Weierstrass Institute for
Applied Analysis and Stochastics

Member of
Leibniz Association

Functional Magnetic Resonance Imaging: Processing Large Dataset

Karsten Tabelow

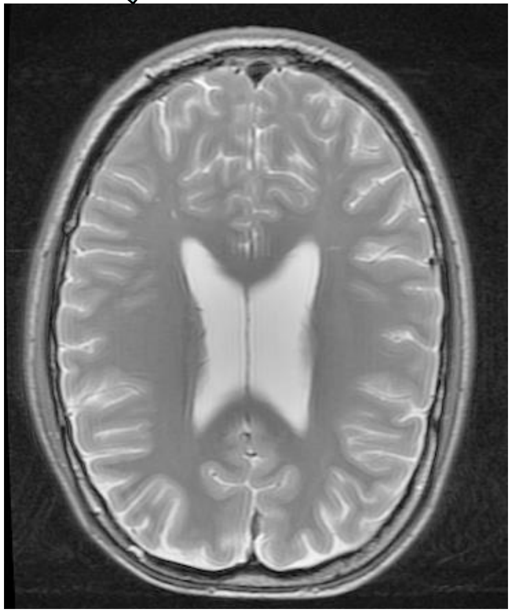
Mapping the human brain

Erwin L. Hahn

(June 9, 1921 – September 20, 2016)

