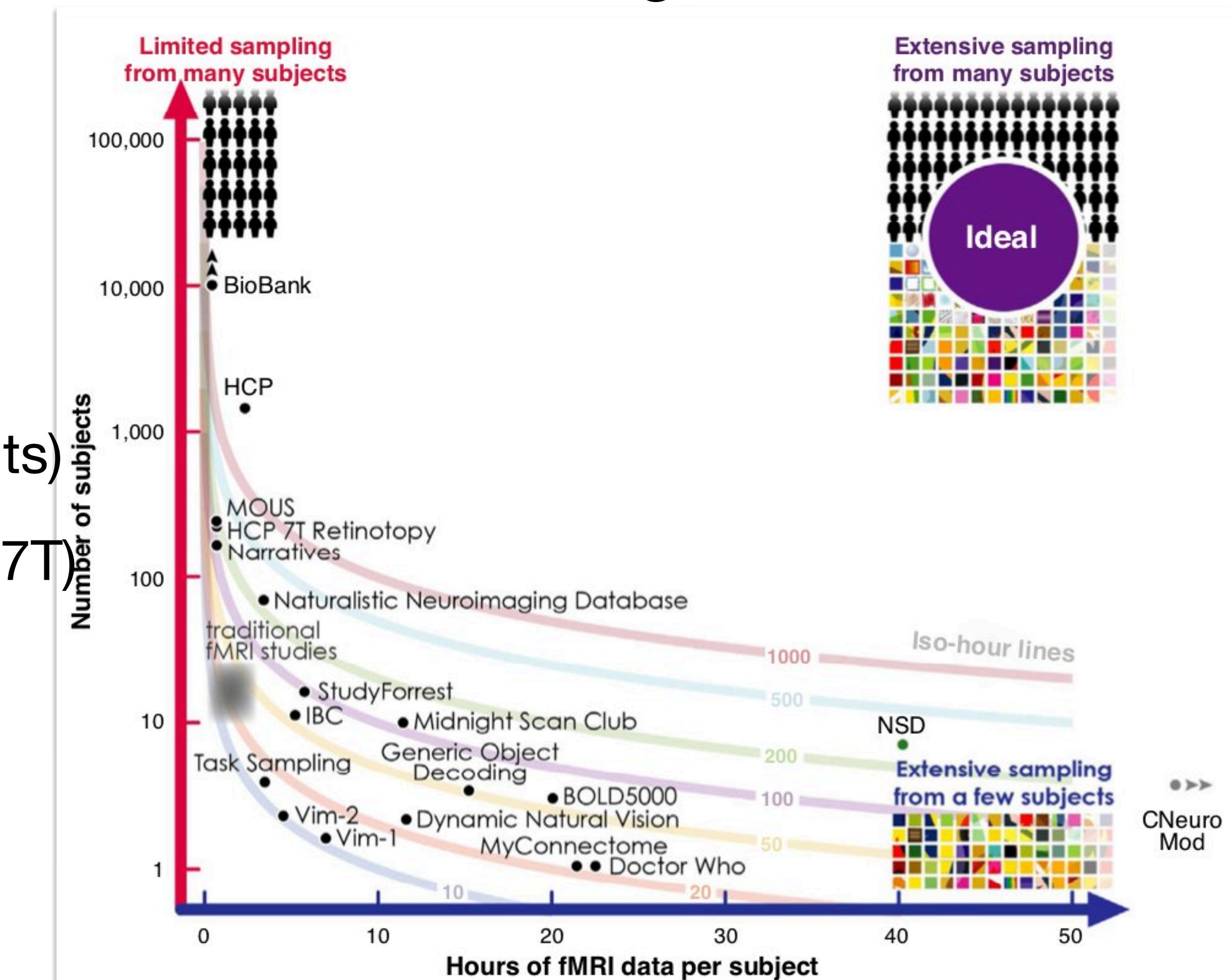


“Modern” fMRI

What's the state of the art?

