NeuroImaging Data Processing

aka. Statistical Parametric Mapping short course

Course 1:

Introduction

LIÈGE université
GIGA
CRC Human Imaging

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fnrs
LA LIBERTÉ DE CHERCHER

Who am I ?

- Electrical (or. electronics) engineer,
  then PhD on "Source reconstruction in EEG".

- FRS-FNRS Research Director at the CRC &
  Professor at the School of Engineering, Montefiore (EEI)

- Linked to
  - "GIGA CRC human imaging" research unit
  - "GIGA in vivo imaging" tech platform
  - Montefiore Institute.

- Office at the Cyclotron Research Centre (B30).
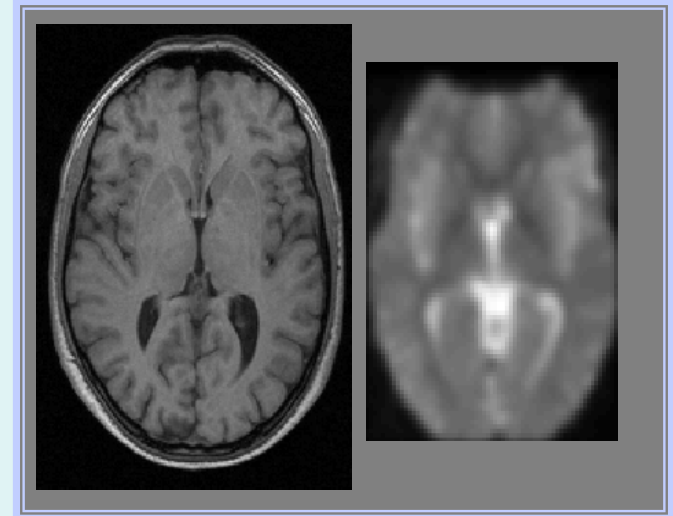
- Interest in neuroimaging:

<div align="center">

"How does the brain work and
what is it made of?"

Contact: c.phillips@uliege.be

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Functional/structural neuroimaging

- functional anatomy –
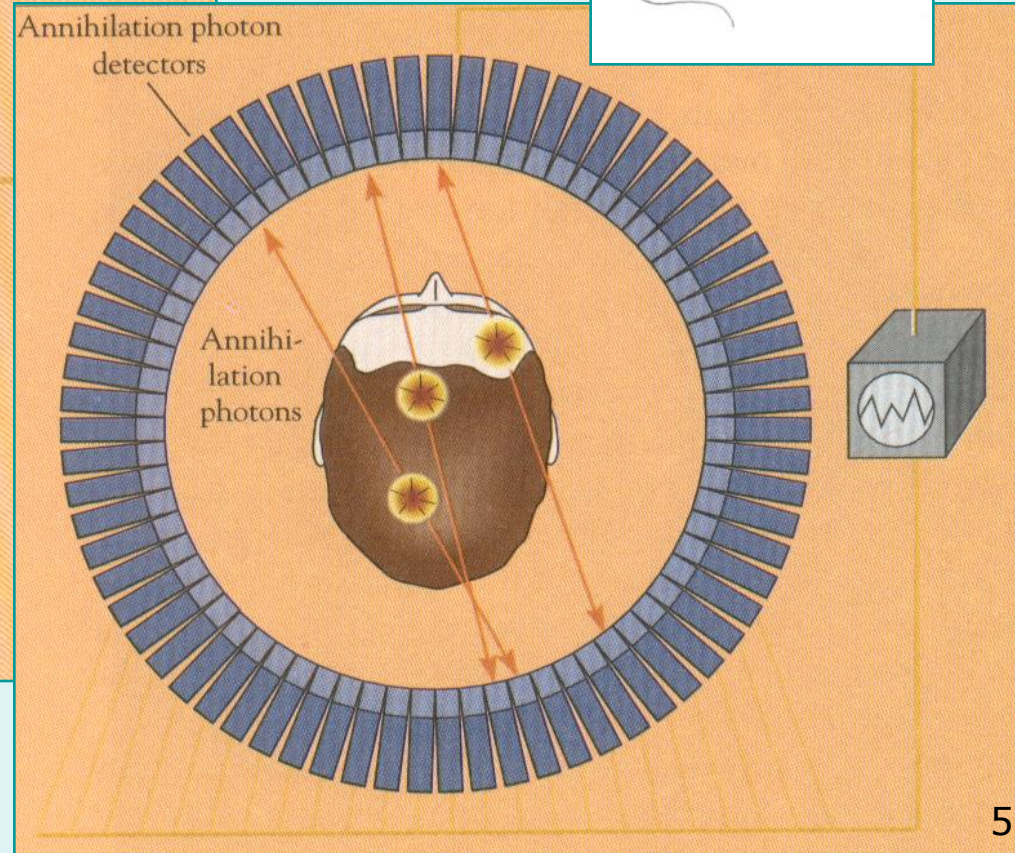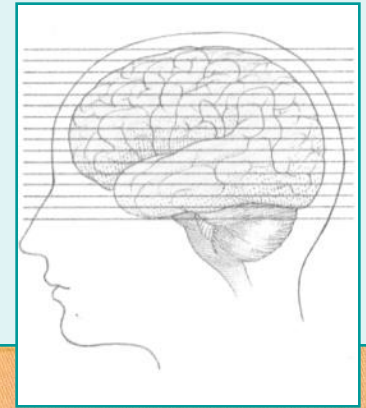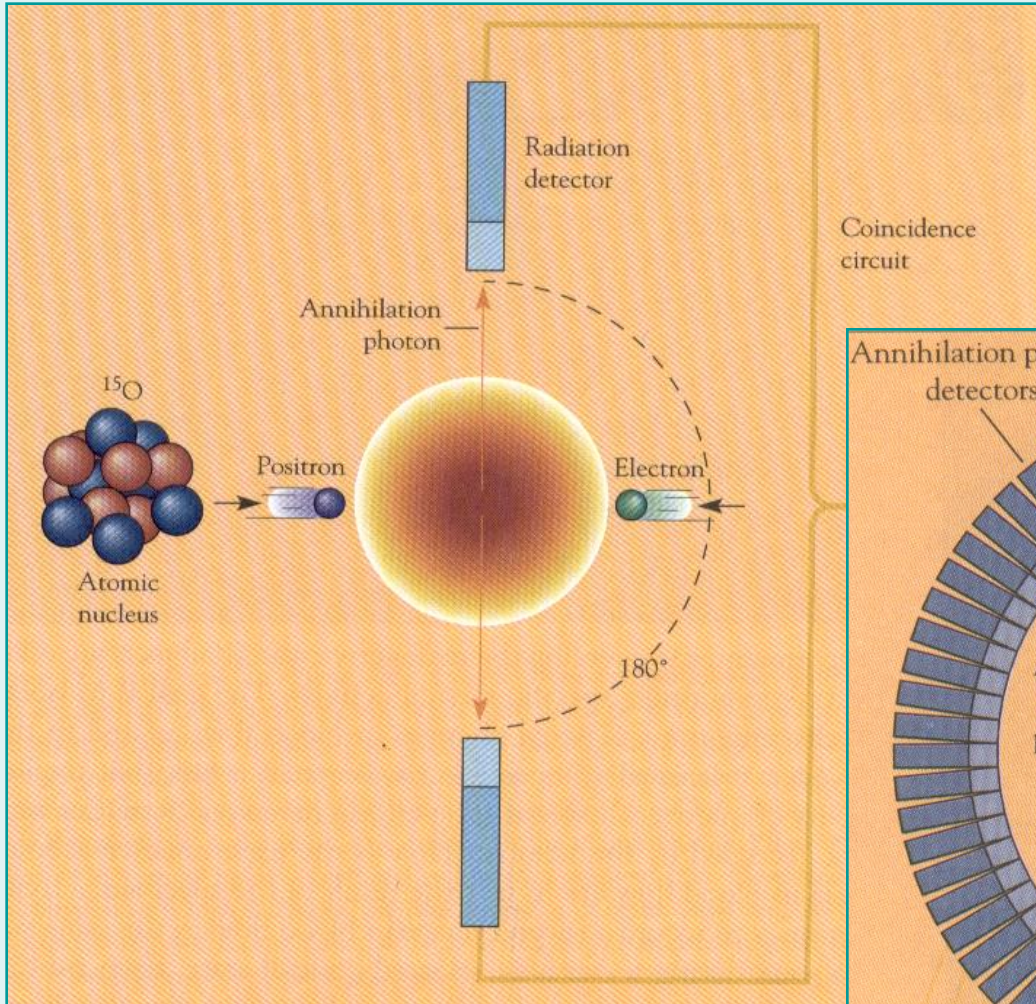 functional segregation

