

NeuroImaging Data Processing

aka. Statistical Parametric Mapping short course

Course 1: Introduction

Who am I ?

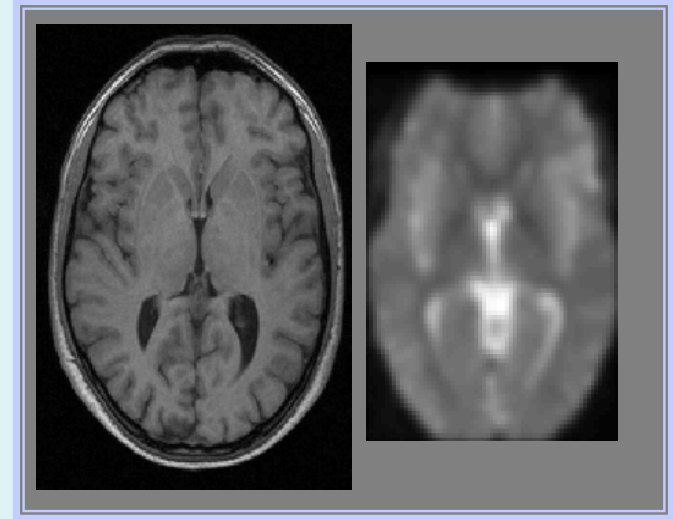
- Electrical (or. electronics) engineer, then PhD on “Source reconstruction in EEG”.
- FRS-FNRS Research Director at the CRC & Professor at the School of Engineering, Montefiore (EEI)
- Linked to
 - “GIGA CRC human imaging” research unit
 - “GIGA in vivo imaging” tech platform
 - Montefiore Institute.
- Office at the Cyclotron Research Centre (B30).
- Interest in neuroimaging:

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

Contact: c.phillips@uliege.be

Functional/structural neuroimaging

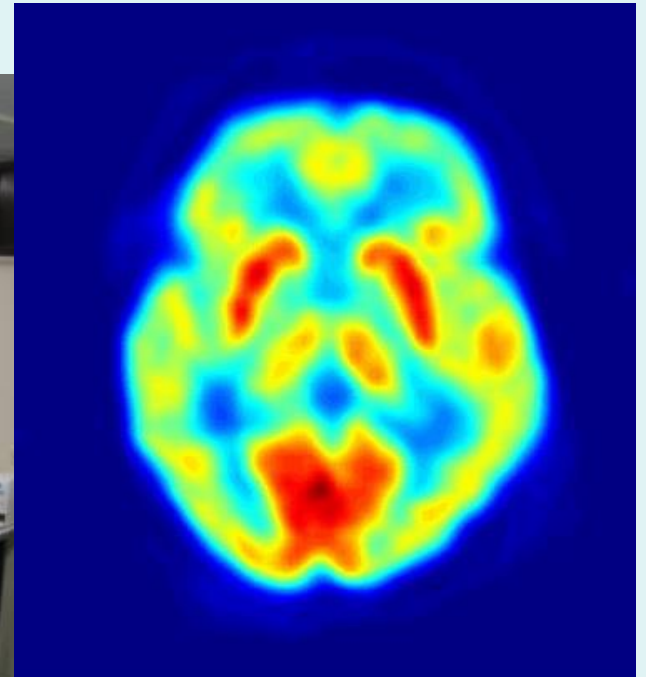
- functional anatomy – functional segregation



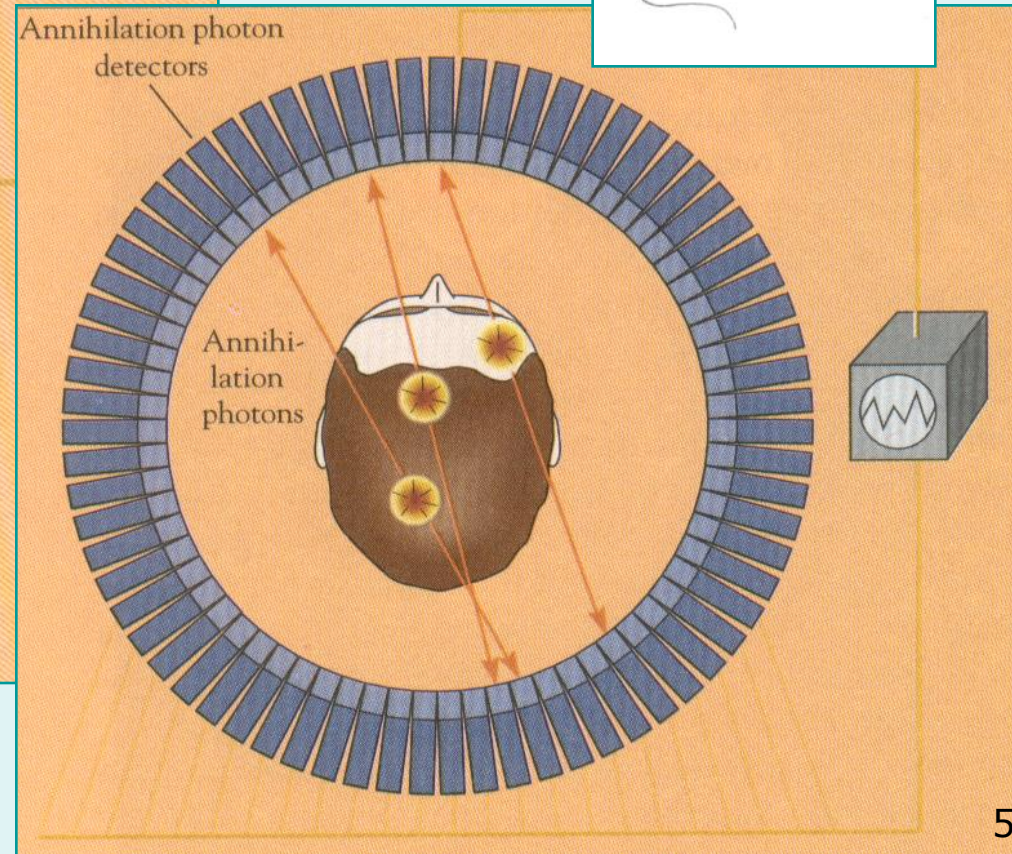
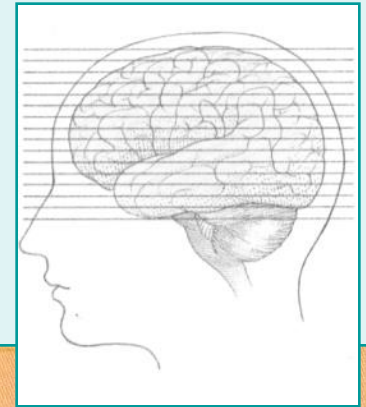
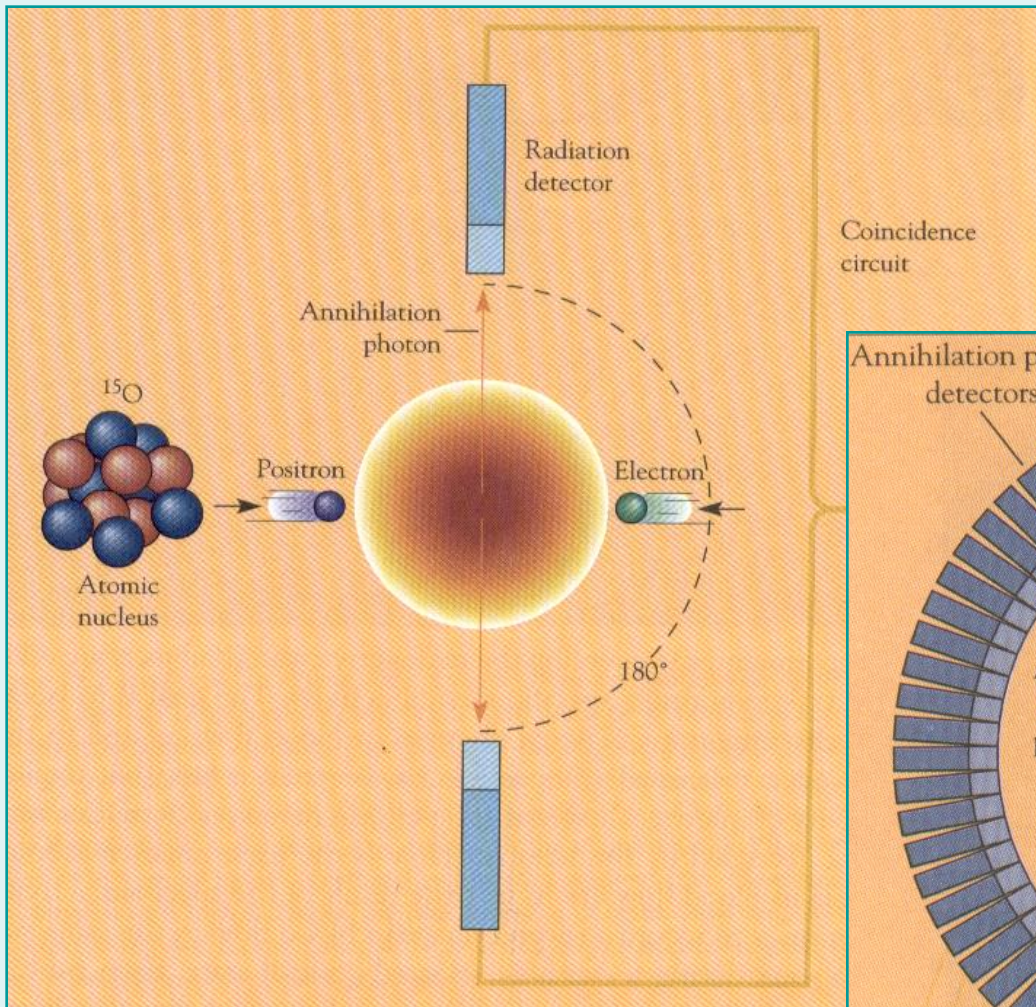
- Positron Emission Tomography (PET) & SPECT
 - regional Cerebral Glucose Uptake
 - other tracers...
- *functional* MRI (fMRI), Blood Oxygenation Level Dependent signal
- *structural* MRI (sMRI + DWI)
 - Grey/White density
 - White matter anisotropy
- *quantitative* MRI (qMRI + spectro + QSM)

