Analysis of Functional Magnetic Resonance Imaging (fMRI)

Resting-State Brain Activity – ALFF/fALFF and ReHo

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Teaching Materials

- http://www.ym.edu.tw/~cflu/CFLu_course_fMRIana.html

- ***Week 9: Resting-State Brain Activity***
- ＜***Handout***＞*Lesson9_slides.pdf*

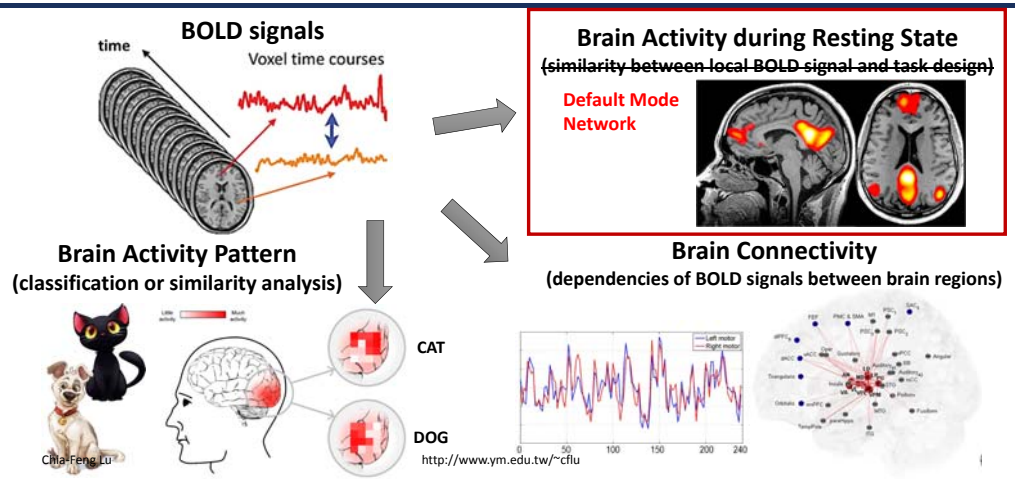
  ＜***Materials***＞*fMRIana09_materials.zip*

Employed Software

- **MRIcro**
  - https://people.cas.sc.edu/rorden/mricro/mricro.html#Installation
  - https://www.mccauslandcenter.sc.edu/crnl/mricro
- **Statistical Parametric Mapping (SPM 12)**
  - http://www.fil.ion.ucl.ac.uk/spm/
- **Data Processing & Analysis for Brain Imaging (DPABI)**
  - http://rfmri.org/dpabi

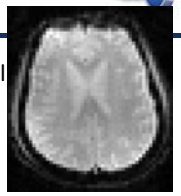
[Caution] File name\path contains Chinese character or space may cause error!

fMRI Analysis

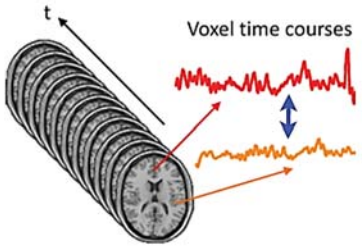


fMRI Protocol

- Siemens 3T MAGNETOM Trio Scanner @ NYMU, 32-channel head coil
- Single-Shot 2D EPI (GRE-EPI), T2* weighting
- Repetition Time = 2000 ms
- Echo Time = 20 ms
- Flip Angle = 70~90°
- NEX = 1
- Slice thickness = 3.4 mm
- Field of View = 220 x 220 mm²
- Matrix size = 64 x 64
- Slice number = 40
- Volume number **(depends on experiment design)**