- Positron Emission Tomography
  (PET) & SPECT
  - regional Cerebral Glucose Uptake
  - other tracers…
- *functional* MRI (*f*MRI), Blood Oxygenation Level Dependent signal
- *structural* MRI (*s*MRI + DWI)
  - Grey/White density
  - White matter anisotropy
- *quantitative* MRI (*q*MRI + spectro + QSM)

Imaging tools: PET
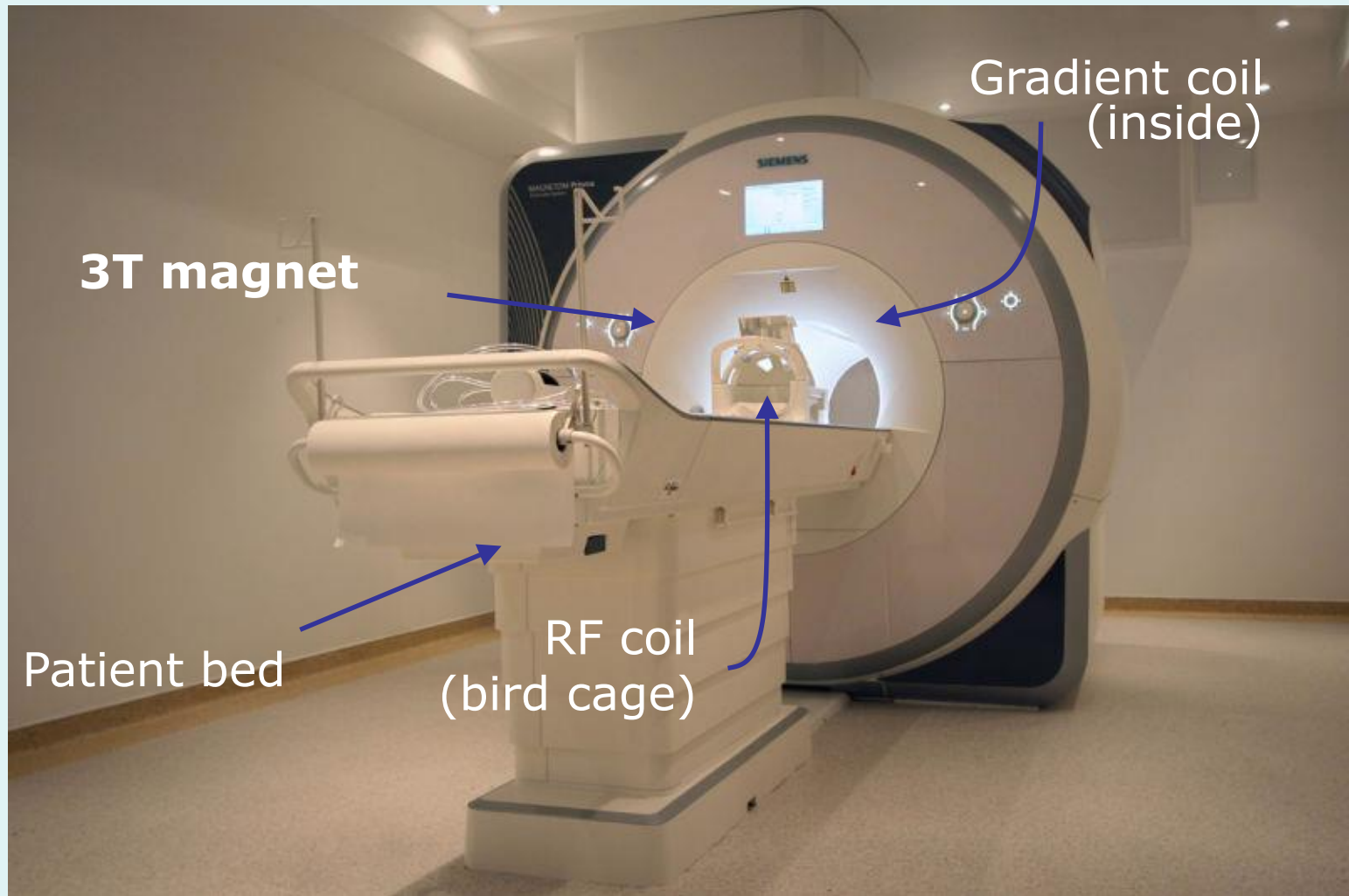
Positron emission tomography
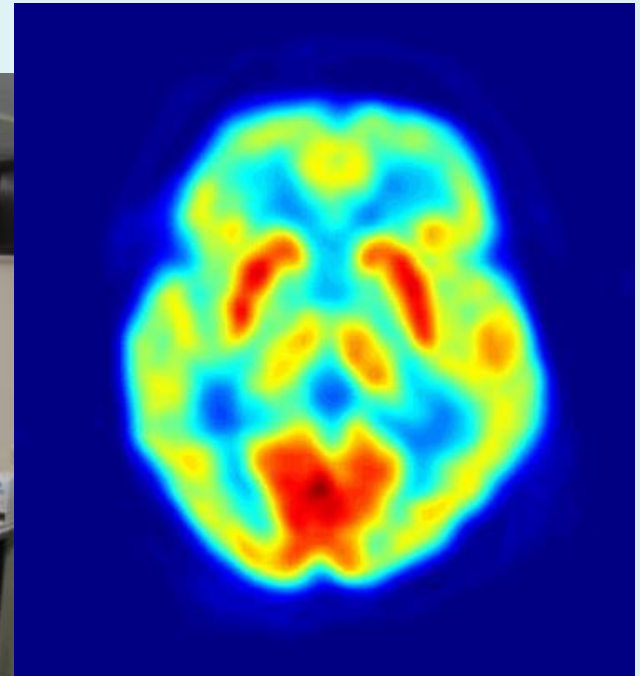
Imaging tools: PET