Imaging tools: PET

Positron emission tomography



Imaging tools: PET

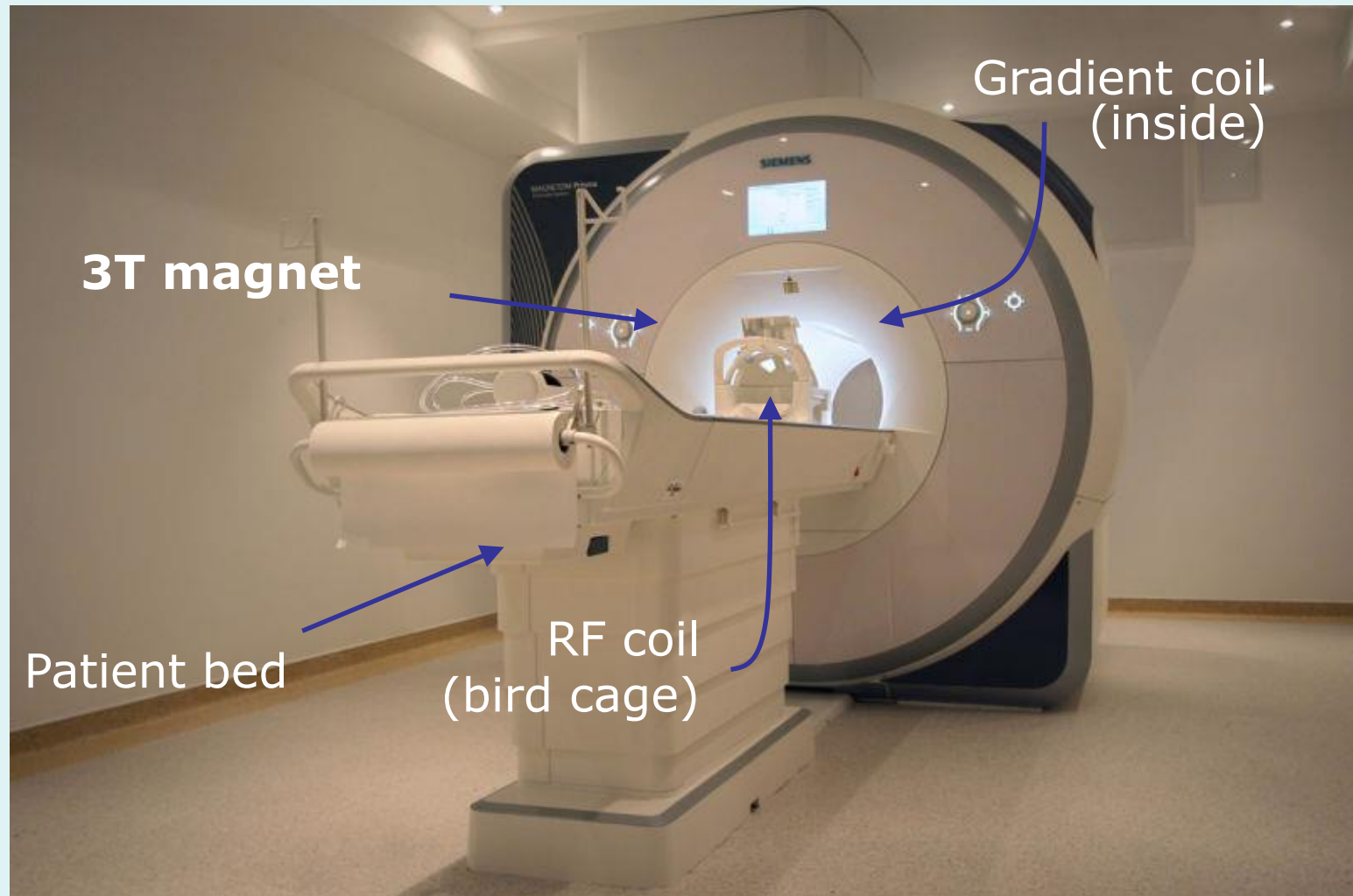


Imaging tools: PET

- 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)