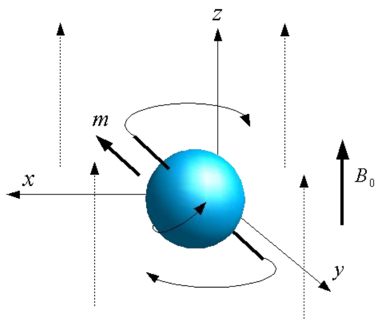
Imaging the human brain

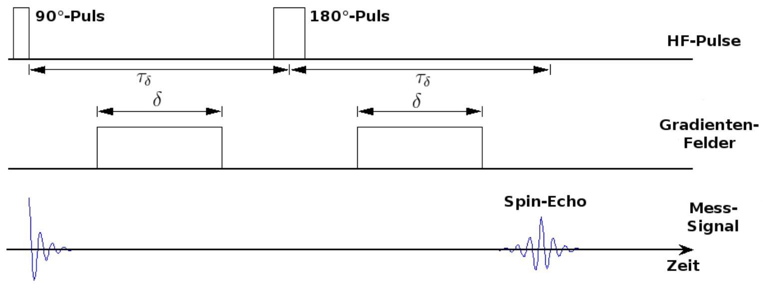
Ex-vivo

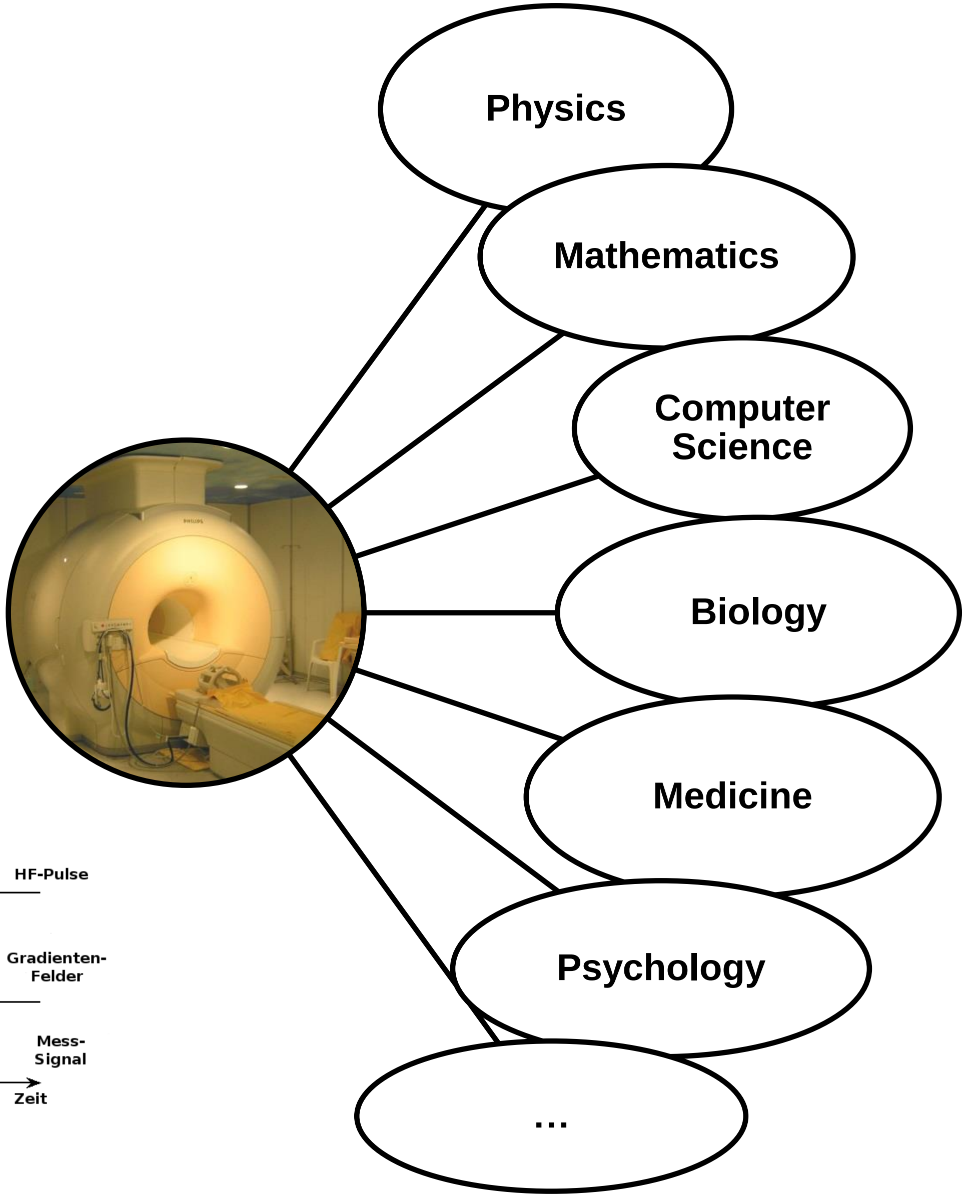


In-vivo

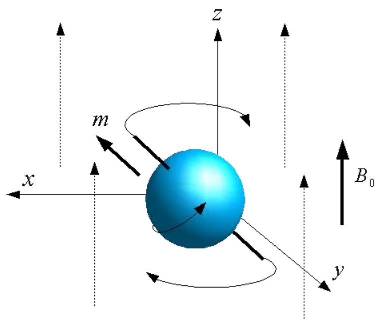
MRI is a melting pot of disciplines

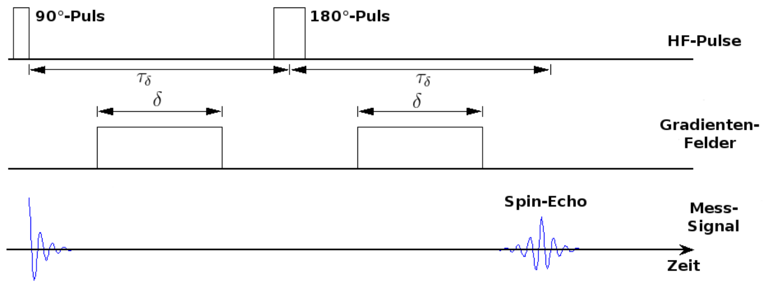


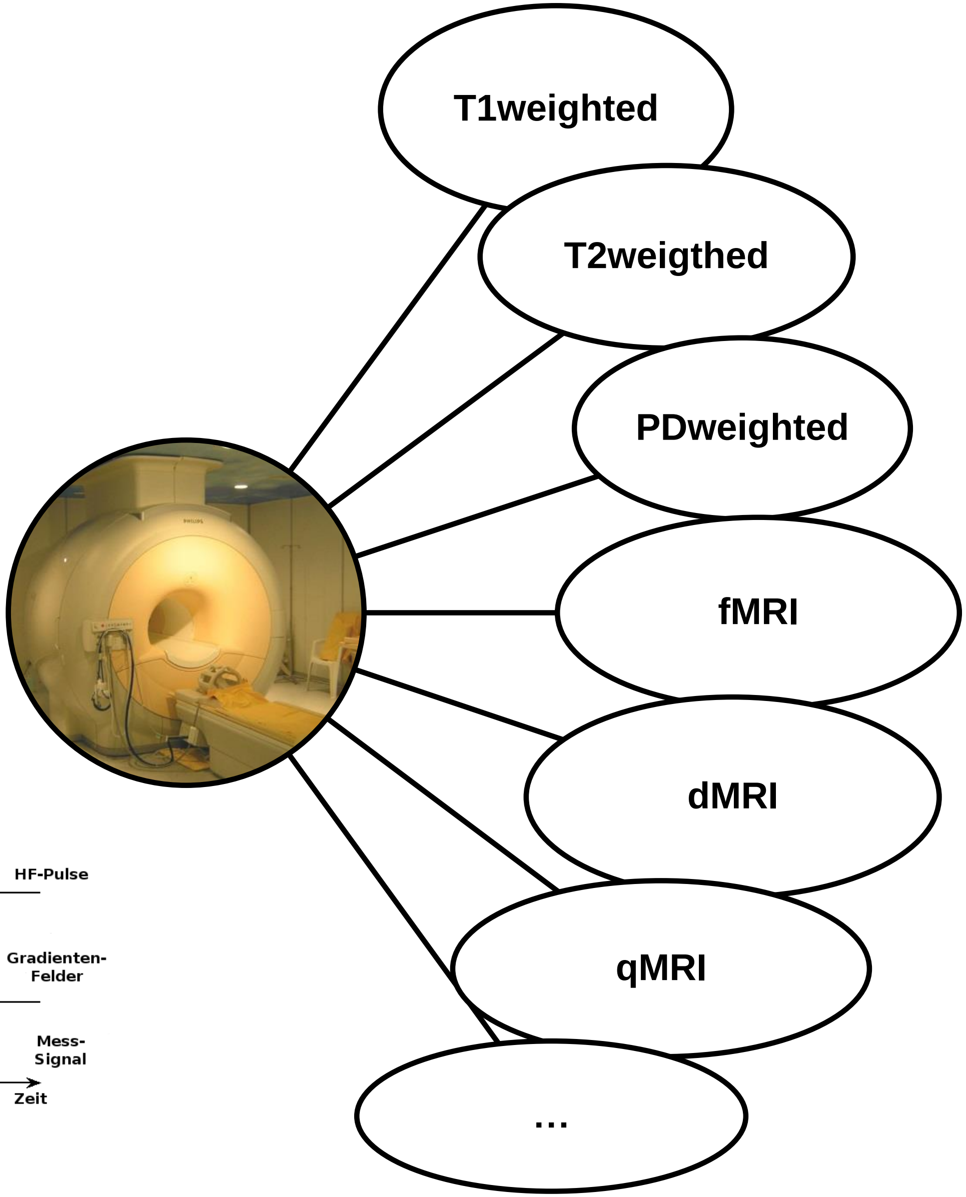




MRI is a versatile tool

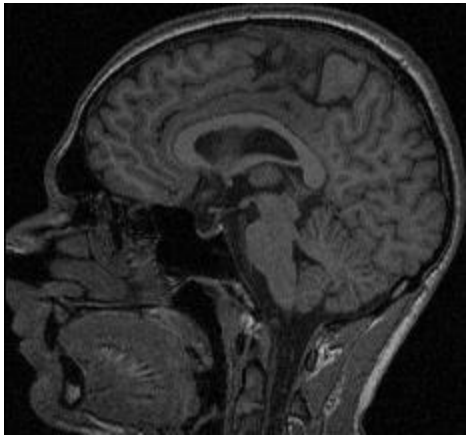


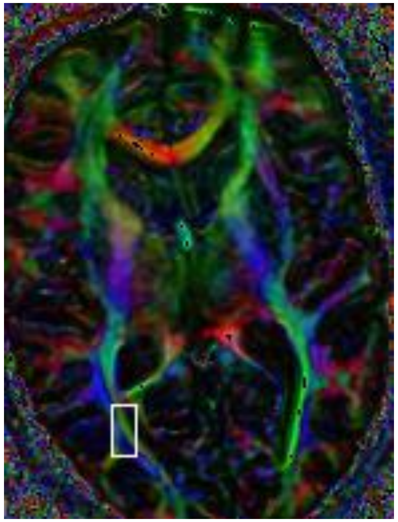


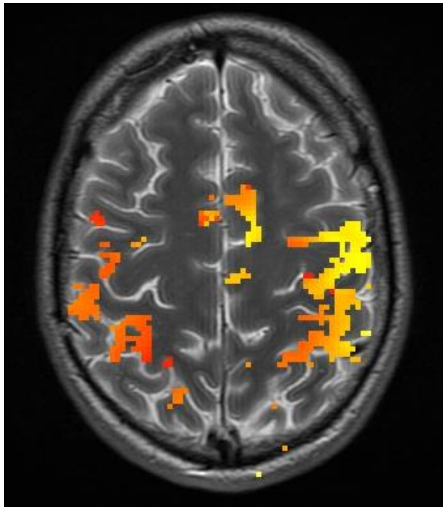


MRI is a versatile tool

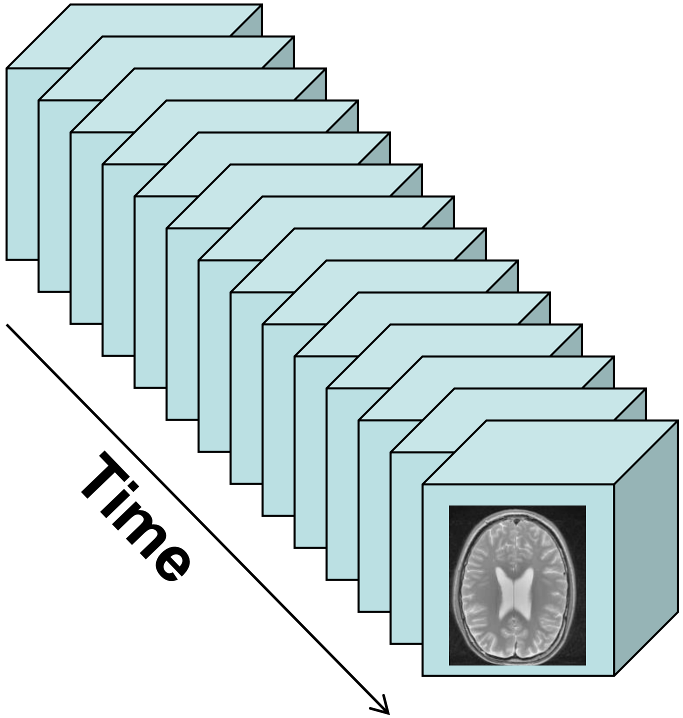
MRI | dMRI | fMRI

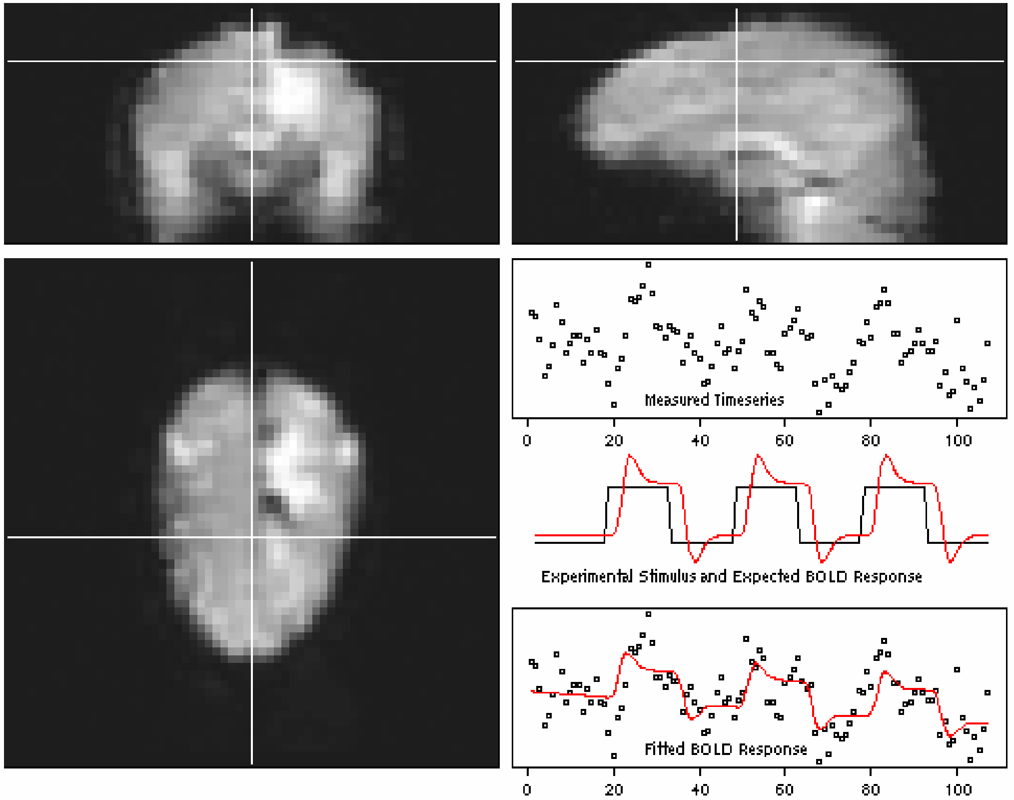