Imaging tools: PET

- H_2O^{15} (a long time ago…)
  - measures blood flow directly
    - ➜ brain activation mapping
  - scan over 1-2 minutes
  - 12-15 scans per patient

- FDG & other/new radiotracers
  - Measures biological process (glucose, protein binding, synaptic density, etc.)
    - ➜ Disease (e.g. Alzheimer/Parkinson/MS) biomarkers
  - Scan over several minutes + modelling
  - 1 (quantitative) image per patient

- Spatial resolution limited by
  - molecule diffusion and scanning duration
  - scanner sensors
  - image reconstruction (artefacts + partial volume effect)

Imaging tools: MRI
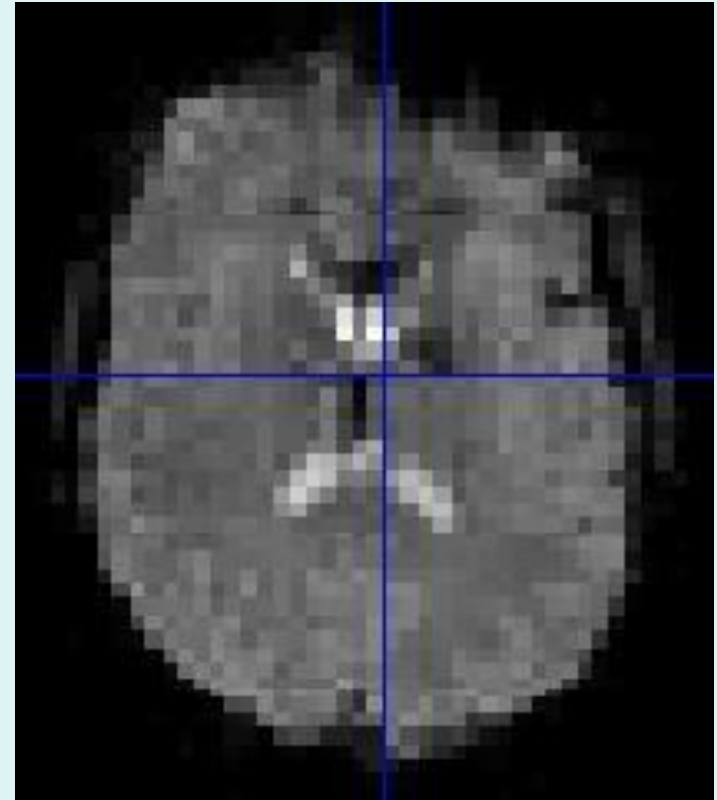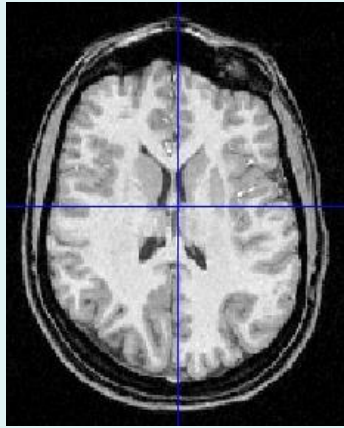
Magnetic Resonance Imaging

Gradient coil (inside)

3T magnet

Patient bed

RF coil (bird cage)

Siemens Prisma, Cyclotron Research Centre, University of Liège.

Imaging tools: MRI

T1 contrast
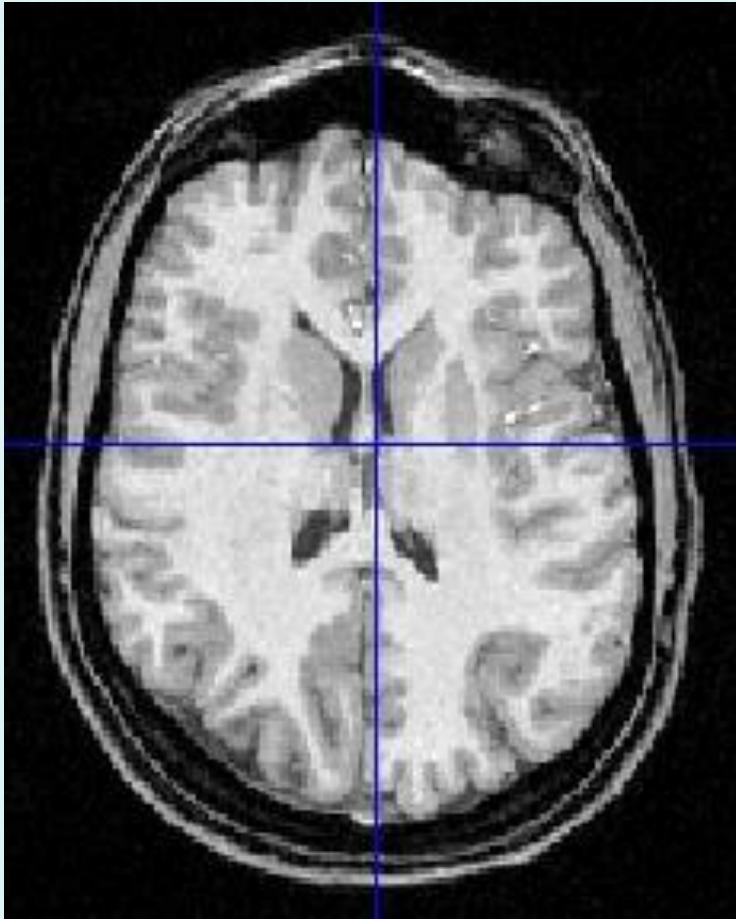
T2* contrast

Acquisition time: a few *minutes* vs. a few *seconds*
Spatial resolution: ~1x1x1 mm3 vs. ~3x3x3 mm3

Imaging tools: MRI

Vs.

Many low resolution image, e.g. 1 image every 2 seconds during 20 minutes

one high resolution image

<u>fMRI signal</u>:

Blood Oxygenation Level Dependent (BOLD) signal, an <u>indirect</u> measure of neural activity.