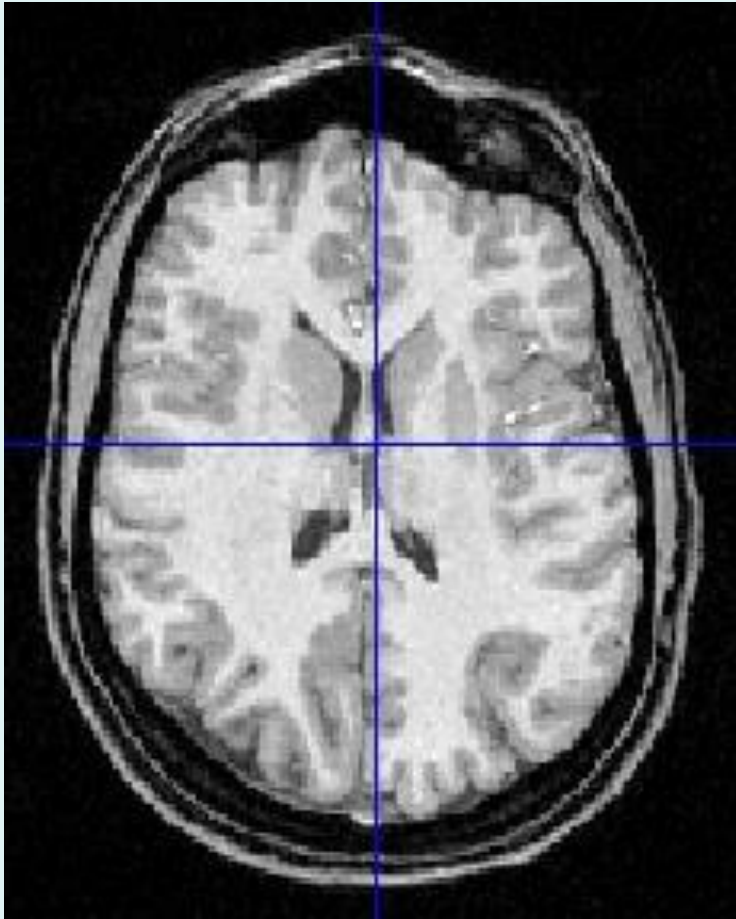
Imaging tools: MRI

Magnetic Resonance Imaging

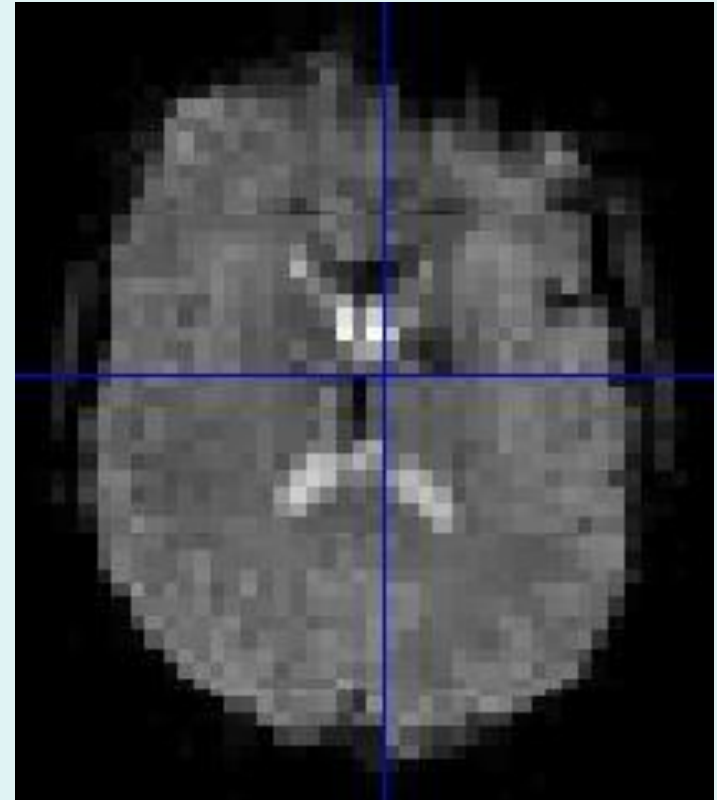


Imaging tools: MRI

T1 contrast

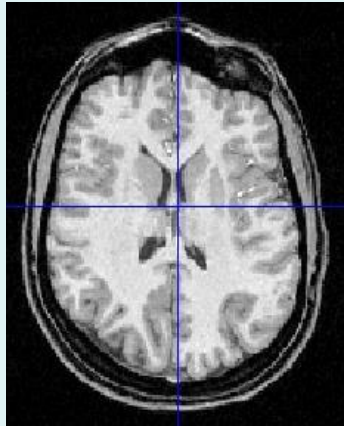


T2* contrast



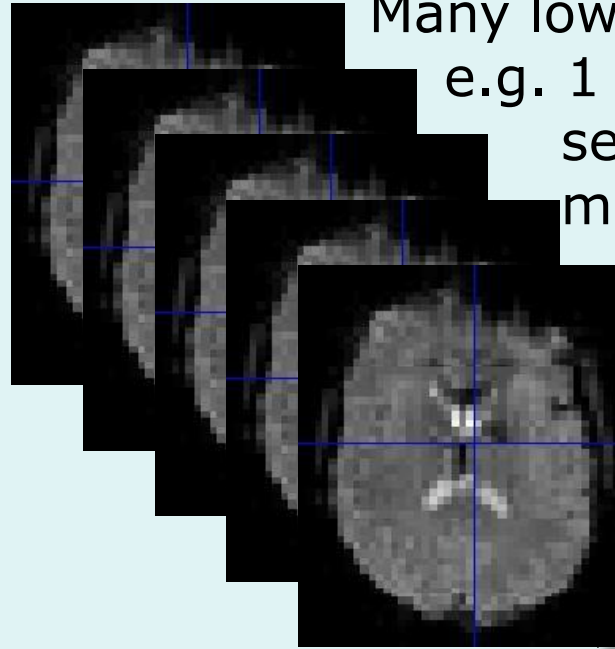
Acquisition time: a few *minutes* vs. a few *seconds*
Spatial resolution: ~1x1x1 mm³ vs. ~3x3x3 mm³

Imaging tools: MRI



one high resolution image

Vs.



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

fMRI signal:

Blood Oxygenation Level Dependent (**BOLD**) signal,
an indirect measure of neural activity.

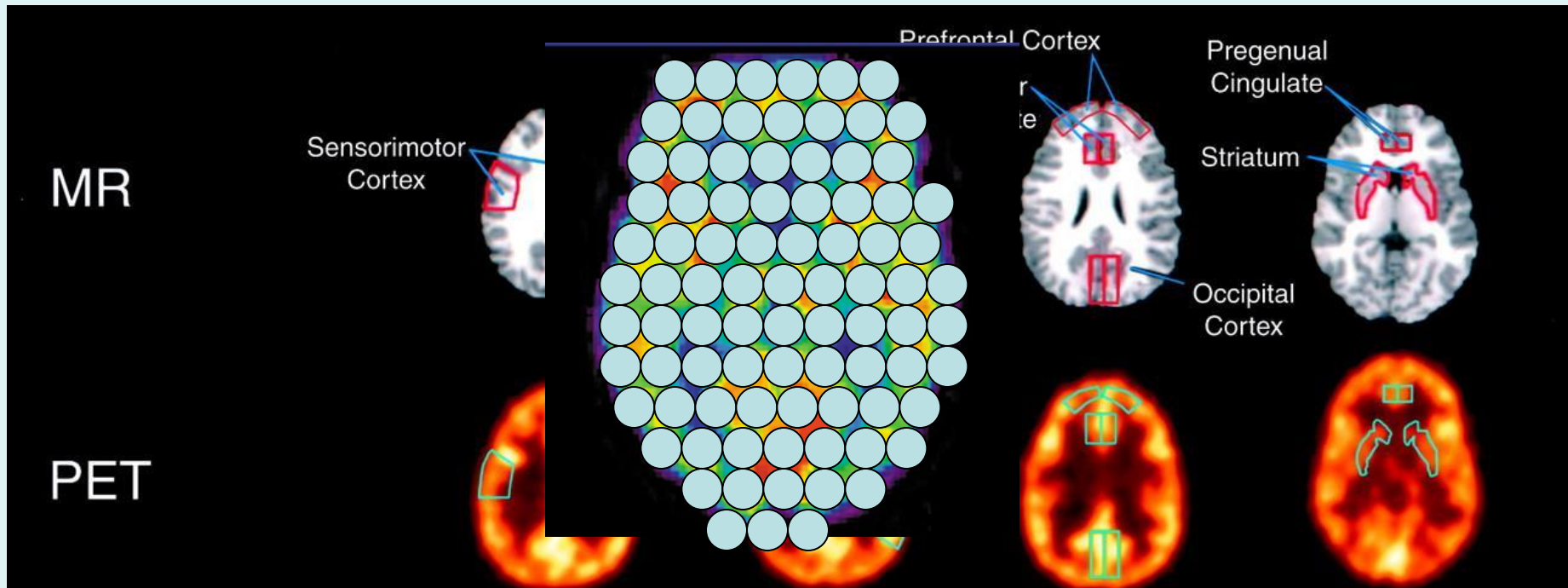
↑ neural activity ⇒ ↑ blood oxygen ⇒ ↑ fMRI signal

Statistical Parametric Mapping

- Concepts
- Software
- Resources

Statistical Parametric Mapping

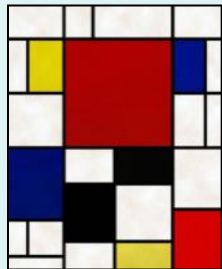
From PET analyses using ROIs...



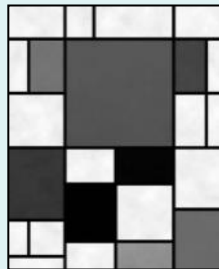
Statistical Parametric Mapping

...to the very first SPM{t}

- An area specialised for the processing of colour, the “colour centre” (V4) highlighted by cognitive subtraction using PET.
- Three subjects:



Colour trials
(2 scans)



Grey trials
(2 scans)

- Compatible with earlier findings on monkeys using electrophysiology.

The colour centre in the cerebral cortex of man

C. J. Lueck^{*†‡}, S. Zeki^{†§}, K. J. Friston^{*}, M.-P. Deiber^{*},
P. Cope[†], V. J. Cunningham^{*}, A. A. Lammertsma^{*},
C. Kennard[‡] & R. S. J. Frackowiak^{*§}

^{*} MRC Cyclotron Unit, Hammersmith Hospital, DuCane Road,
London W12 0HS, UK

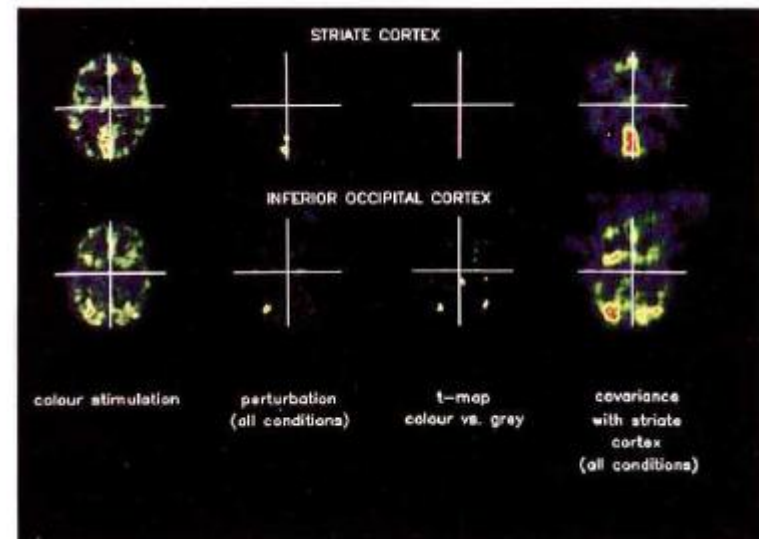
[†] Department of Anatomy, University College London, Gower Street,
London WC1E 6BT, UK

[‡] Department of Neurology, The London Hospital, Whitechapel,
London E1 1BB, UK

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 brain¹. Earlier this century, suggestive clinical evidence for a colour centre in the brain of man^{2,3} was dismissed⁴⁻⁸ 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 cortex⁹, the question of a colour centre in man has been reinvestigated,

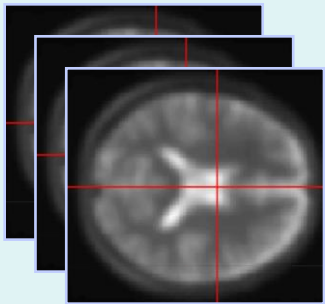
§ To whom reprint requests should be addressed.

