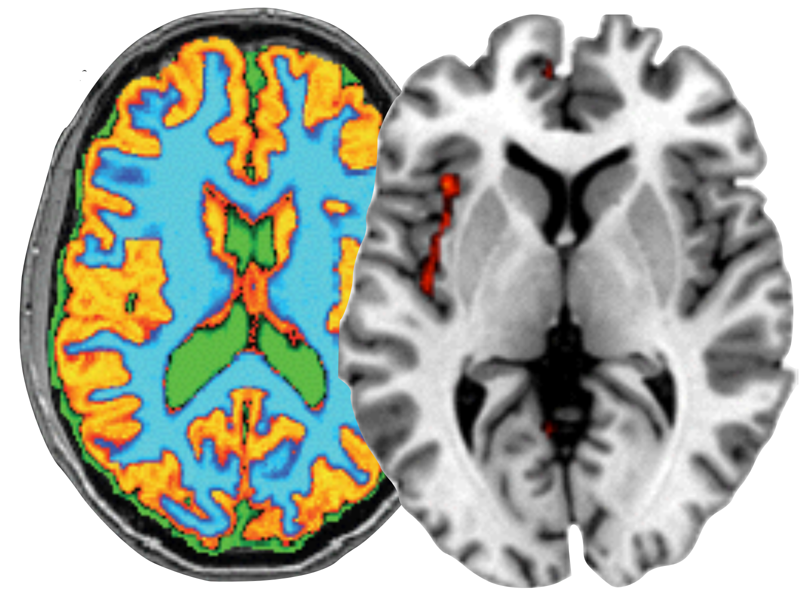
Voxel-based Morphometry

& Group level (2^{nd}-level) analysis



K.H. Chou, Ph.D (周坤賢)

2016.07.14

Assistant research fellow / Brain Research Center / National Yang Ming University

BRC

BRAIN CONNECTIVITY LABORATORY
National Yang-Ming University

Today's Mission

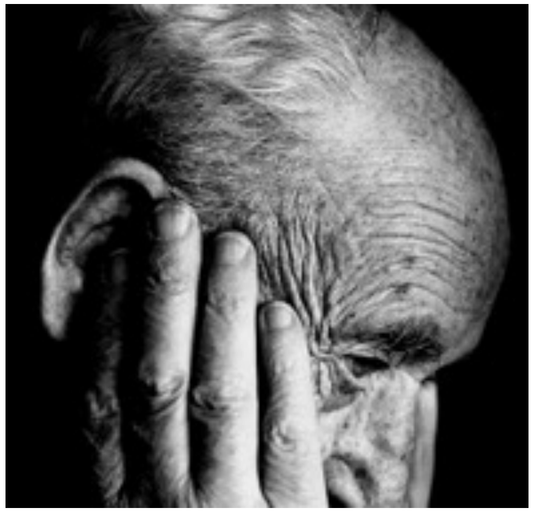
My mission today is to

teach you the basic concept of VBM

and how to use SPM12

to perform basic T1-VBM analysis

(with real world example)



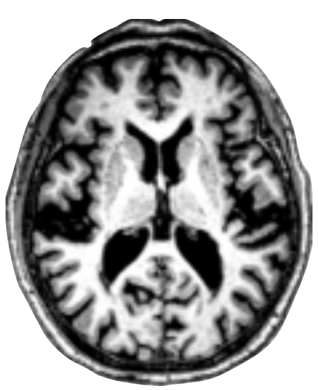
The Notice of Today's Course !

Don't think any shortcut solutions

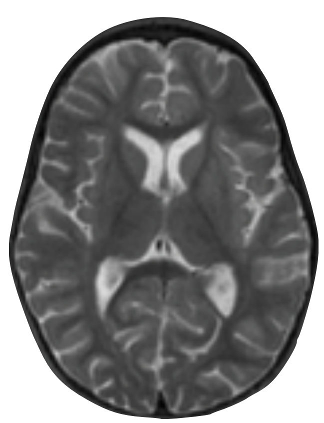
Practice, practice and practice

Ask me questions when we have free time

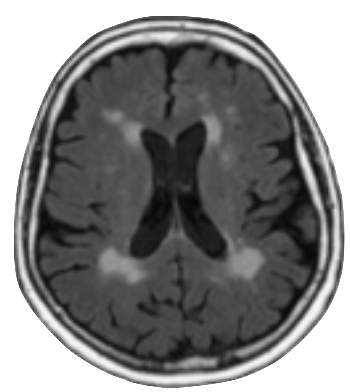
Which Imaging Protocol We Will Focus on ?



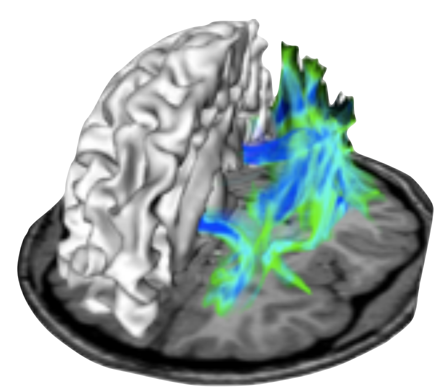
T1



T2

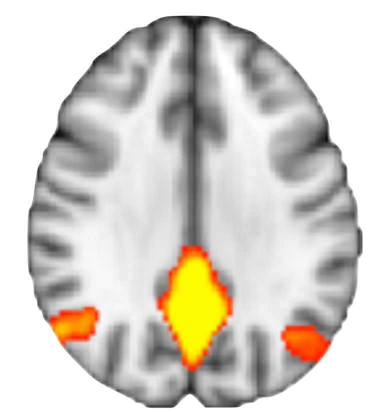


FLAIR-T2



dMRI

SWI



Task / rs-fMRI

Structural MRI
(sMRI)

Functional MRI
(fMRI)

The Real World Example of VBM Study (But Be Careful !)

新聞 政治 財經 生活 地方 社會 運動 娛樂 國際 大陸 新奇 消費 旅遊 寵物 科技

運動最速報 台灣之光 棒球 籃球 綜合 足球 極運動

頭條新聞 速報>>

研究：朋友太少？怪你的杏仁核太小

2010年 12月 28日 00:20

http://www.nownews.com/n/2010/12/28/578022

首頁 > 即時新聞目錄 > 新聞內頁

國・際・新・聞 International

研究：交友廣闊 腦杏仁核也大

時間：2010/12/27 新聞引據：中央社

你常花時間和很多朋友共處嗎？這可能代表你腦中有個特殊部分較大。那就是位於腦部深處的「杏仁核」(amygdala)。

一項初步研究，對58名志願者腦部進行掃描發現，杏仁核愈大，志願者的朋友及家人就越多。

「自然神經科學雜誌」(Nature Neuroscience)26日在線上刊出這項研究，作者巴瑞特(Lisa FeldmanBarrett)表示，這結果合理，因杏仁核是腦部主掌重要社交網絡核心。

http://news.rti.org.tw/index_newsContent.aspx?nid=273628&id=6&id2=2

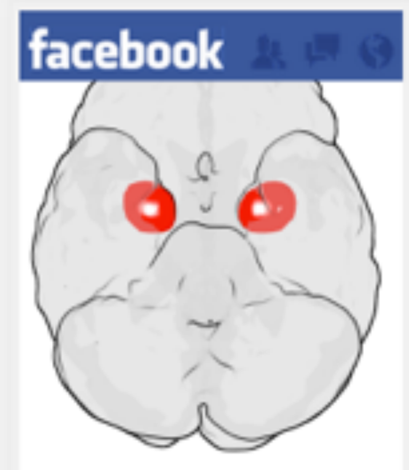
NATURE NEUROSCIENCE | BRIEF COMMUNICATION

Amygdala volume and social network size in humans

Kevin C Bickart, Christopher I Wright, Rebecca J Dautoff, Bradford C Dickerson & Lisa Feldman Barrett

Affiliations | Contributions | Corresponding author

Nature Neuroscience **14**, 163–164 (2011) | doi:10.1038/nn.2724



「哇~你的臉書朋友好多」--> 「哇~你的杏仁體好大」(?)

http://pansci.tw/archives/468

Look Into More Details About VBM Based Research

自由派或保守派 頭腦決定

AFP 法新社 – 2011年4月8日 下午7:20

-字 +字

相關內容

自由派或保守派 頭腦決定

（法新社華盛頓7日電） 每個人都知道談到世界觀，自由派與保守派存在嚴重分歧，然而科學家指出，他們的腦袋構造其實不同。「當代生物」（Current Biology）今天刊出的研究指出，自由派的頭腦，在與瞭解複雜事務相關的部分含有較多灰白質，而保守派的頭腦，腦中處理恐懼的部分較大。研究指出：「我們發現越是傾向自由主義，頭腦的前扣帶皮質內含較多灰白質，反之，越是傾向保守主義則與頭腦右側杏仁核較大有關。」其他研究顯示，那些區域頭腦活動程度不同，造就人們所持的政治觀點，然而，這個研究首度呈現頭腦相同區域，在生理大小上存在差異。這項研究根據90位「健康的年輕人」在標示從非常自由至非常保守的1-5量表上報告他們的政治觀點，而後同意接受腦部掃描。研究指出，頭腦中杏仁核較大的人「對厭惡較敏感」，且「相較於自由派，他們以更具攻擊性的行為回應威脅情境，對具威脅的臉部表情也更敏感」。研究指出，自由派腦內「監視不確定性和衝突」的前扣帶皮質區域較大。（譯者：中央社張詠晴）1

Political Orientations Are Correlated with Brain Structure in Young Adults

Ryota Kanai,[1,*] Tom Feilden,[2] Colin Firth,[2] and Geraint Rees[1,3]
[1]University College London Institute of Cognitive Neuroscience, 17 Queen Square, London WC1N 3AR, UK
[2]BBC Radio 4, Television Centre, Wood Lane, London W12 7RJ, UK
[3]Wellcome Trust Centre for Neuroimaging, University College London, 12 Queen Square, London WC1N 3BG, UK

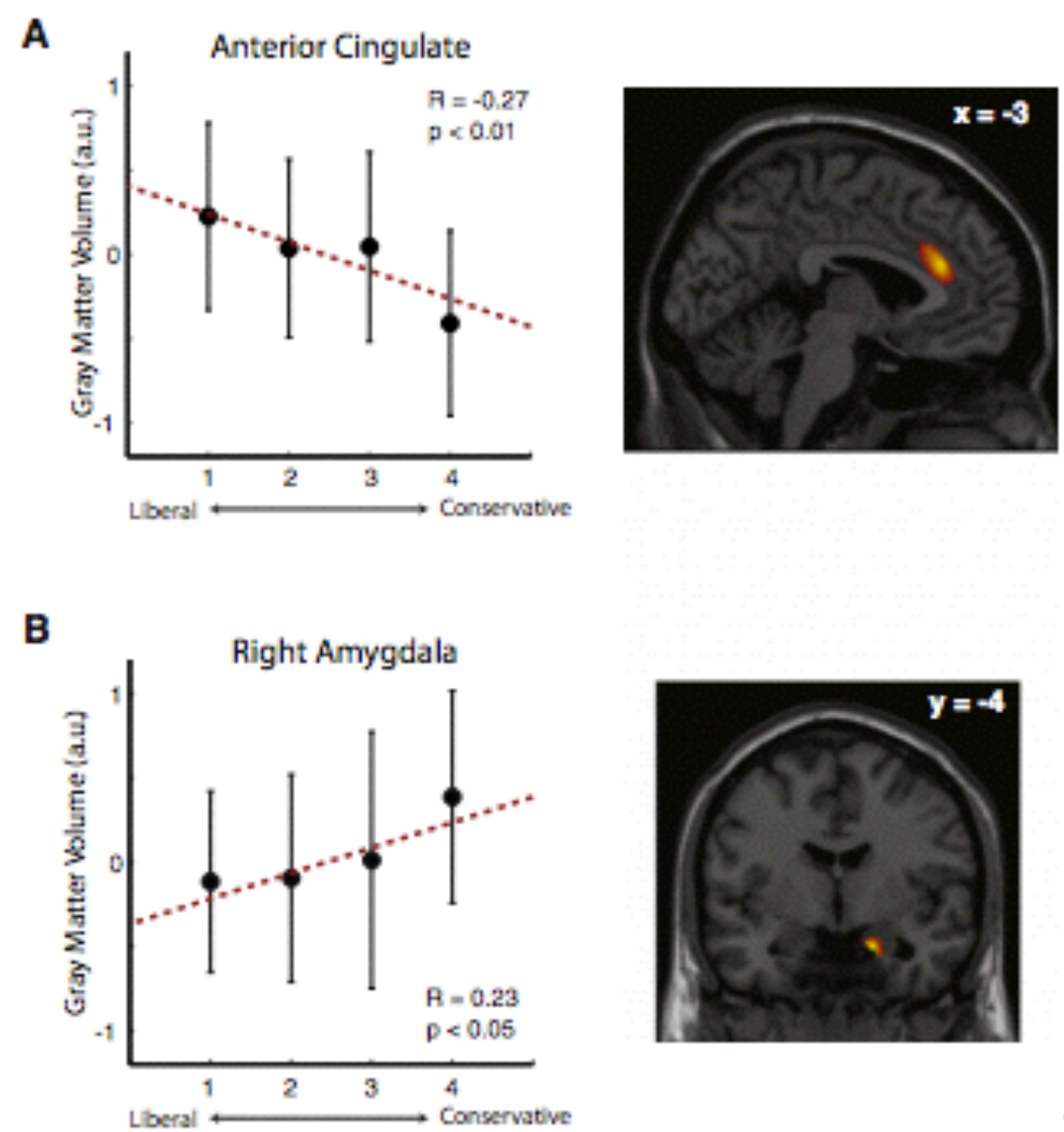
Current Biology *21*, 1–4, April 26, 2011 ©2011 Elsevier Ltd All rights reserved DOI 10.1016/j.cub.2011.03.017

