LIÈGE université
GIGA
CRC In vivo Imaging

Statistical Parametric Mapping

An Open Science adventure.

fnrs
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Christophe Phillips
c.phillips@uliege.be

Statistical Parametric Mapping

- Neuroimaging
- How it started… and where it got
- Open Science & Neuroimaging community

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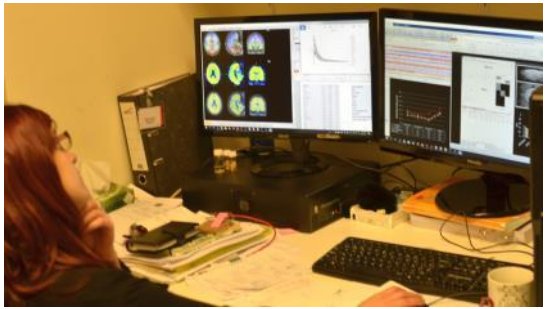
GIGA Cyclotron Research Centre *in vivo* imaging

Human neuroimaging: MRI and PET + electrophysiology



https://www.gigacrc.uliege.be/
https://www.gigacyclotron.uliege.be/

Neuroimaging, some results…

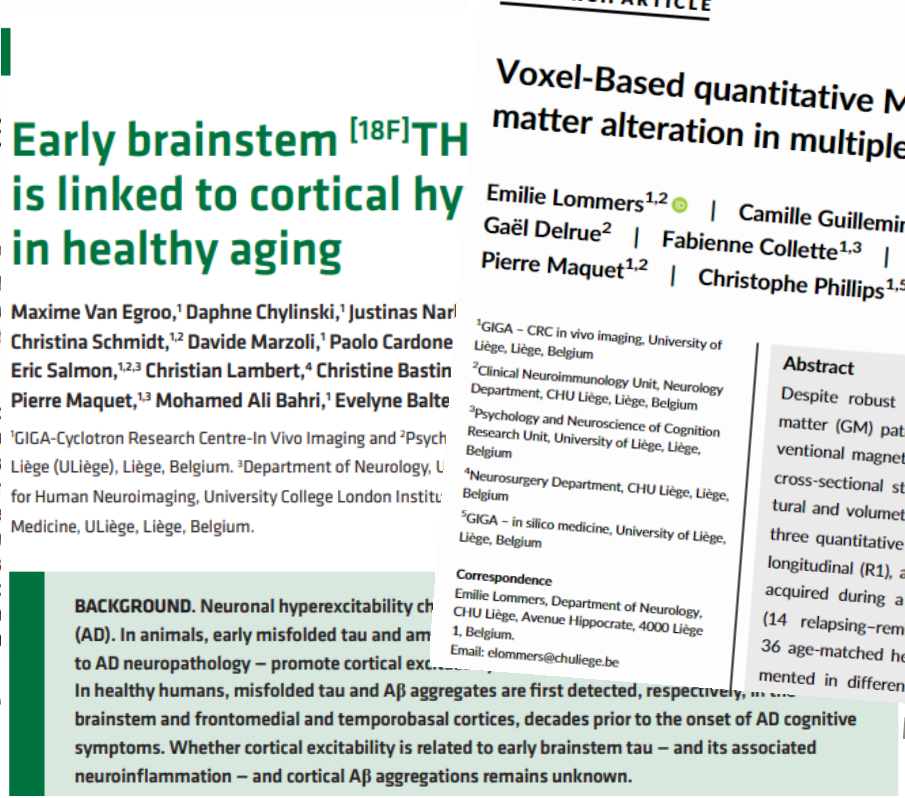
SLEEP RESEARCH

Local modulation responses by circa and sleep debt

Vincenzo Muto,[1,2,3*] Mathieu Jaspar,[1,2,3] Sarah L. Chellappa,[1,2] Christian Degueld Anahita Shaffii-Le Bourdiec,[1,2] André L Christophe Phillips,[1,2,6] Fabienne Collet Derk-Jan Dijk,[5†] Pierre Maquet[1,2,7†‡]

Human performance is modulated by circ Whether and how this interaction is repr established. We quantified changes in br 13 functional magnetic resonance imagir during 42 hours of wakefulness and afte responses showed significant circadian regions. Cortical responses also signific areas exhibited primarily a circadian mo These findings expand our understandin during the day and its deterioration du

https://dx.doi.org/10.1126/



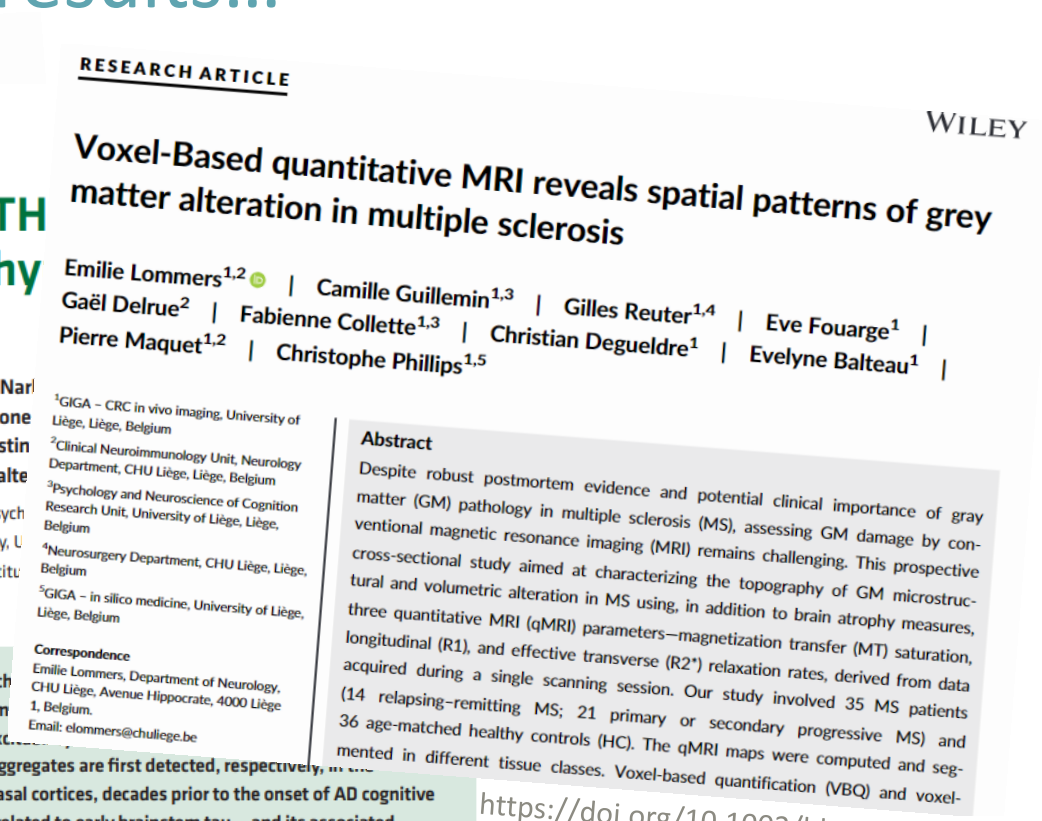
Early brainstem [18F]TH is linked to cortical hy in healthy aging

