

Introduction to Neuroimaging

Lecture Notes

Ahmet Ademoglu, *PhD*
Bogazici University
Institute of Biomedical Engineering

Brain Imaging Modalities

- Anatomical/Structural Brain Imaging
 - 1 Computer Tomography
 - 2 T1/T2 Weighted MR Imaging
 - 3 Diffusion Tensor Imaging
- Functional/Physiological Brain Imaging
 - 1 Positron Emission Tomography (PET) / SPECT
 - 2 Functional Magnetic Resonance Imaging (fMRI)
 - 3 EEG/MEG

In PET, it is the blood flow that we indirectly measure

- A tracer (radionuclide) is used and emitted a pair of gamma rays in opposite directions are detected and converted into (sinograms) and reconstructed into tomographic images
- Different tracers allow various properties to be measured;
- O^{15} can measure blood flow relatively quickly (<1 min) but requires a cyclotron because of its short 2 minute half-life
- F^{18} Fluorodeoxyglucose (FDG) measures glucose metabolism, and has a half life of 110 minutes
- Other tracers exist that bind to interesting receptors (e.g. dopamine, serotonin) or beta-amyloid plaques

Some Disadvantages of PET

- 1 Slow, even compared to haemodynamic delays
- 2 Low spatial resolution
- 3 Ionising radiation

What we measure in fMRI is

Blood oxygen level dependency signal called BOLD

- 1 With fMRI, we typically acquire a scan every few seconds, and wish to study event-related responses
- 2 High spatial resolution
- 3 Low temporal resolution

What we measure in EEG/MEG is

postsynaptic potentials directly related to neuronal activity

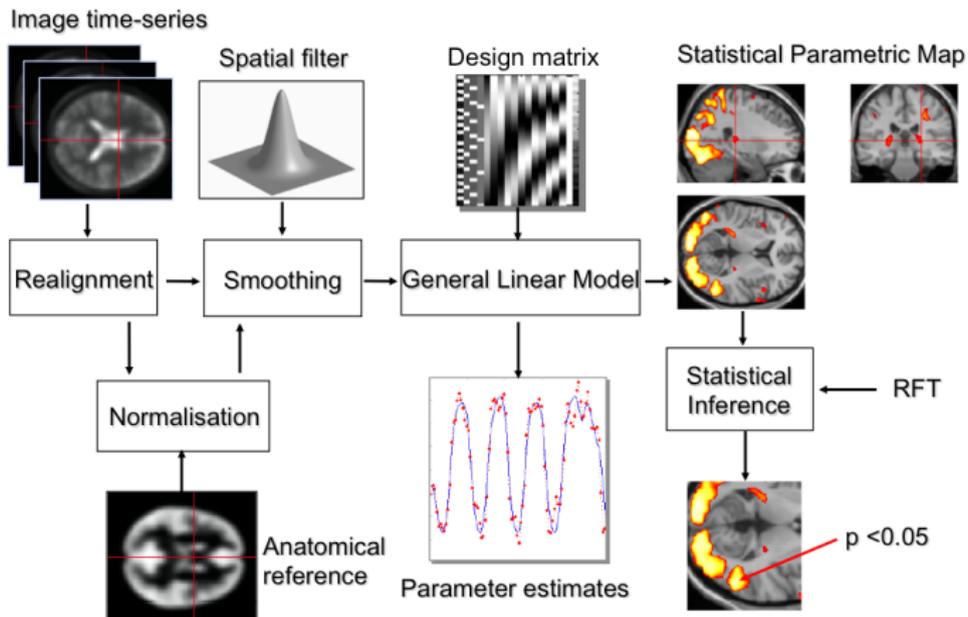
- 1 High temporal resolution
- 2 Low spatial resolution