How is fMRI data acquired?





64 x 64 x 30 x 105 x 2byte = 25MB

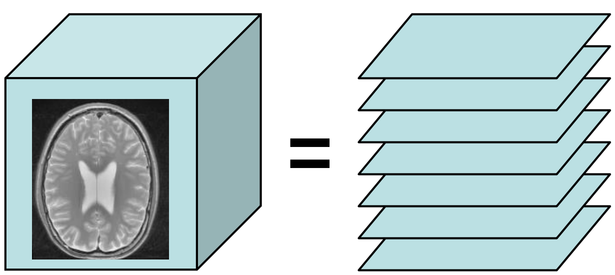
256 x 256 x 30 x 200 x 4byte = 1.5GB

Registration problem I

Sequential Scanning = motion problem

$$Y = A * X + b$$

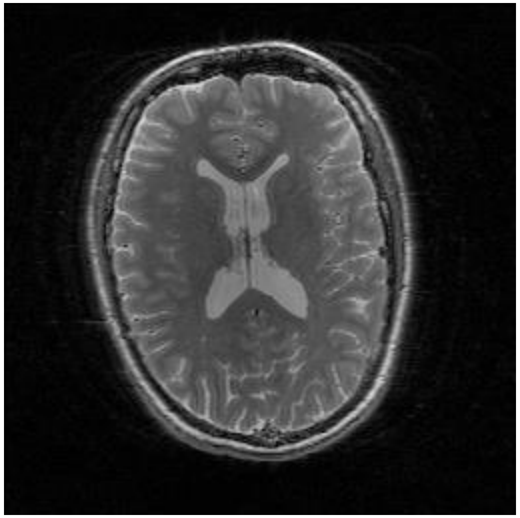
(Affine registration)



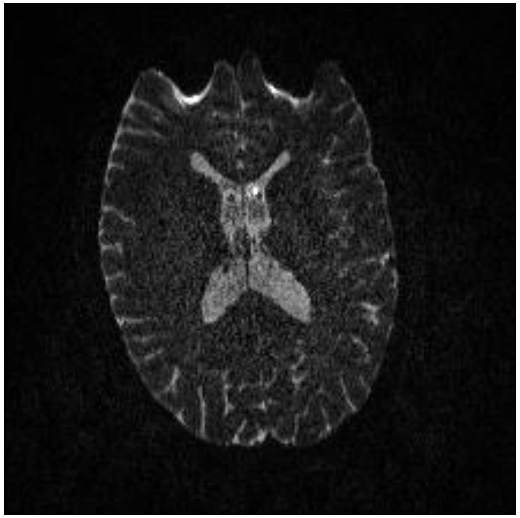
Slice timing problem …

Registration problem II

“EPI images” of fMRI are significantly distorted



Anatomy

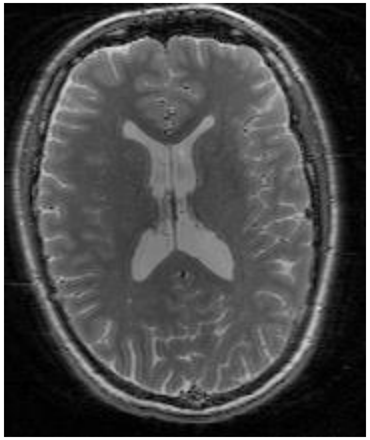


Distorted image

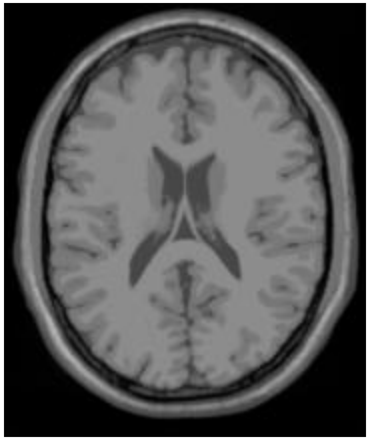
Nonlinear transformation (many methods)