NATURE · VOL 340 · 3 AUGUST 1989

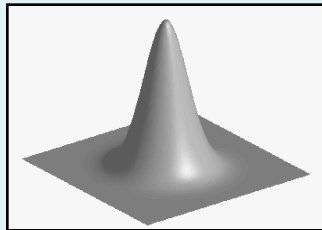


Statistical Parametric Mapping

Image time-series



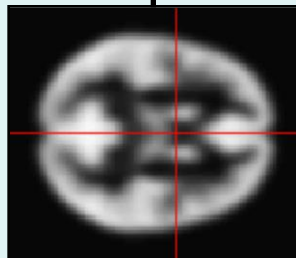
Spatial filter



Realignment

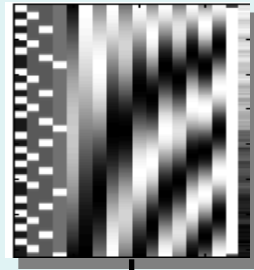
Smoothing

Normalisation

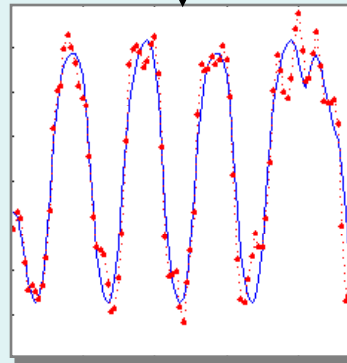


Anatomical reference

Design matrix

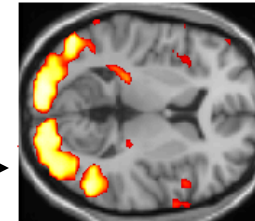
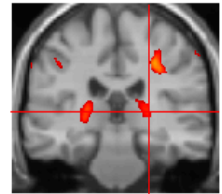
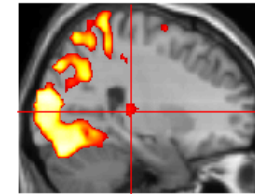


General Linear Model



Parameter estimates

Statistical Parametric Map



Statistical Inference

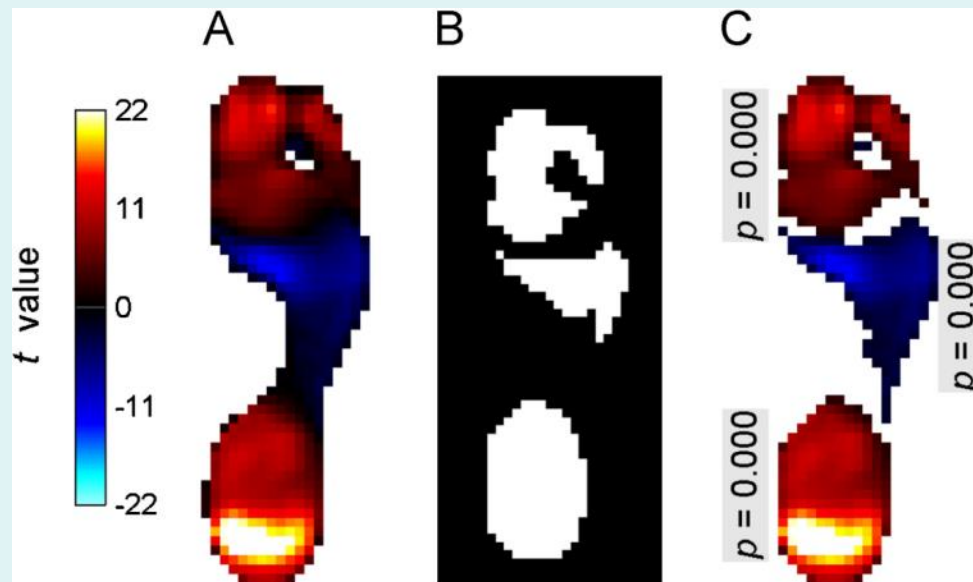
RFT



$p < 0.05$

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.

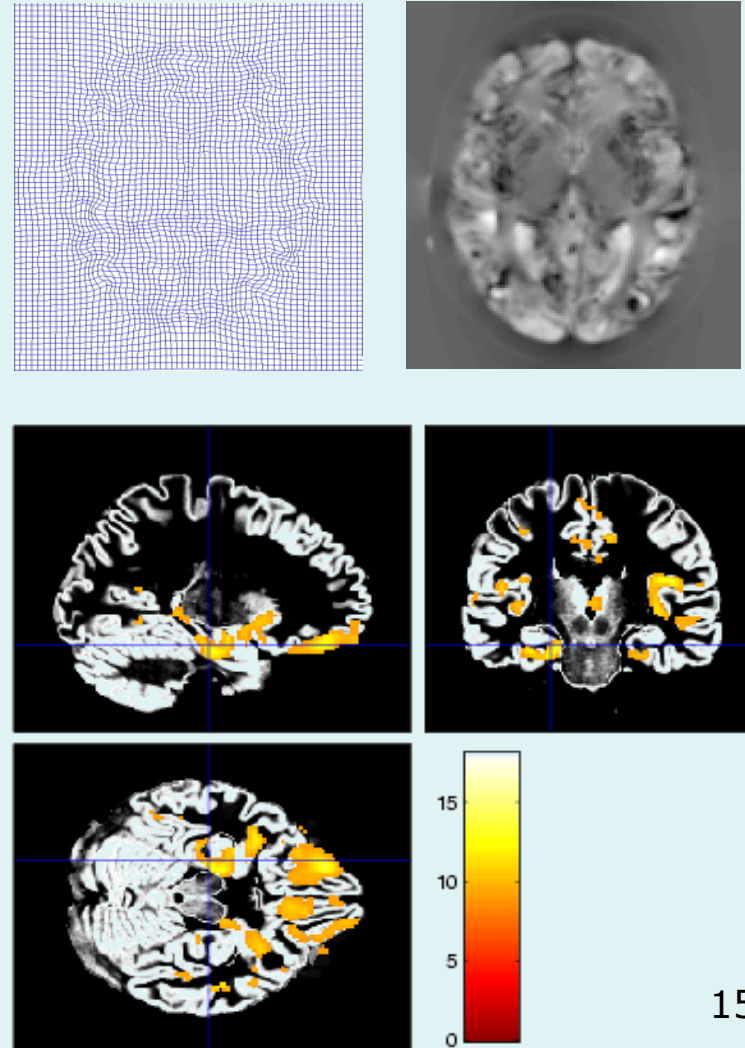


Pedobarographic statistical parametric mapping (pSPM), T. Pataky, Journal of Foot and Ankle Research, 2008.