Platforms/Tools for Brain Imaging Data

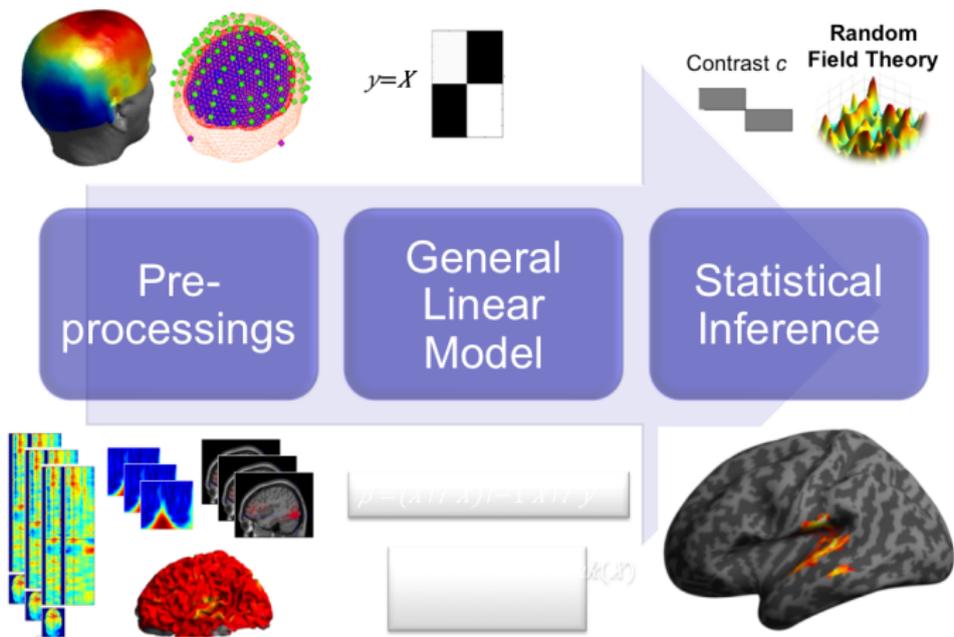
Data Processing, Modeling and Visualization

- 1 Statistical Parameter Mapping (SPM)
- 2 AFNI
- 3 FSL
- 4 Freesurfer
- 5 fMRISat
- 6 ANTs
- 7 BrainVisa
- 8 Caret
- 9 Neuropy
- 10 Nilearn
- 11 fMRIPrep
- 12 EEGlab
- 13 Fieldtrip

PET/fMRI Data Processing Stages

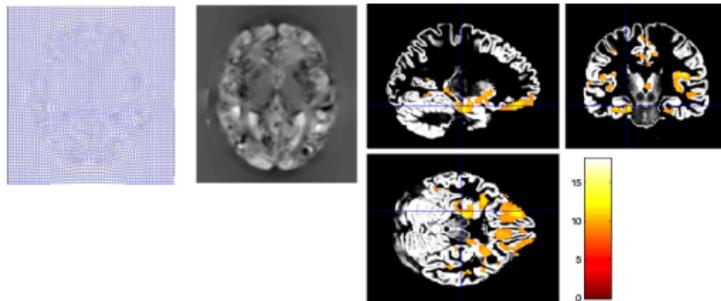


EEG/MEG Data Processing Stages



Voxel Based Morphometry (VBM)

- VBM is the most widely used method for computational neuroanatomy.
- Statistical Parametric Mapping of cortical thickness or volume.
- Anatomical changes caused by a disease or a functional distinction.



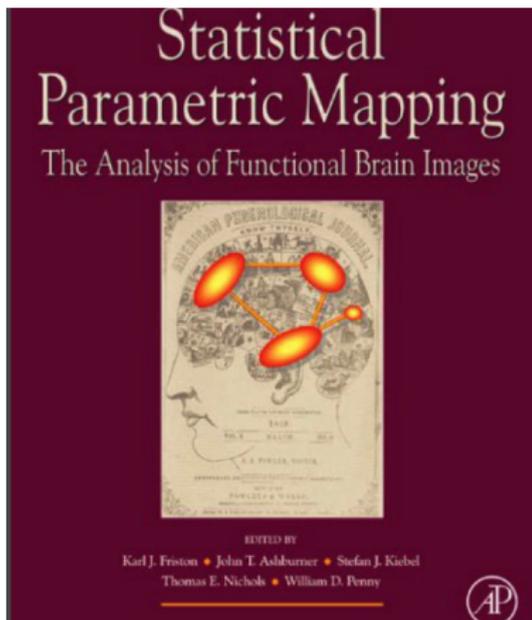
SPM Resources

SPM datasets

The screenshot shows the SPM website interface. At the top, there are browser tabs for 'SPM - Statistical Paramet...', 'SPM Data sets', 'JSCMA2 - SPM Archives...', and 'SPM Extensions'. The address bar shows 'www.fil.ion.ucl.ac.uk/spm/data/'. The main header features the SPM logo with 'UCL' and 'Wellcome' logos, and the text 'By members & collaborators of the Wellcome Trust Centre for Neuroimaging'. Below this are links for 'Introduction | Software | Documentation | Courses | Email list | Data | Extensions'. The main content area is titled 'Data sets and tutorials' and has a sub-section 'Introduction' which states: '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 (REX). They also cover more advanced topics such as Psychophysiological Interactions (PPIs) and Dynamic Causal Modelling (DCM)'. Below this is a sub-section 'fMRI: epoch' which states: '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.' and lists two bullet points: 'Auditory - single subject' and 'Attention to Visual Motion - single subject'. At the bottom of the page, it says: '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)'. On the left side, there is a navigation menu with 'SPM Menu:' containing links for 'Introduction', 'Software', 'Documentation', 'Courses', 'Email list', 'Data sets', and 'Extensions'. Below that is 'This page:' with links for 'Introduction', 'fMRI: epoch', 'fMRI: event-related', 'fMRI: multi-subject', 'fMRI: DCMs', 'EEG: MMN', 'LFP: DCM CSD', and 'Multimodal'.