↑ **neural activity** ⇒ ↑ **blood oxygen** ⇒ ↑ **fMRI signal**

Statistical Parametric Mapping

➢ Concepts

➢ Software

➢ Resources

Statistical Parametric Mapping

From PET analyses using ROIs...
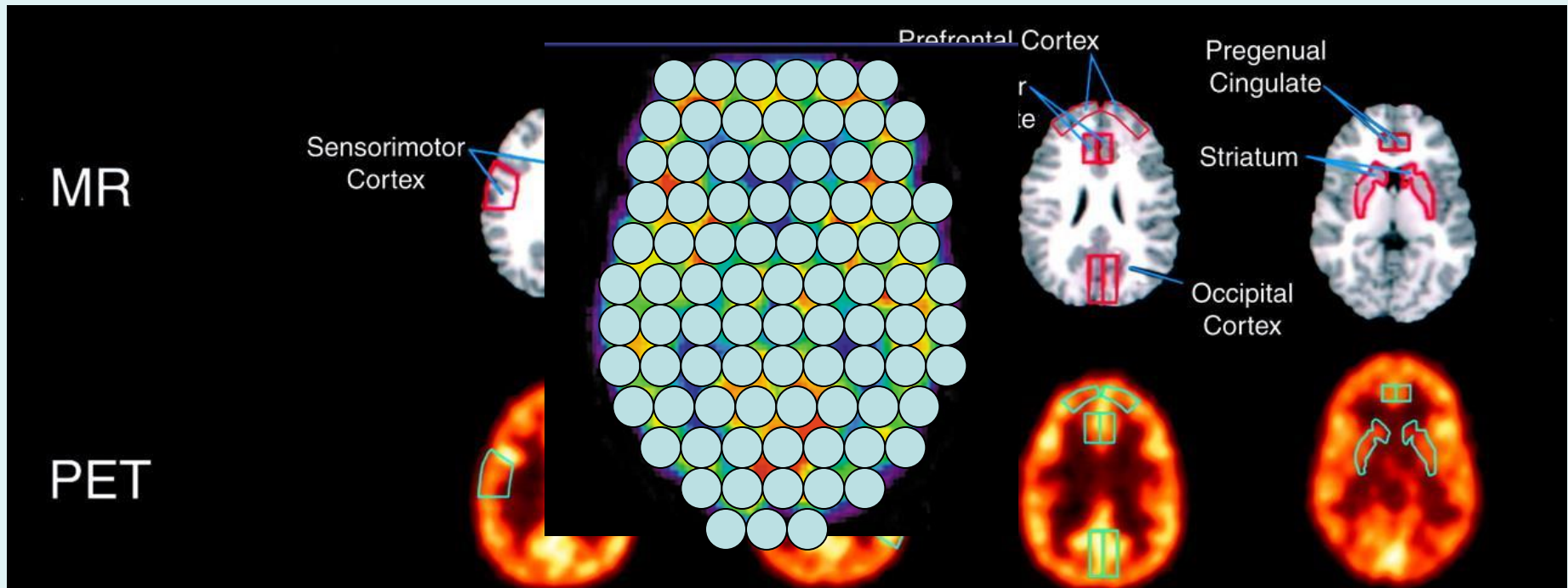
Statistical Parametric Mapping

...to the very first SPM{t}

- An area specialised for the processing of colour, the "colour centre" (V4) highlighted by cognitive substraction using PET.

- Three subjects:
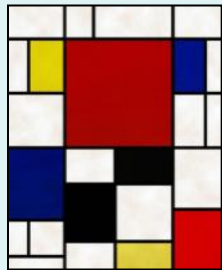
Colour trials
(2 scans)
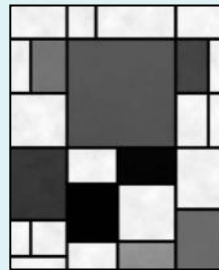
Grey trials
(2 scans)

- Compatible with earlier findings on monkeys using electrophysiology.

ANATOMICAL and physiological studies have shown that there is an area specialized for the processing of colour (area V4) in the prestriate cortex of macaque monkey brain[1]. Earlier this century, suggestive clinical evidence for a colour centre in the brain of man[2,3] was dismissed[4-8] because of the association of other visual defects with the defects in colour vision[4,5,7]. However, since the demonstration of functional specialization in the macaque cortex[9], the question of a colour centre in man has been reinvestigated,
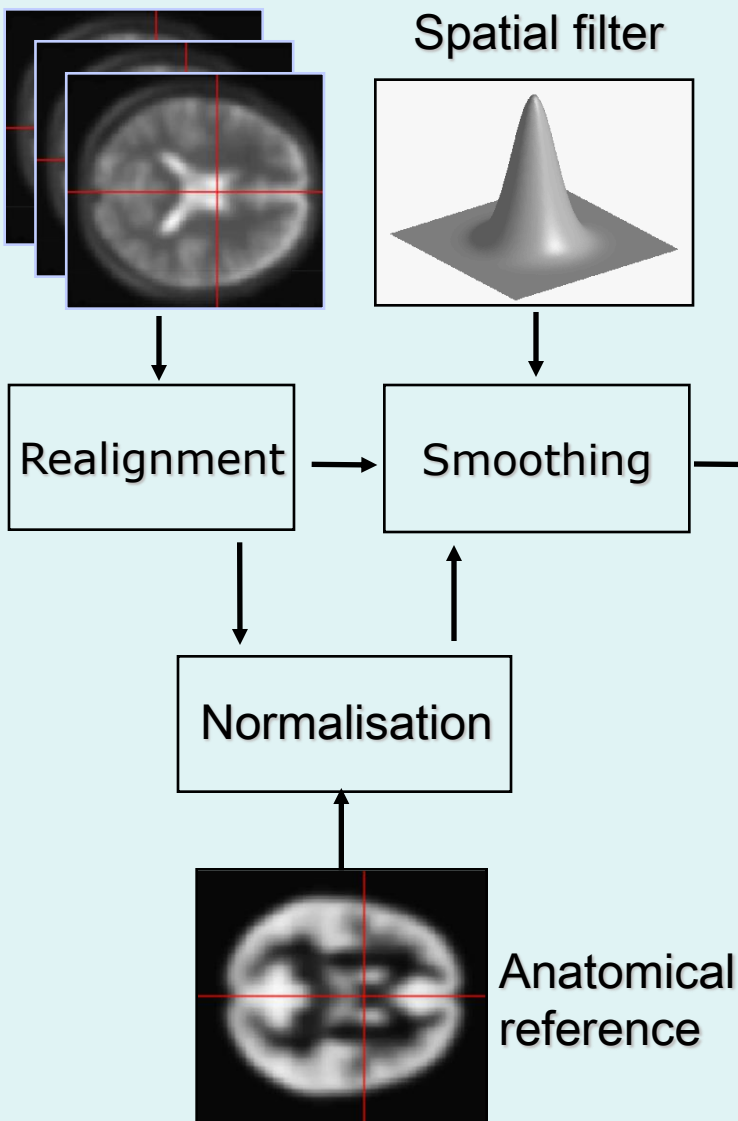
STRIATE CORTEX