Tissue: GM/WM

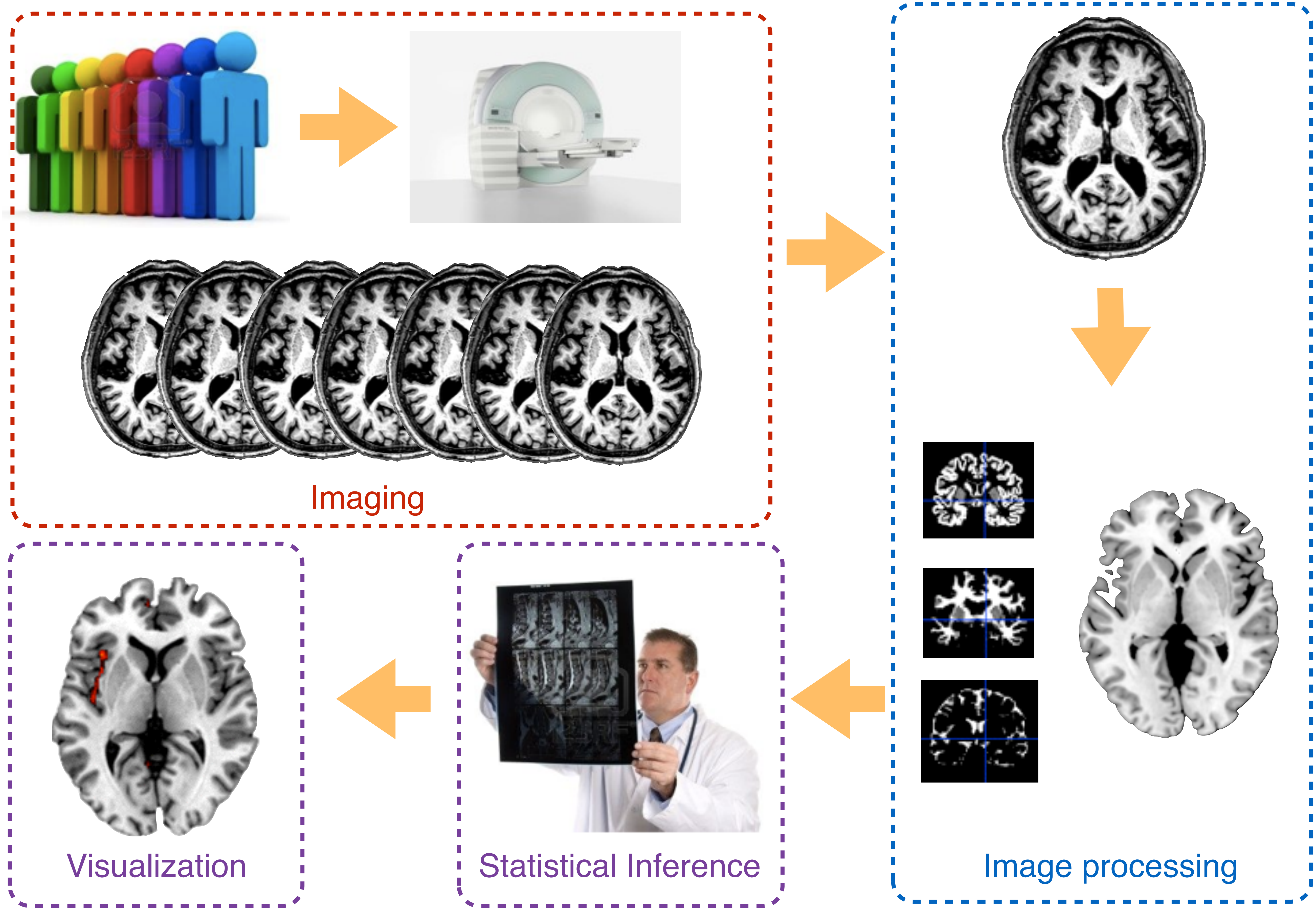
Anatomy location of brain

Statistical analysis

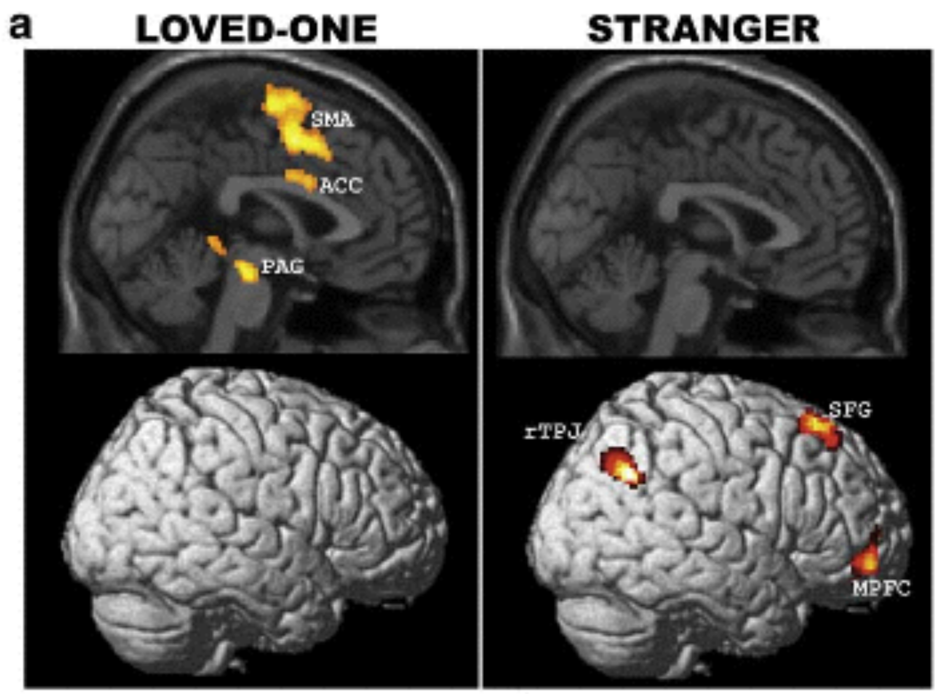
Many subjects

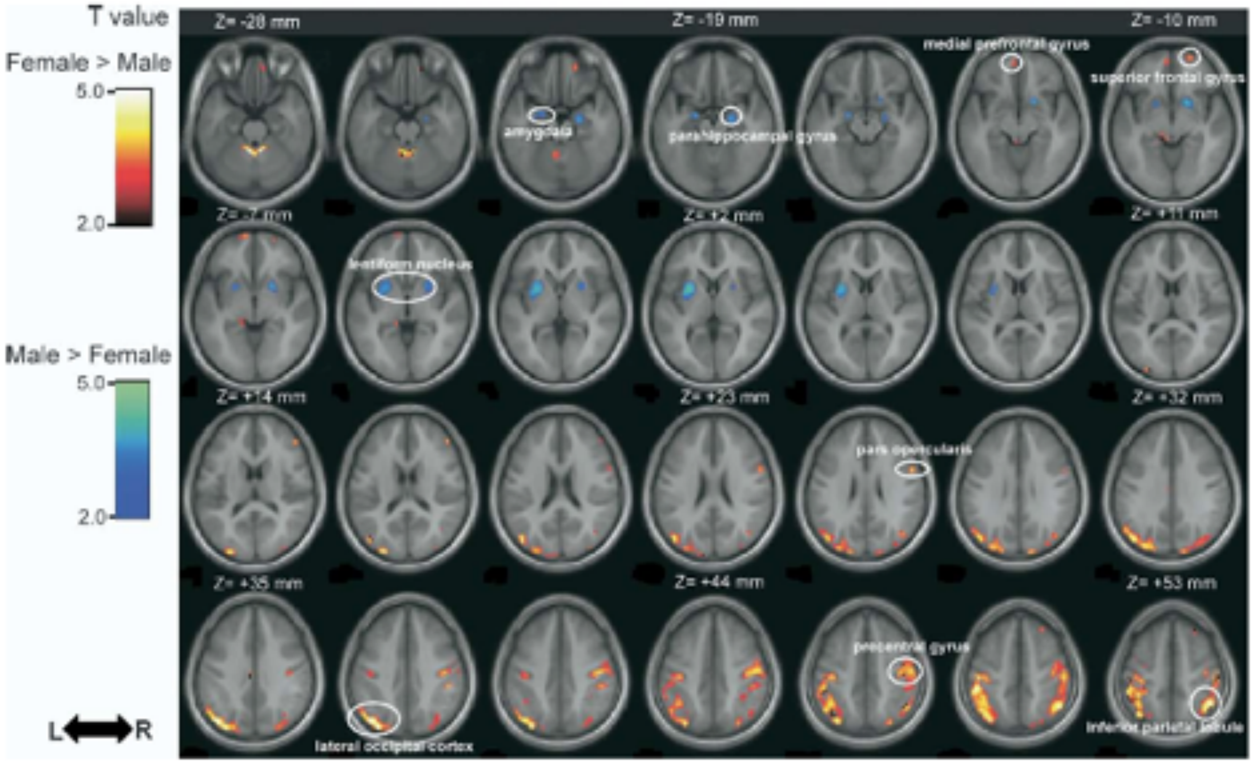


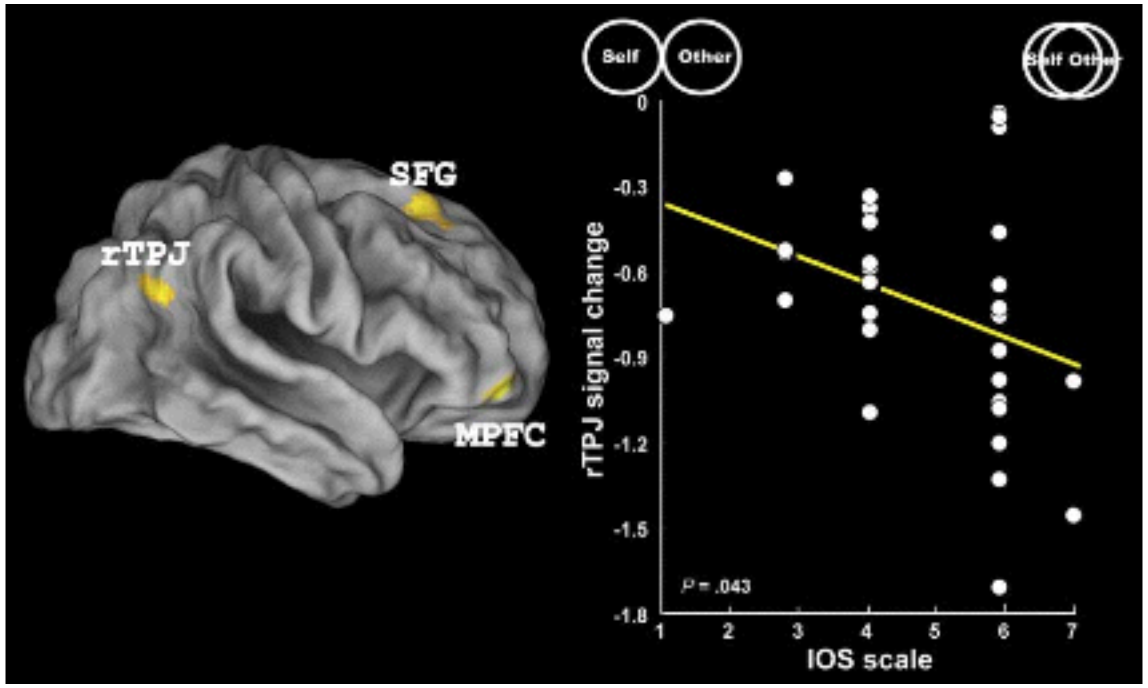
The Possible Flowchart of VBM Based Research

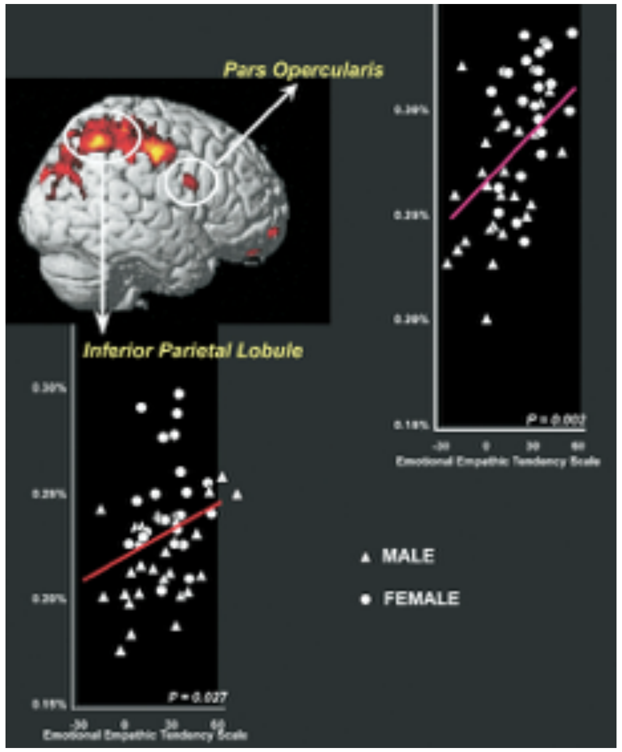


Same Result Presentation ! Same Analysis Pipeline ?