Maxime Van Egroo,[1] Daphne Chylinski,[1] Justinas Narl Christina Schmidt,[1,2] Davide Marzoli,[1] Paolo Cardone Eric Salmon,[1,2,3] Christian Lambert,[4] Christine Bastin Pierre Maquet,[1,3] Mohamed Ali Bahri,[1] Evelyne Balte

[1]GIGA-Cyclotron Research Centre-In Vivo Imaging and [2]Psych Liège (ULiège), Liège, Belgium. [3]Department of Neurology, U for Human Neuroimaging, University College London Institu Medicine, ULiège, Liège, Belgium.

BACKGROUND. Neuronal hyperexcitability ch (AD). In animals, early misfolded tau and am to AD neuropathology – promote cortical exc In healthy humans, misfolded tau and Aβ aggregates are first detected, respectively, in the brainstem and frontomedial and temporobasal cortices, decades prior to the onset of AD cognitive symptoms. Whether cortical excitability is related to early brainstem tau – and its associated neuroinflammation – and cortical Aβ aggregations remains unknown.

https://dx.doi.org/10.1172/jci.insight.142514



RESEARCH ARTICLE

WILEY

Voxel-Based quantitative MRI reveals spatial patterns of grey matter alteration in multiple sclerosis

Emilie Lommers[1,2] | Camille Guillemin[1,3] | Gilles Reuter[1,4] | Eve Fouarge[1] | Gaël Delrue[2] | Fabienne Collette[1,3] | Christian Degueldre[1] | Evelyne Balteau[1] | Pierre Maquet[1,2] | Christophe Phillips[1,5]

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[2]Clinical Neuroimmunology Unit, Neurology Department, CHU Liège, Liège, Belgium
[3]Psychology and Neuroscience of Cognition Research Unit, University of Liège, Liège, Belgium
[4]Neurosurgery Department, CHU Liège, Liège, Belgium
[5]GIGA – in silico medicine, University of Liège, Liège, Belgium

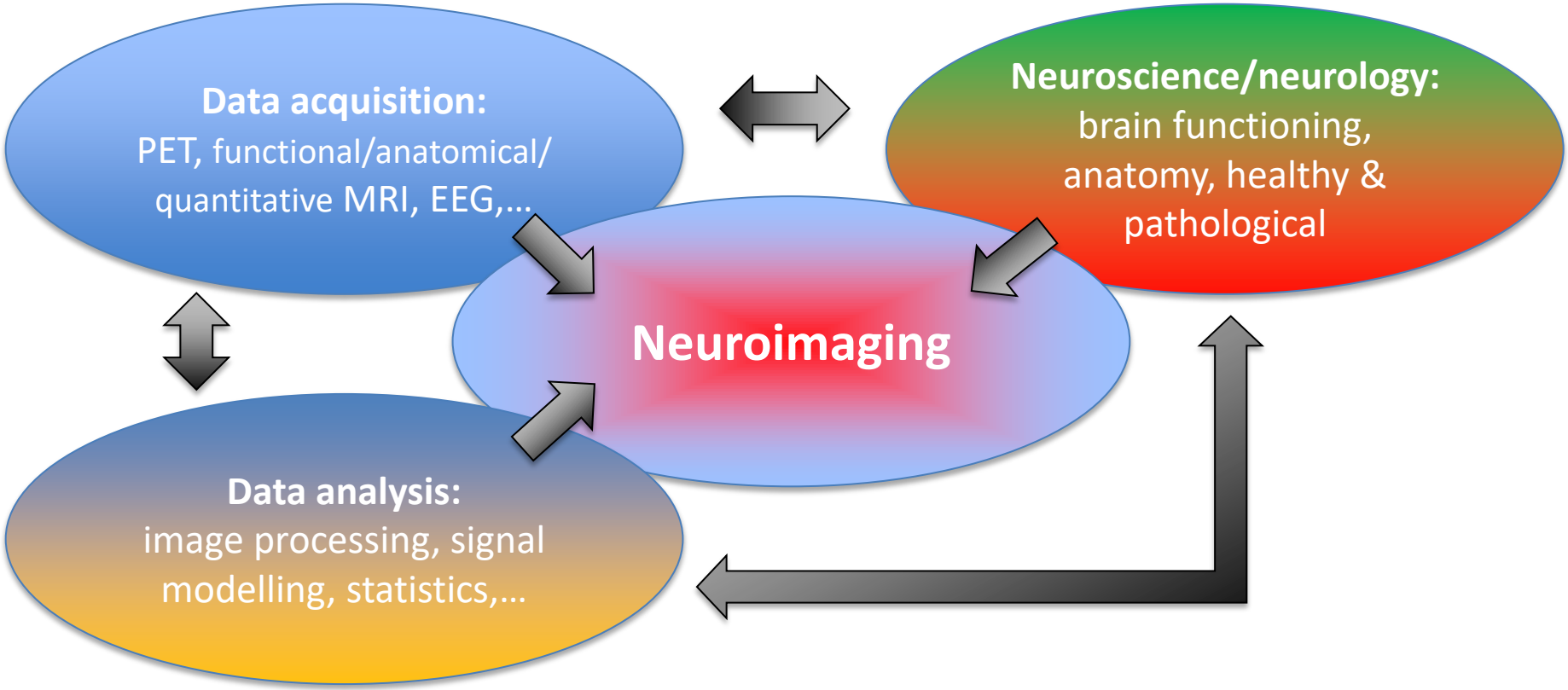
Correspondence
Emilie Lommers, Department of Neurology, CHU Liège, Avenue Hippocrate, 4000 Liège 1, Belgium.
Email: elommers@chuliege.be

