Practice in resting-state fMRI (rs-fMRI) Analysis: PART I

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Download Demo Materials

心智科學腦研究推動網
心智影像研究(MRI)中心 @成大 活動網頁 → 實作資料

http://fmri.ncku.edu.tw/tw/course_view.php?no=126

盧家鋒 個人網頁
靜息態功能性磁振影像分析實作 → 實作資料

http://www.ym.edu.tw/~cflu/CFLu_course_speech.html

Course Arrangement

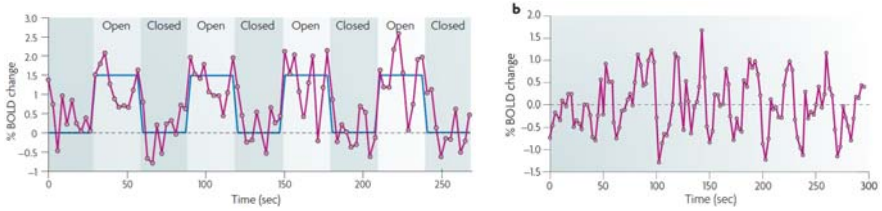
PART I (10/3)
- rs-fMRI pre-processing
- REST and DPARSF
- REST go through: ReHo, Functional Connectivity, ALFF, fALFF, utilities

PART II (10/4)
- Advanced connectivity analysis
- DPARSF go through
- Statistics

Spontaneous Fluctuation

Task-specific fMRI
- ✓ Model-based Analysis
- ✓ Model-free (data-driven) Analysis

Resting-state fMRI (rs-fMRI)
- ✓ Model-free (data-driven) Analysis

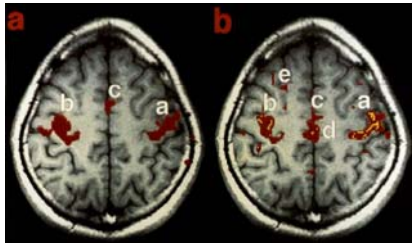


Nature Reviews Neuroscience 8.9 (2007): 700-711.

First rs-fMRI Article (MRM 1995)

Functional Connectivity in the Motor Cortex of Resting Human Brain Using Echo-Planar MRI

Bharat Biswal, F. Zerrin Yetkin, Victor M. Haughton, James S. Hyde



a. Functional activation during tasking
b. rs-fMRI correlation maps
(red: positive, yellow: negative)

Rs-fMRI Analyses

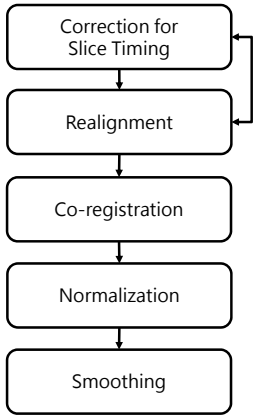
1. Functional connectivity analysis
- Linear correlation
- Granger causality analysis (**GCA**), effective connectivity
- Independent component analysis (**GIFT-ICA**; Calhoun et al., NeuroImage 2001)

2. Depicting local features of BOLD signal
- Regional homogeneity (**ReHo**; Zang et al., NeuroImage 2004)
- Amplitude of low-frequency fluctuation (**ALFF**; Zang et al., Brain & Development 2007)
- Fractional ALFF (**fALFF**; Zou et al., J Neurosci Methods 2008)

Functional Integration ⇔ Functional segregation

Preprocessing for rs-fMRI

Similar to that used for task-specific fMRI analysis
- Slice timing
- Realignment
- Co-registration (with anatomical images)
- Normalization
- Smoothing
- Segment (tissue classification; optional)

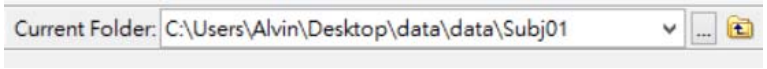


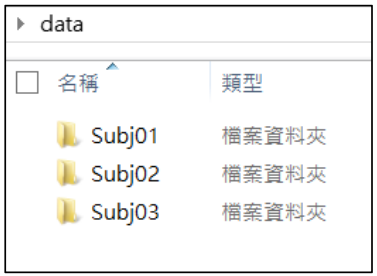
UCL SPM
Standard procedure for fMRI preprocessing

http://www.ym.edu.tw/~cflu/CFLu_course_mriprinp.html, Week 16

Switch current folder to data folder

More convenient to execute the subsequent processing steps….