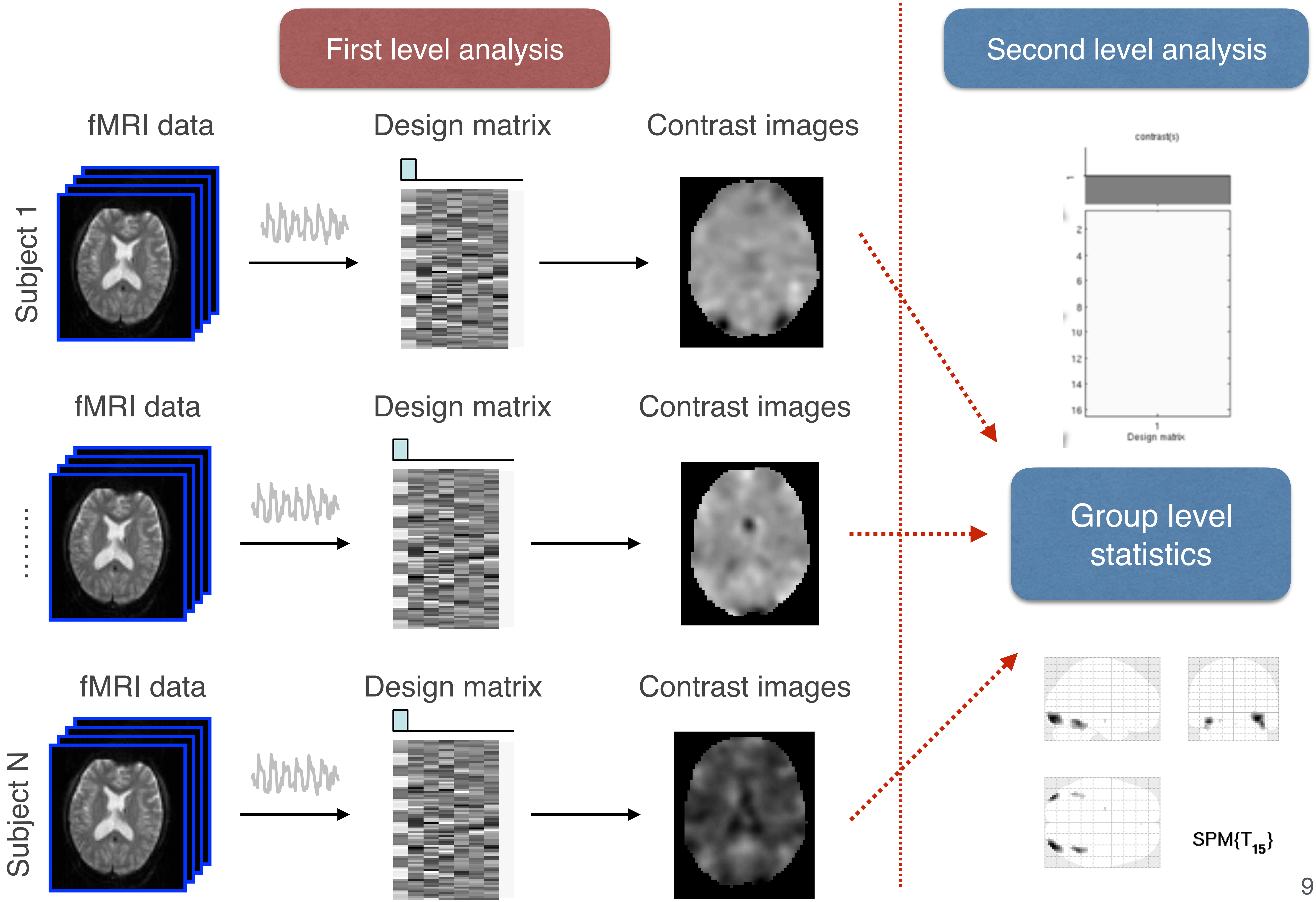




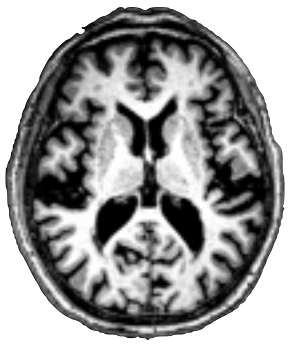
Cheng et al. Neuroimage. 2010.

Cheng et al. Neuroscience. 2009.

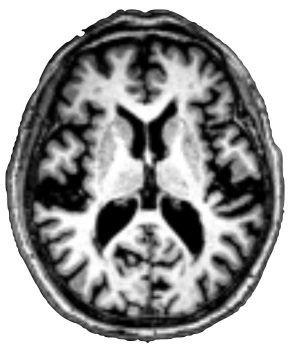
Recall Your Memory - The Classical Pipeline of fMRI Analysis



General Concept of T1 VBM



Subject 1



Subject 2

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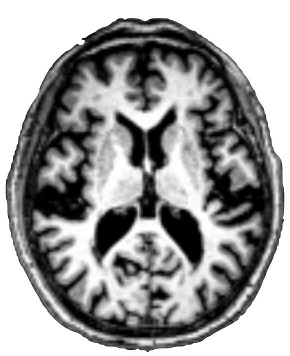
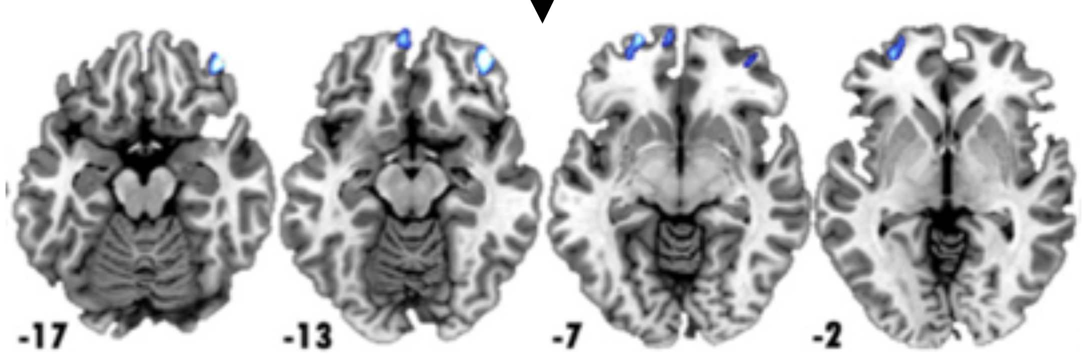


Subject N

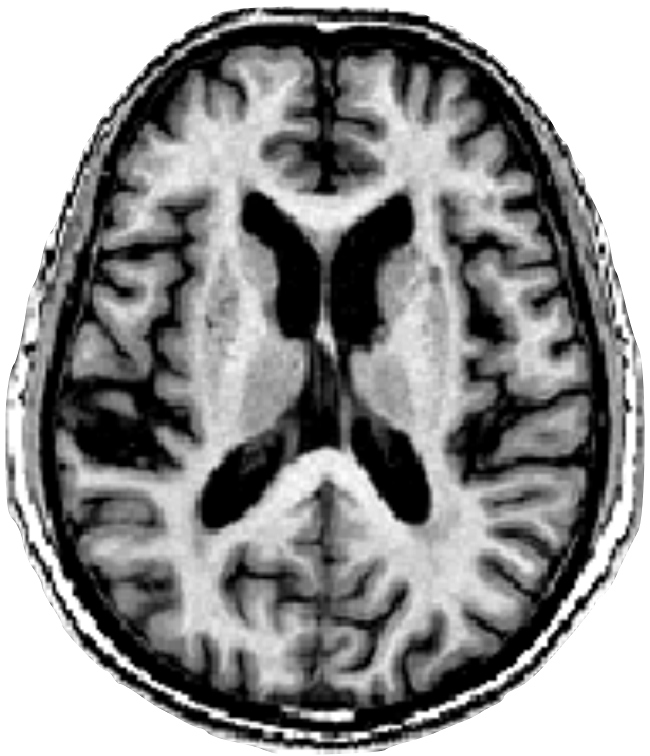
The core modules of VBM

1. Tissue segmentation
2. Spatial normalization
3. Tissue modulation (optional)
4. Tissue smoothing
5. Statistical modeling



Yang et al. Pain. 2013.

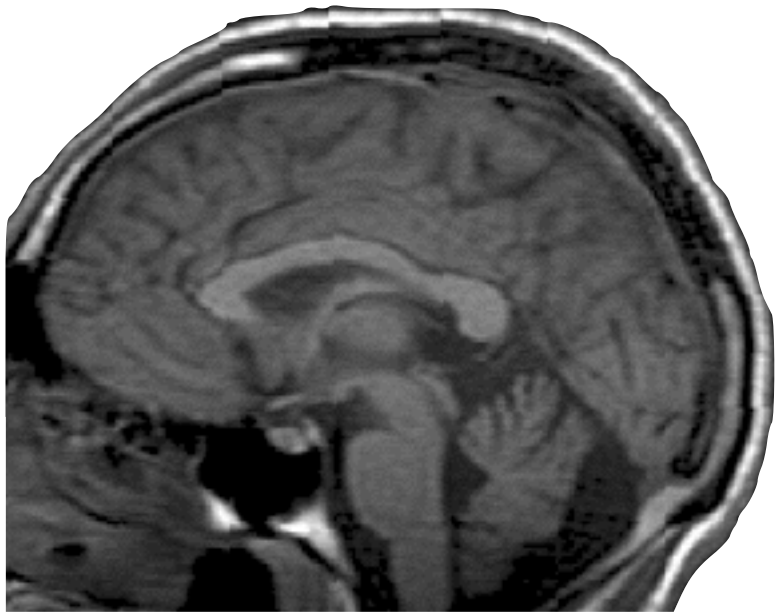
Why Should the Tissue Need to Be Segmented ?



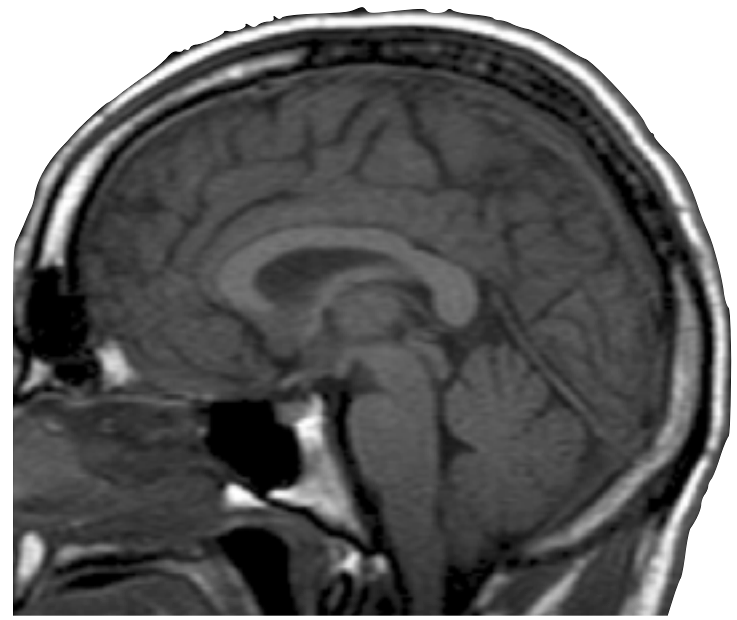
- High-resolution T1 images reveals fine structural detail in the brain, but not all of it reliable or interesting (noise, intensity-inhomogeneity. vasculature ......)
- Intensity of T1 image is usually not quantitatively meaningful (related to imaging parameters)
- Regional volumes of the three main tissue types: gray matter, white matter and CSF, are well-defined and potentially very interesting
- We obtain tissue probability map after segmentation procedure

Why We Need Spatial Normalization ? (1)