Statistical Parametric Mapping

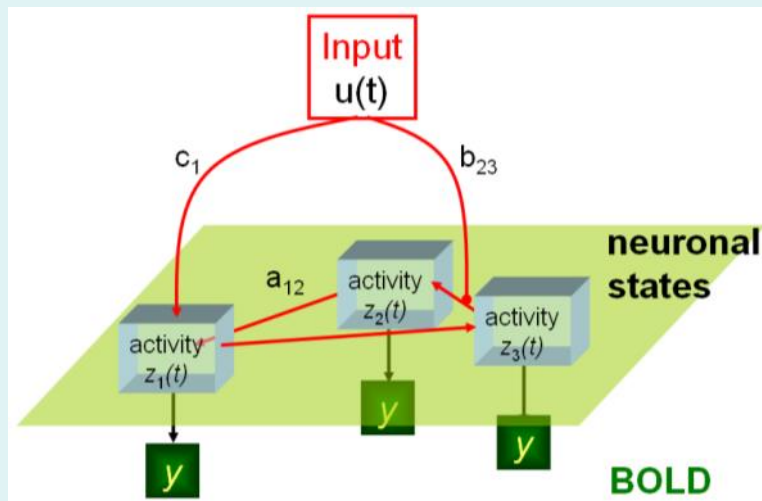
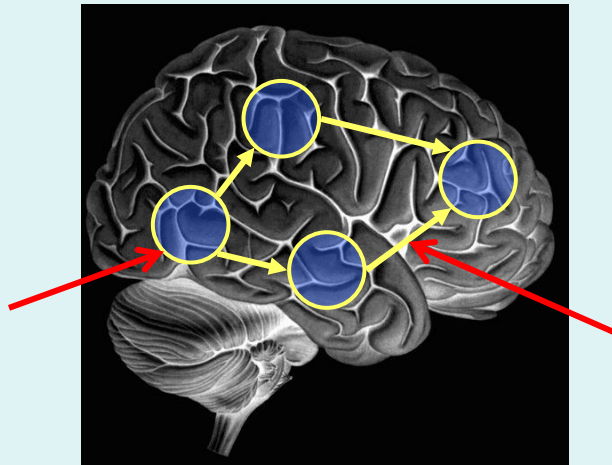
Voxel-Based Morphometry (VBM)

- 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.



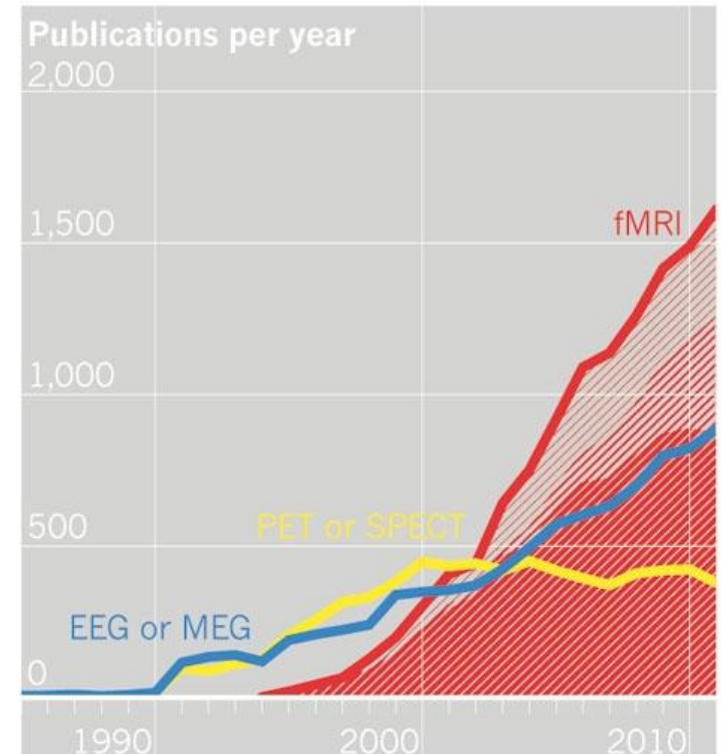
Statistical Parametric Mapping

Dynamic Causal Models



THE RISE OF fMRI

Use of fMRI has rocketed, and now more studies are looking at connectivity between regions.



fMRI publications by subject:

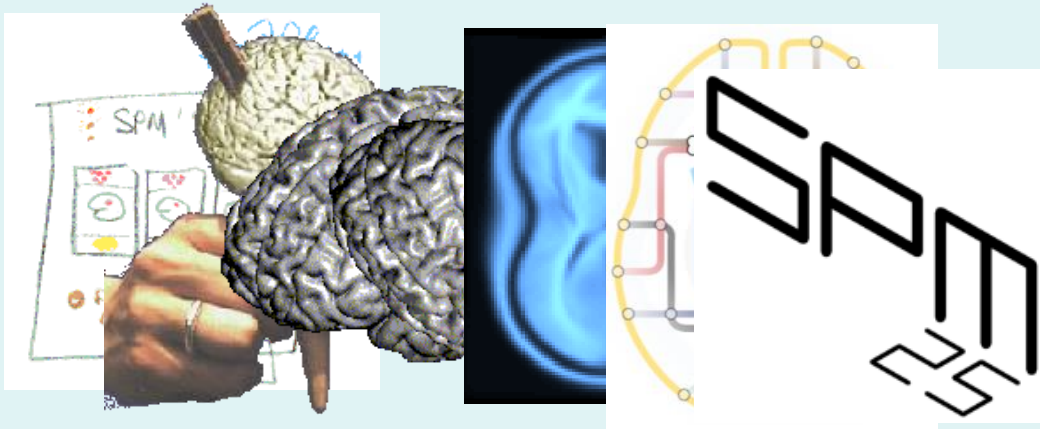
Activation  Connectivity  Other 

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.”

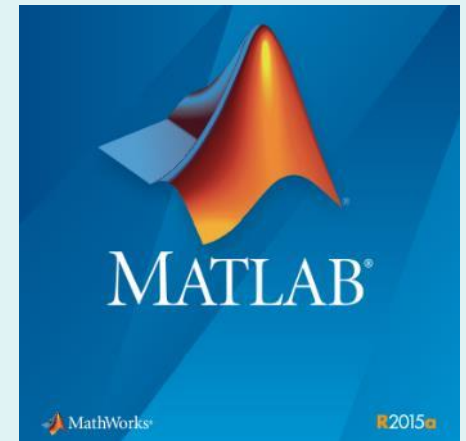


SPMclassic, SPM'94, SPM'96, SPM'99, SPM2, SPM5, SPM8, SPM12 and SPM25 represent the ongoing theoretical advances and technical improvements of the original version.

Statistical Parametric Mapping

Software: **SPM25**

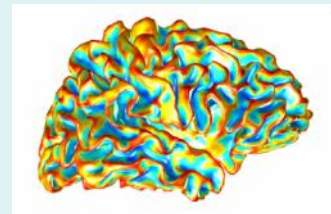
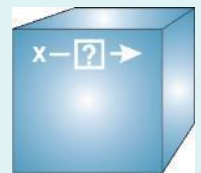
- Free and Open Source Software (GPL)
- Requirements:
 - MATLAB: R2020a and later (and previous too...) no MathWorks toolboxes required
 - Supported platforms: Linux, Windows and Mac
- *Standalone & containerized versions available* → **NO need of Matlab**
- Available on
 - on <https://github.com/spm>
 - 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)
- **AnalyzeTM**: Mayo Clinic Analyze 7.5 file format (*.hdr/*.img)
- **Interoperability**:
 - Compatible with many tools: AFNI, fmriPrep, ANTs, Freesurfer, FSL, ...

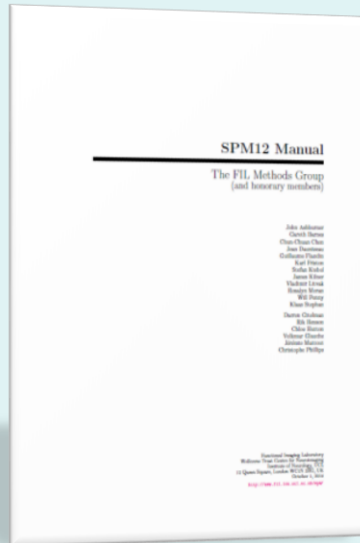


Statistical Parametric Mapping

SPM Documentation

Peer reviewed literature

PDF
Manual

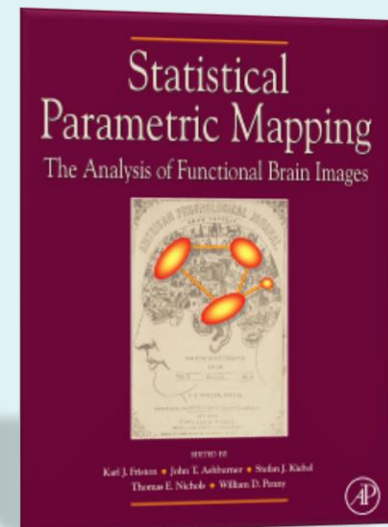


MATLAB
code and
comments

```
% Step 1: ReML estimate of hyperparameters
% Gradient dF/dh (first derivatives)
%
P = IC - IC*Q*IC';
U = speye(n) - P*Y*Y';
for i = 1:m
    % dF/dh = -trace(dF/dIC*IC*Q(i)*IC)
    PQ(i) = P*Q(i);
    dFdh(i,1) = -spm_trace(PQ(i),U)*M/3;
end
% Expected curvature E(dF/dh) (second derivatives)
%
for i = 1:m
    for j = 1:m
        % dF/dhh = -trace(P*Q(i)*P*Q(j))
        %
        dFdh(i,j) = -spm_trace(PQ(i),PQ(j))*M/3;
        dFdh(j,i) = dFdh(i,j);
    end
end
```