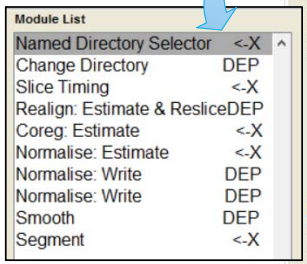


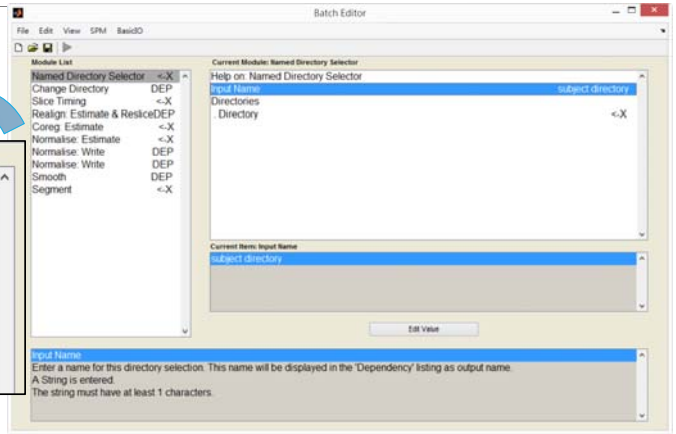


Batch of SPM fMRI preprocessing

>> spm fmri

fMRI_preprocess_v2.mat

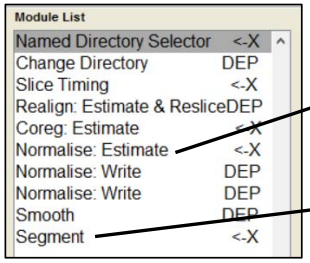




Batch of SPM fMRI preprocessing

>> spm fmri

Save as your own batch template



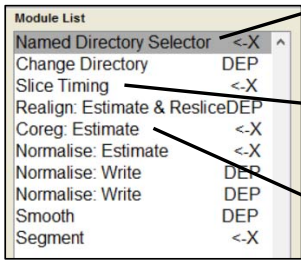
T1 template image
C:\Users\Alvin\Desktop\softwares\spm8\templates\T1.nii,1

Tissue probability maps
C:\Users\Alvin\Desktop\softwares\spm8\tpm\grey.nii,1
C:\Users\Alvin\Desktop\softwares\spm8\tpm\white.nii,1
C:\Users\Alvin\Desktop\softwares\spm8\tpm\csf.nii,1

Batch of SPM fMRI preprocessing

>> spm fmri

Save as subject's batch



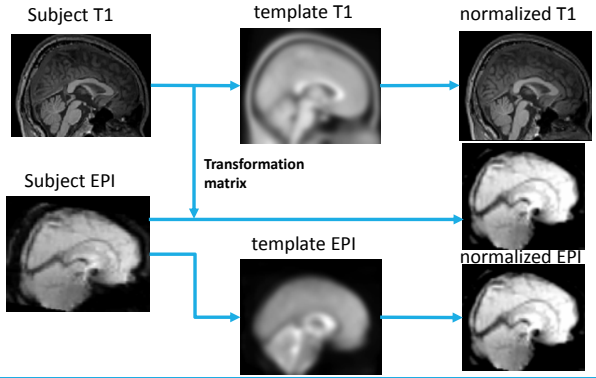
Subject data folder
C:\Users\Alvin\Desktop\data\data\Subj01

rs-fMRI data
C:\Users\Alvin\Desktop\data\data\Subj01\REST.img,1
....
C:\Users\Alvin\Desktop\data\data\Subj01\REST.img,240
240 volumes

T1W data
C:\Users\Alvin\Desktop\data\data\Subj01\anat.img,1

Normalization

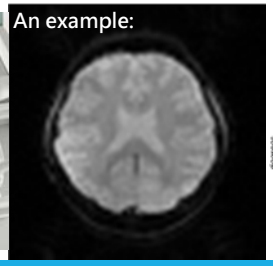
We can perform spatial normalization using either anatomical (T1) images or fMRI (EPI) data.

