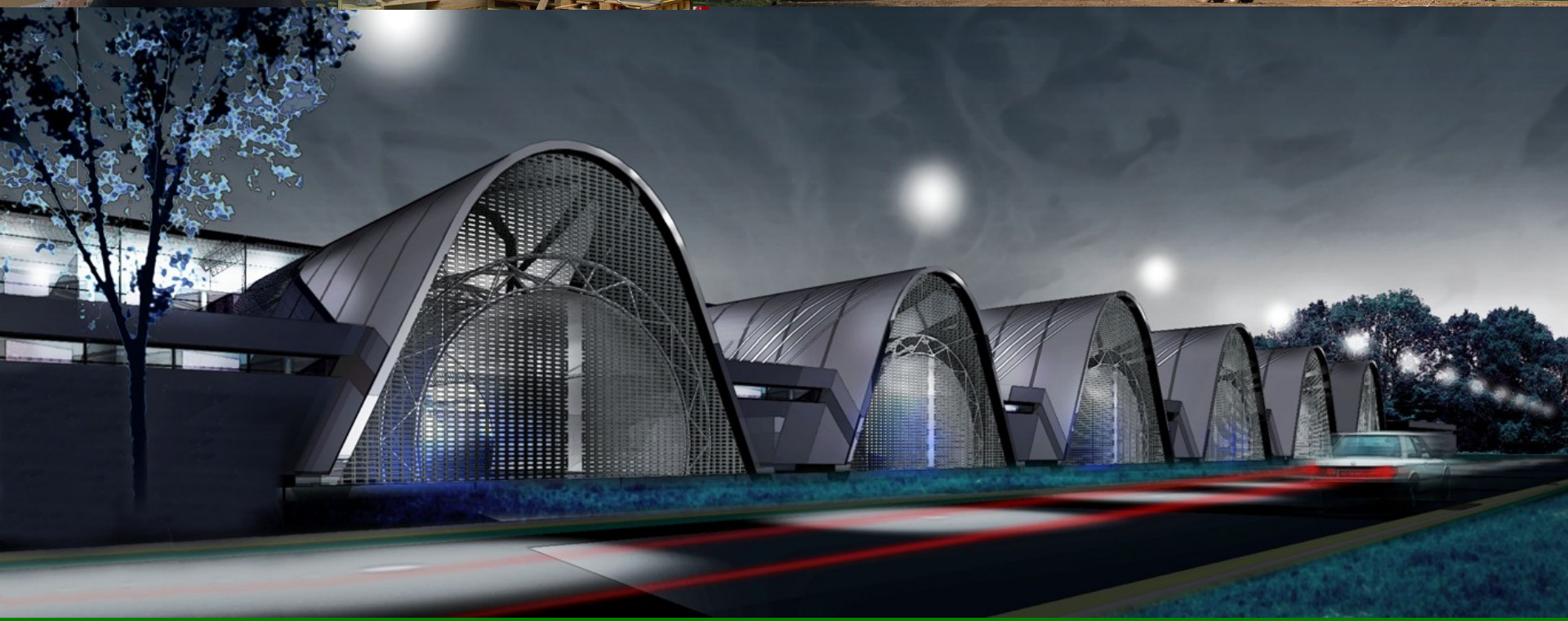
Mapping the brain with functional Magnetic Resonance Imaging



Outline

1. Cognitive imaging
2. Understanding the nature of the data
   - MRI
   - Functional MRI
3. The secrete life of fMRI data: preprocessing

Cognitive neuroscience

How are cognitive activities affected or controlled by neural circuits in the brain ?

Cognitive neuroscience

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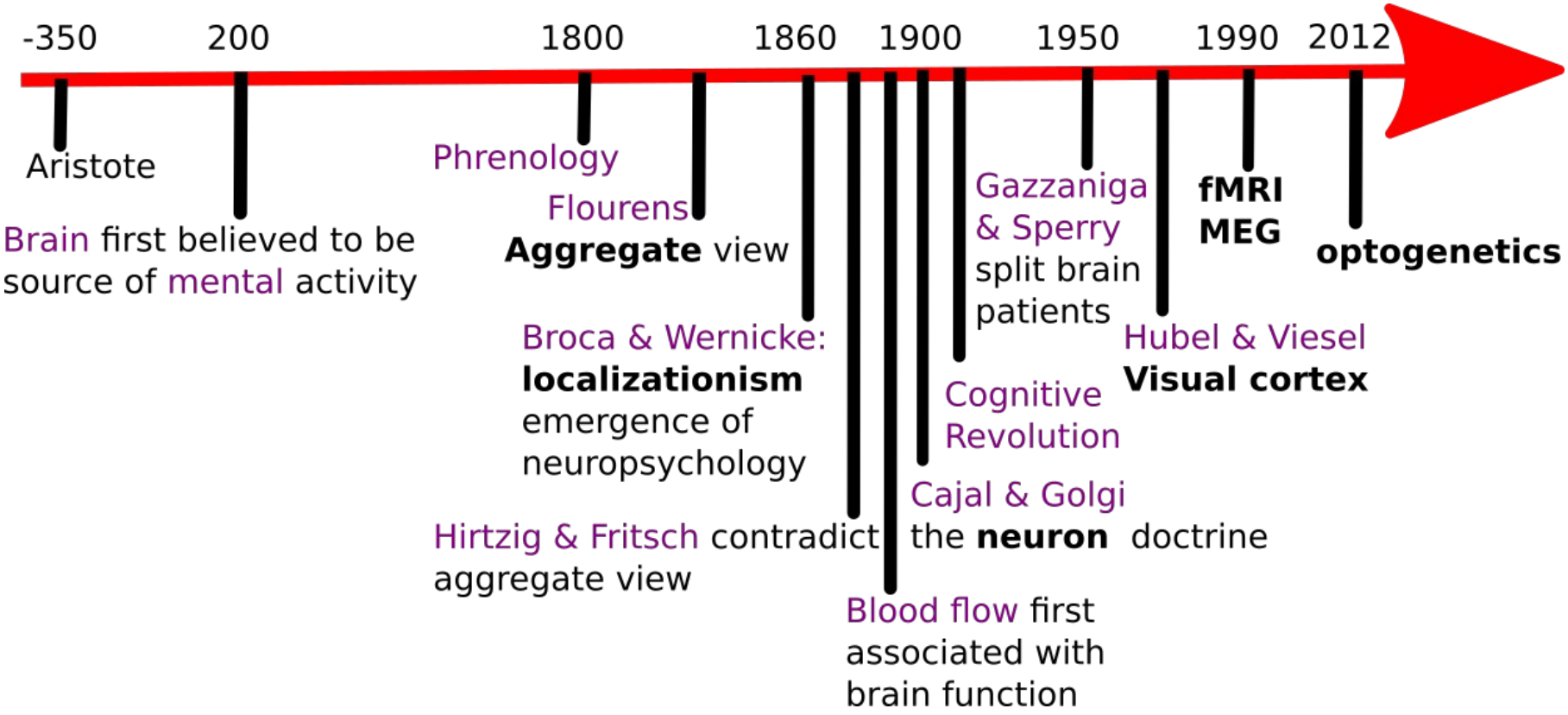
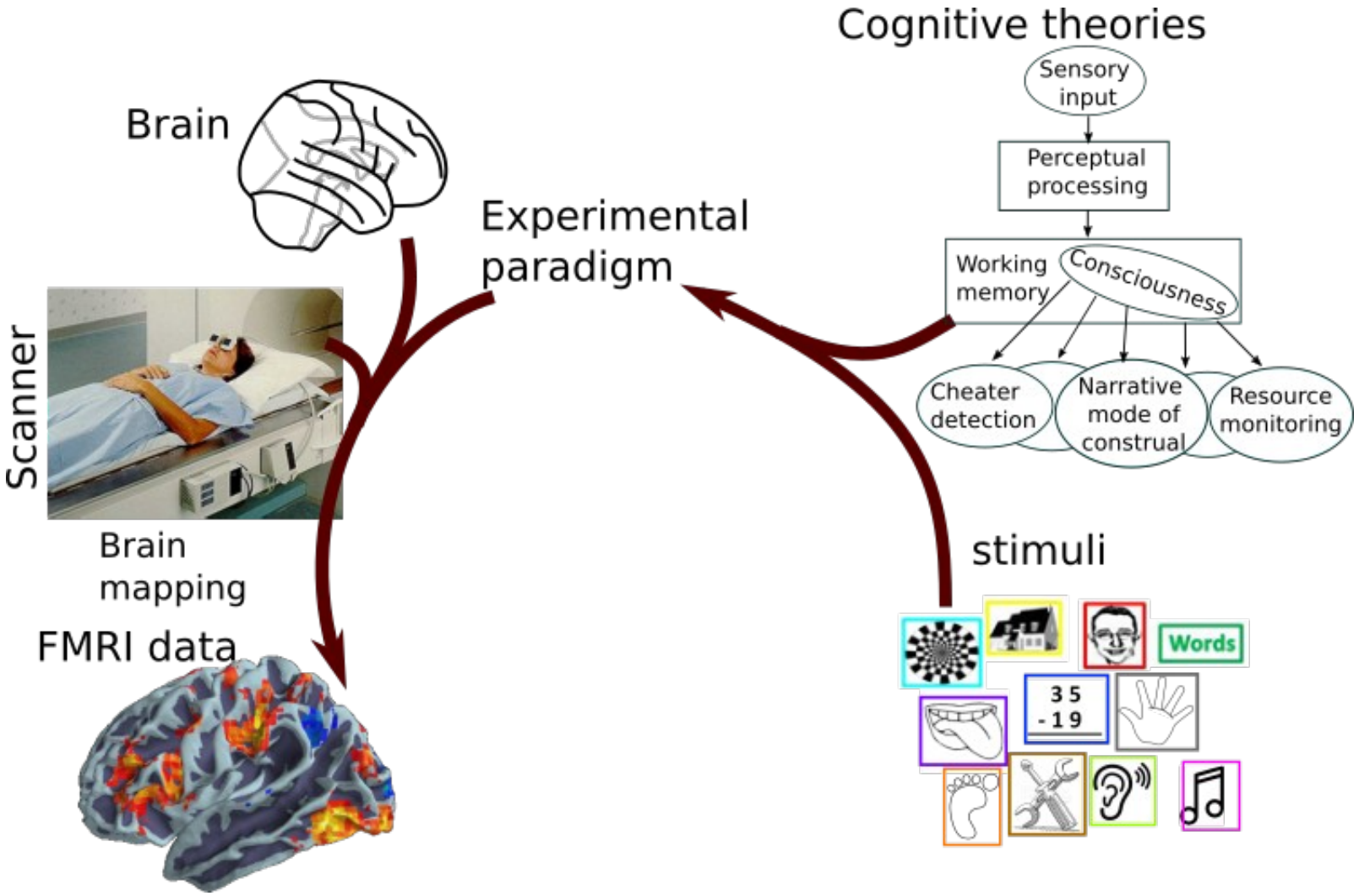