INFERIOR OCCIPITAL CORTEX

colour stimulation   perturbation (all conditions)   t-map colour vs. grey   covariance with striate cortex (all conditions)
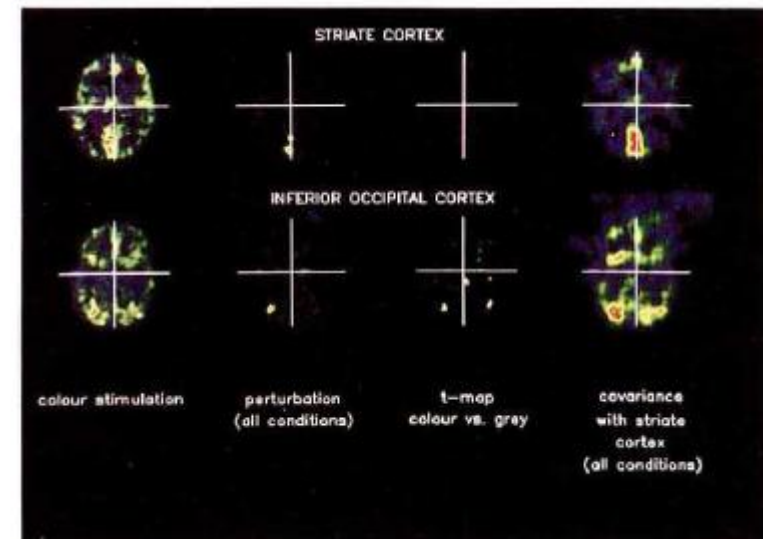
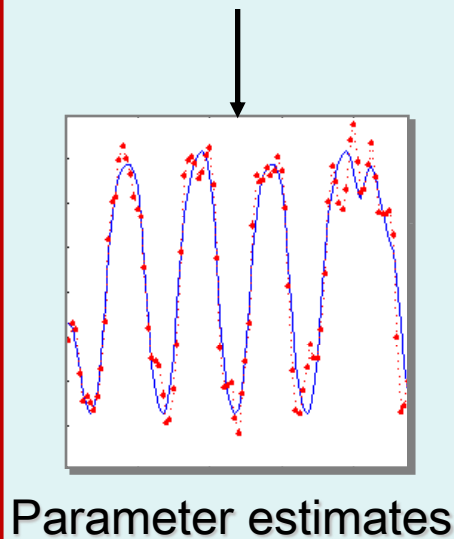# Statistical Parametric Mapping

Image time-series

Spatial filter

Realignment → Smoothing

Normalisation

Anatomical reference

Design matrix

General Linear Model

Parameter estimates
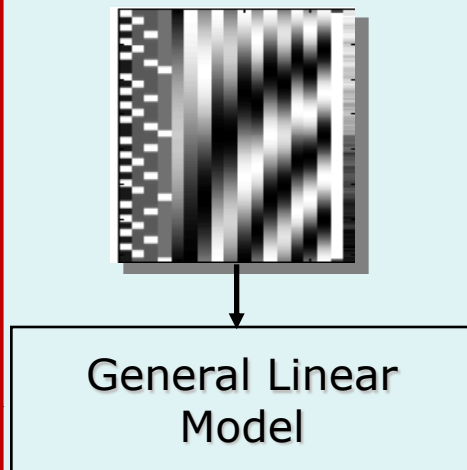
Statistical Parametric Map
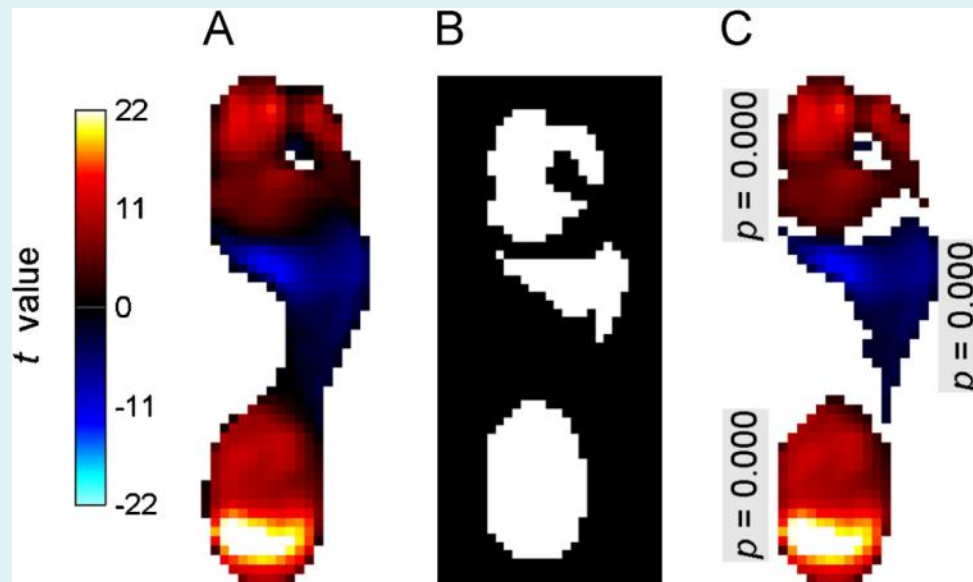
Statistical Inference ← RFT

p <0.05

13
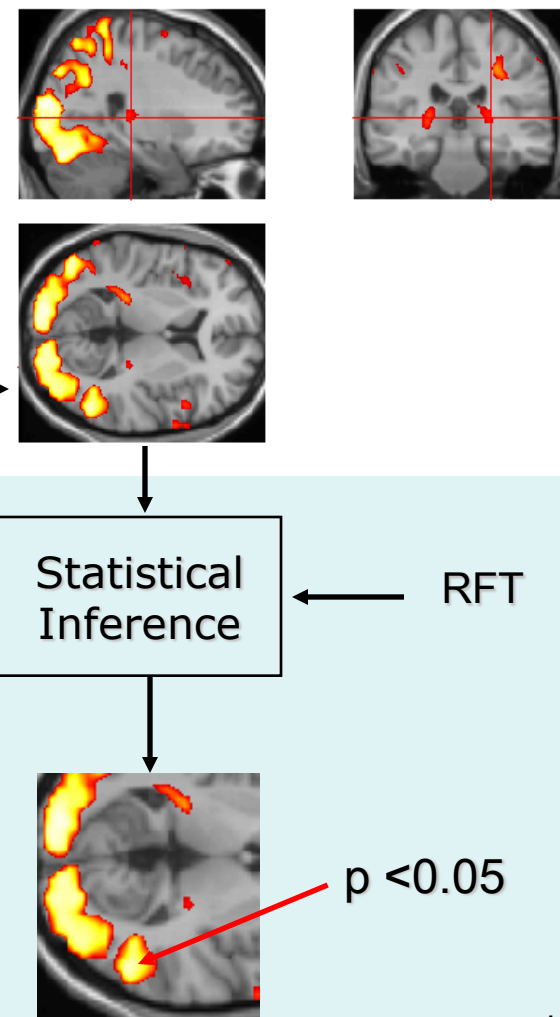
Statistical Parametric Mapping

- **Statistical Parametric Mapping** refers to the construction and assessment of *spatially extended statistical processes* used to test hypotheses about functional imaging data.


Pedobarographic statistical parametric mapping (pSPM), T. Pataky, Journal of Foot and Ankle Research, 2008.

Statistical Parametric Mapping

Voxel-Based Morphometry (VBM)

- VBM is the most widely used method for computational neuroanatomy.

- It is essentially Statistical Parametric Mapping of regional segmented tissue density or volume.