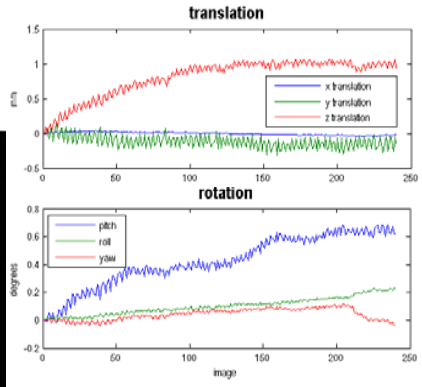


Realignment of head motion

The signal variation from movement is larger than hemodynamic response.

6-parameter Rigid body registration
& transformation (align to the 1st volume)
➔ 6 co-variates for rs-fMRI analysis



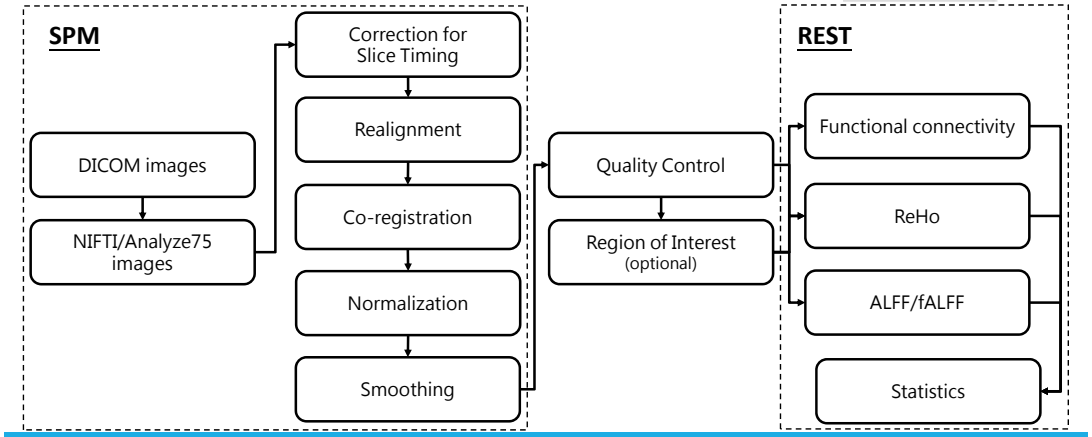


Employed Software/Package

1. **SPM** preprocessing
   - http://www.fil.ion.ucl.ac.uk/spm/
2. **REST** functional connectivity, ReHo, ALFF, fALFF, VMHC
   - http://restfmri.net/forum/index.php?q=rest
3. **DPARSF/DPABI**
   - http://rfmri.org/DPARSF
   - Data Processing Assistant for Resting-State fMRI (DPARSF)
   - Based on SPM and REST toolbox

REST: Song et al., PLoS ONE, 2011.
DPARSF: Yan et al., Frontiers in System Neuroscience, 2010.

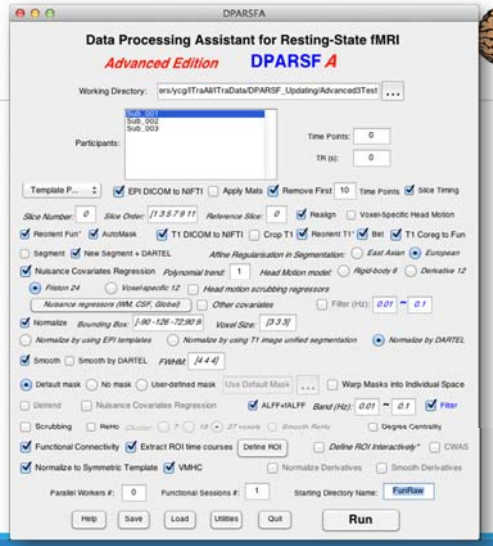
Processing Flow in DPARSF



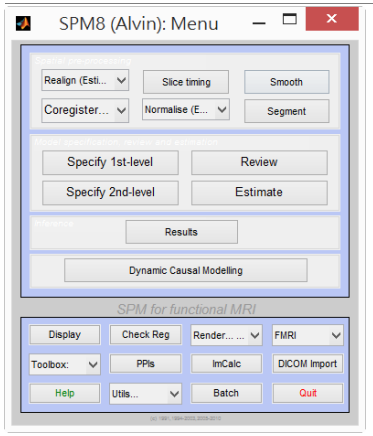
DPARSF GUI

One-stop service

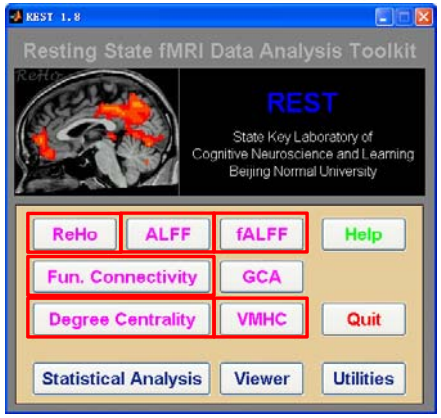
- Similar to the SPM batch
- Easy to process, but…
- Obscure to novice : (