Registration problem III

Group studies require common space



Subject space

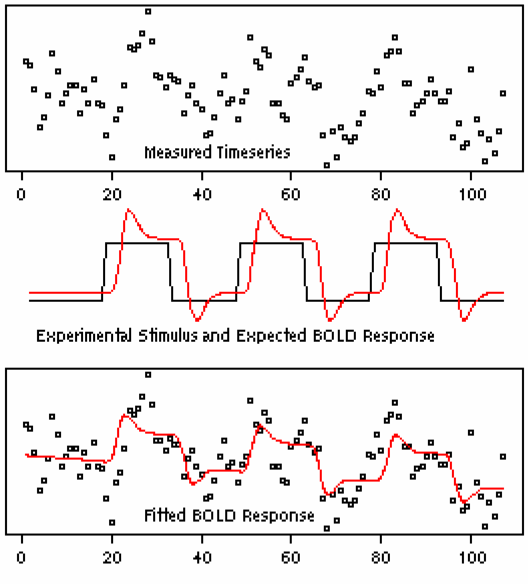


MNI space

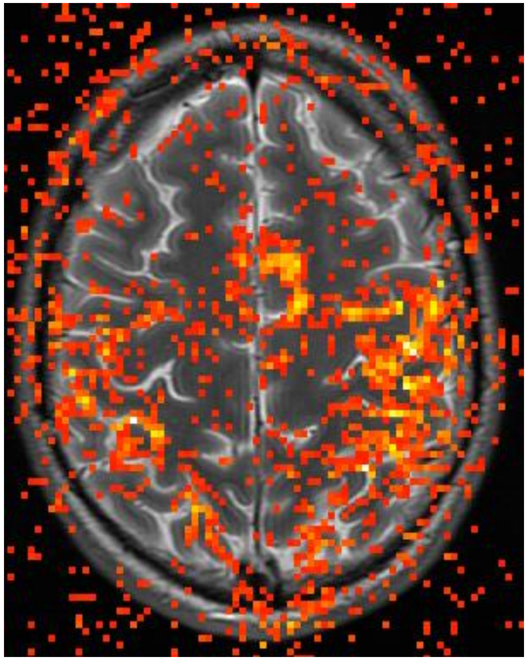
The GLM for fMRI data

$$Y = X * \beta + \varepsilon$$

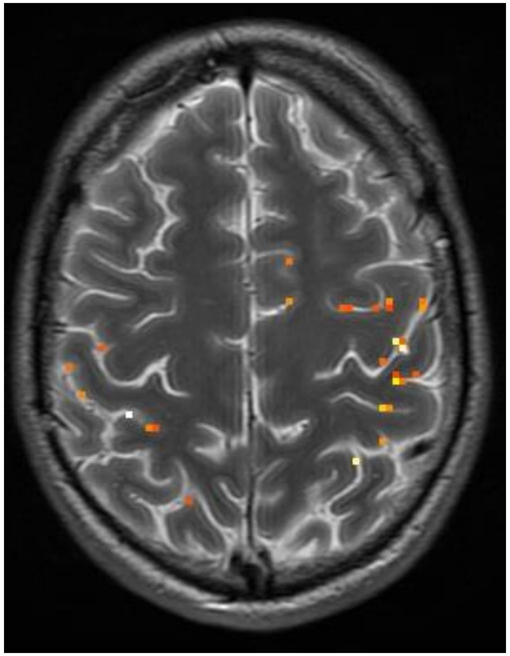
- Y … Time series data
- X … Design matrix
- β … Parameters
- ε … Noise



Multiple test problem



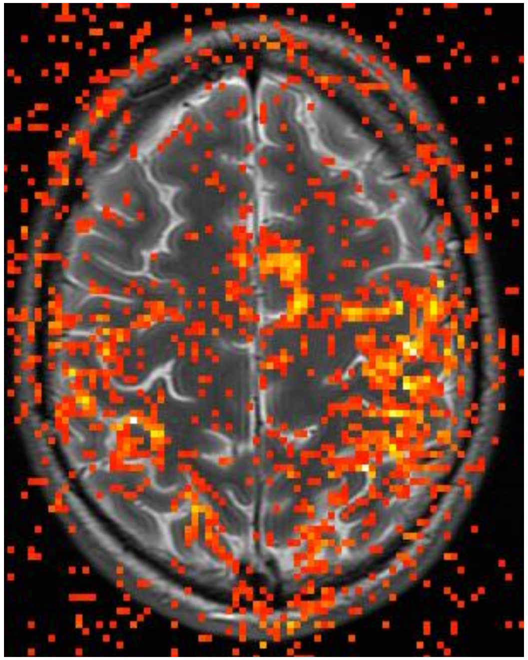
Voxelwise test of hypotheses $H_0 : \beta = 0$



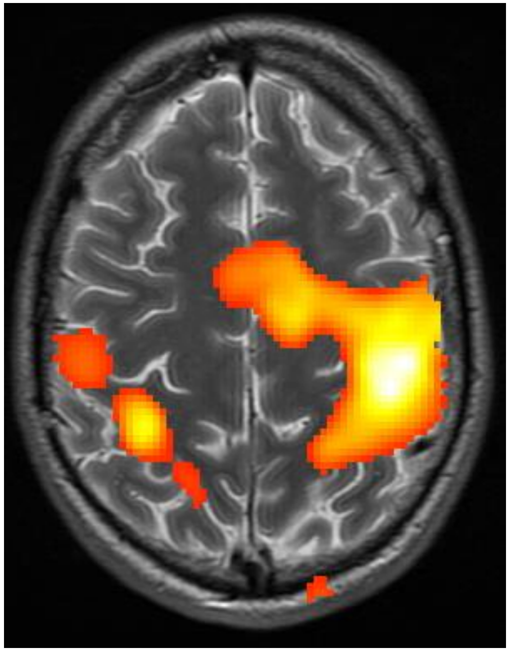
Adjust threshold for tests!