The brain, the mind and the scanner



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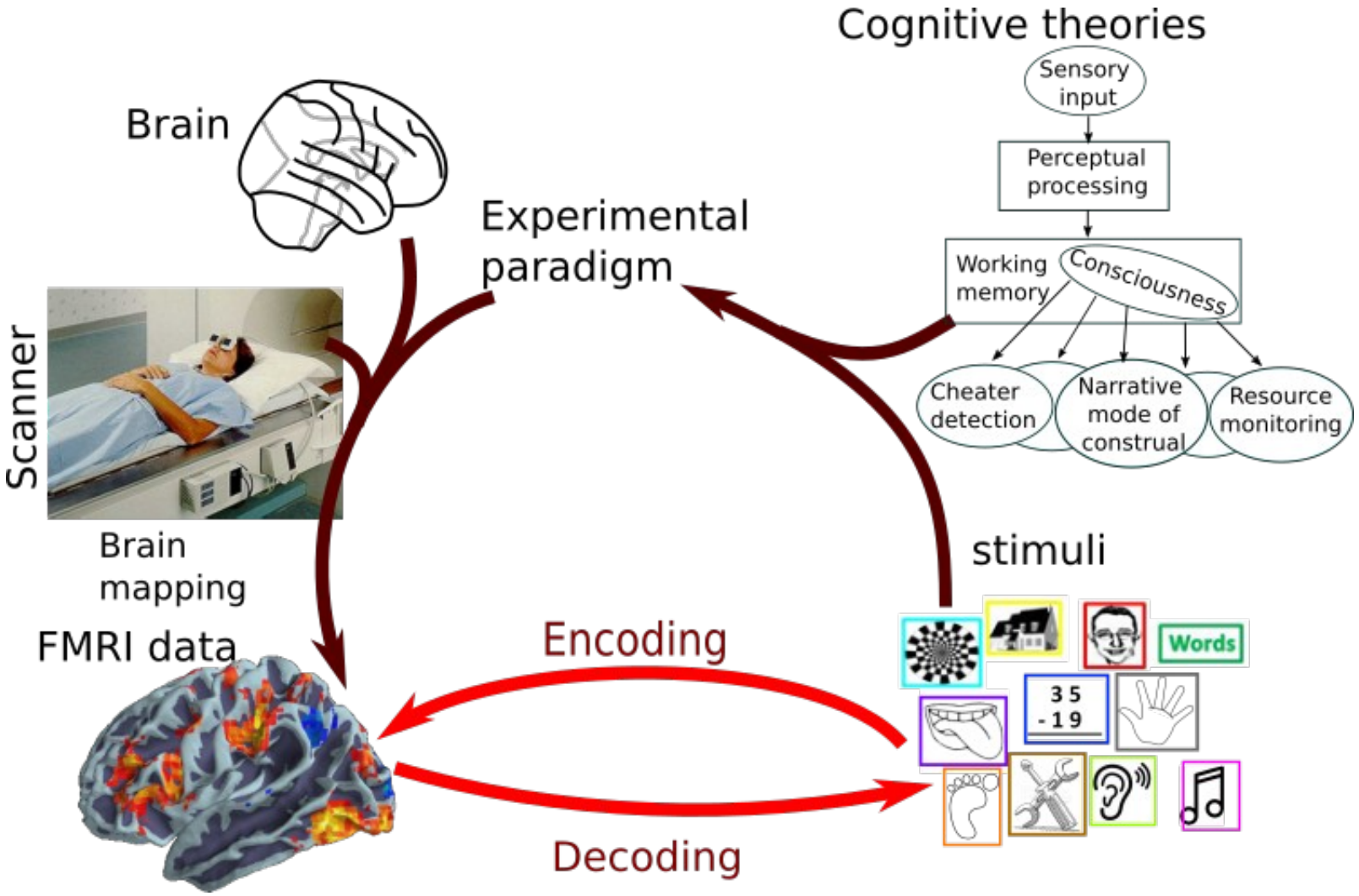