Shape and size of the brain can vary among subjects

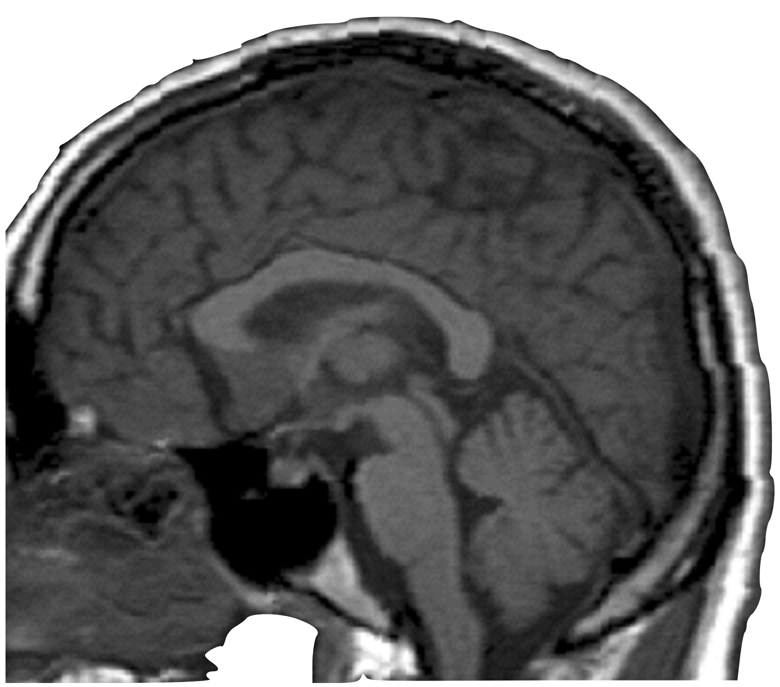


Subject 1



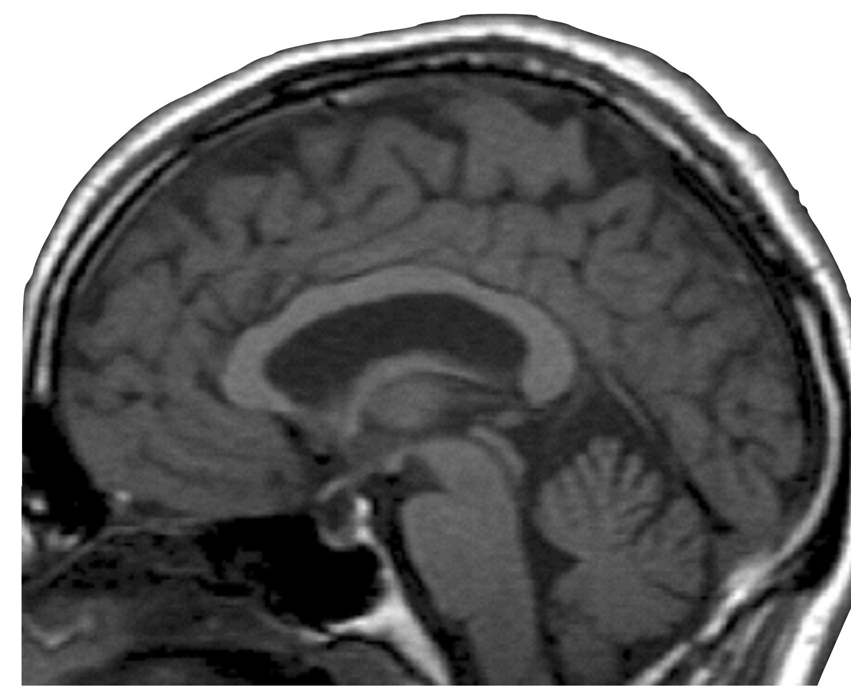
Subject 2

Subject 3



Subject 4

Subject 5



Subject 6

Why We Need Spatial Normalization ? (2)

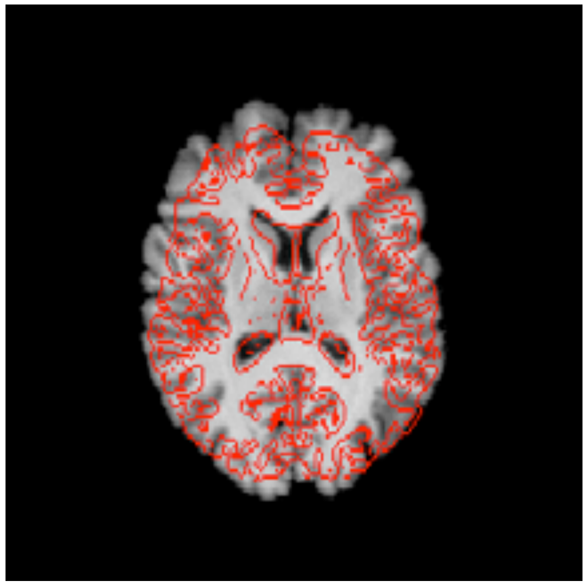
Report final result in the standard template space (MNI)

TABLE II. Anatomical regions with significant gray matter volume reductions in patients with Parkinson's disease compared with the healthy control group

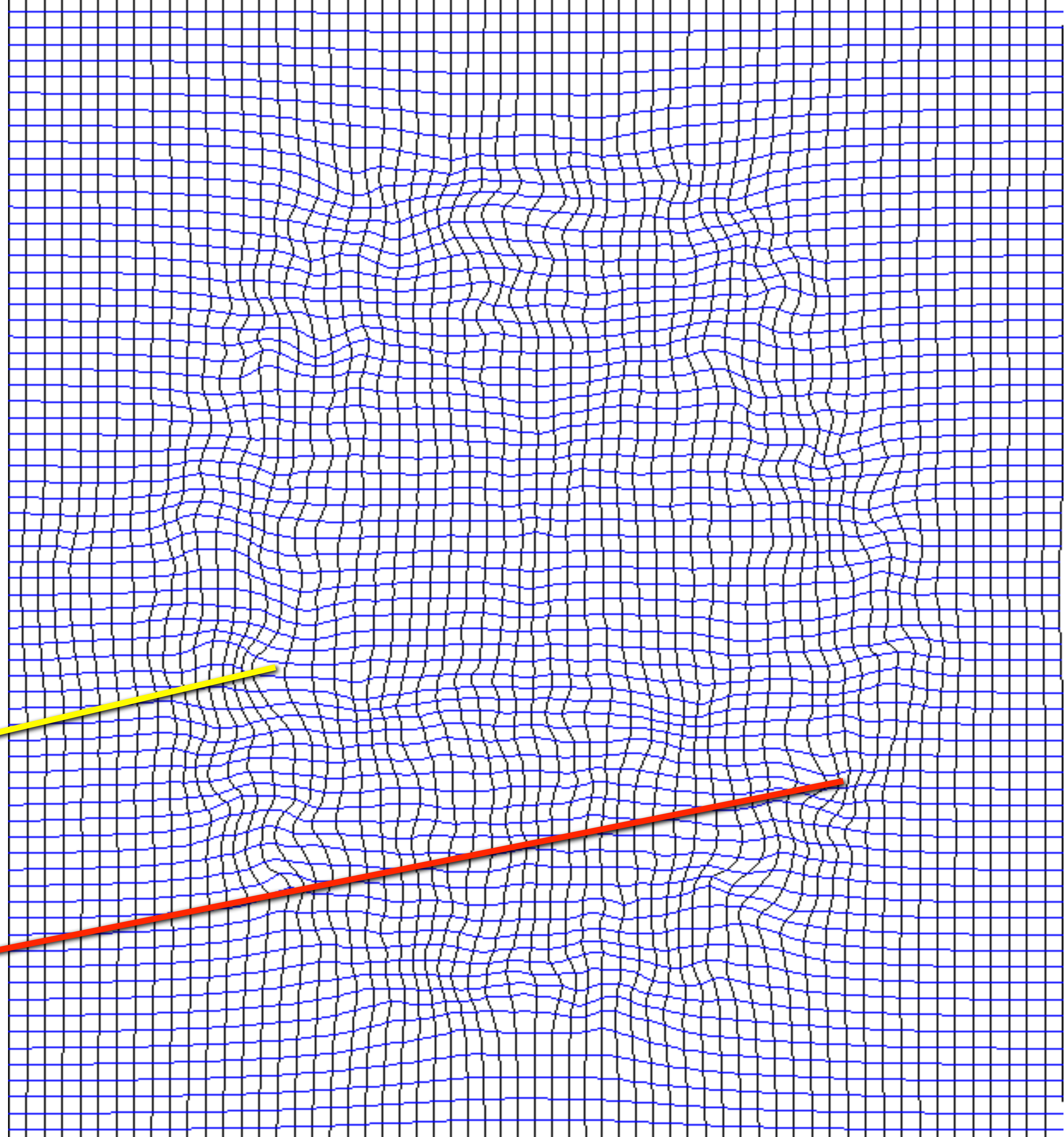
MNI coordinates							
x	*y*	*z*	Cluster size	Side	Anatomical region	Brodmann area	Z-score
−12	−45	−53	8657	Lt.	Cerebellar tonsil	[a]	5.42
33	−70	−33		Rt.	Cerebellar tonsil	[a]	5.11
8	18	−3	3331	Rt.	Caudate	[a]	5.15
−2	8	−11		Lt.	Anterior cingulate	BA 25	4.70
−6	17	−2		Lt.	Caudate	[a]	4.67
−35	−12	−39	3303	Lt.	Parahippocampal gyrus	[a]	4.54
51	−9	4	2777	Rt.	Precentral gyrus	BA 6	5.07
56	−15	9		Rt.	Transverse temporal gyrus	BA 41	4.94
−3	−34	33	792	Lt.	Cingulate gyrus	BA 31	4.89
−48	−24	12	691	Lt.	Transverse temporal gyrus	BA 41	4.77
59	−40	4	552	Rt.	Middle temporal gyrus	BA 22	4.33
−18	−70	12	519	Lt.	Posterior cingulate	BA 30	5.13
29	−3	−21	456	Rt.	Parahippocampal gyrus	[a]	4.23
41	45	24	423	Rt.	Middle frontal gyrus	BA 10	4.32
15	−72	7	339	Rt.	Lingual gyrus	BA 18	4.25
33	−27	−26	328	Rt.	Parahippocampal gyrus	BA 35	4.11
56	−3	−26	264	Rt.	Middle temporal gyrus	BA 21	3.83
−8	−18	18	192	Lt.	Thalamus	[a]	3.76
24	62	1	166	Rt.	Superior frontal gyrus	BA 10	4.11
47	−33	62	164	Rt.	Inferior parietal lobule	BA 40	3.73
−45	−34	40	125	Lt.	Inferior parietal lobule	BA 40	4.28
−51	−13	−41	122	Lt.	Inferior temporal gyrus	BA 20	3.71
41	−76	13	121	Rt.	Middle occipital gyrus	BA 19	3.64

Chou et al. HBM. 2015.