Bonferroni, Random Field Theory, Family-wise tests, Cluster-wise thresholds…

Smoothing the data

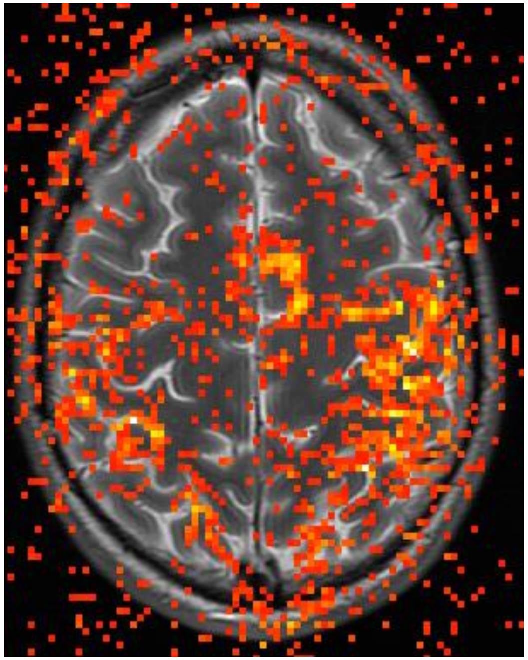


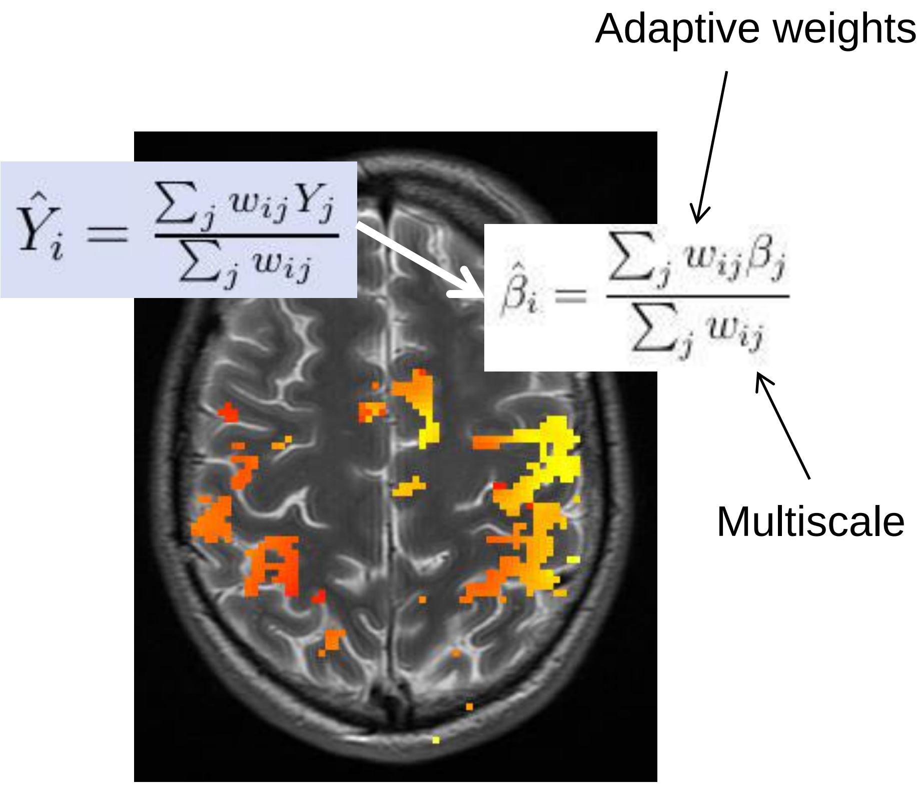
Voxelwise test of hypotheses $H_0 : \beta = 0$



Gaussian filtering of all volumes

Adaptive smoothing the data





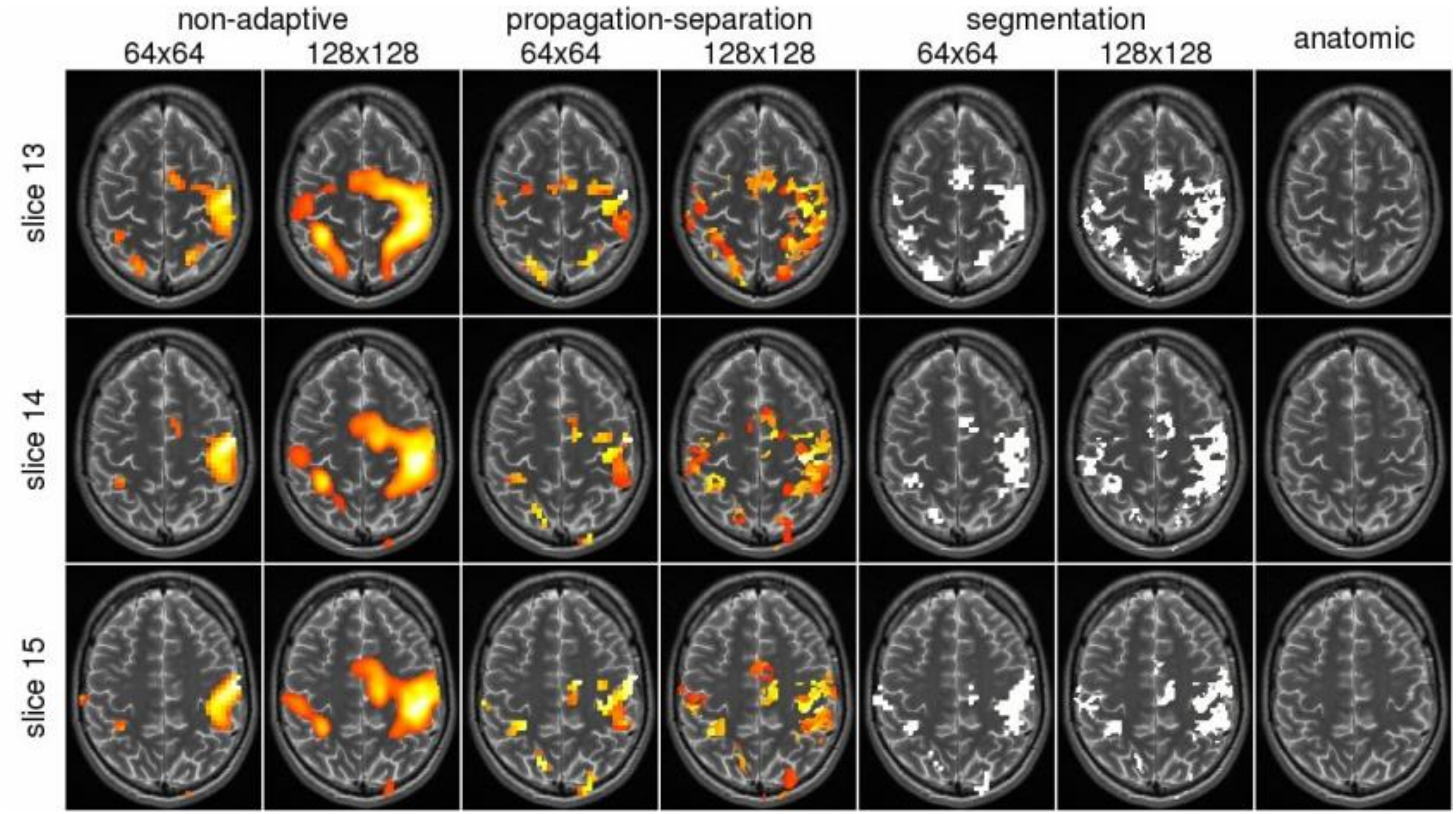
$$\hat{Y}_i = \frac{\sum_j w_{ij} Y_j}{\sum_j w_{ij}}$$

$$\hat{\beta}_i = \frac{\sum_j w_{ij} \beta_j}{\sum_j w_{ij}}$$

Voxelwise test of hypotheses $H_0: \beta = 0$

Adaptive smoothing

More gain at higher resolution



Clinical application (presurgical planning)