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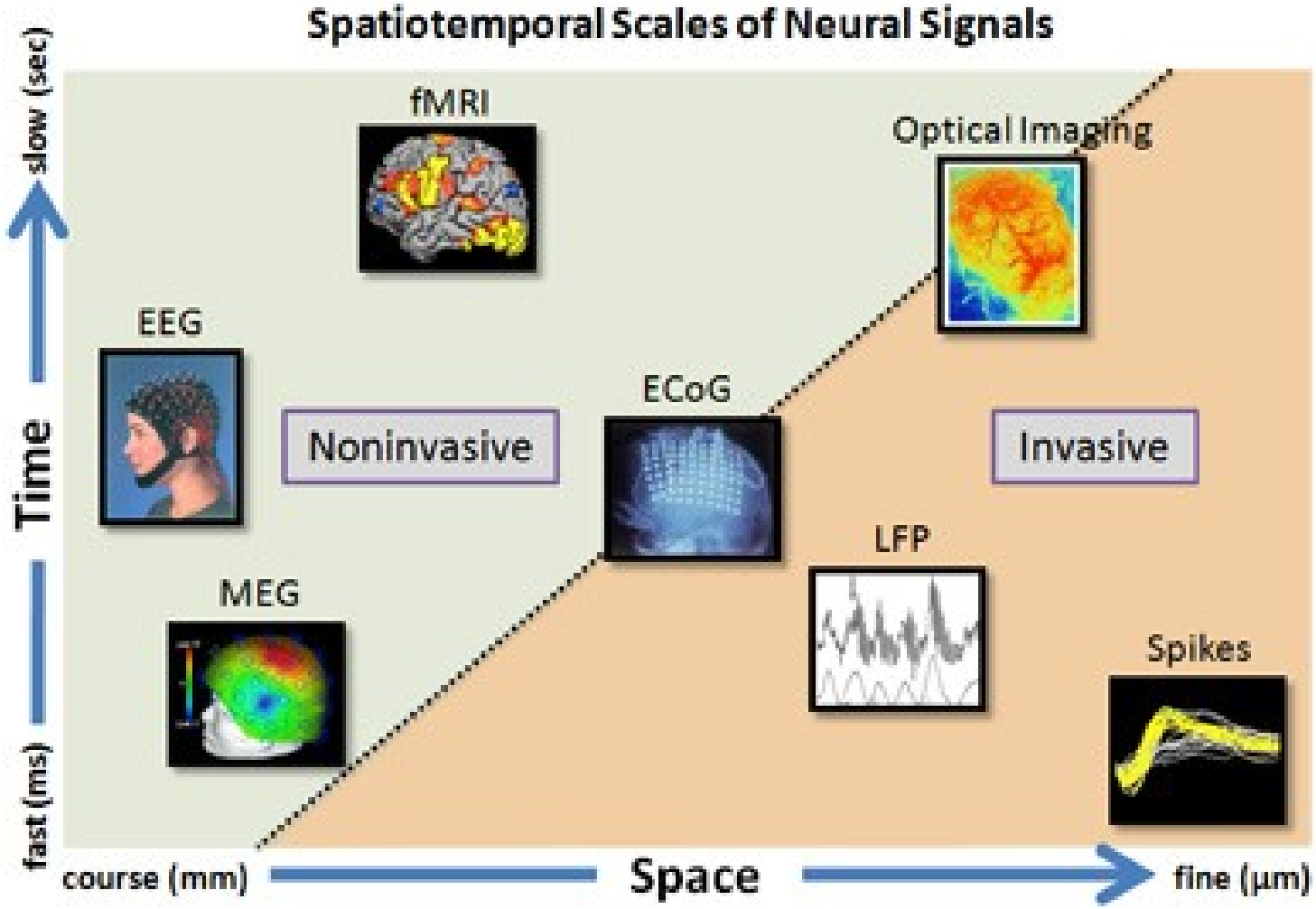
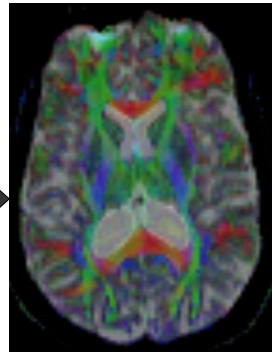
The resolution of different functional brain imaging modalities

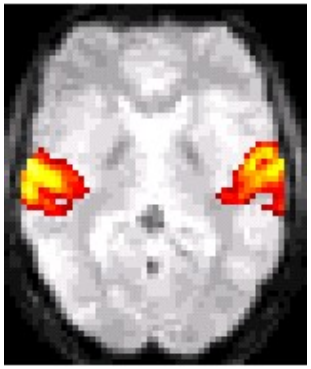


http://lifesciences.ieee.org/publications/newsletter/april-2012/96-building-brain-machine-interfaces-neuroprosthetic-control-with-electrocorticographic-signals