Easier Way to Learn :)



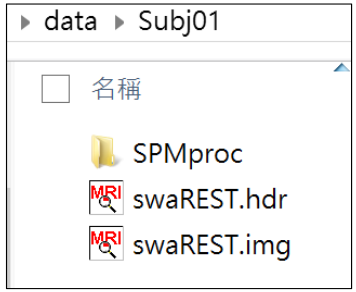
SPM+REST



Organize data folder

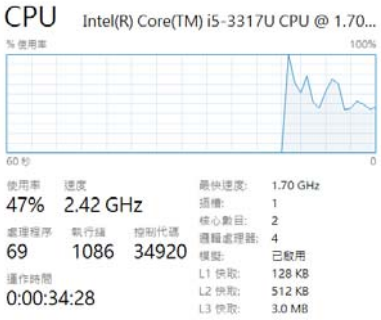
Before using REST toolbox,

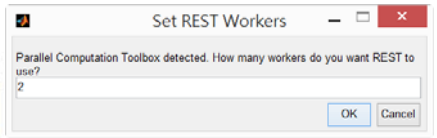
Create a new subfolder to archive all SPM-processed data except the file pair of "**swaREST.hdr/img**"

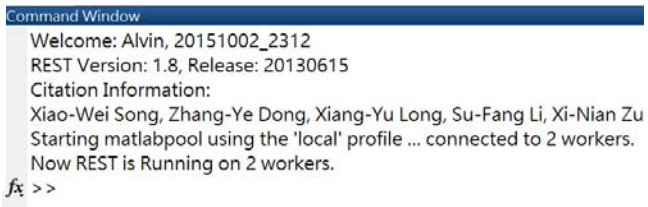


Initialize REST environment

>> rest

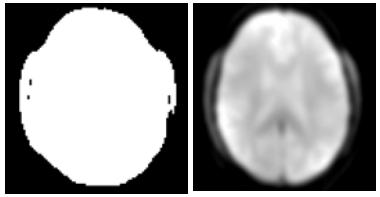






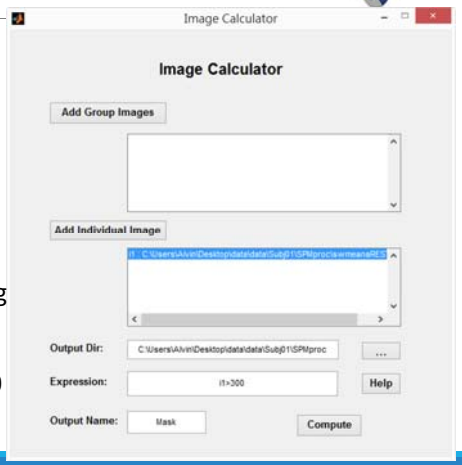
Create Brain Mask

Utilities → REST Image Calculator



Import subject's swmeanaREST.img

i1 > 300

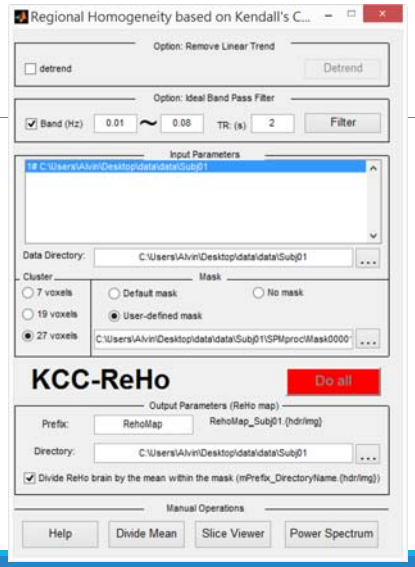


ReHo Setup

Assign folder with Analyze75 image pair (.img/.hdr), smoothed images

Select the user-defined mask

Select output directory and prefix



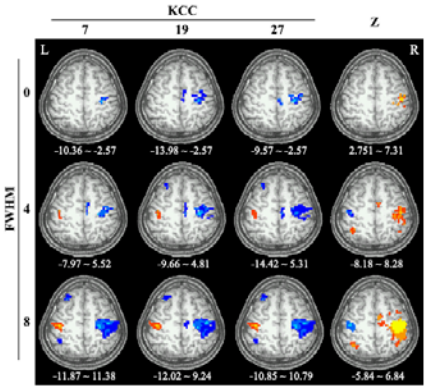
About 2~6 minutes~

What does ReHo represent?

Regional homogeneity, temporal similarity between neighbor voxels within a small cluster.

"ReHo supposed that voxels within a functional brain area were more temporally homogeneous when this area is involved in a specific condition."

Model-free, data-driven ReHo can reflect cortical activation.



Zang et al., NeuroImage 2004.

An example of ReHo (KCC)

OBJECTS

rank — i: 5 time points (number of ranks) — n=5

JUDGES