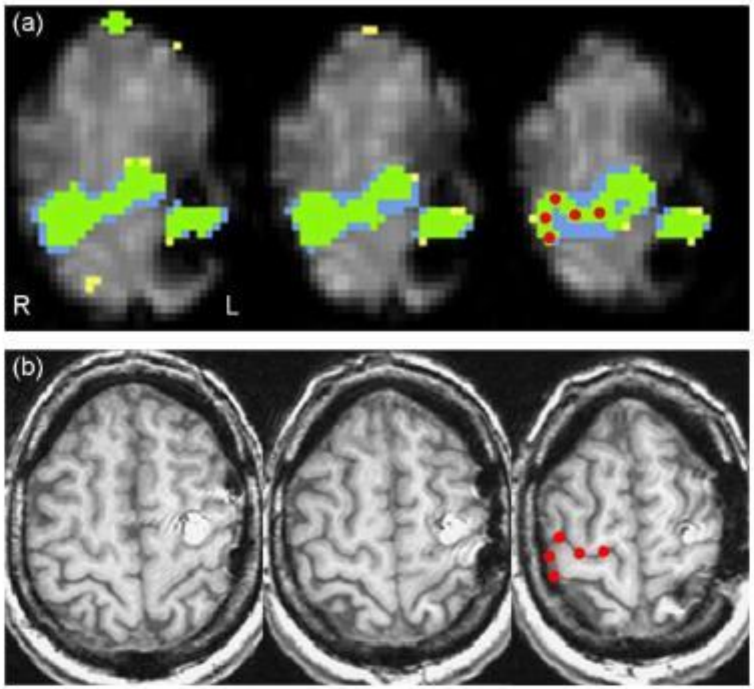


Fig. 6. Three consecutive EPI slices with functional activations (a) and corresponding anatomical images (b) of the brain of an epilepsy patient during a

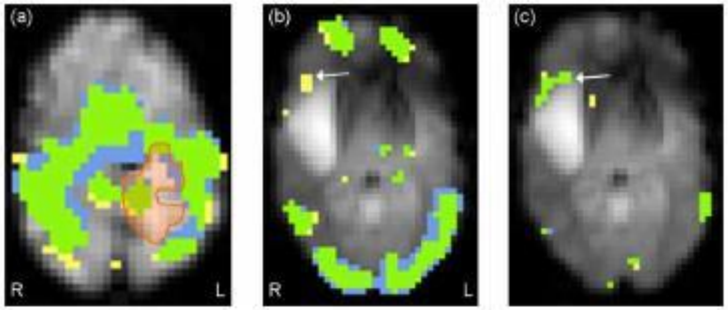
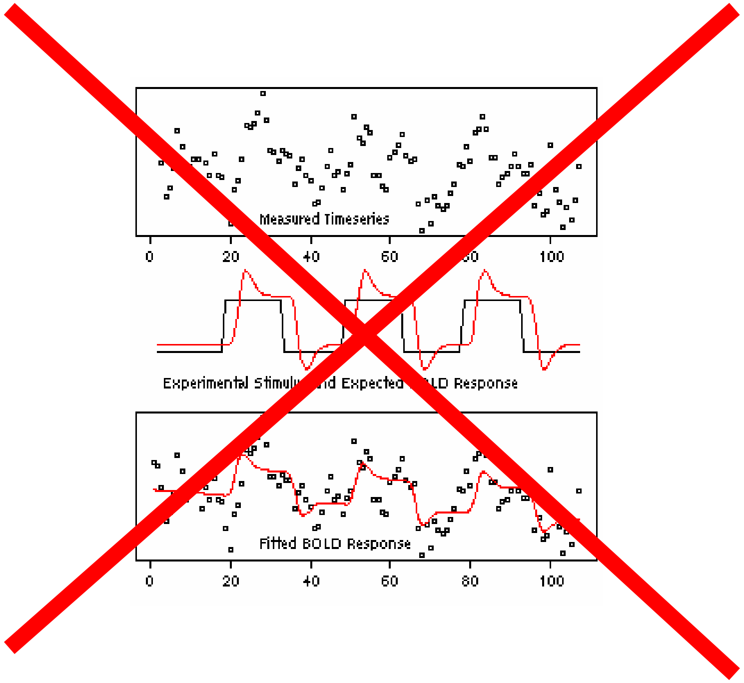


Fig. 5. Examples of activations seen only with Gaussian smoothing (blue: darkest in grayscale image), only with PS (yellow: brightest in grayscale image), and with both methods (green). (a) In the bilateral finger tapping task, PS (yellow) and Gaussian smoothing alone (blue) yielded different results in the vicinity of the tumor which is delineated by the red area. (b), (c) In the picture naming task, PS detected activation next to a tumor [(b), arrow] which was not seen with Gaussian smoothing. The potential neuronal activity of this region is known from a motor task (bilateral finger tapping), in which both methods detected this area [(c), arrow]; thus, Gaussian smoothing probably yielded false negative activations. In all plots $p = 0.001$, $h = 10$ mm.

Tabelow et al. (2008) IEEE TMI.

Beyond mass-univariate analysis

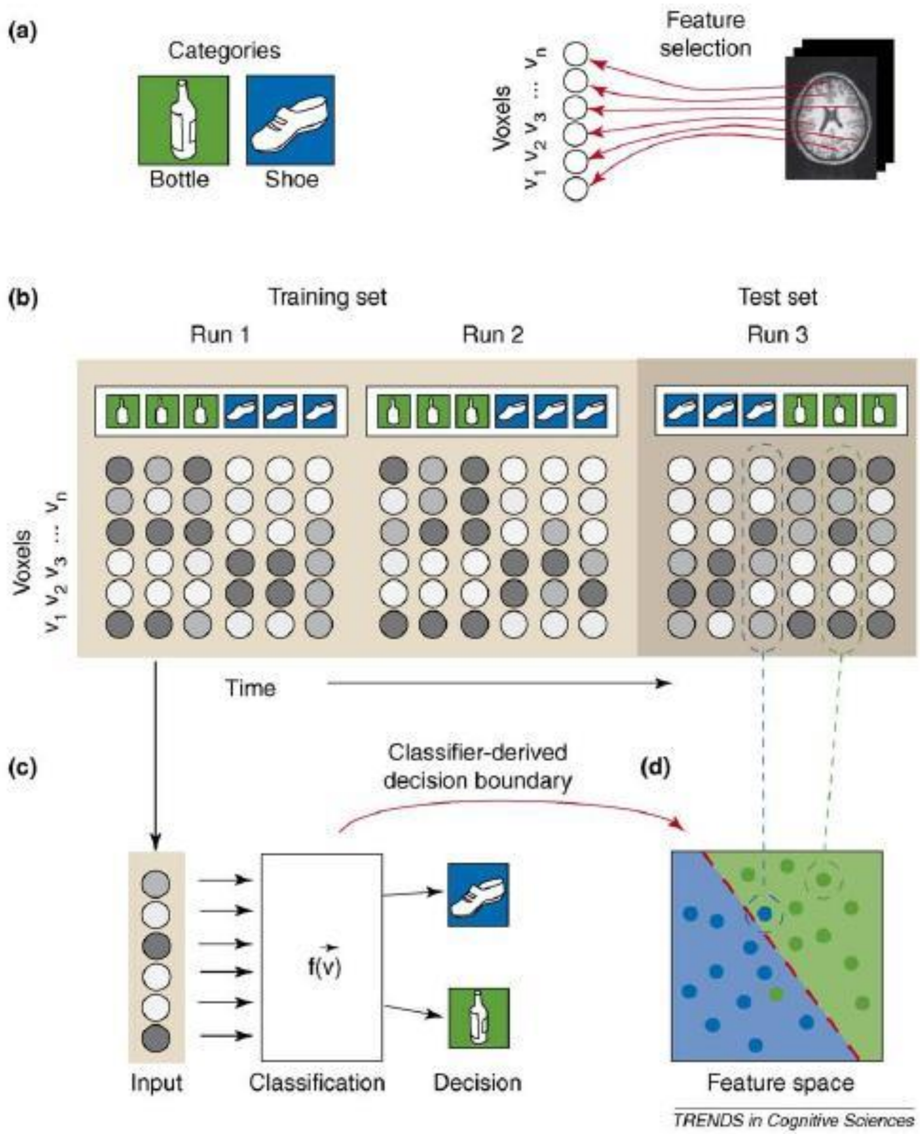


www.studyforrest.org

4D volumetric images (160x160x36x450x8)