(T1)
Anatomical MRI

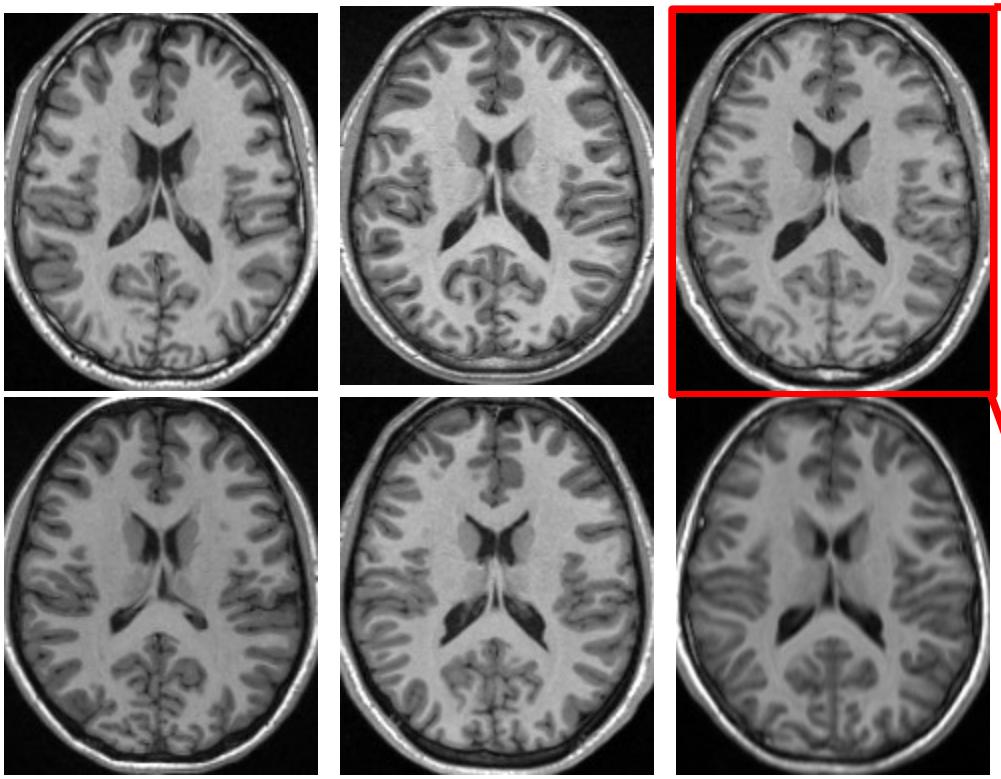


Diffusion-
weighted MRI



functional MRI

T1 images

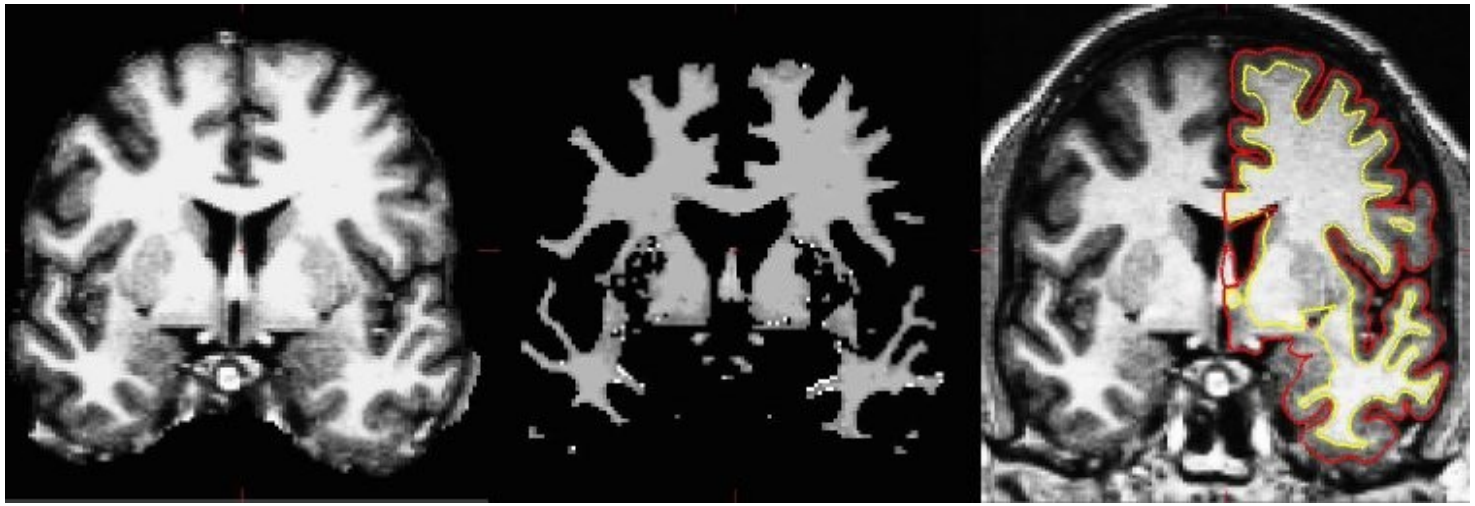


Grey matter

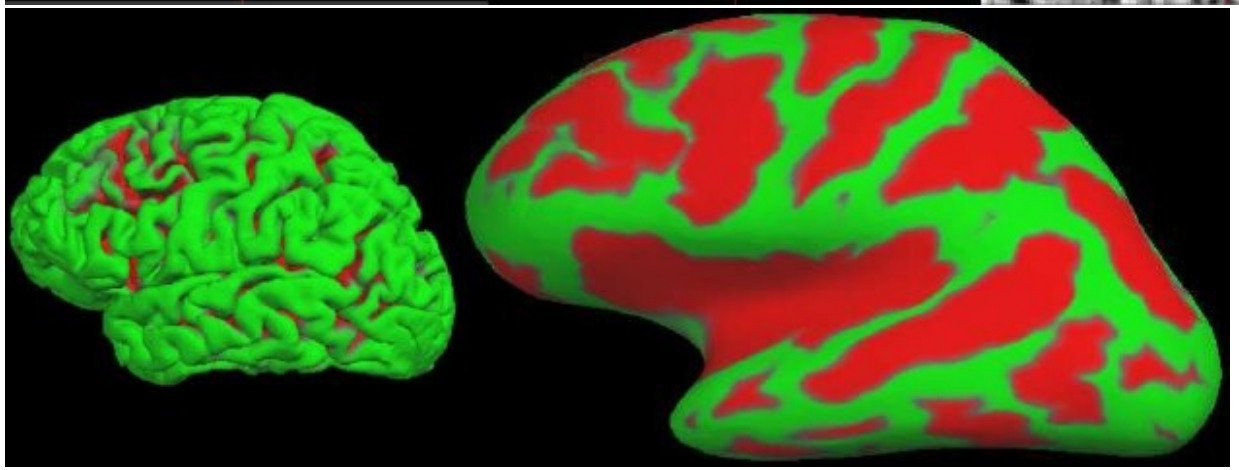
White matter

256x256x128, 1mm in x, y, z
Contrast varies across the brain

T1 image processing



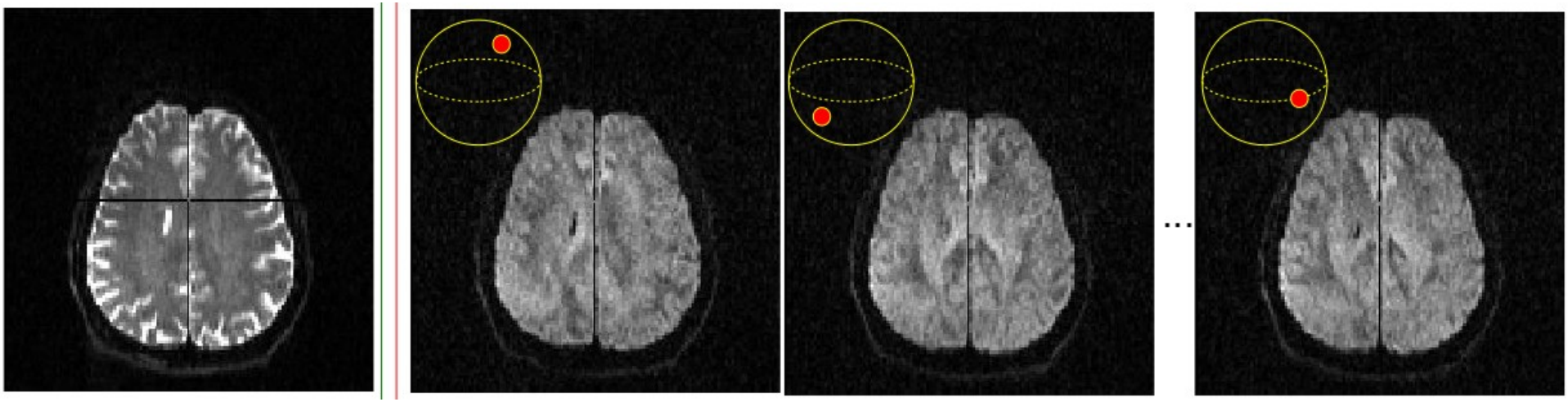
- skull stripping,
- white matter segmentation
- grey matter segmentation