Abstract

Despite robust postmortem evidence and potential clinical importance of gray matter (GM) pathology in multiple sclerosis (MS), assessing GM damage by conventional magnetic resonance imaging (MRI) remains challenging. This prospective cross-sectional study aimed at characterizing the topography of GM microstructural and volumetric alteration in MS using, in addition to brain atrophy measures, three quantitative MRI (qMRI) parameters—magnetization transfer (MT) saturation, longitudinal (R1), and effective transverse (R2*) relaxation rates, derived from data acquired during a single scanning session. Our study involved 35 MS patients (14 relapsing–remitting MS; 21 primary or secondary progressive MS) and 36 age-matched healthy controls (HC). The qMRI maps were computed and segmented in different tissue classes. Voxel-based quantification (VBQ) and voxel-

https://doi.org/10.1002/hbm.25274

Neuroimaging, a multi-disciplinary field



Statistical Parametric Mapping

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- How it started… and where it got
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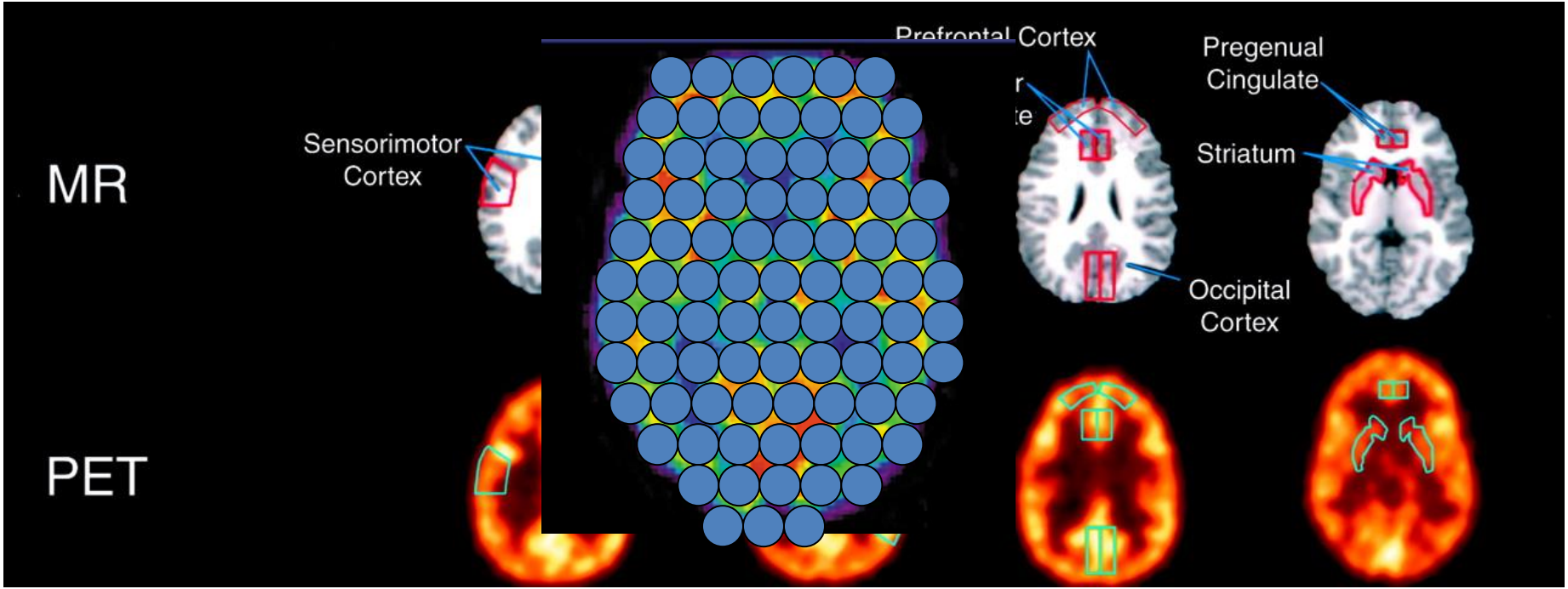
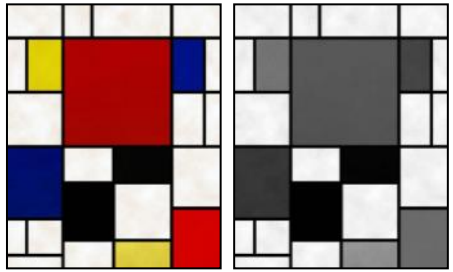
From PET analysis using ROIs in the late 80's…



…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.

The colour centre in the cerebral cortex of man

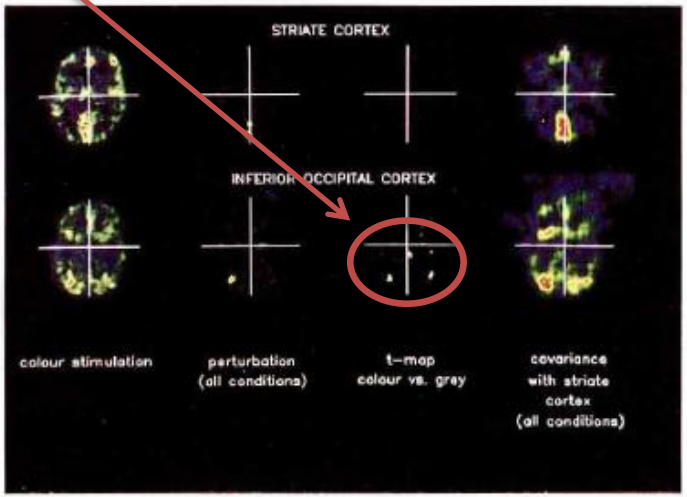
C. J. Lueck*†‡, S. Zeki†§, K. J. Friston*, M.-P. Deiber*, P. Cope†, V. J. Cunningham*, A. A. Lammertsma*, C. Kennard‡ & R. S. J. Frackowiak*§

* 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 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,

§ To whom reprint requests should be addressed.