Deformation Field



Encode how we map individual brain into MNI space

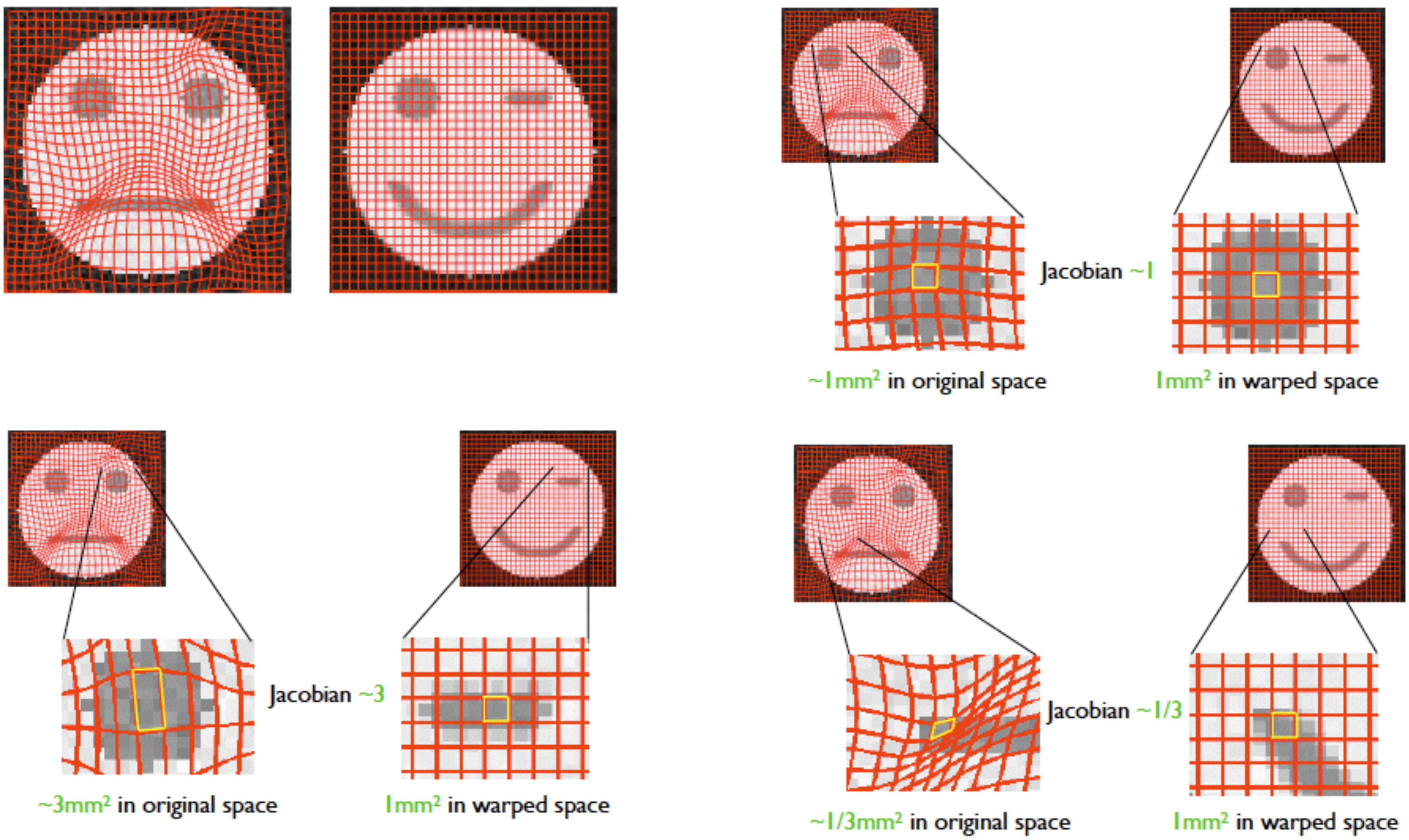


Local Expansion

Local Shrinkage

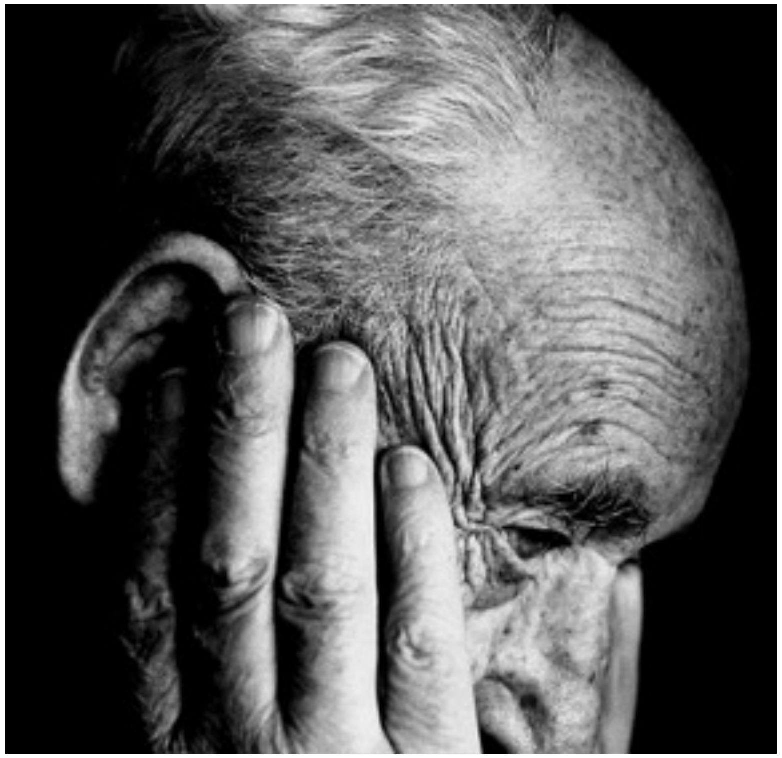
Do We Need Tissue Modulation !? (Optional)

Corrects for changes in brain VOLUME caused by non-linear spatial normalization



Figures were adapted from FSL course 2009

The Material of Today's Course



Subjects: [Put the demo dataset into your folder]

10 healthy controls and 10 patients with Alzheimer's disease

Scientific question:

Do AD patients show less gray matter volume than healthy controls ?

Analysis approach:

Whole brain gray matter volume voxel based morphometry analysis

Statistical approach:

(1) 2 sample T-test with covariate of non-interest (Analysis of covariance test ; ANCOVA)

The Interface of Statistical Parametric Mapping (1)

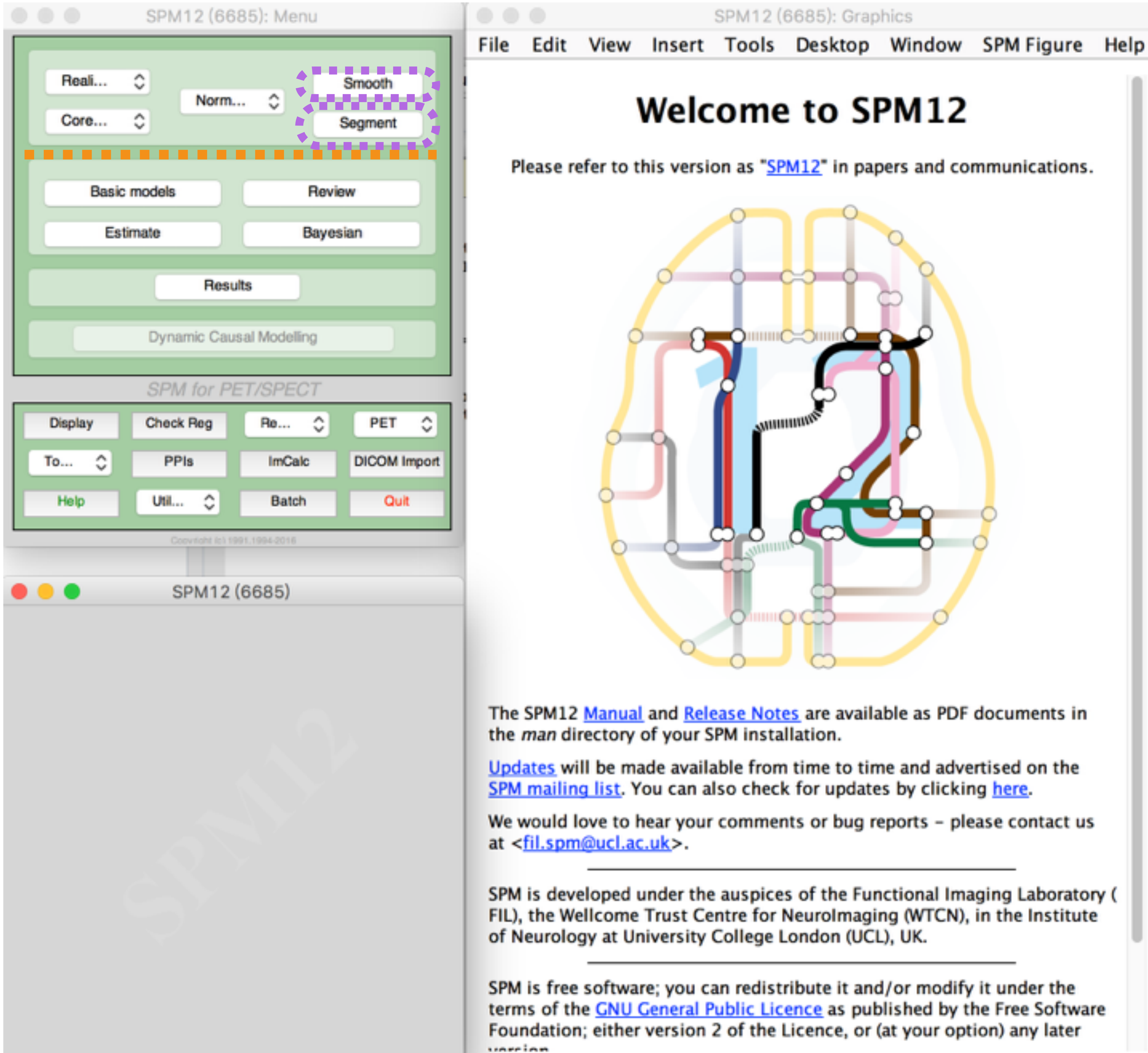


Image Preprocessing

Practice in 5 mins

Obtain Normalized Modulated / Unmodulated Tissue Segments in One Step

Volumes:

Input dataset

Output file:

(1) Bias field (BiasField_*.nii) and bias field corrected (m*.nii) native space T1 image

(2) Native (c1~c3) and DARTEL imported (rc1~rc3) tissue segments - Optional

(3) Modulated (mwc1~mwc3) and unmodulated tissue segments (wc1~wc3)

- The most important output files

(4) Deformation field of each participants (y_*.nii and iy_*.nii)

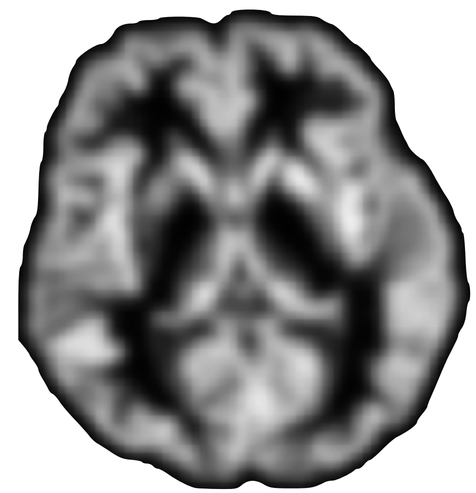
Practice in 15 mins

Why Do We Need to Smooth Data ?

- Primary reason:
  - Make data become more gaussian distributed (for parametric statistical analysis)
  - Compensates for inaccuracies in spatial normalization procedure
- Recommendation : 6 ~ 12 mm

2mm smooth

4mm smooth



6mm smooth

Original data

8mm smooth

12mm smooth

Smoothing Data with SPM12

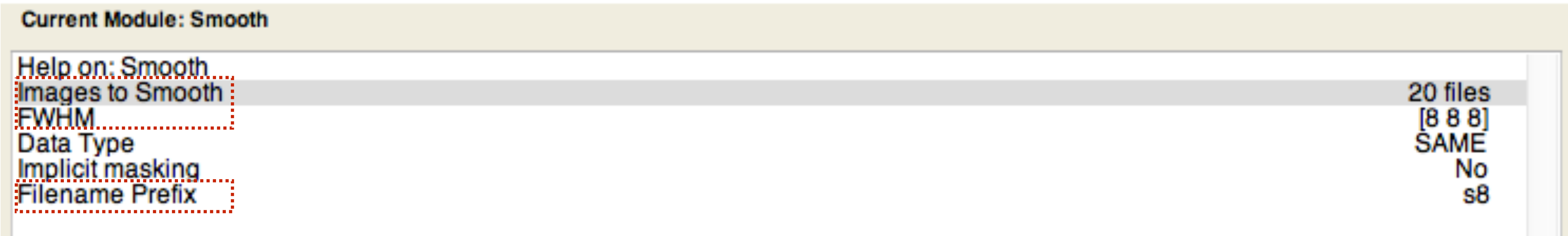


Image to Smooth:

Input dataset : Modulated gray matter segments (mwc1*.nii)

FWHM:

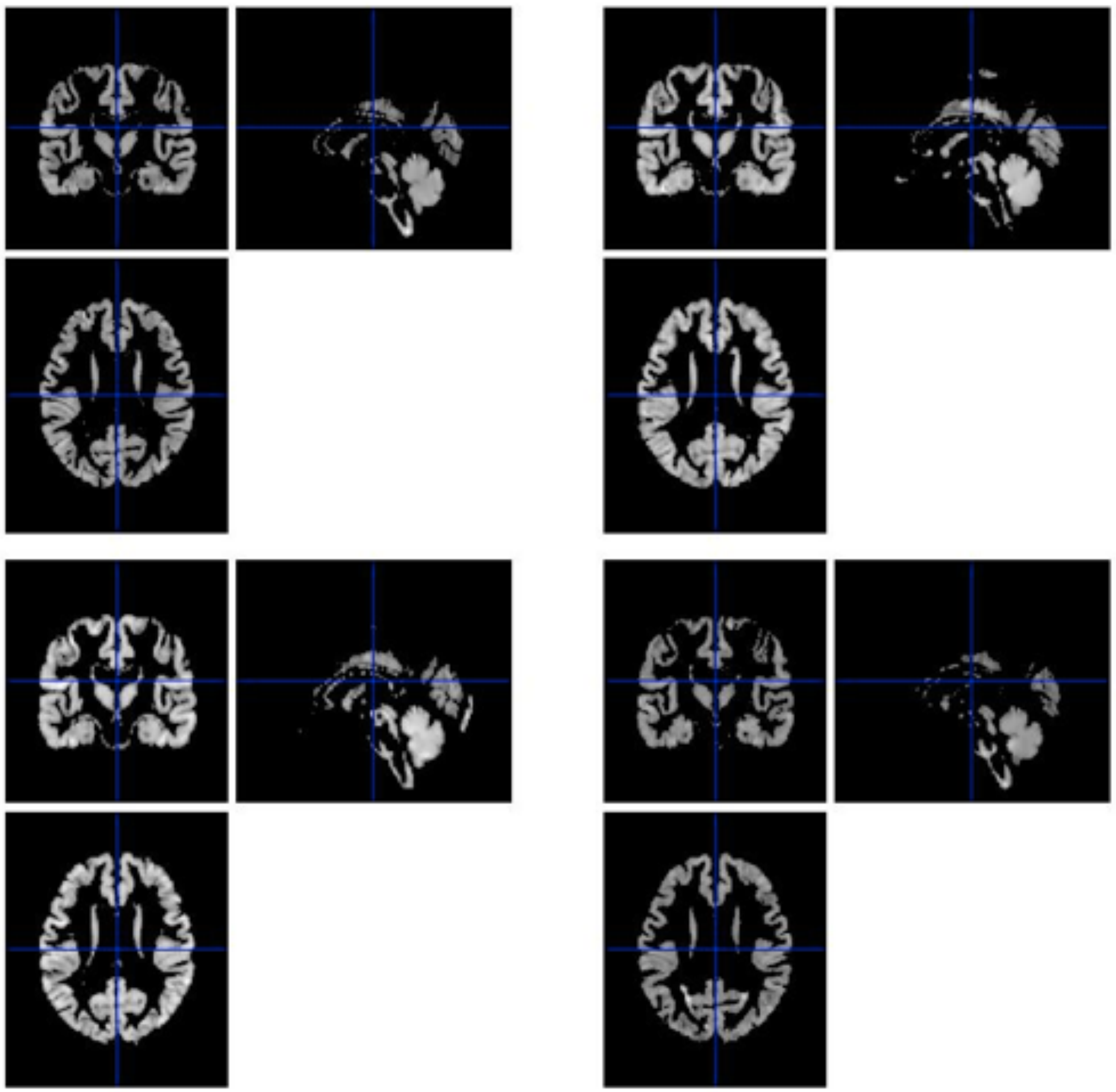
The FWHM of Gaussian smooth kernel in mm