Surface matching based on sulci/gyri

http://surfer.nmr.mgh.harvard.edu

Diffusion images

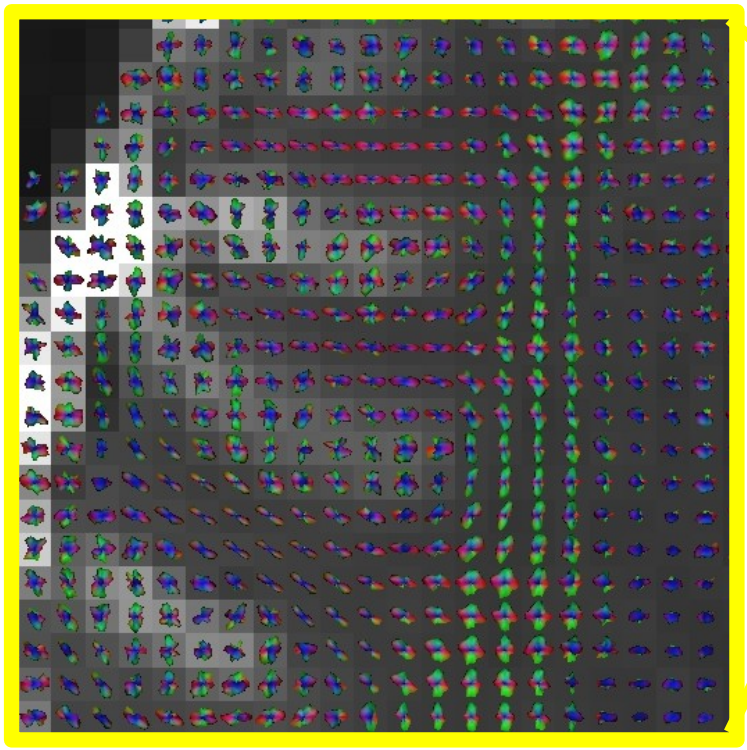


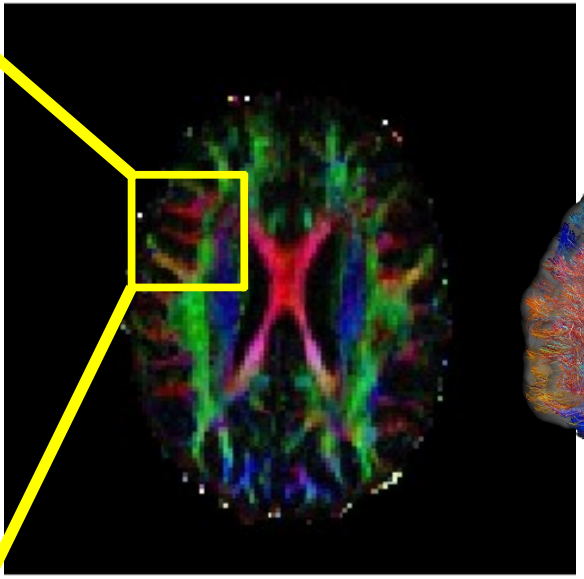
Measure water diffusion in k (>5) directions in « q-space » + non-diffusion-weighted reference image(s)

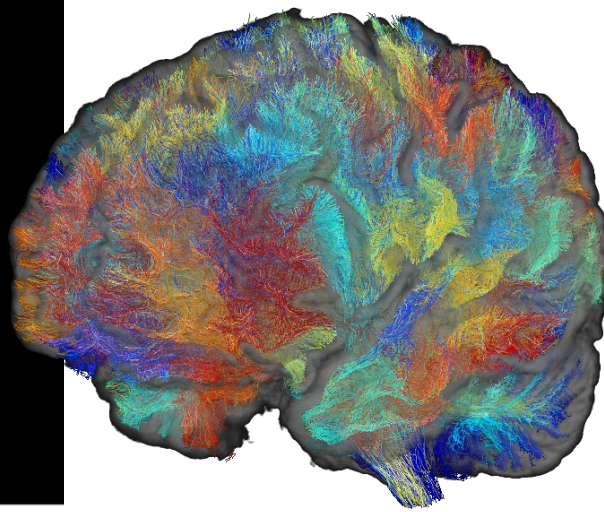
Subject to distorsions and artefacts related to EPI acquisitions

Resolution improving ~ $(1\ mm)^3$

High Angular Resolution Diffusion Imaging







Local diffusion model
Courtesy C. Poupon

Tractography

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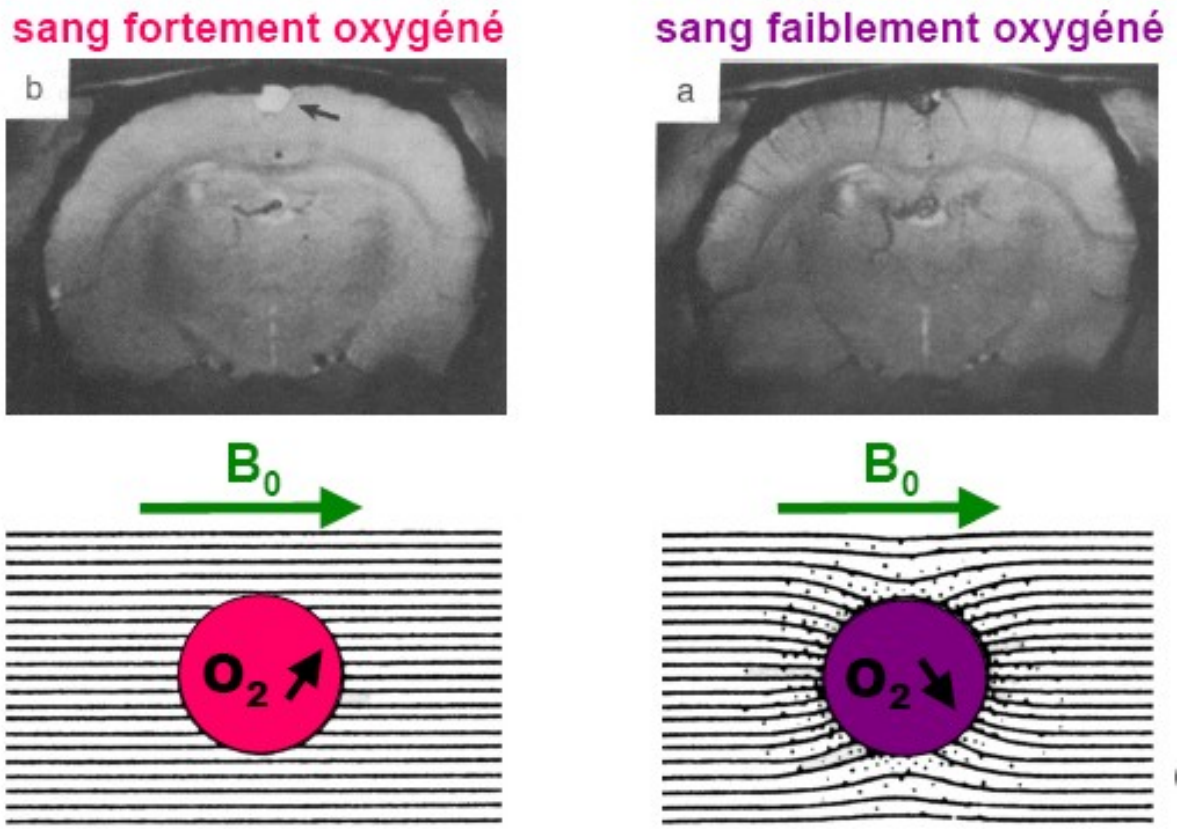
BOLD effect