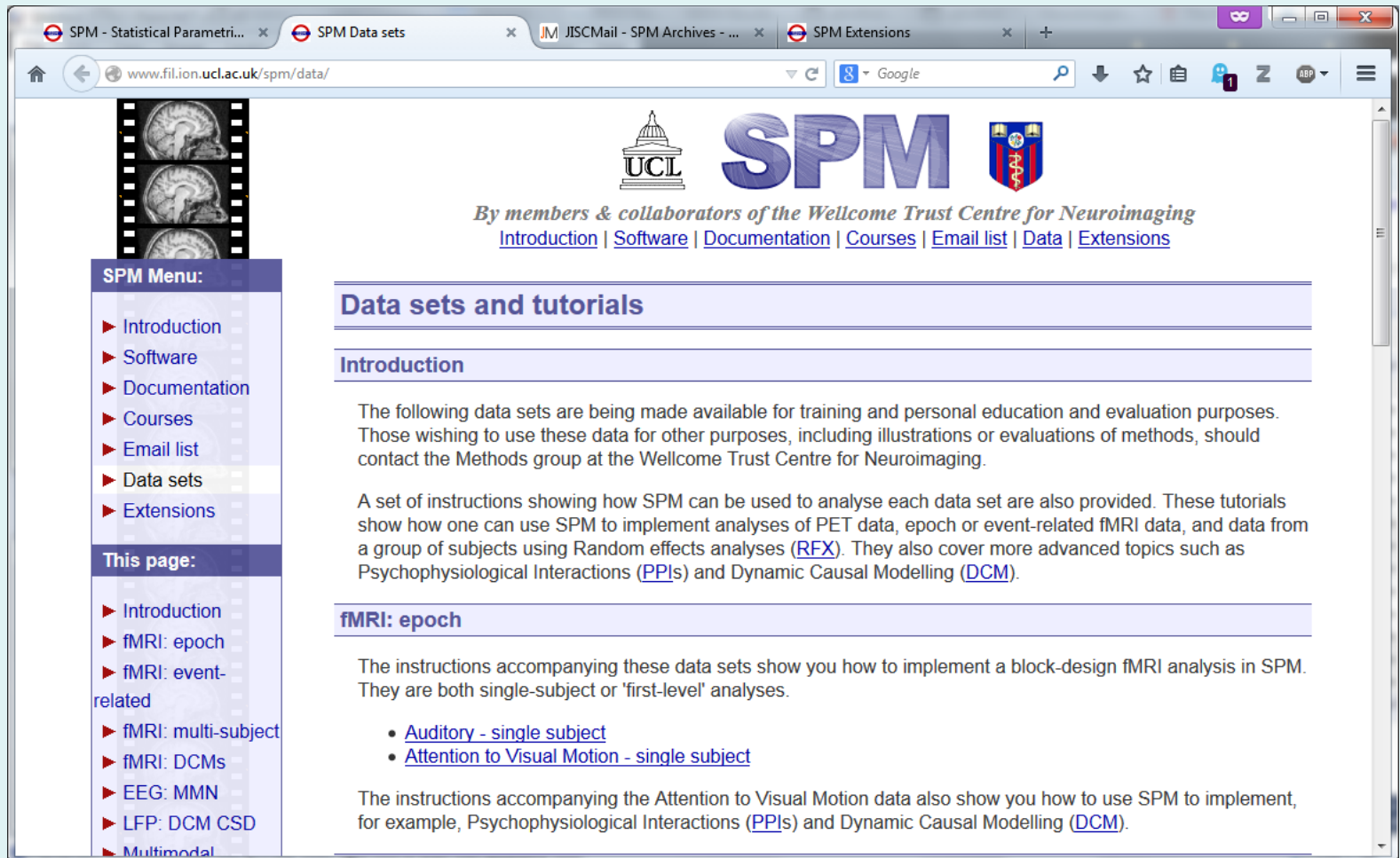


SPM
Book



Statistical Parametric Mapping

SPM datasets



The screenshot shows a web browser window with the URL www.fil.ion.ucl.ac.uk/spm/data/. The page features the SPM logo and the text "By members & collaborators of the Wellcome Trust Centre for Neuroimaging". A navigation menu on the left lists various resources, with "Data sets" highlighted. The main content area is titled "Data sets and tutorials" and includes an "Introduction" section. This section states that data sets are available for training and education, and that tutorials are provided for analyzing each data set. The "fMRI: epoch" section is also visible, detailing instructions for block-design fMRI analysis, including links to "Auditory - single subject" and "Attention to Visual Motion - single subject" data sets.

SPM - Statistical Parametri... x SPM Data sets x JISC Mail - SPM Archives - ... x SPM Extensions x

www.fil.ion.ucl.ac.uk/spm/data/

UCL SPM

By members & collaborators of the Wellcome Trust Centre for Neuroimaging

[Introduction](#) | [Software](#) | [Documentation](#) | [Courses](#) | [Email list](#) | [Data](#) | [Extensions](#)

SPM Menu:

- ▶ Introduction
- ▶ Software
- ▶ Documentation
- ▶ Courses
- ▶ Email list
- ▶ Data sets
- ▶ Extensions

This page:

- ▶ Introduction
- ▶ fMRI: epoch
- ▶ fMRI: event-related
- ▶ fMRI: multi-subject
- ▶ fMRI: DCMs
- ▶ EEG: MMN
- ▶ LFP: DCM CSD
- ▶ Multimodal

Data sets and tutorials

Introduction

The following data sets are being made available for training and personal education and evaluation purposes. Those wishing to use these data for other purposes, including illustrations or evaluations of methods, should contact the Methods group at the Wellcome Trust Centre for Neuroimaging.

A set of instructions showing how SPM can be used to analyse each data set are also provided. These tutorials show how one can use SPM to implement analyses of PET data, epoch or event-related fMRI data, and data from a group of subjects using Random effects analyses ([RFX](#)). They also cover more advanced topics such as Psychophysiological Interactions ([PPIs](#)) and Dynamic Causal Modelling ([DCM](#)).

fMRI: epoch

The instructions accompanying these data sets show you how to implement a block-design fMRI analysis in SPM. They are both single-subject or 'first-level' analyses.

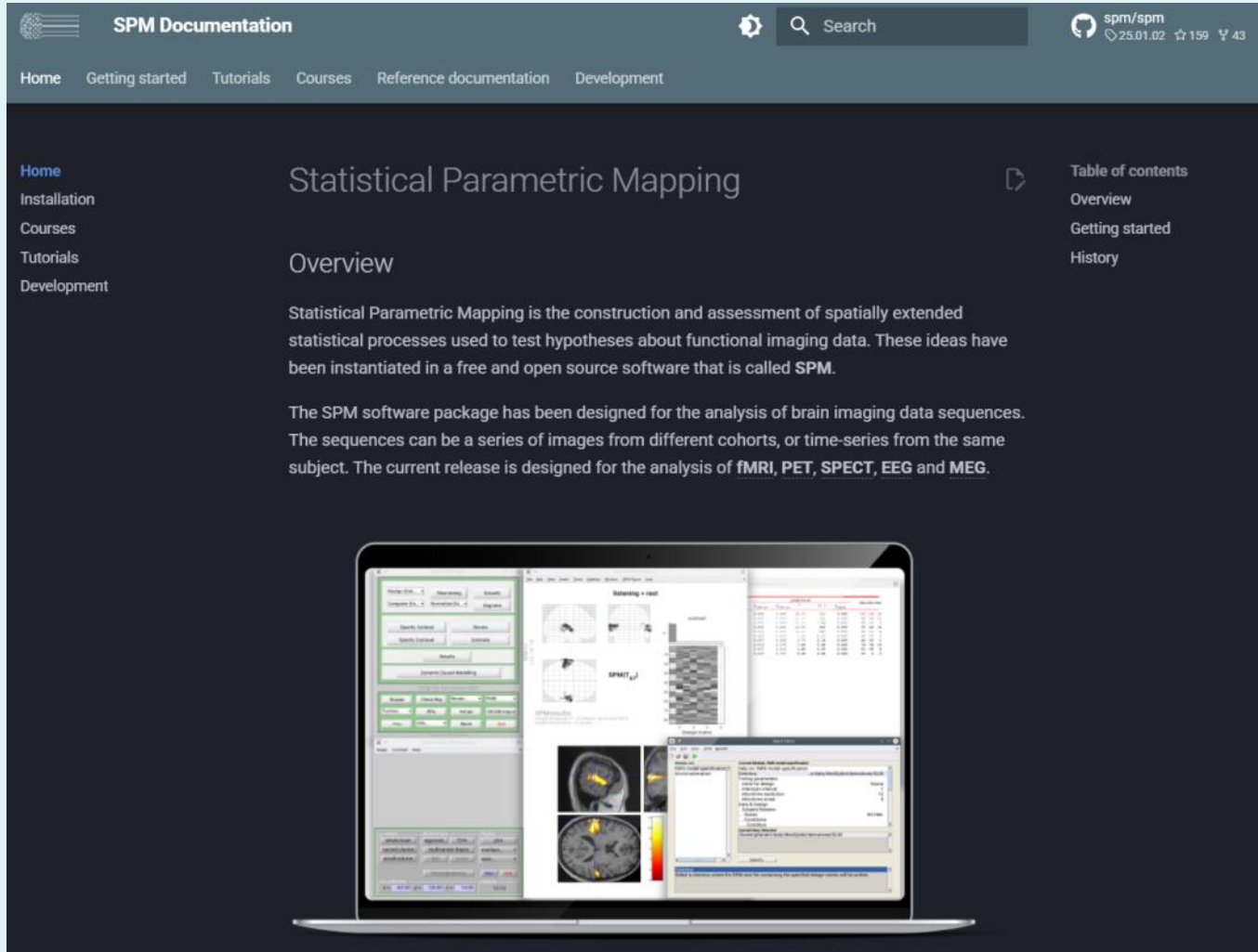
- [Auditory - single subject](#)
- [Attention to Visual Motion - single subject](#)