- The same general linear modelling & RFT machinery in SPM can then be used to study differences in structure.
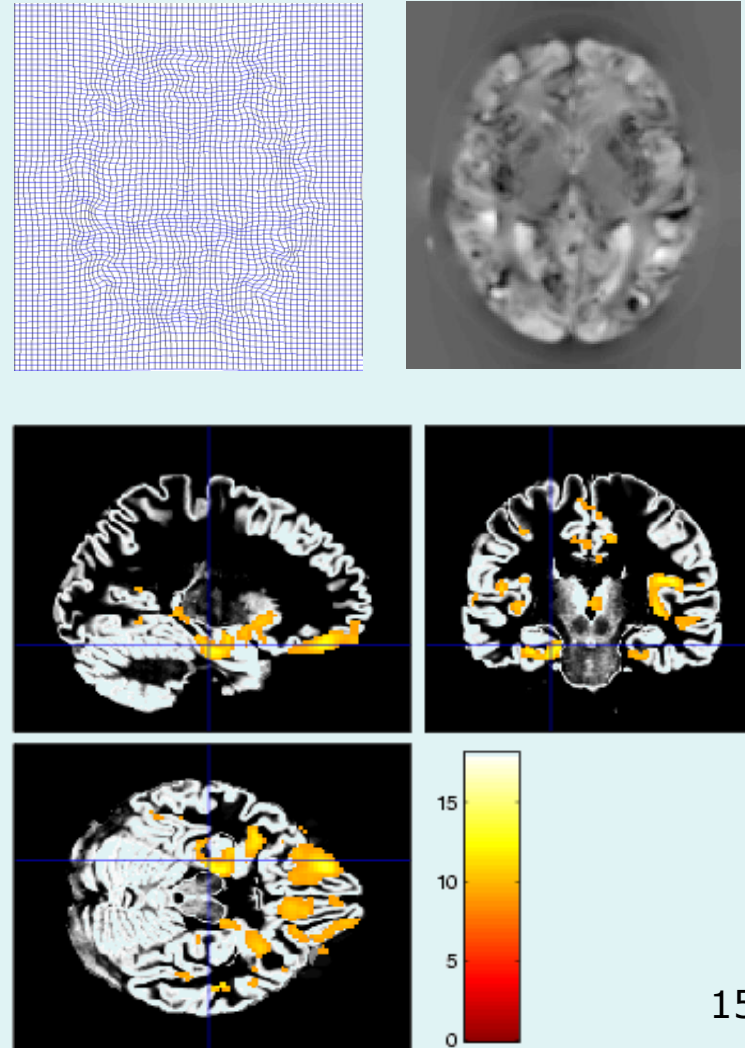
Statistical Parametric Mapping

Dynamic Causal Models
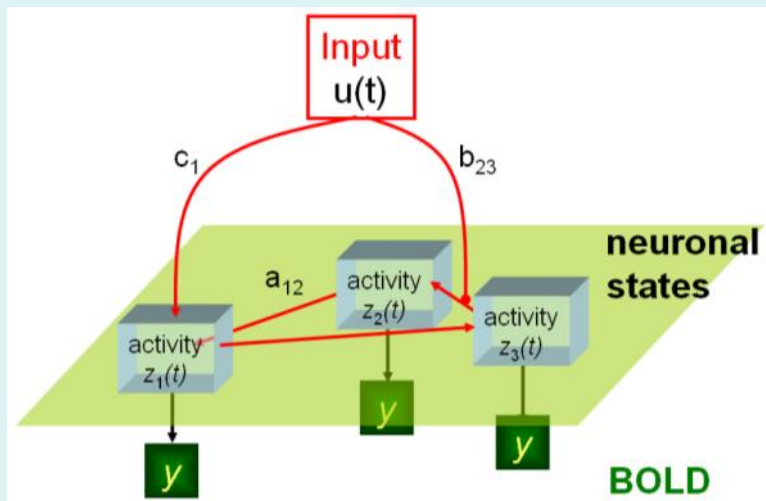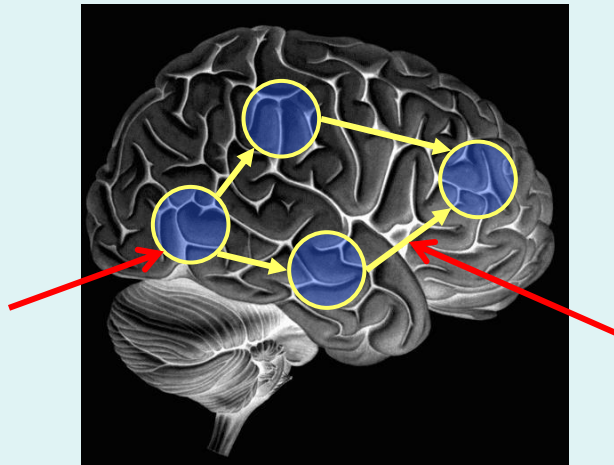
THE RISE OF fMRI

Use of fMRI has rocketed, and now more studies are looking at connectivity between regions.
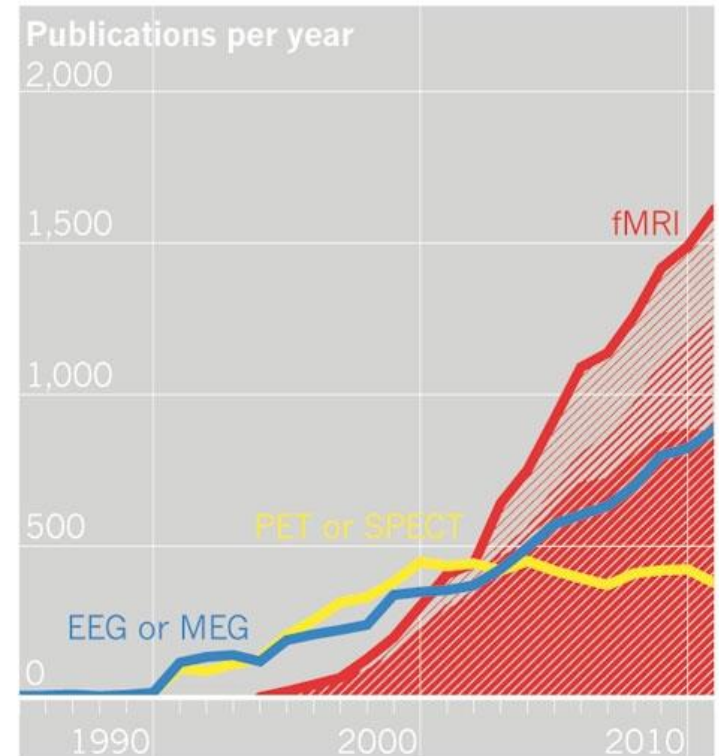
fMRI, functional magnetic resonance imaging; PET, positron emission tomography; SPECT, single-photon emission computed tomography; EEG, electroencephalography; MEG; magnetoencephalography
Data from ISI Web of Knowledge.