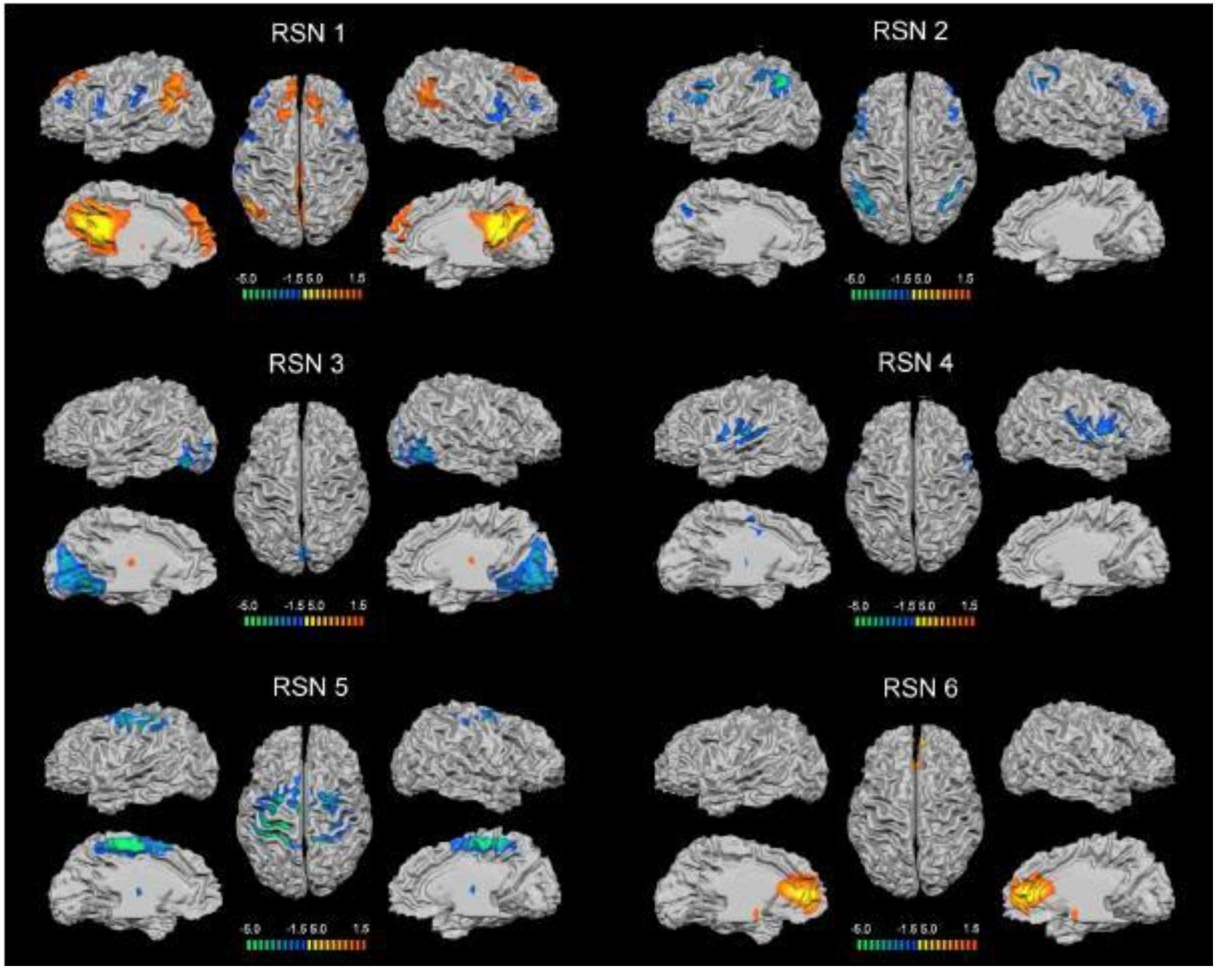
[bold_raw.tar ~80GB]

Multivariate-pattern analysis (MVPA)



Norman et al. (2008)

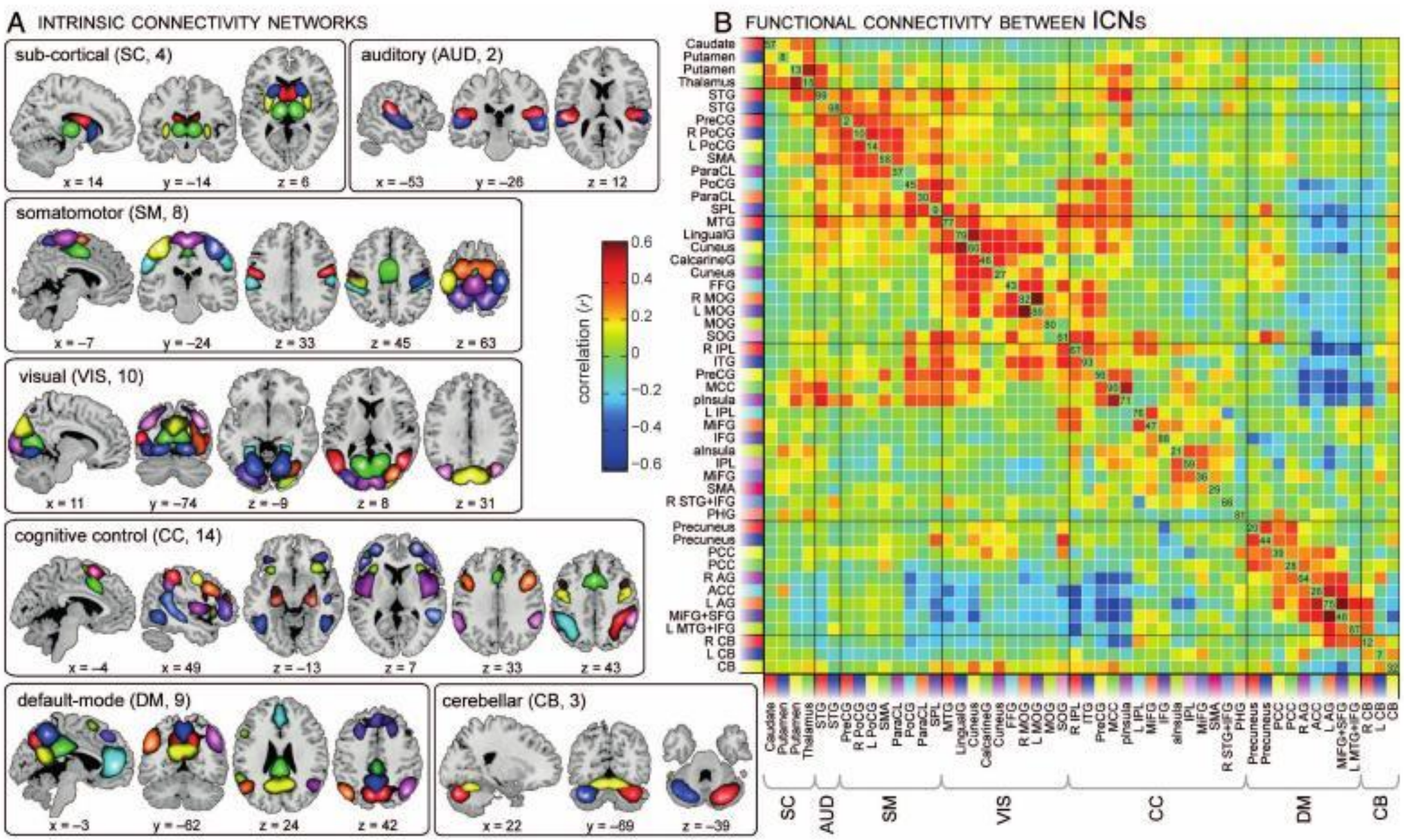
What does the brain at rest?