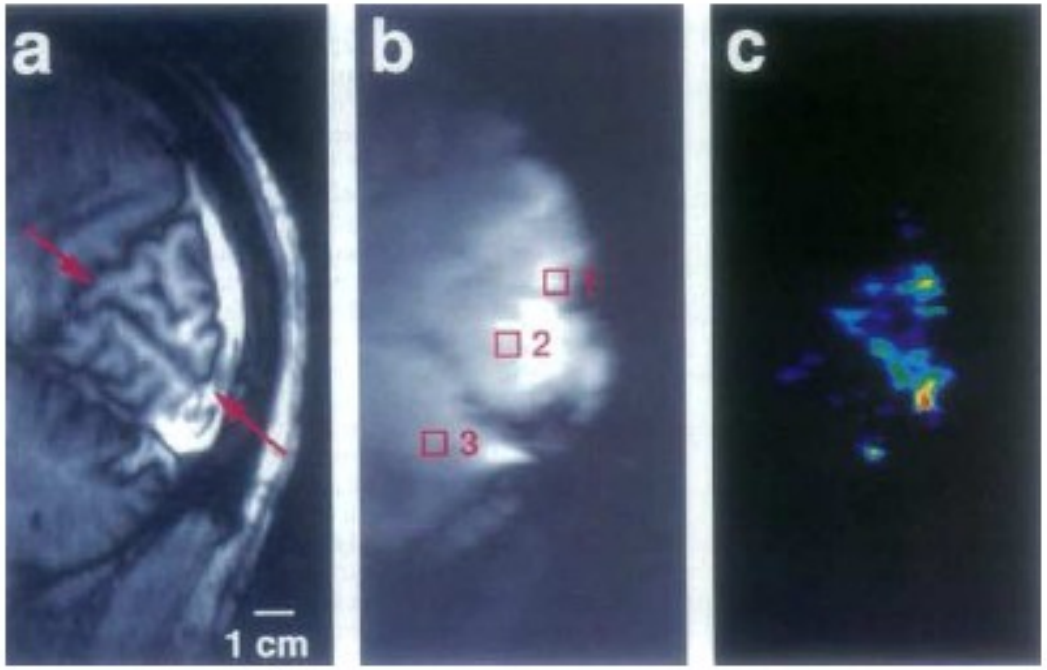
BOLD = Blood Oxygen-Level Dependent signal

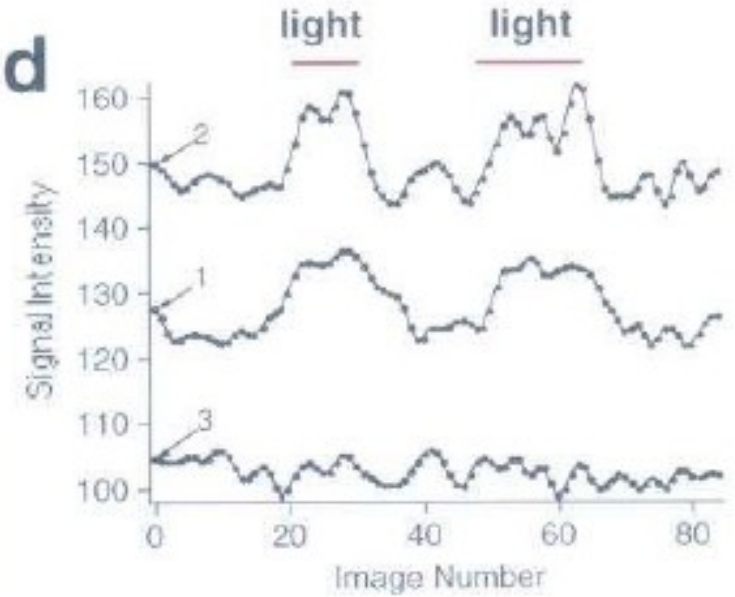


Observed first in rodents [Ogawa et al, PNAS, 1990]

BOLD in humans (1992)

[Ogawa et al, 1992, PNAS]

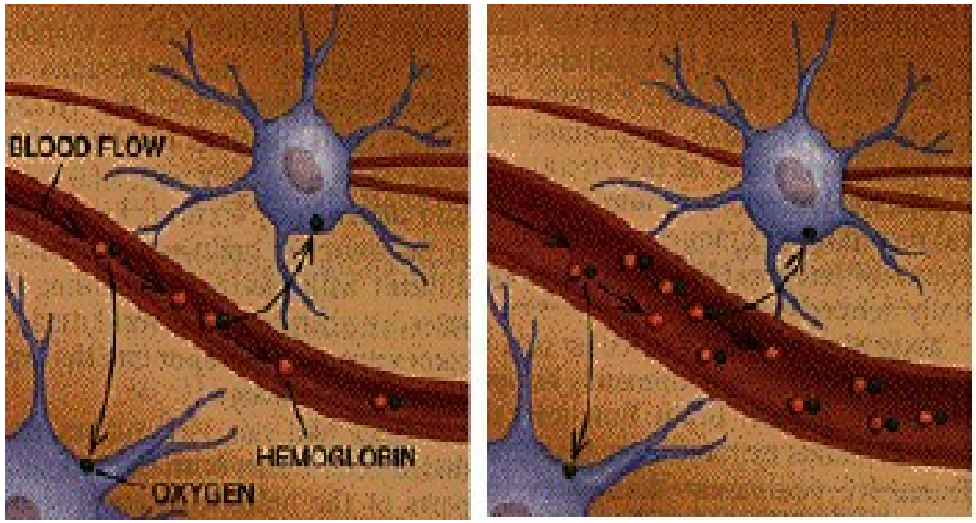




The BOLD effect

BOLD= Blood oxygenation level dependent signal

Intrinsic contrast agent:
oxyhemoglobine[O_2Hb]:
diamagnetic
deoxy hemoglobine[HHb]:
paramagnetic