Nature, April 2012

Statistical Parametric Mapping

SPM software

"The SPM software was originally developed by Karl Friston for the routine statistical analysis of functional neuroimaging data from PET while at the Hammersmith Hospital in the UK, and made available to the emerging functional imaging community in 1991 to promote collaboration and a common analysis scheme across laboratories."
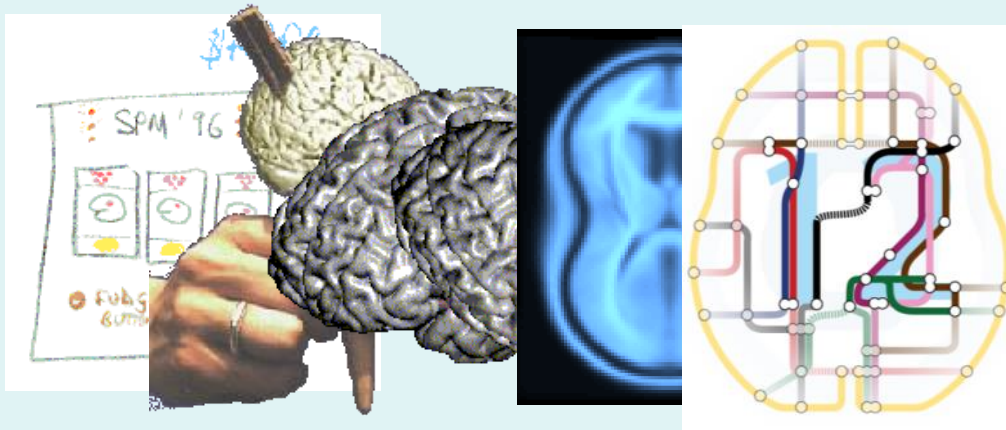
SPMclassic, SPM'94, SPM'96, SPM'99, SPM2, SPM5, SPM8 and SPM12 represent the ongoing theoretical advances and technical improvements of the original version.

Statistical Parametric Mapping

Software: **SPM12**

- Free and Open Source Software (GPL)

- Requirements:
  - MATLAB: **7.4** (R2007a) to **9.15** (R2023b)
    no MathWorks toolboxes required
  - Supported platforms:
    Linux, Windows and Mac

- *Standalone & containerized versions available.*

- Available on
  - on https://github.com/spm
  - through https://www.fil.ion.ucl.ac.uk/spm/
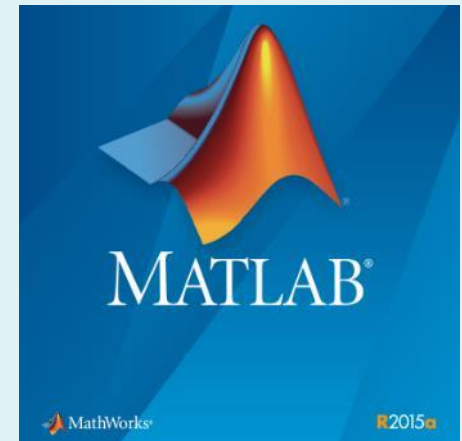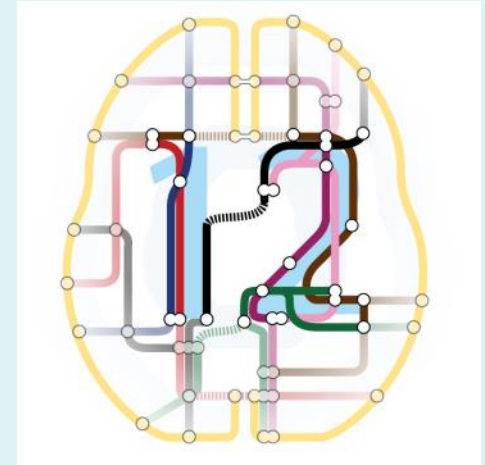
Statistical Parametric Mapping

Data File Formats

- **DICOM**: Digital Imaging and Communications in Medicine

- **NIfTI**: Neuroimaging Informatics Technology Initiative
  - NifTI: volumetric data format (`*.nii,*.hdr/*.img`)
  - GIfTI: geometry data format (`*.gii`)

- **Analyze™**: Mayo Clinic Analyze 7.5 file format (`*.hdr/*.img`)

- **Interoperability:**
  - Compatible with many tools: AFNI, fmriPrep, ANTs, Freesurfer, FSL, …
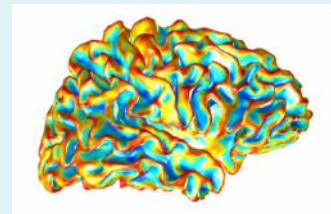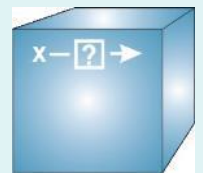
Statistical Parametric Mapping

Brain Imaging Data Structure (BIDS)

"A simple and intuitive way to organise and describe your neuroimaging and behavioural data."

http://bids.neuroimaging.io/

K.J. Gorgolewski et al. The brain imaging data structure, a format for organizing and describing outputs of neuroimaging experiments. *Scientific Data* (2016)
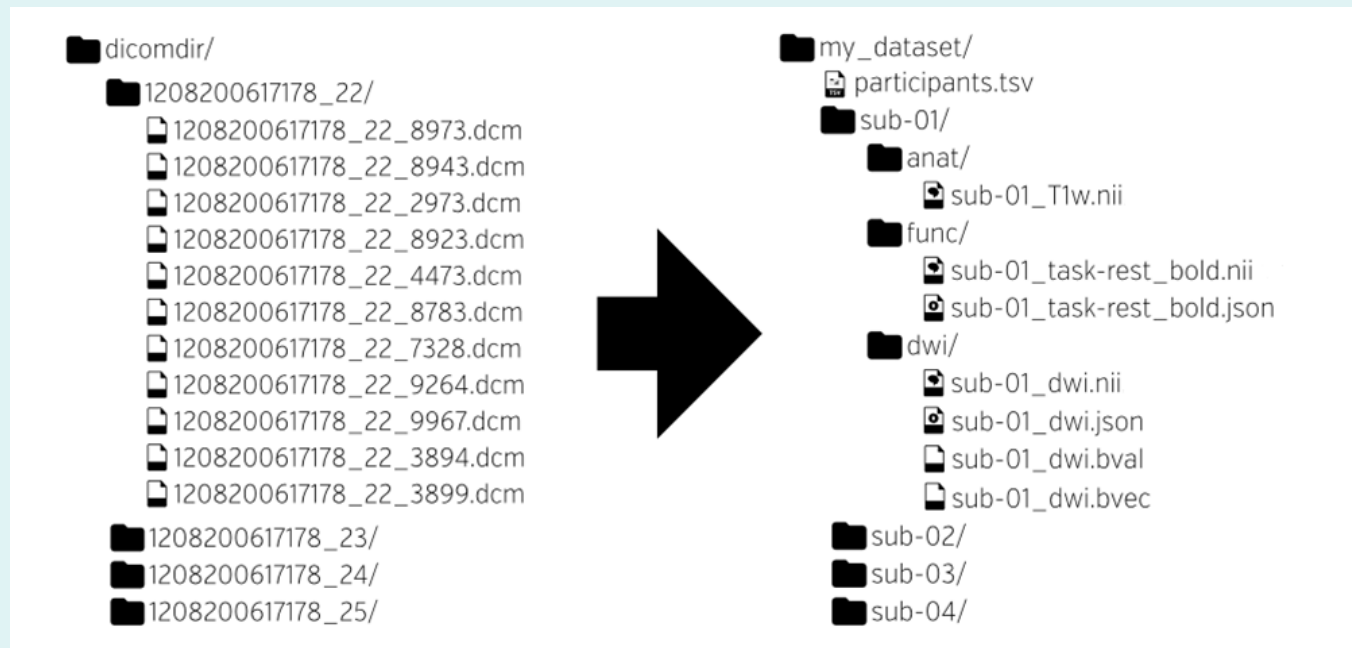
Statistical Parametric Mapping