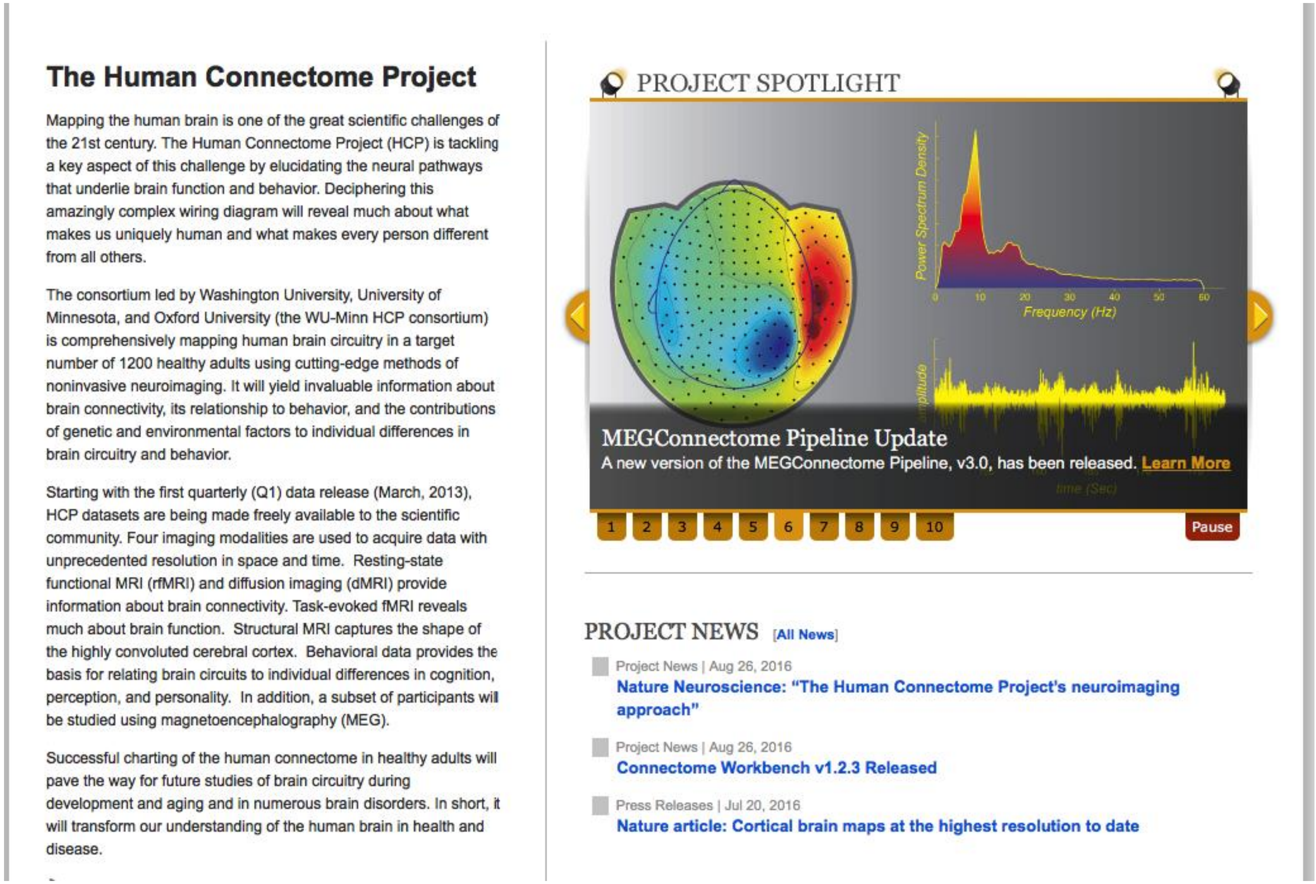
ICA analysis of Y

Mantini et al. (2007)

Estimate covariance structure Σ of ε



Human Connectome Project



The Human Connectome Project

Mapping the human brain is one of the great scientific challenges of the 21st century. The Human Connectome Project (HCP) is tackling a key aspect of this challenge by elucidating the neural pathways that underlie brain function and behavior. Deciphering this amazingly complex wiring diagram will reveal much about what makes us uniquely human and what makes every person different from all others.

The consortium led by Washington University, University of Minnesota, and Oxford University (the WU-Minn HCP consortium) is comprehensively mapping human brain circuitry in a target number of 1200 healthy adults using cutting-edge methods of noninvasive neuroimaging. It will yield invaluable information about brain connectivity, its relationship to behavior, and the contributions of genetic and environmental factors to individual differences in brain circuitry and behavior.

Starting with the first quarterly (Q1) data release (March, 2013), HCP datasets are being made freely available to the scientific community. Four imaging modalities are used to acquire data with unprecedented resolution in space and time. Resting-state functional MRI (rfMRI) and diffusion imaging (dMRI) provide information about brain connectivity. Task-evoked fMRI reveals much about brain function. Structural MRI captures the shape of the highly convoluted cerebral cortex. Behavioral data provides the basis for relating brain circuits to individual differences in cognition, perception, and personality. In addition, a subset of participants will be studied using magnetoencephalography (MEG).

Successful charting of the human connectome in healthy adults will pave the way for future studies of brain circuitry during development and aging and in numerous brain disorders. In short, it will transform our understanding of the human brain in health and disease.

PROJECT SPOTLIGHT

MEGConnectome Pipeline Update
A new version of the MEGConnectome Pipeline, v3.0, has been released. Learn More

1 2 3 4 5 6 7 8 9 10 Pause

PROJECT NEWS [All News]

Project News | Aug 26, 2016
Nature Neuroscience: "The Human Connectome Project's neuroimaging approach"

Project News | Aug 26, 2016
Connectome Workbench v1.2.3 Released

Press Releases | Jul 20, 2016
Nature article: Cortical brain maps at the highest resolution to date

- > 900 subjects
- Resting state fMRI, task-based fMRI, diffusion MRI, structural MRI
- > 20TB data (ask for shipping the hard drive, or download for days …)