j: 3 voxels within a cluster

K=3

4	3	1	5	2
4	3	1	5	2
4	3	1	5	2

R_1=12, R_2=9, R_3=3, R_4=15, R_5=6,

$$R_i = \sum_{j=1}^{K} r_{i,j}$$

$$\bar{R} = \frac{1}{n}\sum_{i=1}^{n} R_i$$

$$S = \sum_{i=1}^{n} (Ri - \bar{R})^2$$

$$W = \frac{12S}{K^2(n^3 - n)}$$

$\bar{R} = 9, \; S = 90$

$$W = \frac{12 \times 90}{9(125 - 5)} = 1$$ ➔ **unanimous measurements**

An example of ReHo (KCC)

OBJECTS

rank — i: 5 time points (number of ranks) — n=5

JUDGES

j: 3 voxels within a cluster

K=3

4	3	1	5	2
5	1	2	3	4
3	2	4	1	5

R_1=12, R_2=6, R_3=7, R_4=9, R_5=11,

$$R_i = \sum_{j=1}^{K} r_{i,j}$$

$$\bar{R} = \frac{1}{n}\sum_{i=1}^{n} R_i$$

$$S = \sum_{i=1}^{n} (Ri - \bar{R})^2$$

$$W = \frac{12S}{K^2(n^3 - n)}$$

$\bar{R} = 9, \; S = 24$

$$W = \frac{12 \times 24}{9(125 - 5)} = 0.27$$ ➔ **Lower concordance**

An example of ReHo (KCC)

OBJECTS

rank — i: 5 time points (number of ranks) — n=5

JUDGES

j: 3 voxels within a cluster

K=3

4	3	1	5	2
3	5	4	1	2
2	1	4	3	5
R_1=9,	R_2=9,	R_3=9,	R_4=9,	R_5=9,

$$R_i = \sum_{j=1}^{K} r_{i,j}$$

$$\bar{R} = \frac{1}{n}\sum_{i=1}^{n} R_i$$

$$S = \sum_{i=1}^{n} (Ri - \bar{R})^2$$

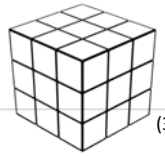
$$W = \frac{12S}{K^2(n^3 - n)}$$

$$\bar{R} = 9, \quad S = 0$$

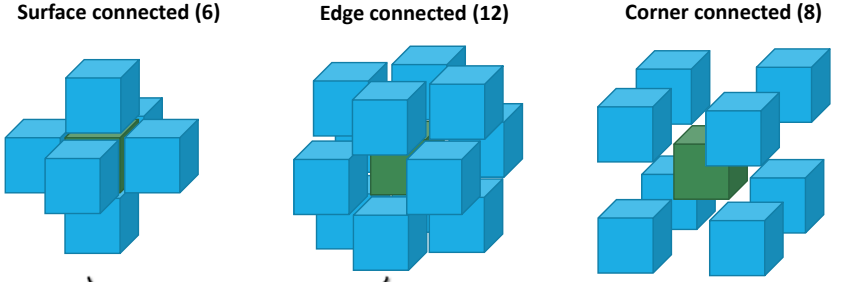
$$W = \frac{12 \times 0}{9(125 - 5)} = 0$$