NATURE · VOL 340 · 3 AUGUST 1989



SPM inception by Prof. Karl J. Friston

Back in 1991, emerging “functional imaging community”

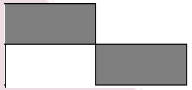
→ **SPMclassic**

- providing *valid inferences* about signals across the entire brain

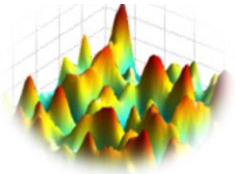
Main concepts

$$y = \begin{array}{|c|c|}\hline & \blacksquare \\ \hline \blacksquare & \\ \hline \end{array}\ \beta + \varepsilon$$

Contrast *c*



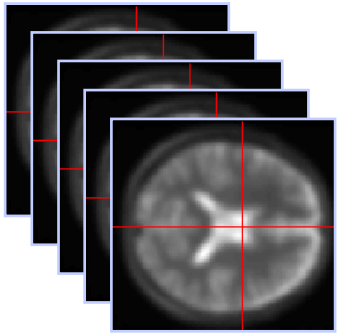
Random Field Theory



Spatial Pre-processings

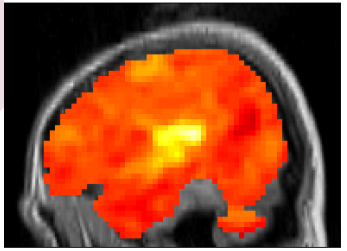
General Linear Model

Statistical Inference



$$\hat{\beta} = (X^T X)^{-1} X^T y$$

$$\hat{\sigma}^2 = \frac{\hat{\varepsilon}^T \hat{\varepsilon}}{rank(X)}$$



$SPM\{T, F\}$

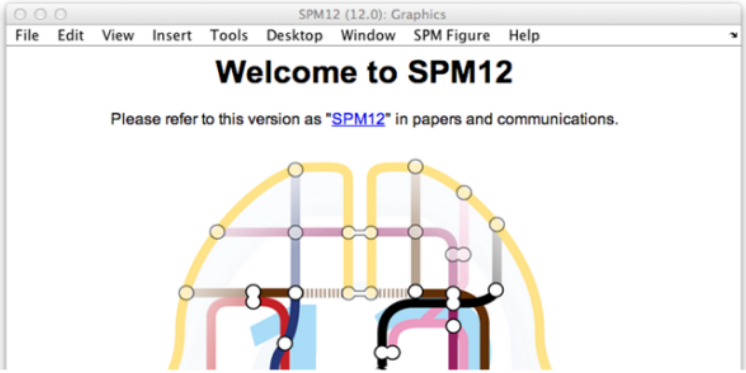
SPM inception by Prof. Karl J. Friston

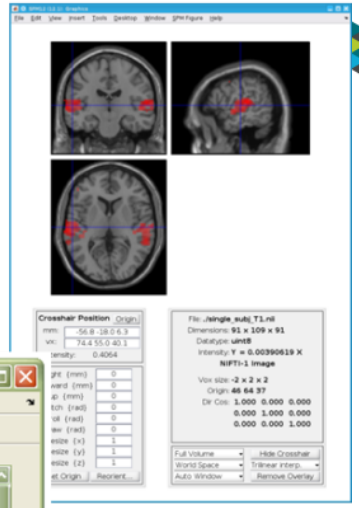
Back in 1991, emerging “functional imaging community”

→ **SPMclassic**

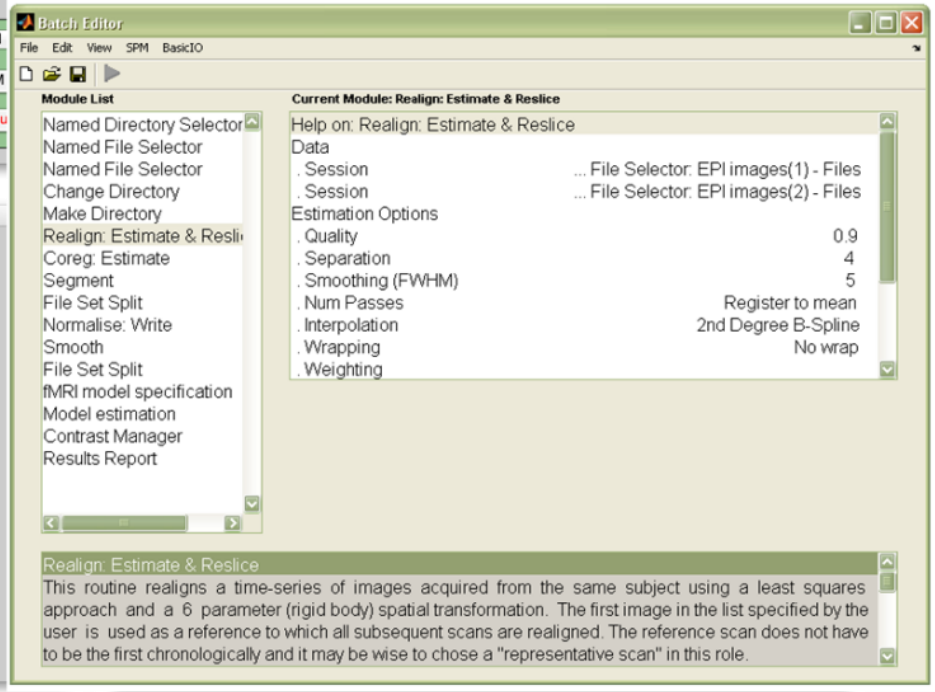
- providing *valid inferences* about signals across the entire brain
- open source and freely available to
  - promote *collaboration* and a *common analysis scheme* across laboratories,
  - allow the methods to be closely *scrutinised by others.*