Filename Prefix:

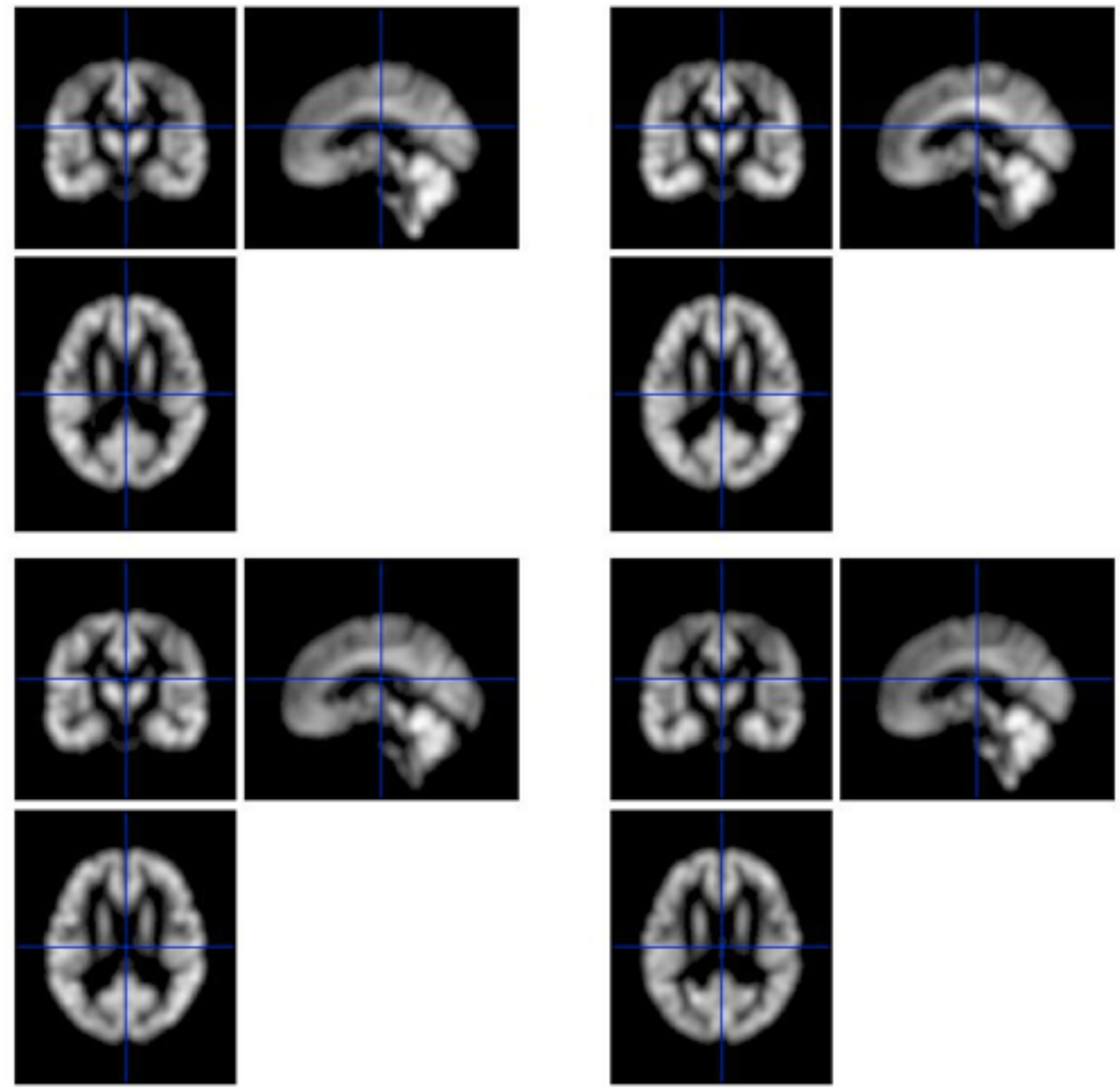
The prefix of output file: s8mwc1*.nii

Practice in 5 mins

The Result You Obtained After VBM Image Preprocessing



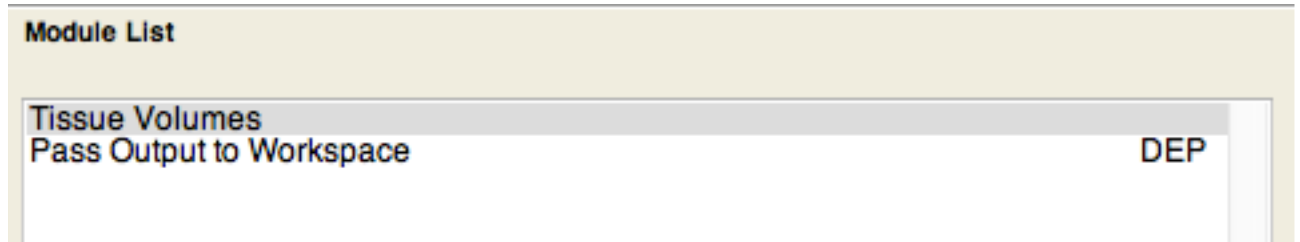
Normalized and modulated GM segments



Normalized, modulated and smoothed GM segments

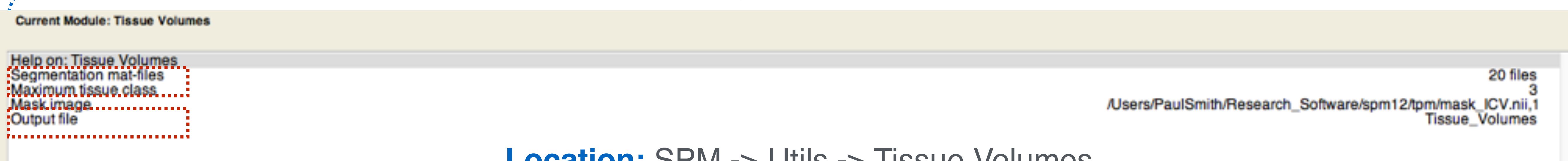
Calculate Global Tissue Volume With SPM12

Using two modules in a single batch



Practice in 15 mins

1st module



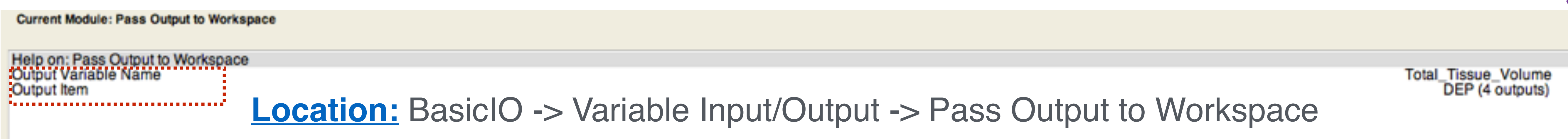
Location: SPM -> Utils -> Tissue Volumes

Segmentation mat-files: Input files (*_seg8.mat)

Maximum tissue class: 3 (GMV, WMV and CSFV) or 2 (GMV and WMV)

Output file: filename of output CSV file

2nd module

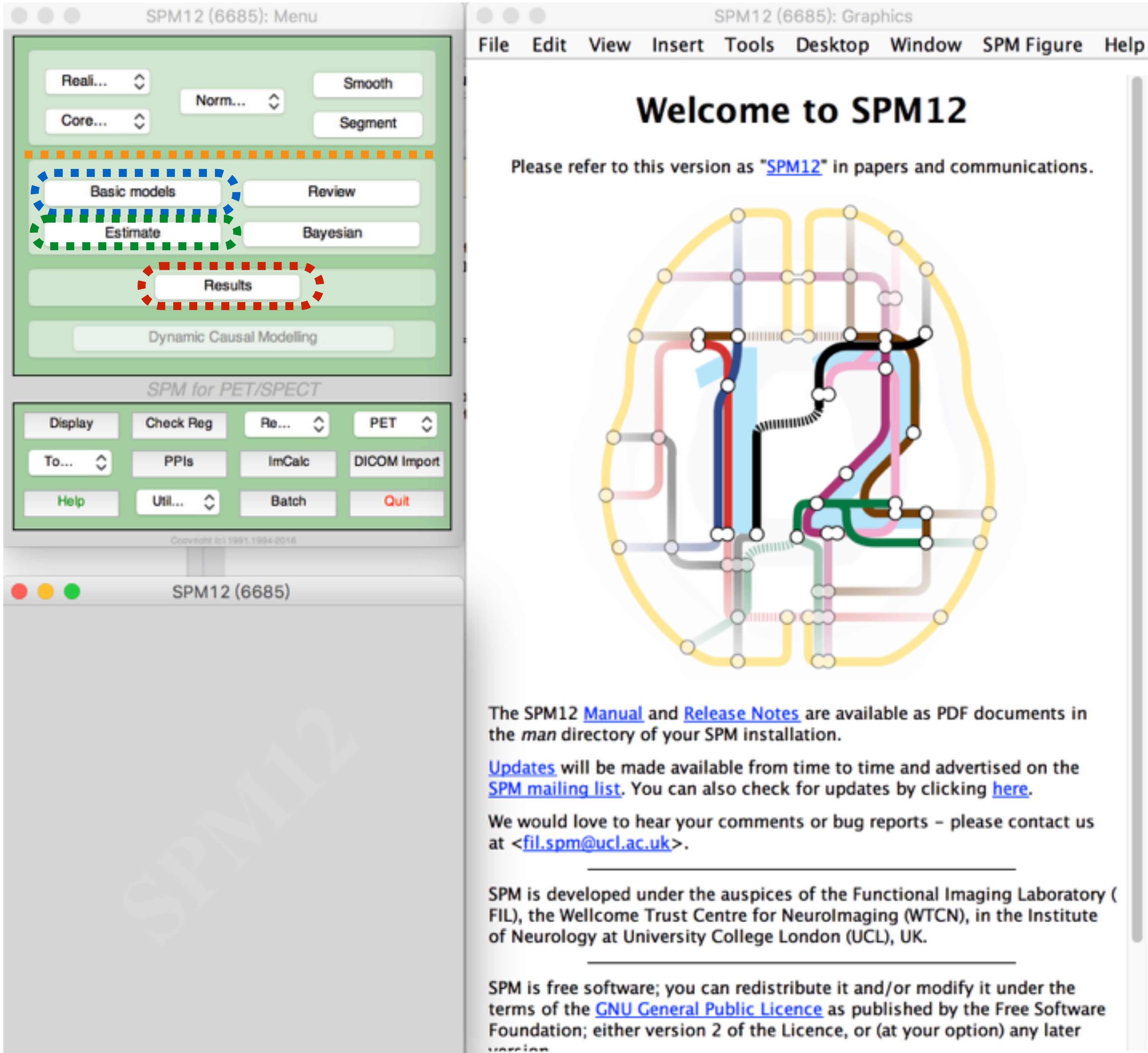


Location: BasicIO -> Variable Input/Output -> Pass Output to Workspace

Output Variable Name: Name of output variable

Output item: Use "Dependency" option [related to the option of 1st module]

The Interface of Statistical Parametric Mapping (2)