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

SPM Resources



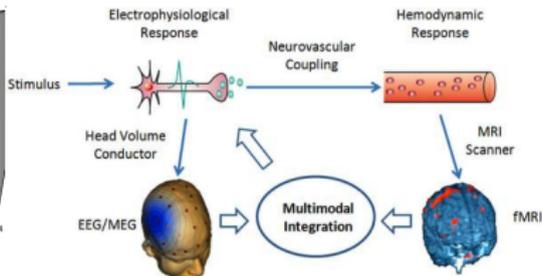
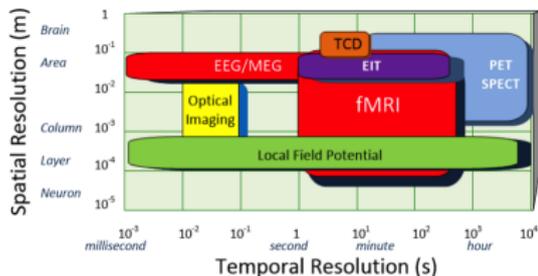
SPM12 Manual

The FIL Methods Group
(and honorary members)

John Ashburner
Clayton Barnes
Chun-Chieh Chen
Jean Durrleman
Guillaume Flandin
Karl Friston
Stefan Kiebel
James Kilner
Vandana Lavrakas
Brendyn Moran
Waji Pany
Abdul Raai
Klaus Stephan
Sanghoon Yuh
Peter Zeigler
Dierckx Christiaan
Hik Honein
Chloe Horton
Yohann LeClerc
Johann Maass
Christophe Phillips

Functional Imaging Laboratory
Wellcome Trust Centre for Neuroimaging, UCL
Institute of Neurology, UCL
12 Queen Square, London WC1N 3AR, UK
April 15, 2010
<http://www.fil.ion.ucl.ac.uk/spm/>

MULTIMODAL INTEGRATION



EEG-fMRI Fusion

- Merging the high temporal resolution of EEG/MEG with the high spatial resolution of fMRI.

EEG/fMRI Behavioral Data Fusion

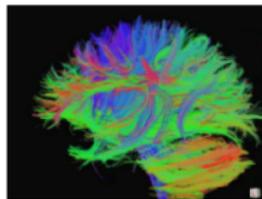
- Merging the EEG/fMRI with the data from behavioral response.

Brain Connectivity

Connectivity

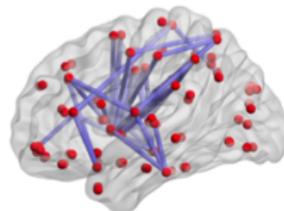
- **Structural Connectivity**

Physical connections of the brain



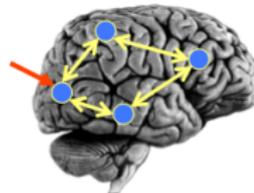
- **Functional Connectivity**

Dependencies between BOLD observations



- **Effective Connectivity**

Causal relationships between brain regions



Human Connectome Project

USC Mark and Mary Stevens Neuroimaging and Informatics Institute

The NIH Human Connectome Project

USC University of Southern California

Human Connectome Project

Enter search keyword

Home About Data Informatics Gallery Publications News

The Human Connectome Project

Navigate the brain in a way that was never before possible: fly through major brain pathways, compare essential circuits, zoom into a region to explore the cells that comprise it, and the functions that depend on it.

The Human Connectome Project aims to provide an unparalleled compilation of recent data, an interface to graphically navigate this data and the opportunity to achieve never before realized conclusions about the living human brain.

Download Data

Laboratory of Neuro-Imaging

News

RSS News

National Geographic features the Human Connectome Project

New research from members of our HCP team suggests that brain circuitry is organized more like Manhattan's



Human Connectome Project



HUMAN
Connectome
PROJECT

Mapping structural and functional connections in the human brain

1) Acquire data on brain structure, function, and connectivity in healthy adults (twins and non-twin siblings).

- Improved scanners, pulse sequences
- Multimodal imaging (~4 hours total scan – 4 x 1h sessions)
- Data quality: exceptionally high!
- 1200 subjects studied, ~1100 with MRI (completed September, 2015)
- 184 subjects scanned at 7T (completed November, 2015)
- Behavioral data (478 'subject measures')
- Magnetoencephalography (95 subjects): Task-MEG, resting-state MEG
- Blood for genotyping (sent to dbGAP, to be released 'soon')

2) Analyze the data

- Improved HCP preprocessing pipelines
- Better visualization (Connectome Workbench)
- Advanced analyses