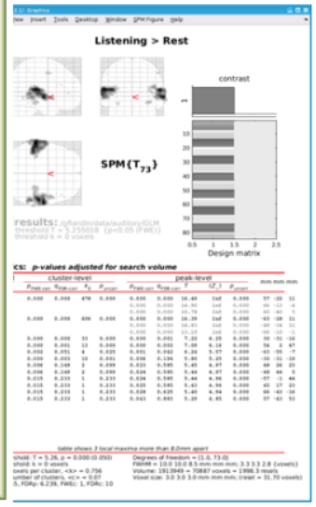

SPM12 (12.0): Menu
Realign ...
Slice timing
Smooth
Coregist...
Normali...
Segment
Specify 1st-level
Review
Specify 2nd-level
Estimate
Results
Dynamic Causal Modelling
SPM for functional MRI
Display
Check Reg
Rend...
FMRI
Toolb...
PPIs
ImCalc
DICOM
Help
Utils...
Batch
Copyright (c) 1991,1994-2014


SPM12 (12.0): Graphics
File Edit View Insert Tools Desktop Window SPM Figure Help
Welcome to SPM12
Please refer to this version as "SPM12" in papers and communications.




SPM12 (12.0)


Batch Editor
File Edit View SPM BasicIO
Module List
Named Directory Selector
Named File Selector
Named File Selector
Change Directory
Make Directory
Realign: Estimate & Resli
Coreg: Estimate
Segment
File Set Split
Normalise: Write
Smooth
File Set Split
fMRI model specification
Model estimation
Contrast Manager
Results Report
Current Module: Realign: Estimate & Reslice
Help on: Realign: Estimate & Reslice
Data
. Session ... File Selector: EPI images(1) - Files
. Session ... File Selector: EPI images(2) - Files
Estimation Options
. Quality 0.9
. Separation 4
. Smoothing (FWHM) 5
. Num Passes Register to mean
. Interpolation 2nd Degree B-Spline
. Wrapping No wrap
. Weighting
Realign: Estimate & Reslice
This routine realigns a time-series of images acquired from the same subject using a least squares approach and a 6 parameter (rigid body) spatial transformation. The first image in the list specified by the user is used as a reference to which all subsequent scans are realigned. The reference scan does not have to be the first chronologically and it may be wise to chose a "representative scan" in this role.


Listening > Rest
contrast
SPM{T23}
Design matrix

Software

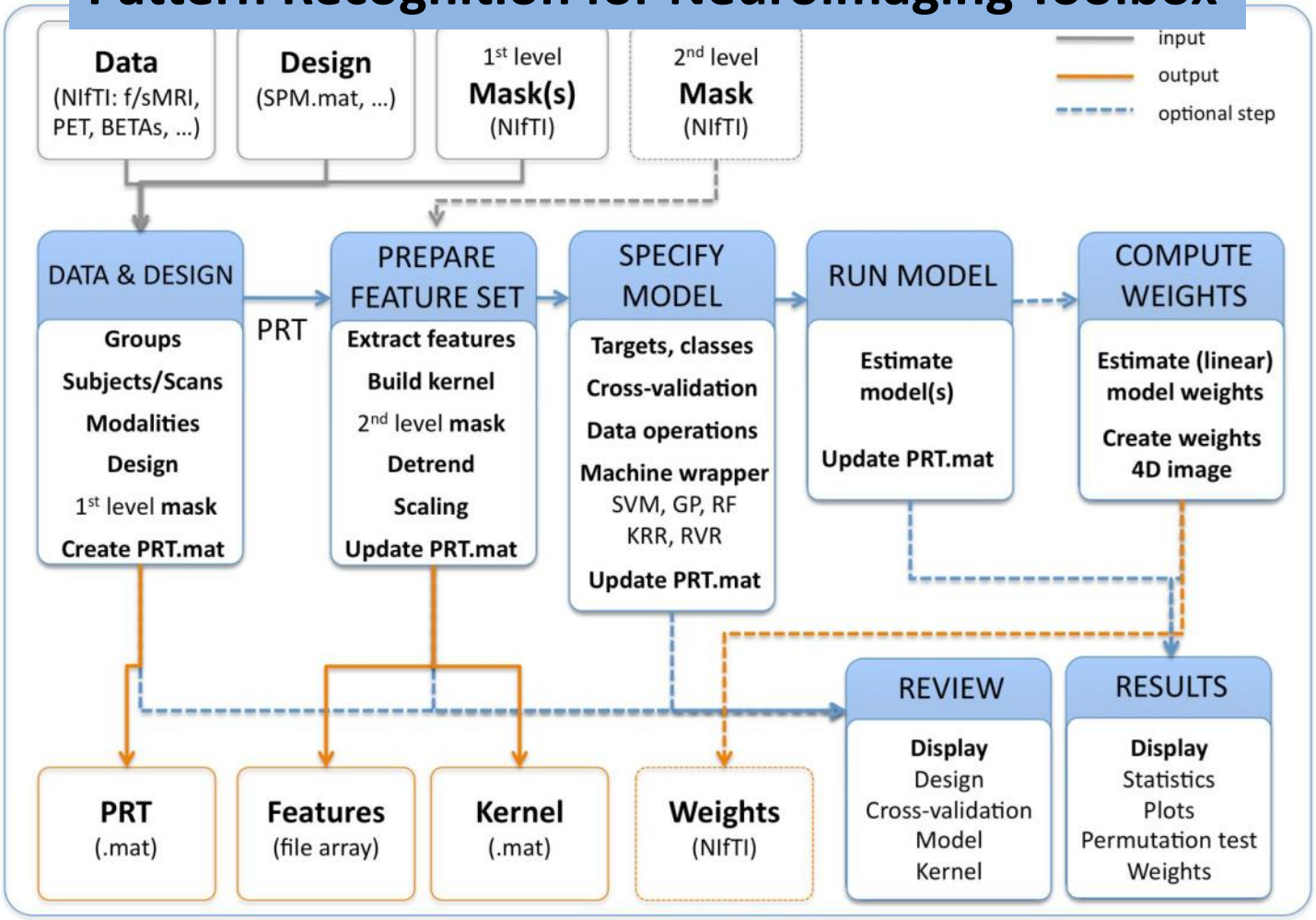
- Matlab based (Octave compatible + stand-alone compiled version)
- Over 700k lines of Matlab code and close to 5000 files…
  available on GitHub (previously SubVerioN)
- 9 major releases over 32 years, about 38 core contributors
- Extensions from PET data (1991) to
  - functional MRI (~1998) & morphometry (~2002)
  - EEG/MEG (~2005)
  - Dynamic causal modelling (~2005)
- Open source, GNU GPL v.2/v.3