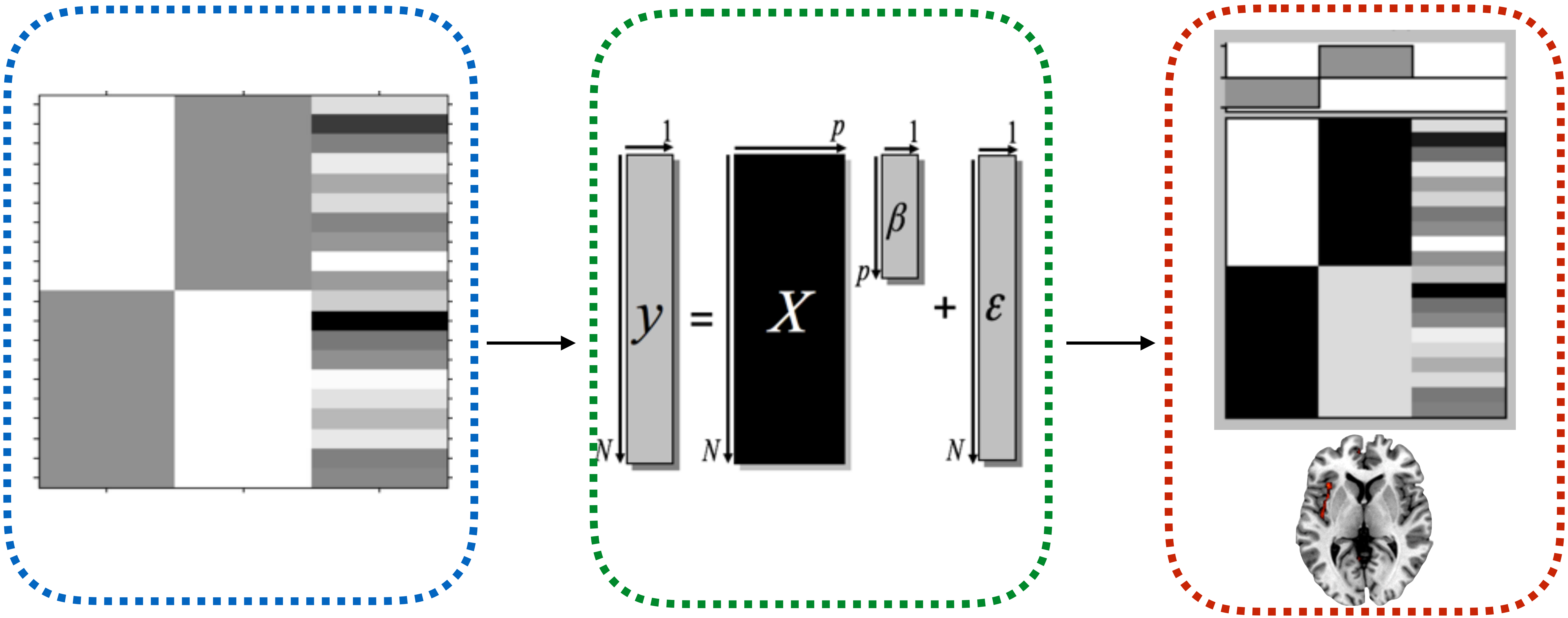
Model Construction

Model Estimation

Statistical Inference

Practice in 5 mins

The Basic Statistical Pipeline of SPM



Model Construction

Model Estimation

Statistical Inference

General Linear Model - Modeling Tissue Segments

Why? Make inferences about effects of interest

How?
- Decompose data into effects and error
- Form statistic using estimates of effects and error

$$Y = X \times \beta + E$$

Y	X	β	E
Dependent Variable (What you are measuring)	Independent Variable (What you are manipulating)	Relative Contribution (These need to be estimated)	Error (The difference between the observed data and that which is predicted by the model)

Aim: To explain as much of the variance in Y by using X, and thus reducing E

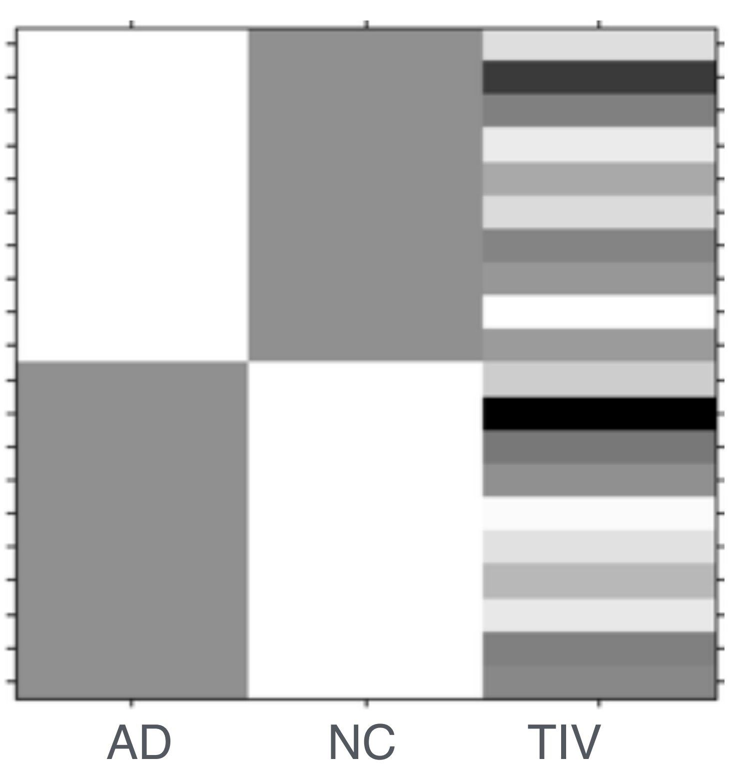
More than 1 EV ? $Y = X_1\beta_1 + X_2\beta_2 + \ldots X_n\ \beta_n \ldots + E$

Univariate analysis !!

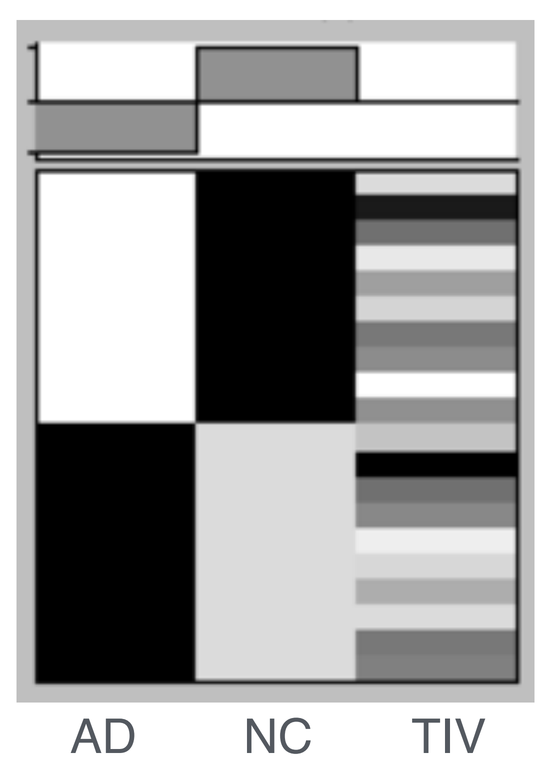
Gray Matter Volume Atrophy in Patients with Alzheimer's Disease

"Is there significantly lower gray matter volume
in the patients with Alzheimer disease than in the healthy controls
after adjusting total intracranial volume ? (2 sample T-test)"

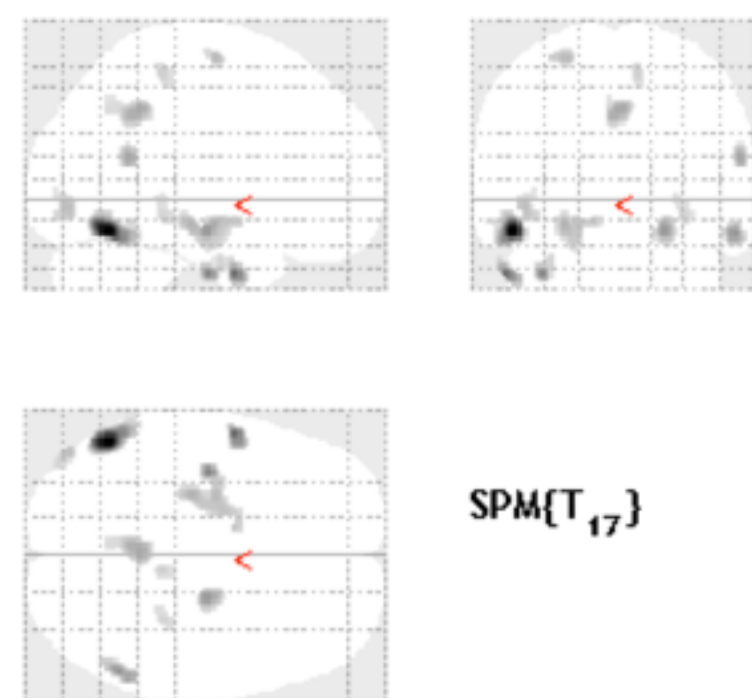
$$Y = \beta_1(AD) + \beta_2(NC) + \beta3(TIV) + \varepsilon$$



Model construction



Statistical inference



Result visualization

2 Sample T-test with Covariate of Non-interest (Model Construction)

Directory: The output directory of your statistical model

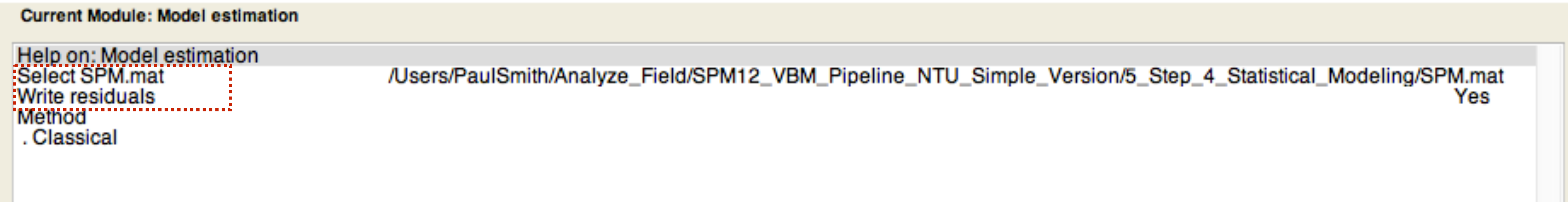
Design: The statistical model you want to use (Two sample T-test)

Covariates: The effect you want to adjust (TIV)