neuronal activation →

little increase of 0_2 consumption

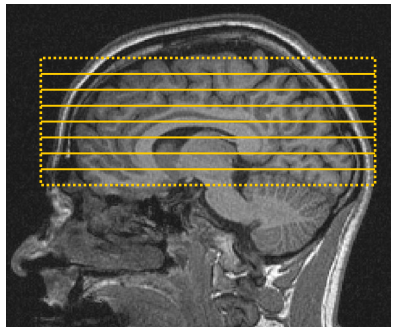
large change of oxygenated blood flow

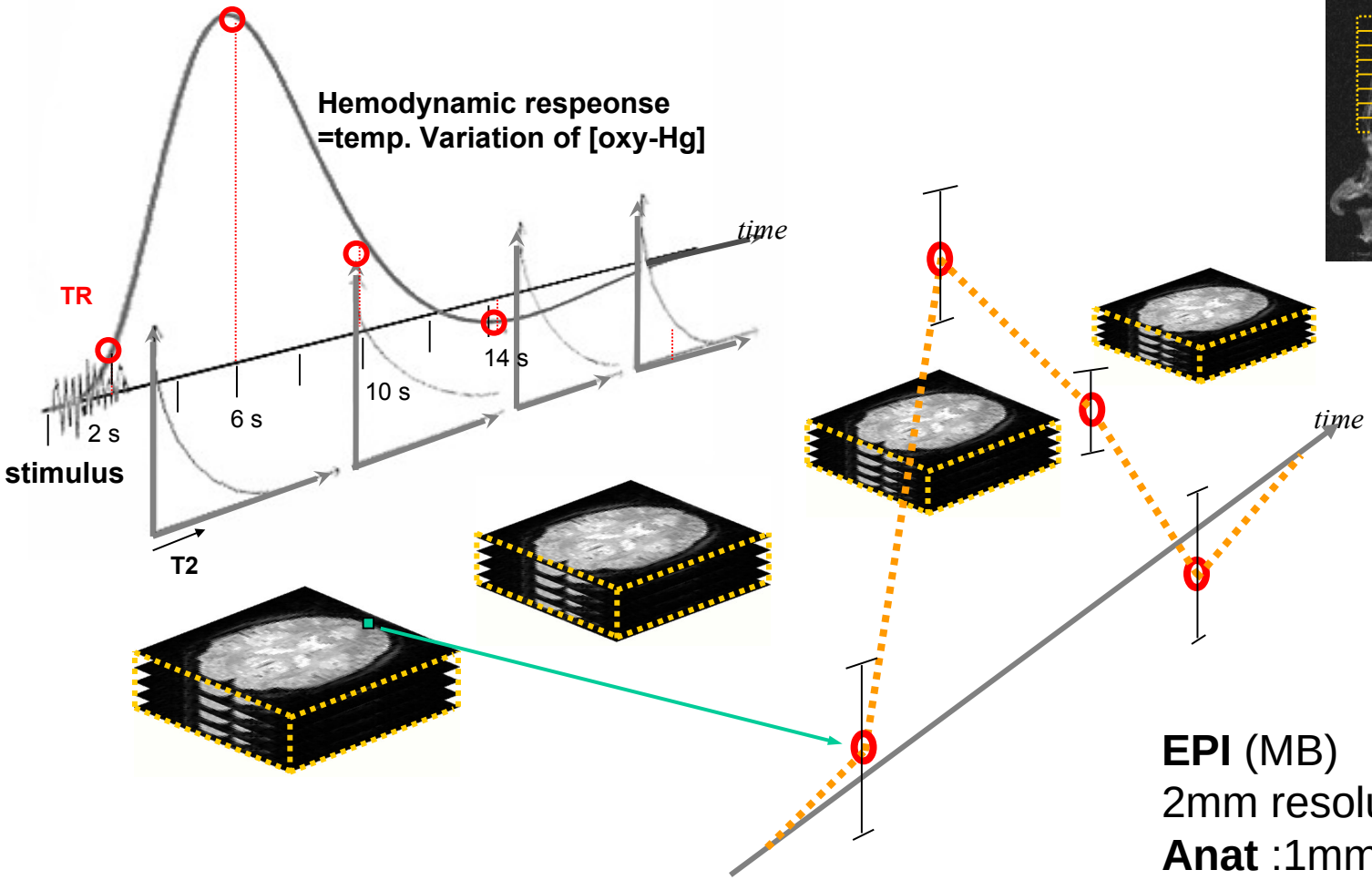
[oxygenated blood] / [deoxygenated blood] **increases**