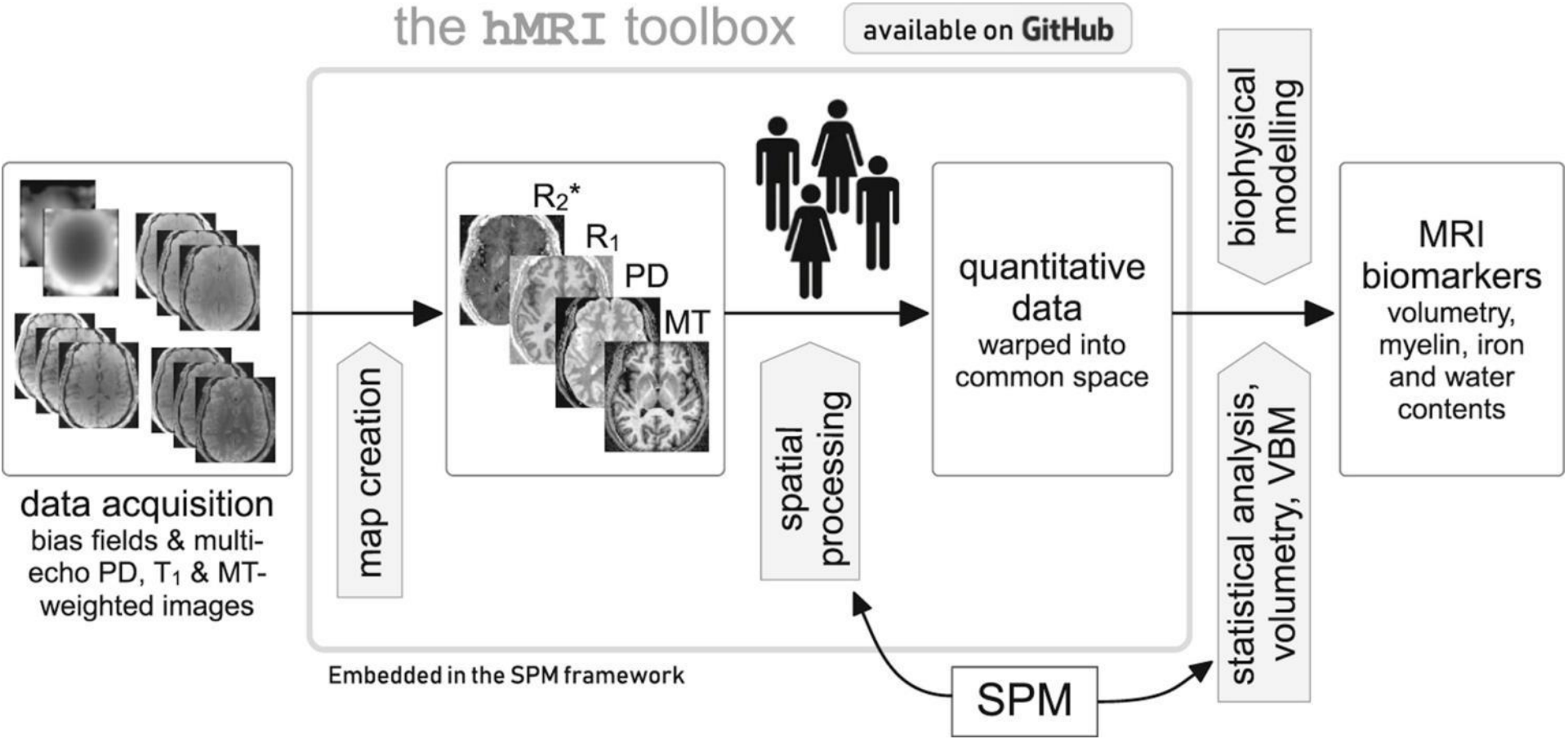
https://github.com/spm

Software extensions

- includes external packages, e.g. `FieldTrip` and `MatlabBatch`
- relying on I/O, batching, display, etc. functions:
  - extra methods/tools (>65): resting fMRI, repeated measures, multivariate statistics, machine learning,…