Masking: The region you want to do statistical inference

Practice in 10 mins

2 Sample T-test with Covariate of Non-interest (Model Estimation)

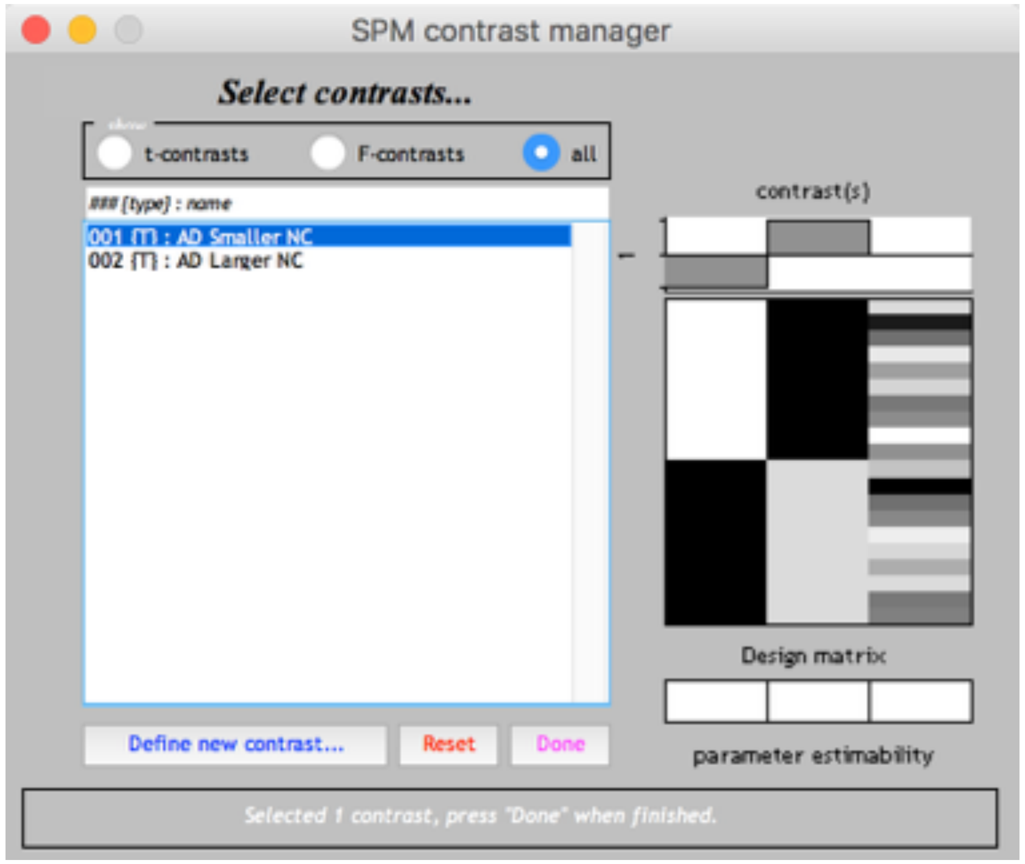


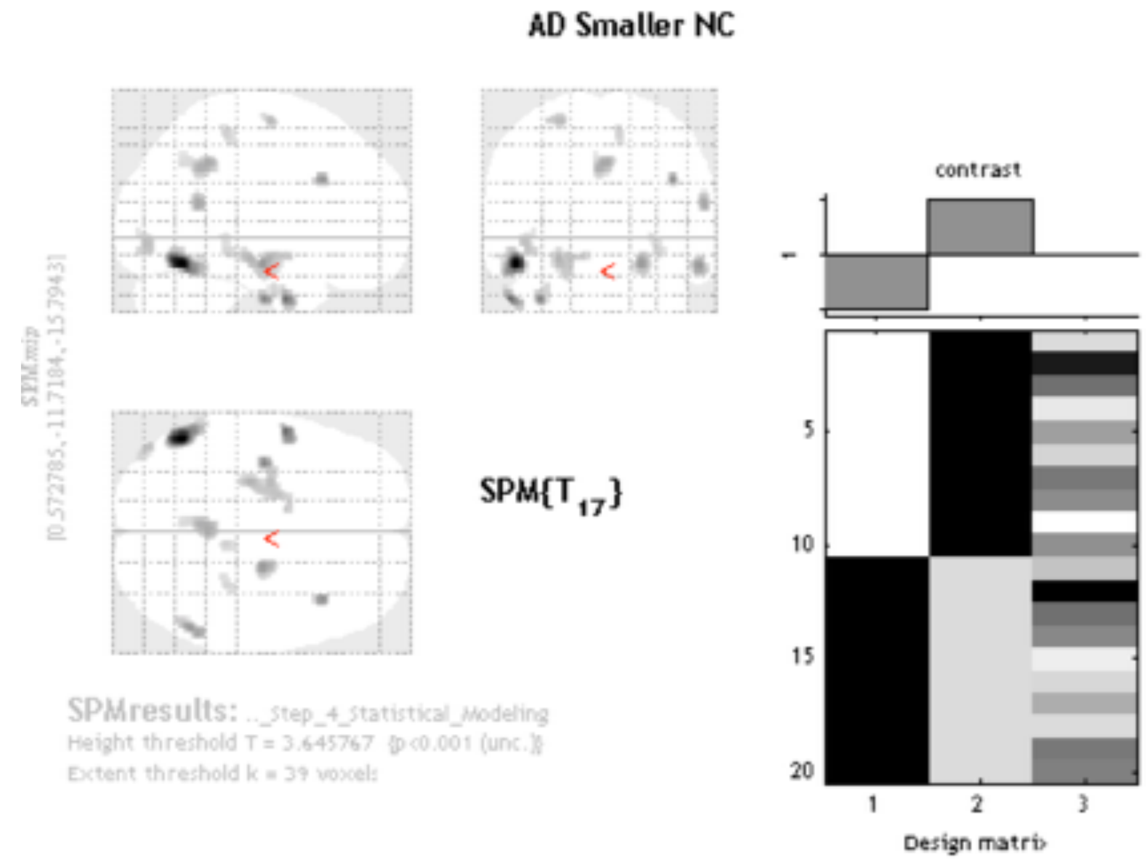
Select SPM.mat: The statistical model file of your design (SPM.mat)

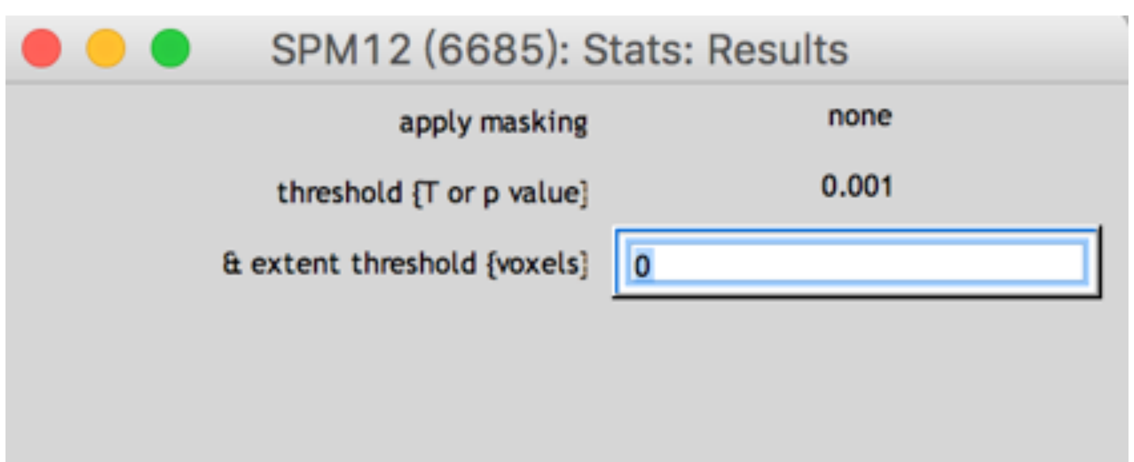
Write residuals: Save the residual file of GLM estimation

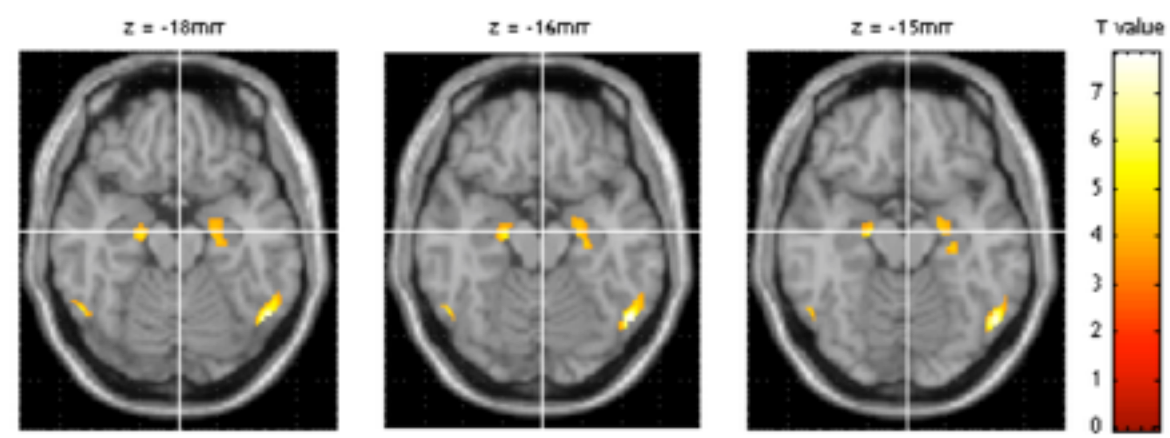
Practice in 5 mins

2 Sample T-test with Covariate of Non-interest (Statistical Inference & Result Visualization)









Statistical criteria:

Uncorrected voxel $p < 0.001$ with 39 extended voxels

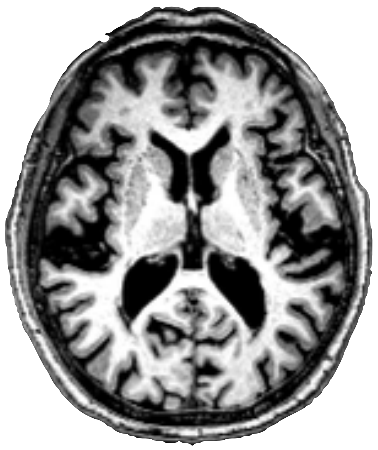
Cluster location:

(x,y,z) = (21 , -15 , -16)

Practice in 10 mins

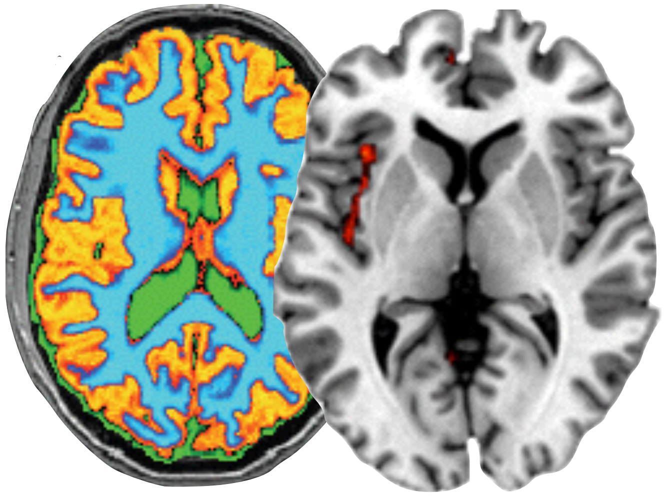
Take Home Messages

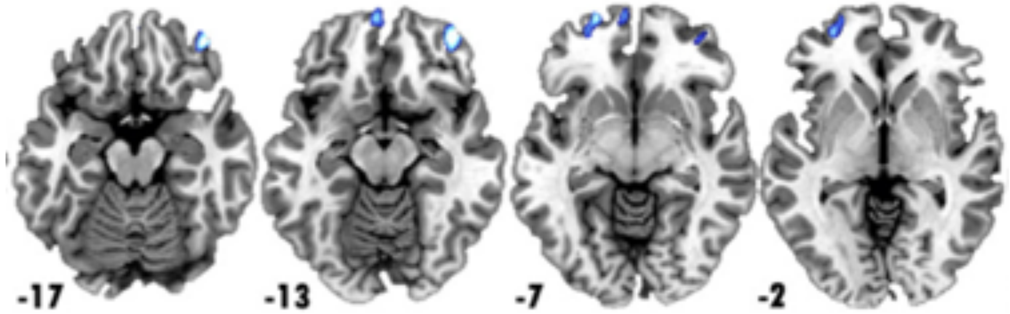
Select the appropriate MR modality to served as input for VBM analysis

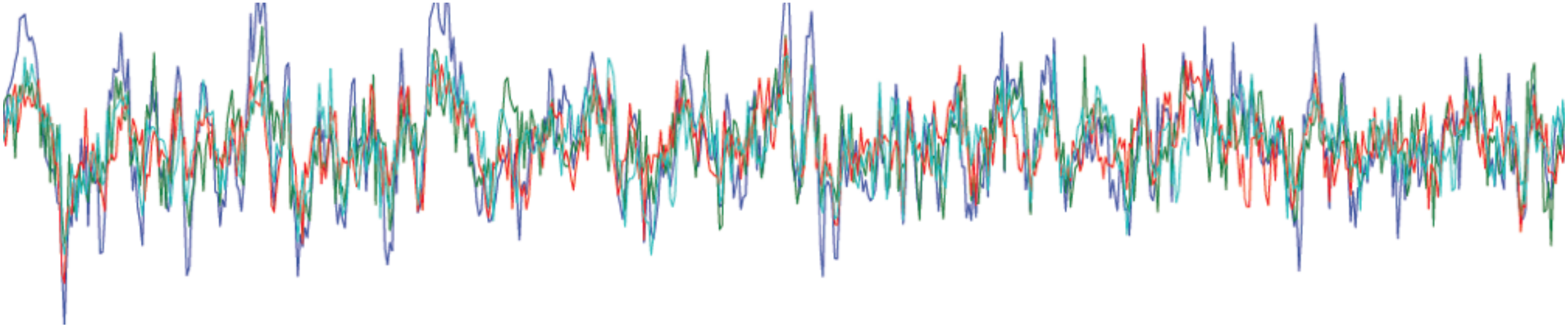


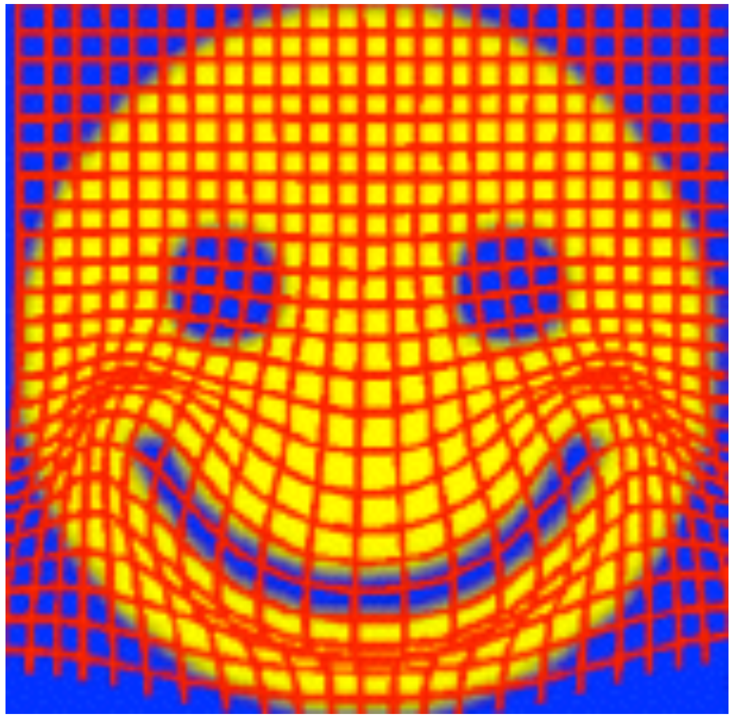
The core modules of VBM

1. Tissue segmentation
2. Spatial normalization
3. Tissue modulation (optional)
4. Tissue smoothing
5. Statistical modeling









Analyzing Your

Structural Data for Fun ! !

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