➔ **Total disagreement**

Neighbors & Cluster size

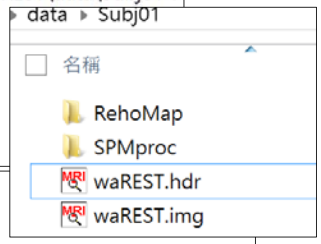


(3 by 3 cube)



Computation time: 2 ~6 mins

```
Ideal rectangular filter: "C:\Users\Alvin\Desktop\NCKU-REST\data\Subj01"
        Read 3D EPI functional images: "C:\Users\Alvin\Desktop\NCKU-REST\data\Subj01".

        Load mask "".
        Band Pass Filter working.       Wait.....
        Saving filtered images. Wait...
        Band pass filter over.
       Elapsed time is 194.178927 seconds.
```



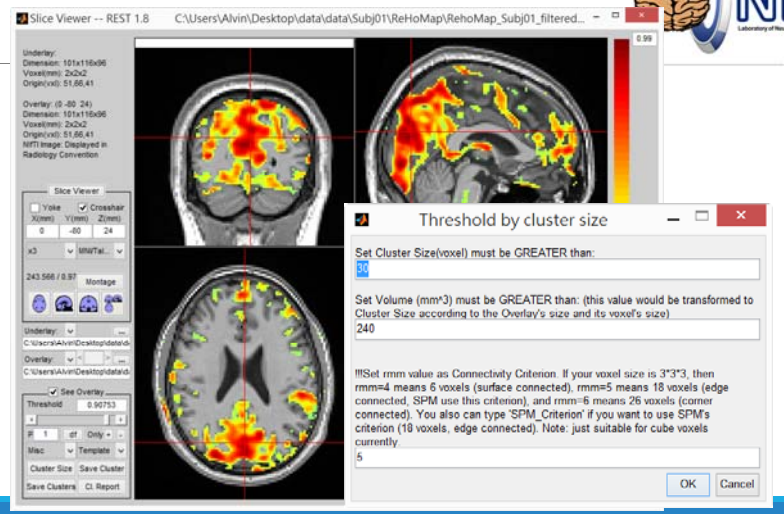

```
ReHo :

        Read these 3D EPI functional images.  wait...
        Read 3D EPI functional images: "C:\Users\Alvin\Desktop\NCKU-REST\data\Subj01_filtered".

        Rank calculating.....
        Calculate the kcc on voxel by voxel for the data set.....

       Regional Homogeneity computation over, elapsed time: 167.781 seconds
```


Slice Viewer

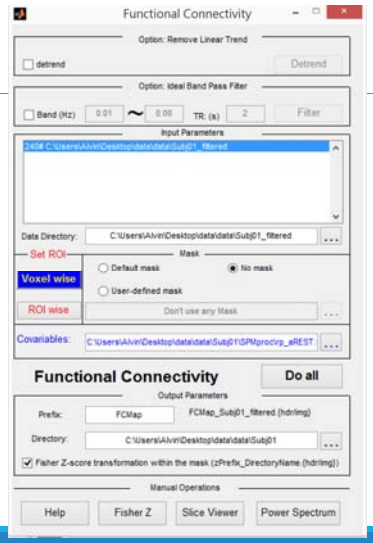
Underlay:
manat.img

overlay:
RehoMap*.nii

Adjust threshold



Functional Con.