The instructions accompanying the Attention to Visual Motion data also show you how to use SPM to implement, for example, Psychophysiological Interactions ([PPIs](#)) and Dynamic Causal Modelling ([DCM](#)).

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

Statistical Parametric Mapping

SPM support & tutorial: “from A to Z”



The screenshot displays the SPM Documentation website. The header includes the SPM logo, the title 'SPM Documentation', a search bar, and user statistics for 'spm/spm'. The navigation menu lists 'Home', 'Getting started', 'Tutorials', 'Courses', 'Reference documentation', and 'Development'. The main content area is titled 'Statistical Parametric Mapping' and includes a sidebar with links to 'Home', 'Installation', 'Courses', 'Tutorials', and 'Development'. The 'Overview' section describes SPM as a free and open source software for analyzing brain imaging data sequences, specifically mentioning fMRI, PET, SPECT, EEG, and MEG. Below the text is an image of a laptop displaying the SPM software interface, which shows various windows for data processing, including a 'Retrieving + root' window, a 'SPM12' window, and a 'SPM12: Results' window.

SPM Documentation

Home Getting started Tutorials Courses Reference documentation Development

Statistical Parametric Mapping

Overview

Statistical Parametric Mapping is the construction and assessment of spatially extended statistical processes used to test hypotheses about functional imaging data. These ideas have been instantiated in a free and open source software that is called **SPM**.

The SPM software package has been designed for the analysis of brain imaging data sequences. The sequences can be a series of images from different cohorts, or time-series from the same subject. The current release is designed for the analysis of **fMRI**, **PET**, **SPECT**, **EEG** and **MEG**.