Pattern Recognition for Neuroimaging Toolbox



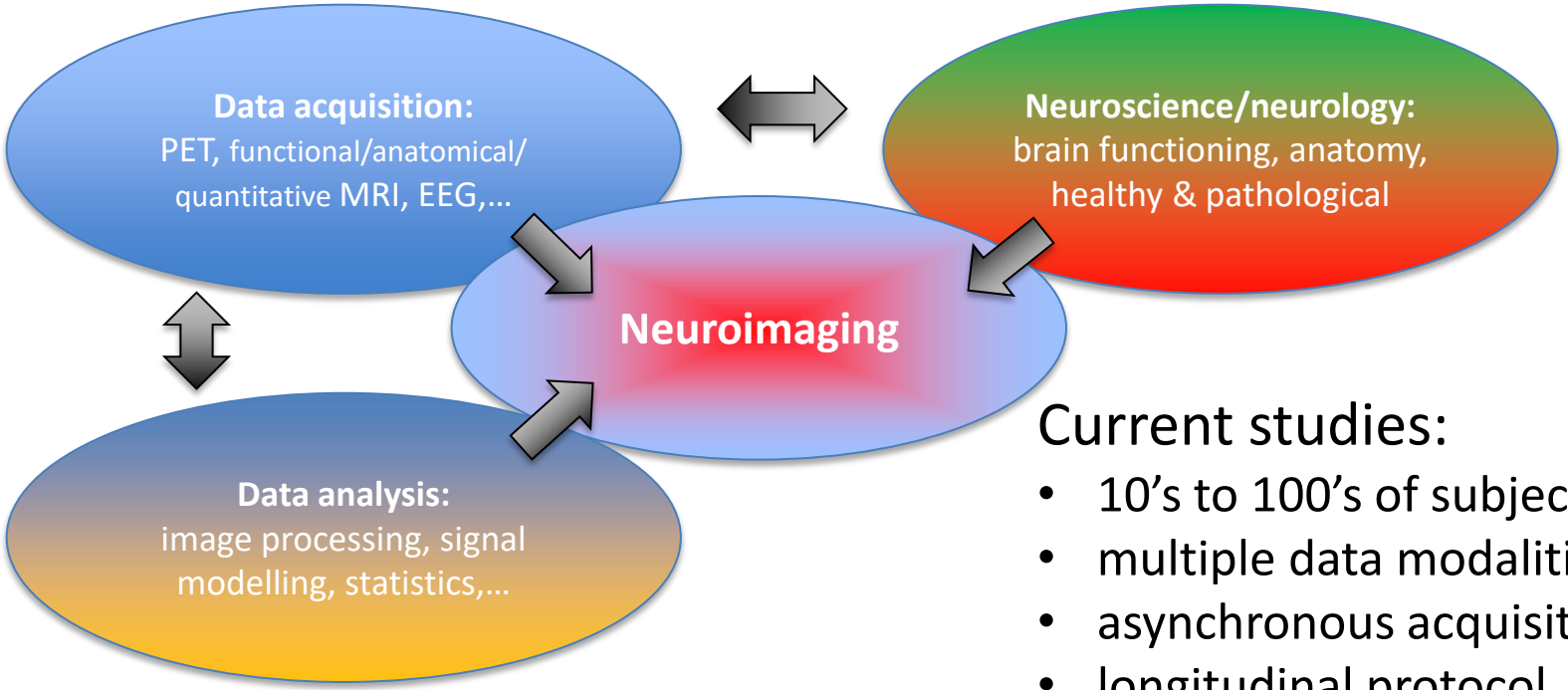

the hMRI toolbox
available on GitHub
data acquisition
bias fields & multi-echo PD, T1 & MT-weighted images
map creation
R2*
R1
PD
MT
spatial processing
quantitative data
warped into common space
biophysical modelling
MRI biomarkers
volumetry, myelin, iron and water contents
statistical analysis, volumetry, VBM
SPM
Embedded in the SPM framework

Software extensions

- includes external packages, e.g. `FieldTrip` and `MatlabBatch`
- relying on I/O, batching, display, etc. functions:
  - extra methods/tools (>65): resting fMRI, repeated measures, multivariate statistics, machine learning,…
  - extra modalities: NIRS, diffusion & quantitative MRI,…
  - extra fields: mice, rats, monkeys,…
- additional atlases & tissue templates

Compatibility with other tools, thanks to images NIfTI data format (open & community defined)

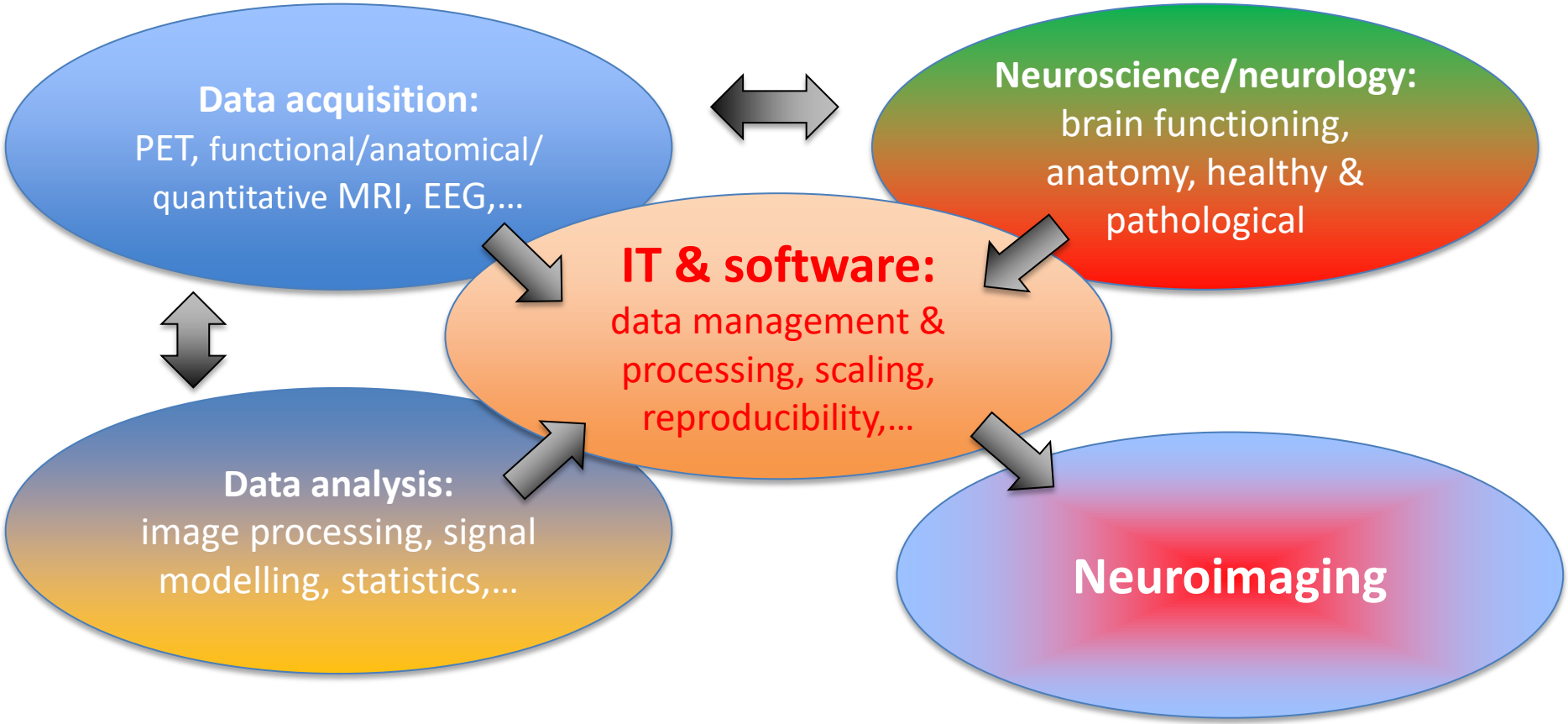
Neuroimaging, a multi-disciplinary field