- With higher field strengths, more is possible. For instance, higher resolution means “laminar” resolution
- Large, open science projects:
 - Human Connectome Project (HCP, 1200 sjs, >5 hours, 3T & 7T)
 - UK BioBank (10000 sjs, repeated measurements)
 - Natural Scenes Dataset (NSD, 8 sjs, 40 hours, 7T)
- Sophisticated data analysis techniques
- Open source software**
- Containerized for reproducibility**

*Naselaris et al, 2021
paper on Perusall*



The Future of fMRI

Beyond the state of the art

- ***Higher field strengths & improved sequences:***

Increased resolution and signal-to-noise ratio

allows us to regard a single voxel as a ‘unit’ (cf. single-cell electrophysiology)

- ***Computation:***

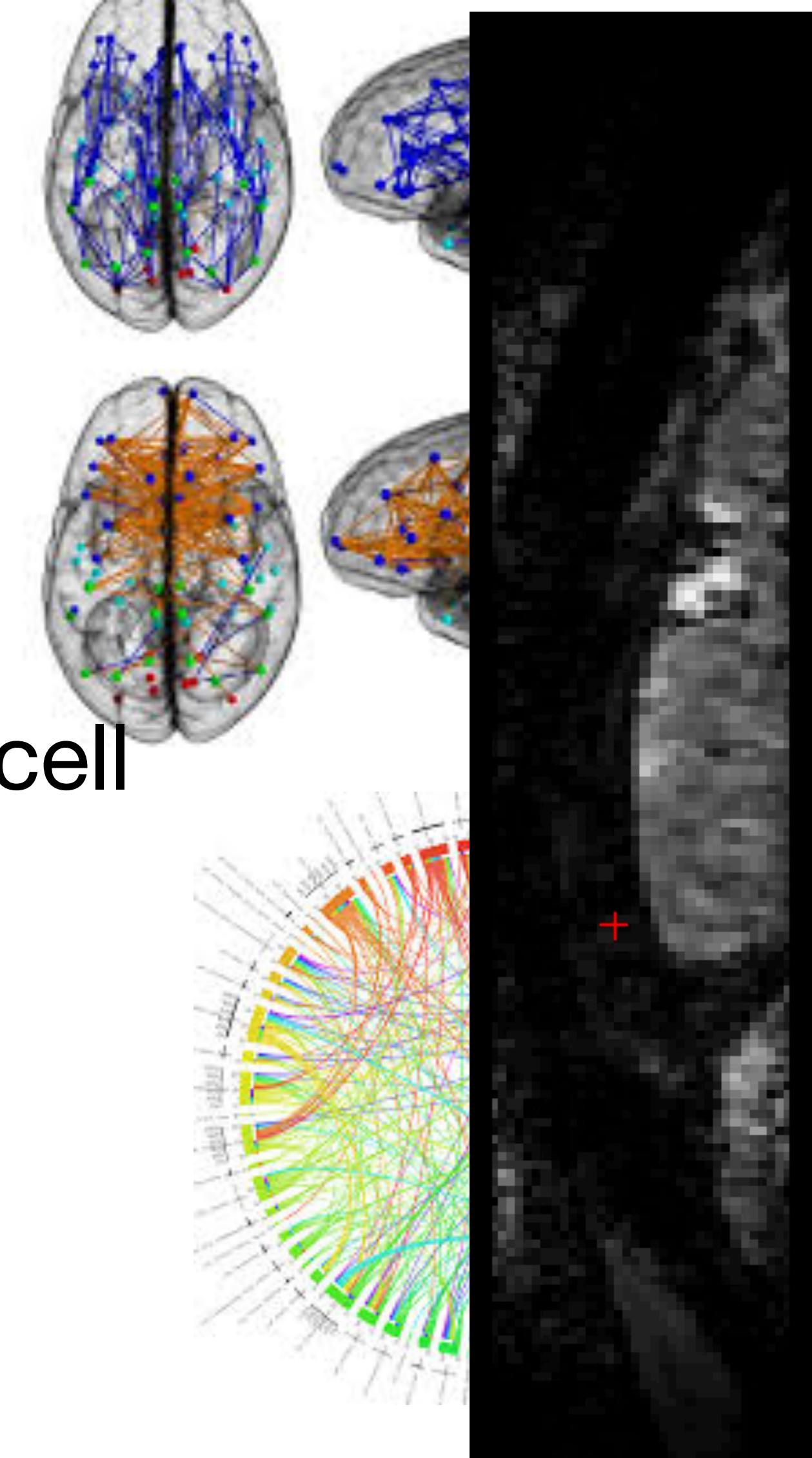
Fit models of what units do, *computationally*

Understand how the brain represents information

<https://gallantlab.org/huth2016/>

- ***Connectivity:***

Understand how brain regions communicate, and what information they share



Go!

Start reading article pdfs, and watching the YouTube videos...

The detailed list of specific clips that are exam material will follow soon.