Table of contents

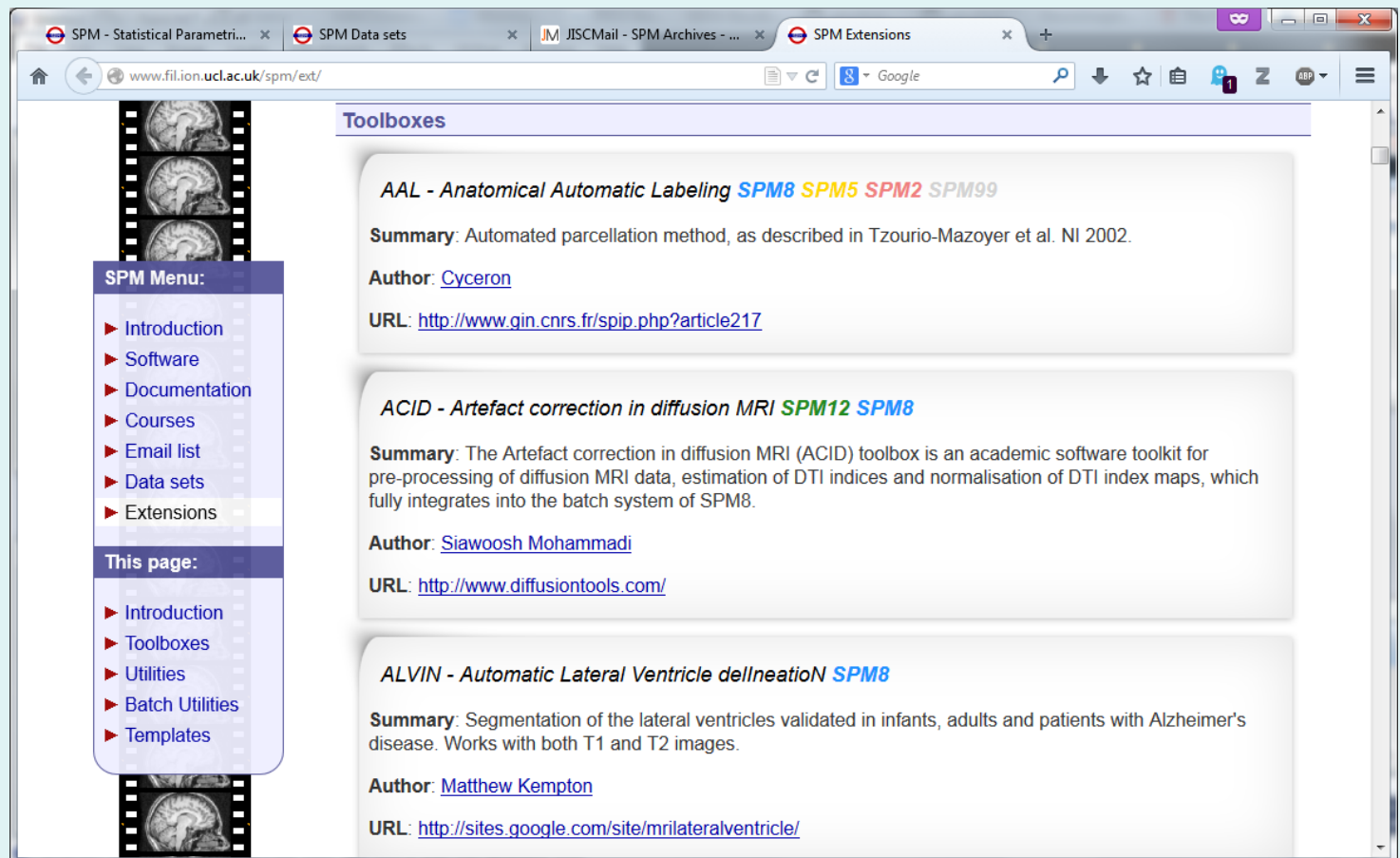
- Overview
- Getting started
- History



Statistical Parametric Mapping

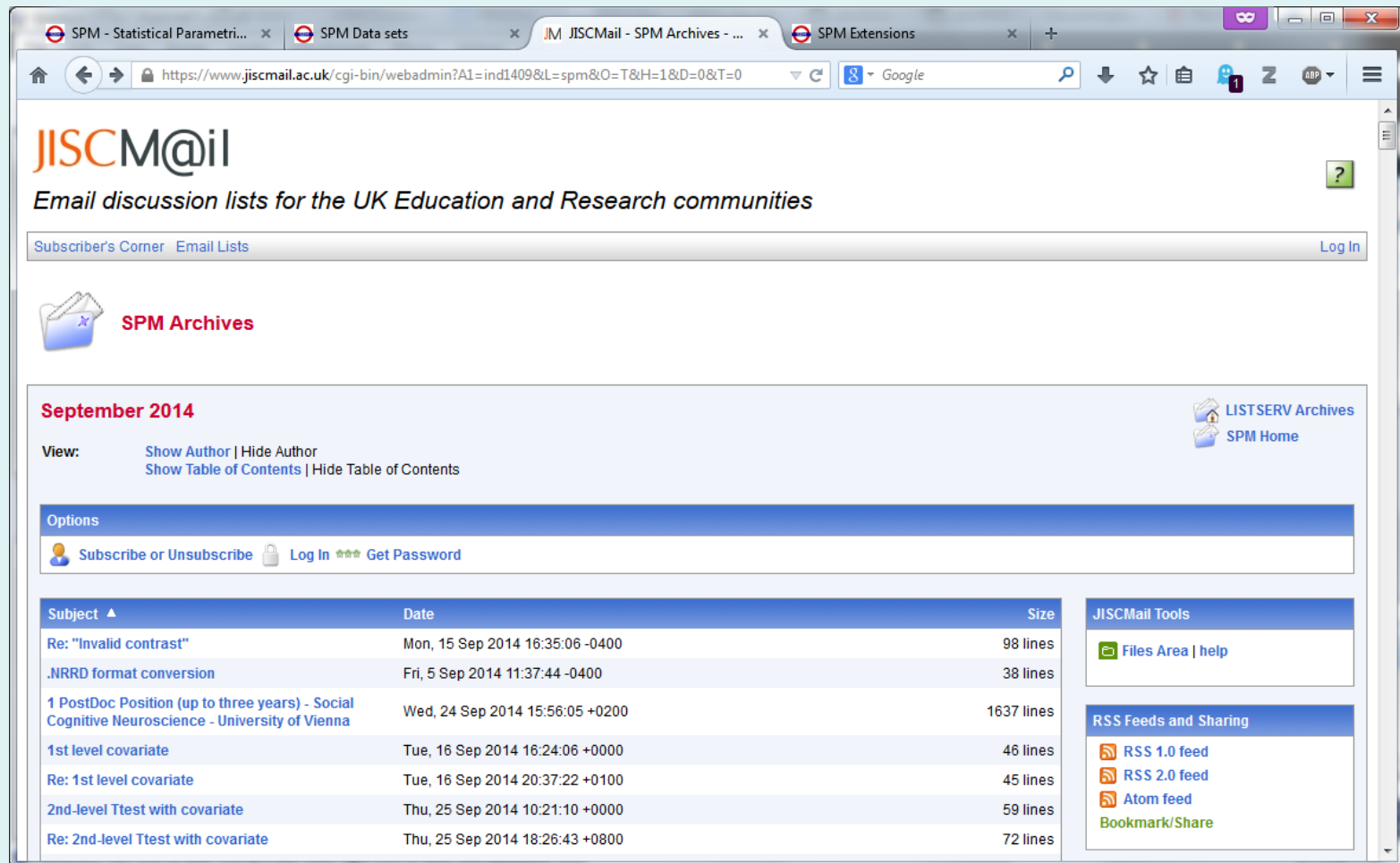
SPM Toolboxes

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



Statistical Parametric Mapping

SPM Mailing List



The screenshot shows a web browser window with multiple tabs. The active tab is titled "JISCMAIL - SPM Archives - ...". The address bar shows the URL: <https://www.jiscmail.ac.uk/cgi-bin/webadmin?A1=ind1409&L=spm&O=T&H=1&D=0&T=0>. The page header features the "JISCMAIL" logo and the text "Email discussion lists for the UK Education and Research communities". Below the header, there are links for "Subscriber's Corner", "Email Lists", and a "Log In" button. A section titled "SPM Archives" is visible. The main content area displays a list of email messages for "September 2014". The list includes columns for "Subject", "Date", and "Size". To the right of the list, there are links for "LISTSERV Archives" and "SPM Home". Below the list, there is a "JISCMAIL Tools" section with links for "Files Area" and "help". At the bottom right, there is an "RSS Feeds and Sharing" section with links for "RSS 1.0 feed", "RSS 2.0 feed", "Atom feed", and "Bookmark/Share".

September 2014

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[Show Table of Contents](#) | [Hide Table of Contents](#)

Options

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Subject	Date	Size
Re: "Invalid contrast"	Mon, 15 Sep 2014 16:35:06 -0400	98 lines
.NRRD format conversion	Fri, 5 Sep 2014 11:37:44 -0400	38 lines
1 PostDoc Position (up to three years) - Social Cognitive Neuroscience - University of Vienna	Wed, 24 Sep 2014 15:56:05 +0200	1637 lines
1st level covariate	Tue, 16 Sep 2014 16:24:06 +0000	46 lines
Re: 1st level covariate	Tue, 16 Sep 2014 20:37:22 +0100	45 lines
2nd-level Ttest with covariate	Thu, 25 Sep 2014 10:21:10 +0000	59 lines
Re: 2nd-level Ttest with covariate	Thu, 25 Sep 2014 18:26:43 +0800	72 lines

JISCMAIL Tools

[Files Area](#) | [help](#)

RSS Feeds and Sharing

[RSS 1.0 feed](#)
[RSS 2.0 feed](#)
[Atom feed](#)
[Bookmark/Share](#)

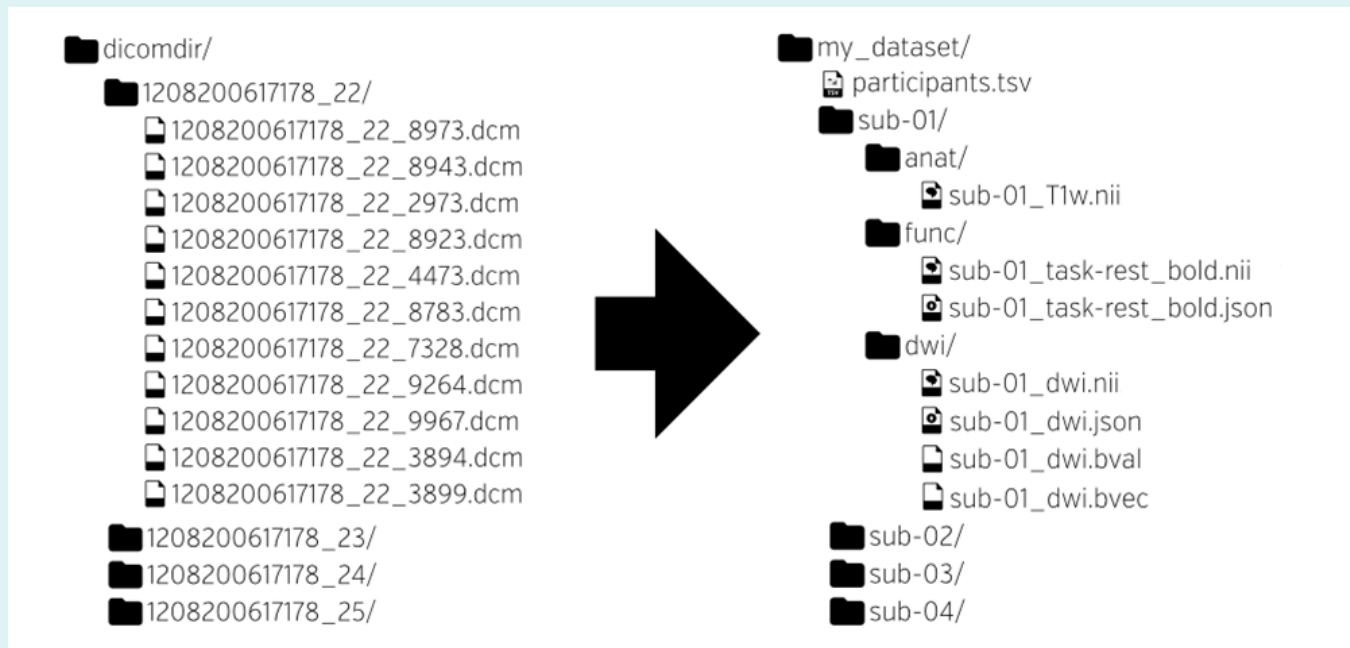
SPM co-authors

- Jesper Andersson
- John Ashburner
- Nelson Trujillo-Barreto
- Gareth Barnes
- Matthew Brett
- Christian Buchel
- CC Chen
- Justin Chumbley
- Jean Daunizeau
- Olivier David
- Guillaume Flandin
- Karl Friston
- Darren Gitelman
- Daniel Glaser
- Volkmar Glauche
- Lee Harrison
- Rik Henson
- Andrew Holmes
- Chloe Hutton
- Maria Joao
- Stefan Kiebel
- James Kilner
- Oliwia Kowalczyk
- Vladimir Litvak
- Andre Marreiros
- Jérémie Mattout
- Rosalyn Moran
- Tom Nichols
- Robert Oostenveld
- Will Penny
- Christophe Phillips
- Dimitris Pinotsis
- Jean-Baptiste Poline
- Ged Ridgway
- Holly Rossiter
- Mohamed Seghier
- Klaas Enno Stephan
- Sungho Tak
- Bernadette Van Wijk
- Peter Zeidman

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/>

Open Science

- Open Methodology
- Open Source
- Open Data
- Open Access
- Open Peer Review
- Open Educational Resources