→ decreased magnetic susceptibility

→ **increased fMRI signal**

Sampling of the BOLD response in fMRI experiments

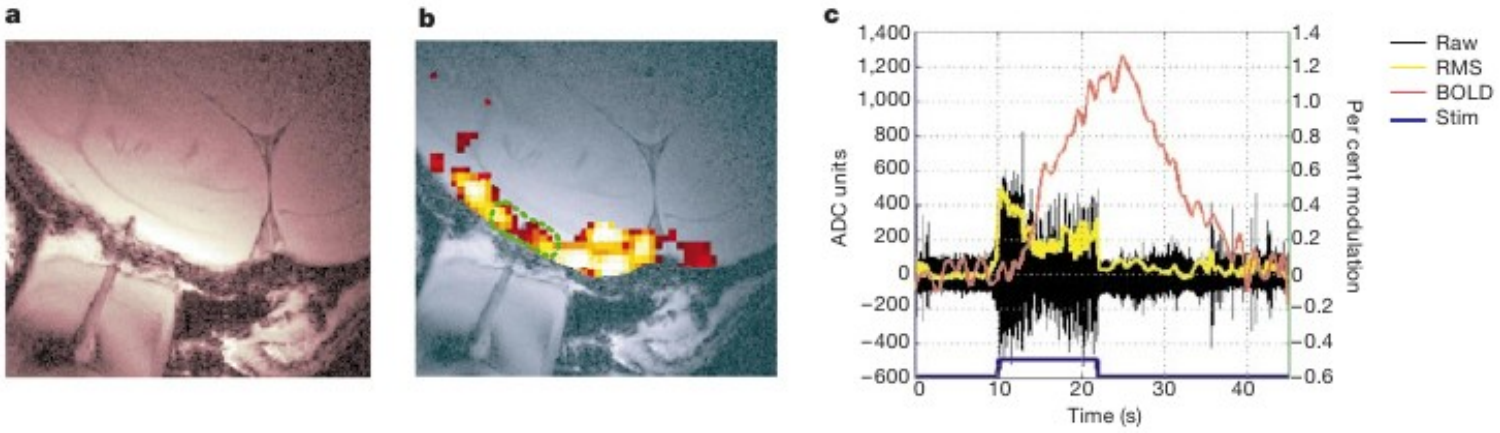


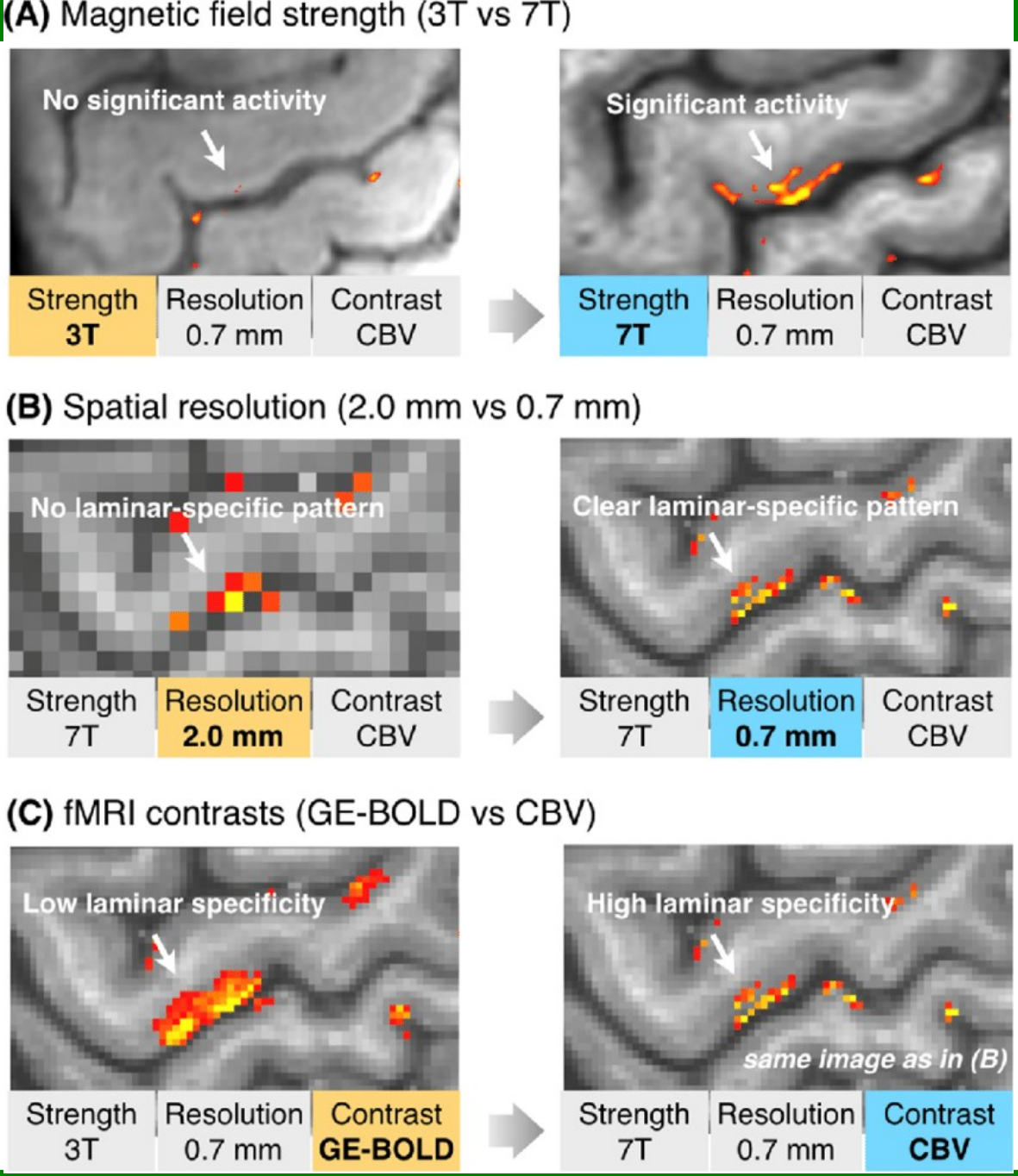


EPI (MB)
2mm resolution, TR=2s
Anat :1mm resolution

30 years of human BOLD imaging

1. The BOLD response is approximately linear in the stimulus
   - ➔ Simple linear model for data analysis [Friston et al. Nimg 1995]
2. The BOLD signal is highly correlated with LFPs [Logothetis et al. Nature 2001]
3. High spatial accuracy (~2mm) [Ugurbil et al. Nimg 2007]
4. Poor temporal resolution, no consensual model on the signal





High-field high-res fMRI

[Yang et al. Neuroscience & Biobehavioral Reviews 2021]

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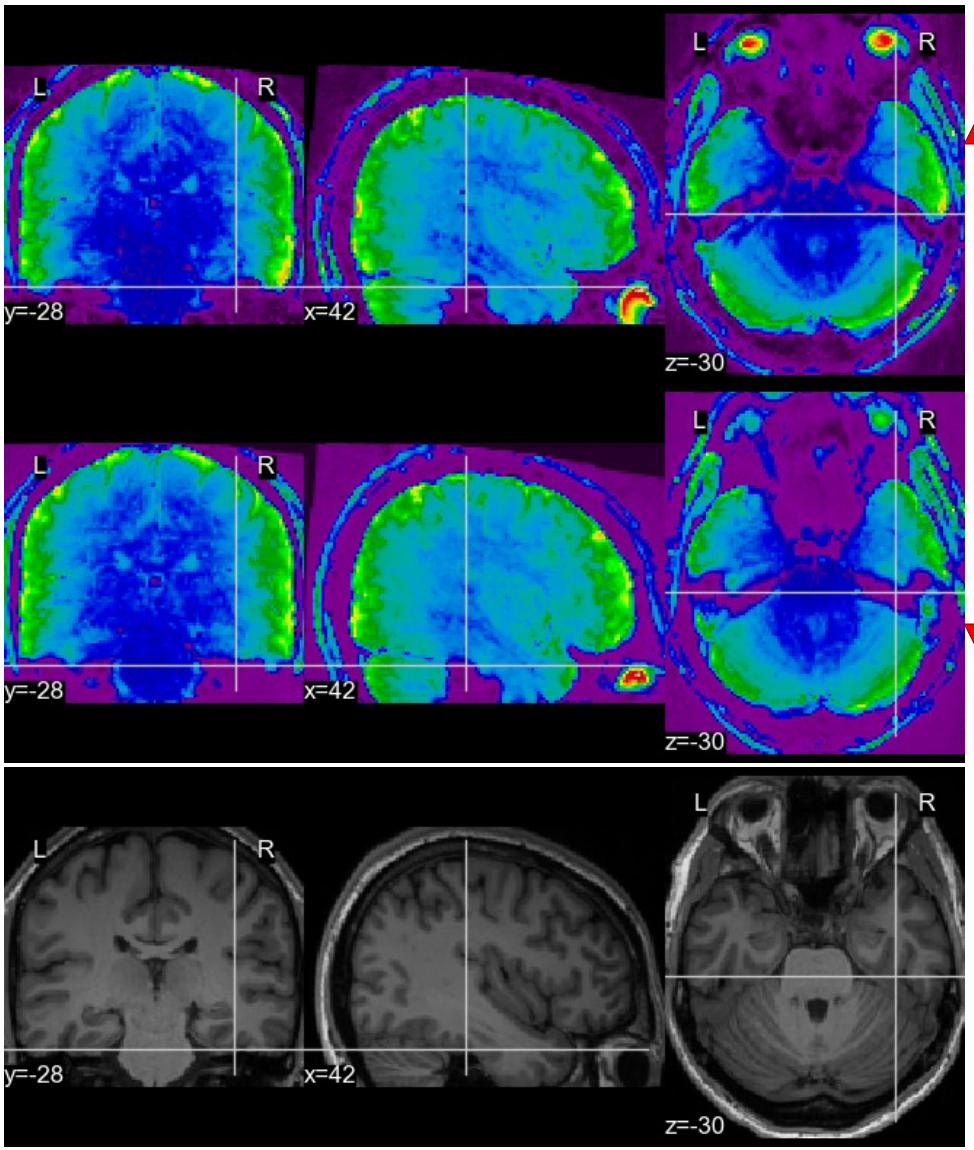
Image distorsions

fMRI images are distorted

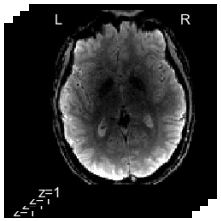
They are noisy

Don’t have signal everywhere in the brain

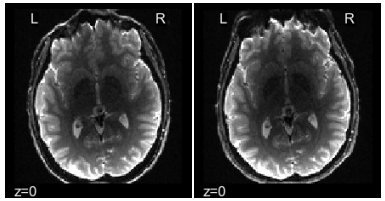
Depend on many parameters: T2*, B0, TE, …



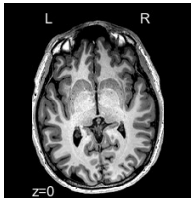
FMRI preprocessing pipeline



BOLD images



Spin echo images



T1 image

dcm2nii conversion

anonymization

distortion correction

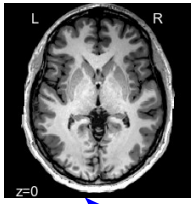
FSL / Topup

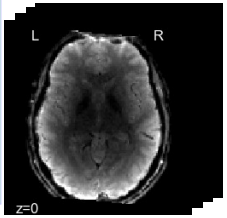
realignment

coregistration with anatomy

spatial normalization

SPM + pypreprocess





mask extraction

compcorr

QC

motion parameters

Nilearn + pypreprocess

experimental paradigm

session-glm

fixed effects across AP/PA

Nistats