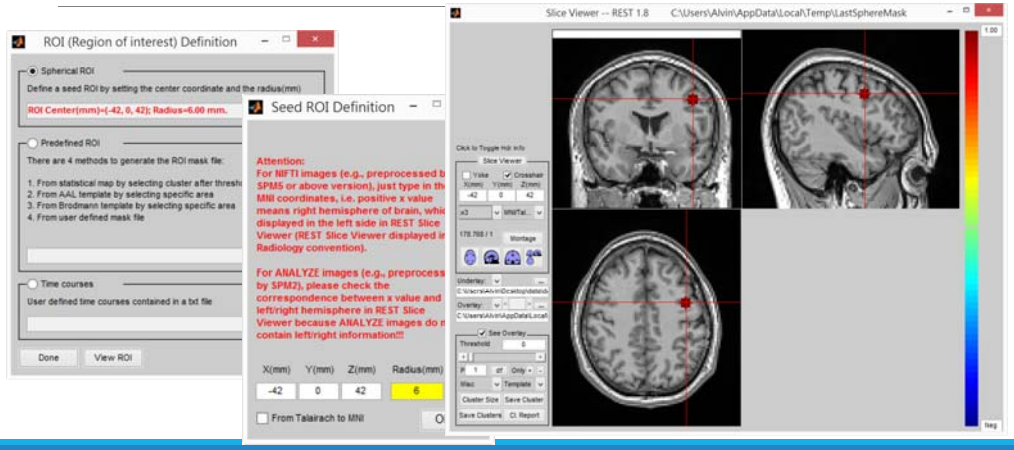


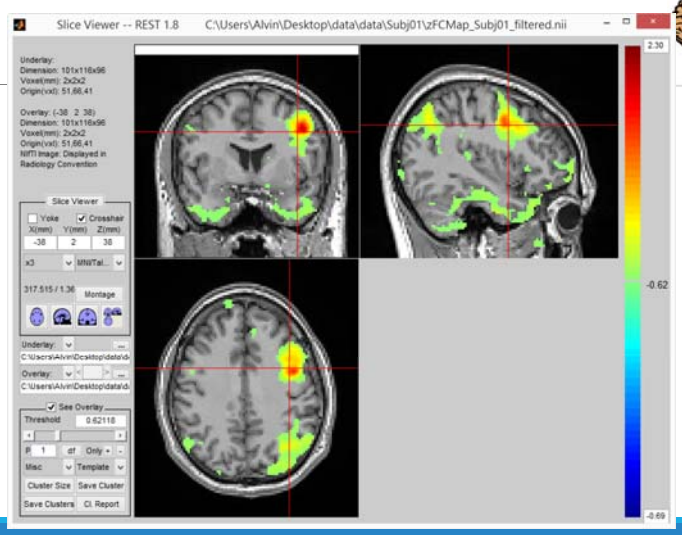
Select folder of Subj01_filtered (No need to apply filter and mask again)

Voxel wise ⇔ ROI wise

6 motion parameters as covariates

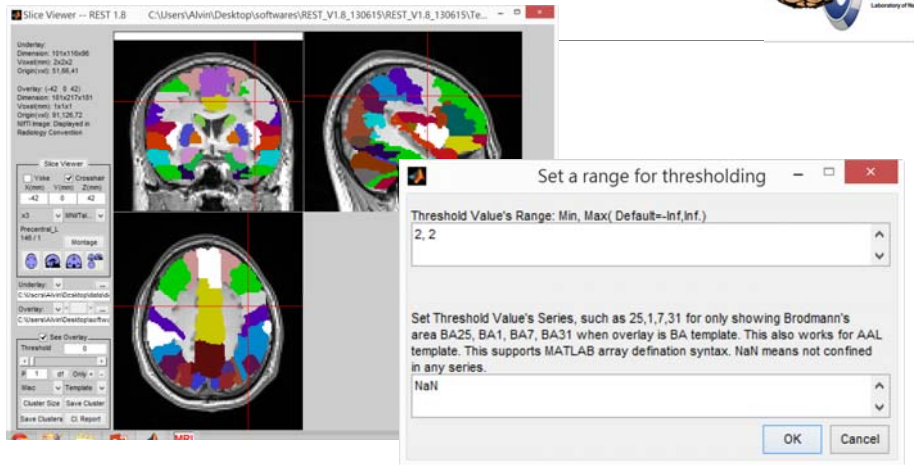
Sphere ROI





Atlas ROI

IBASPM 64-bit version
http://www.ym.edu.tw/~cflu/software/Ibaspm_64.zip



ALFF

What does ALFF represent?

Regional activation (regional activity during resting state).

Regional spontaneous neural activity

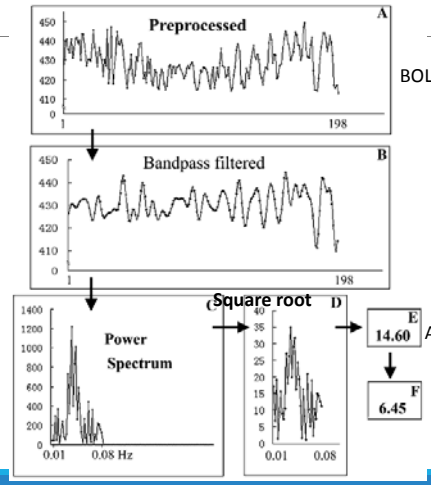
- ALFF is higher in grey matter than in white matter (Biswal et al., 1995).
- Kiviniemi et al. [22] reported activation in the visual cortex due to low-frequency fluctuations at about 0.034 Hz using the power spectrum method.