Current studies:

- 10’s to 100’s of subjects
- multiple data modalities
- asynchronous acquisition
- longitudinal protocol
- complex processing & modelling
- …

Neuroimaging, a multi-disciplinary field



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SPM is Open

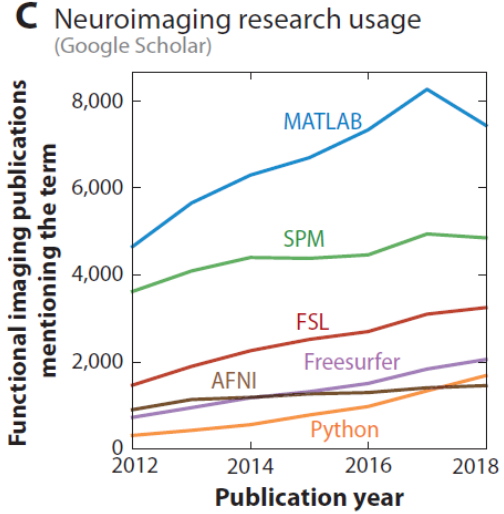
- Open source, since 1991
- Open access, (most) methods publications, papers & books, available online for free since 1994
- Open education,
  - course material, slides & videos
  - demo data & instructions
  - mailing lists with 1st hand support

  since 1995, ~62 official “SPM short courses” in UK & around the world + 10’s of self organized local courses.

https://www.fil.ion.ucl.ac.uk/spm/

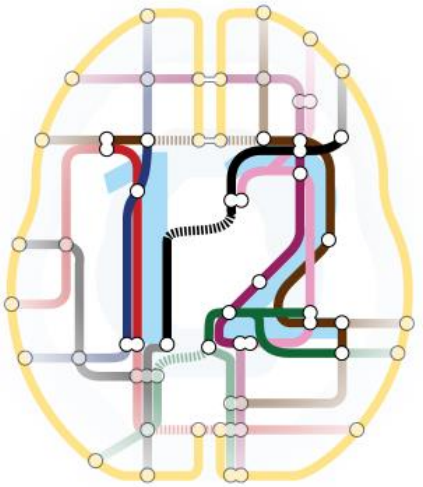
Now…

- Many other (open!) software solutions since 1991
  - in ~1995, “Analysis of Functional NeuroImages” (NIH, USA), aka AFNI, https://afni.nimh.nih.gov/
  - in ~2000, “FMRIB Software Library” (Oxford, UK), aka. FSL, https://fsl.fmrib.ox.ac.uk/fsl/fslwiki
  - also FreeSurfer (~1999), ANTs (2014),…
- SPM still the most used software (up to 2019) for neuroimaging data analysis!



R. A. Poldrack, et al. (2019)

…and then?



- Keep on educating users **and** developers!
- Taken for granted by many…
- …but still need support and developments!
- Adapt to recent IT developments
  - Stick to Matlab? Or switch to Python/Julia?
  - Or move to containerized/cloud/web-based version of the tool?
- Follow latest recommendations in neuroimaging, e.g. “Brain Imaging Data Structure” (BIDS).

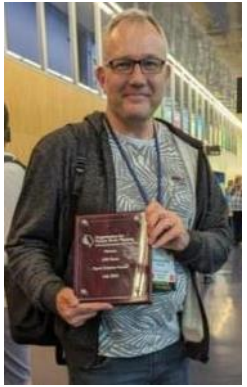
Neuroimaging community

Fairly open community

- Relies (mostly) on open tools
- Hackathons & Brainhack events culture
- Increasing number of open data sets (RGPB & ethical issues)
- Attempt at fair(er) editing & journals: Aperture Neuro (APC USD800/1000), Imaging Neuroscience (APC USD1600)
- Self criticizing :
  - “cluster level inference” crisis (2016)
  - “1 data set, 70 pipelines & as many different results” (2020)
  - …

https://doi.org/10.1101/296798
https://doi.org/10.1038/s41586-020-2314-9

Awards & Recognition



- Karl Friston made ULiège Doctor Honoris Causa in 2021.
- OHBM Open Science award to the “SPM Team” in 2023.

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Thank you for your attention!

Special thanks to
Karl Friston, Father of SPM,
Guillaume Flandin, Head of SPM development,
and all the SPM developers

Key dates

- 1973, beginning of PET imaging
- early-1980's, application of PET to brain imaging
- Early-1990s, development of "functional MRI"
- 1991, World Wide Web (linked html pages) opens to the public
- 1993, Adobe Acrobat "Portable Document Format", aka .pdf
- ~1993, first email servers and Internet access @ULiège
- ~1998, start of Open Source movement
- ~2001, start of Open Science movement

References

- SPM code, references, courses, example data, extensions,…
  https://www.fil.ion.ucl.ac.uk/spm/
- SPM on GitHub
  https://github.com/spm
- R. A. Poldrack, et al., Computational and Informatic Advances for Reproducible Data Analysis in Neuroimaging, Annu. Rev. Biomed. Data Sci. 2019. 2:119–38.
  https://doi.org/10.1146/annurev-biodatasci-072018-021237
- P. Bandettini, Twenty years of functional MRI: The science and the stories, NeuroImage, 2012.
  http://dx.doi.org/10.1016/j.neuroimage.2012.04.026
- “FMRIB Software Library”, aka. FSL, https://fsl.fmrib.ox.ac.uk/fsl/fslwiki
- “Analysis of Functional NeuroImages”, aka AFNI, https://afni.nimh.nih.gov/

Neuroimaging, a multi-disciplinary field