SPM Documentation

Peer reviewed literature

PDF
Manual
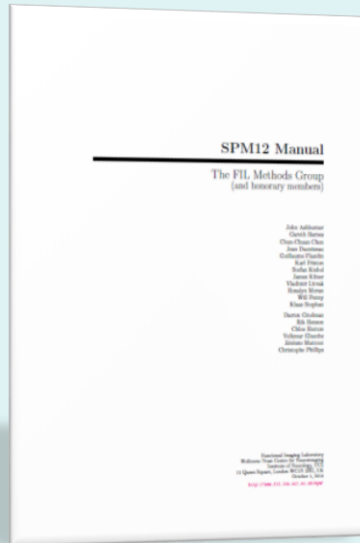
MATLAB
code and
comments
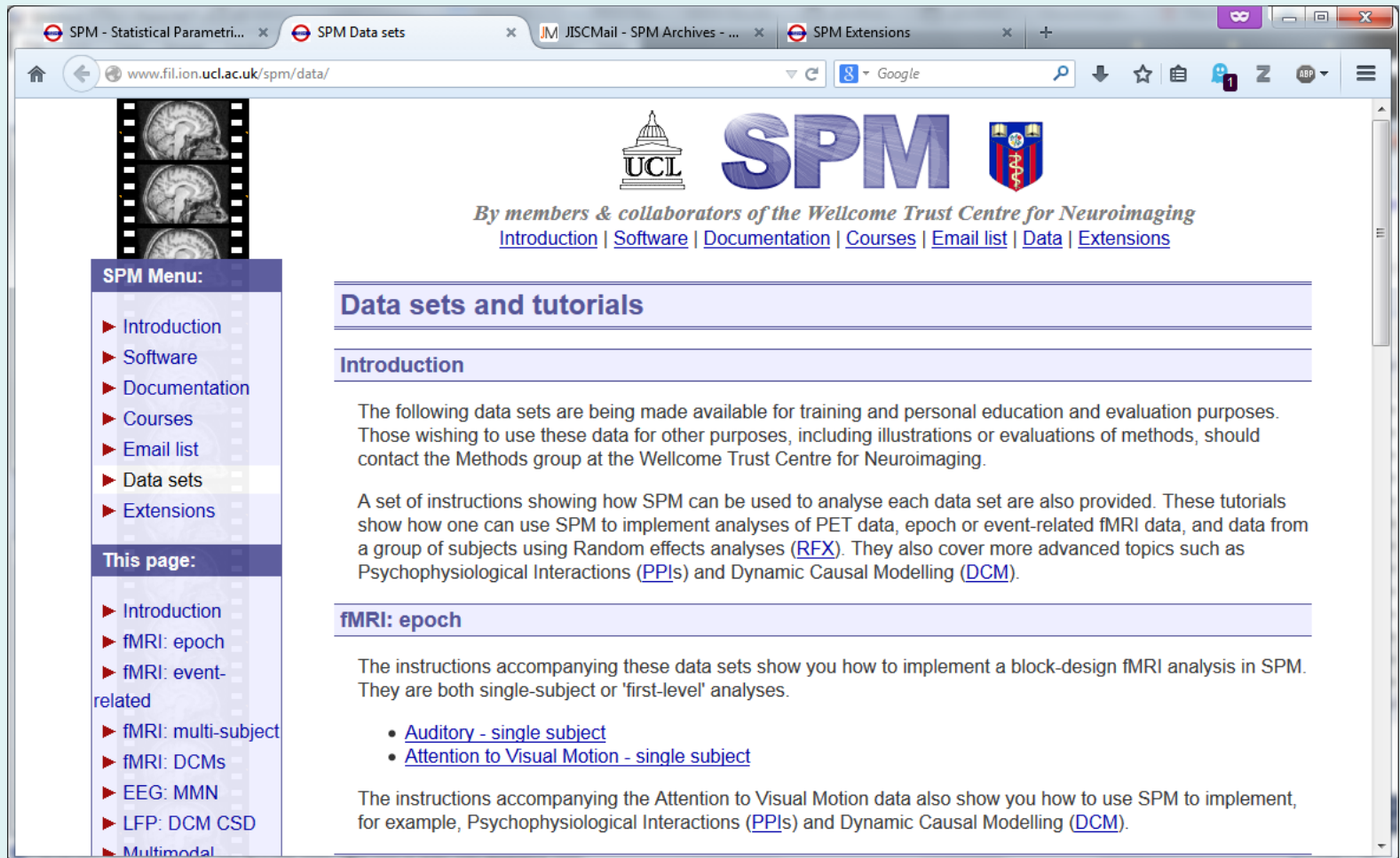
SPM
Book
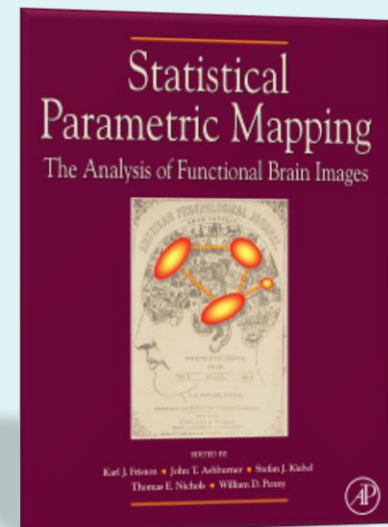
Statistical Parametric Mapping

SPM datasets

PET, fMRI (1ˢᵗ and 2ⁿᵈ level), PPI, DCM, EEG, MEG, LFP.

Statistical Parametric Mapping

SPM Toolboxes

User-contributed SPM extensions: *http://www.fil.ion.ucl.ac.uk/spm/ext/*
+ GitHub now!

Statistical Parametric Mapping

SPM Mailing List

http://www.fil.ion.ucl.ac.uk/spm/support/   spm@jiscmail.ac.uk

SPM co-authors

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- Darren Gitelman

- Daniel Glaser
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- Rik Henson
- Andrew Holmes
- Chloe Hutton
- Maria Joao
- Stefan Kiebel
- James Kilner
- Oliwia Kowalczyk
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- Mohamed Seghier
- Klaas Enno Stephan
- Sungho Tak
- Bernadette Van Wijk
- Peter Zeidman

Open Science

- Open Methodology

- Open Source

- Open Data

- Open Access

- Open Peer Review

- Open Educational Resources