ReHo and functional connectivity analyses focus on the similarities of intra- and inter-regional time series, respectively, and ALFF measures the amplitude of regional activity.

Zang et al., Brain & Development 2007

ALFF

ALFF flowchart



BOLD time series for a given voxel

ALFF = Average over 0.01~0.08 Hz

Standardized by divided the ALFF by global mean

Zang et al., Brain & Development 2007

fALFF

Fractional ALFF

However, it has been indicated that the ALFF is also sensitive to the physiological noise.

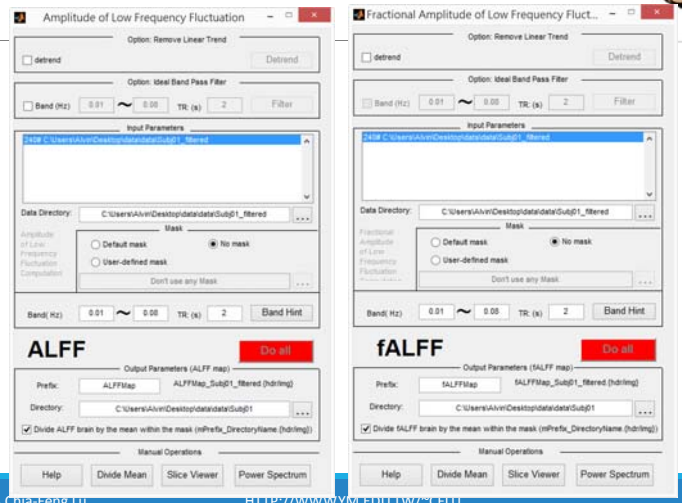
A fractional ALFF (fALFF) approach, i.e., the ratio of power spectrum of low-frequency (0.01–0.08 Hz) to that of the entire frequency range.

The non-specific signal components in the cistern areas in resting-state fMRI were significantly suppressed, indicating that the fALFF approach improved the sensitivity and specificity in detecting spontaneous brain activities.

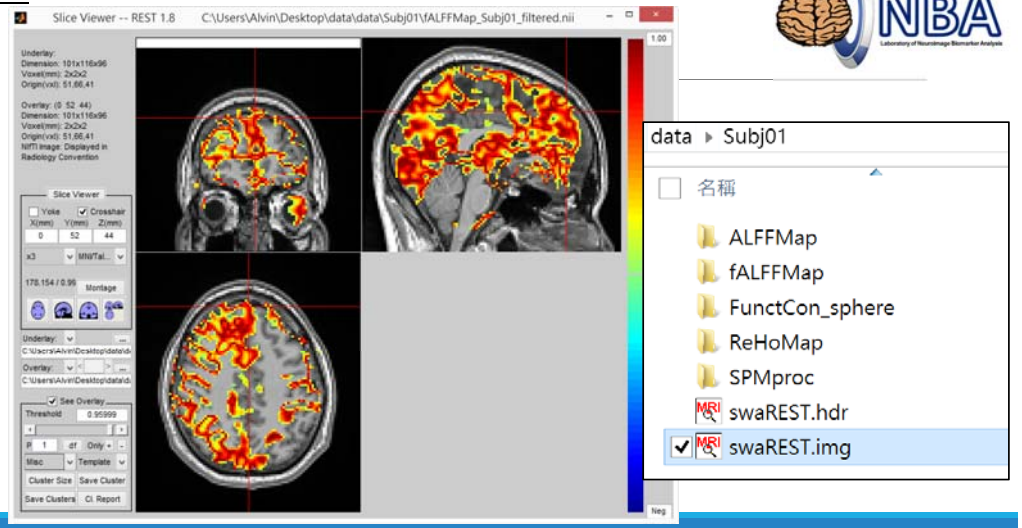
Zou et al., J Neurosci Methods 2008

ALFF & ALFF

ALFF/fALFF Setup



fALFF



Q & A

臺北醫學大學
轉譯影像研究中心
Translational Imaging Research Center
Taipei Medical University

TIRC Team
2015.7.20 at TMU