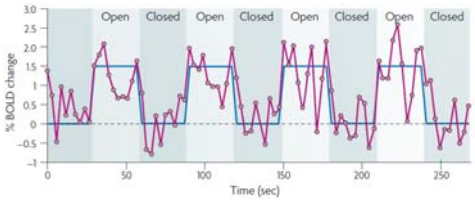
3.44 x 3.44 x 3.40 mm³



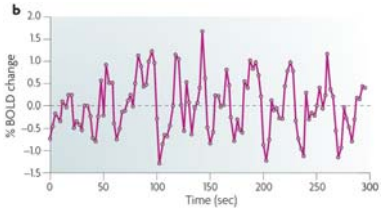
Resting-State fMRI

Spontaneous Fluctuation

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



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

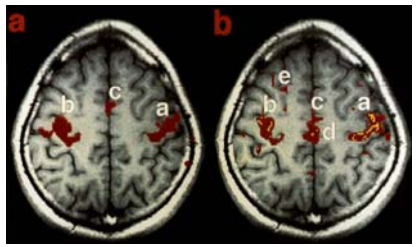


Nature Reviews Neuroscience 8.9 (2007): 700-711.

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. 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)

2. Functional connectivity analysis

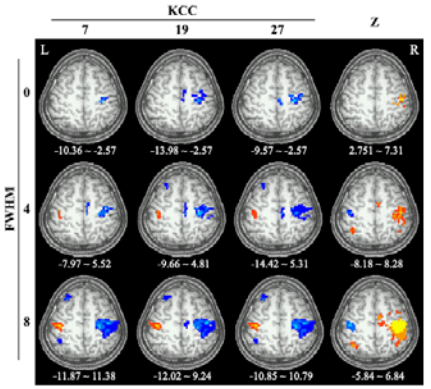
- Linear correlation
- Granger causality analysis (**GCA**), effective connectivity
- Independent component analysis (**GIFT-ICA**; Calhoun et al., NeuroImage 2001)

ReHo

What does ReHo represent?

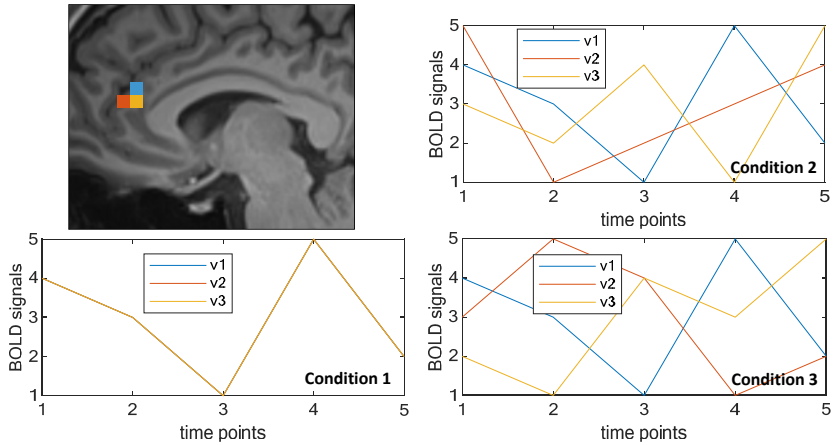
- Regional homogeneity, temporal similarity between neighbor voxels within a small cluster.
- "ReHo supposed that voxels within a functional brain area were more temporally homogeneous when this area is involved in a specific condition."
- Model-free, data-driven ReHo can reflect cortical activation.

KCC: Kendall's coefficient of concordance



Zang et al., NeuroImage 2004.

Measuring similarity between local signals



ReHo

An example of ReHo (KCC)

Condition 1

OBJECTS

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

rank

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)

Condition 2

OBJECTS

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

JUDGES					
	4	3	1	5	2
j: 3 voxels within a cluster	5	1	2	3	4
	3	2	4	1	5

K=3

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)

Condition 3

OBJECTS

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

JUDGES					
	4	3	1	5	2
j: 3 voxels within a cluster	3	5	4	1	2
	2	1	4	3	5

K=3

R_1=9, R_2=9, R_3=9, R_4=9, R_5=9,

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

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

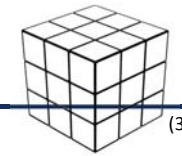
$$S = \sum_{i=1}^{n} (Ri - \bar{R})^2$$

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

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

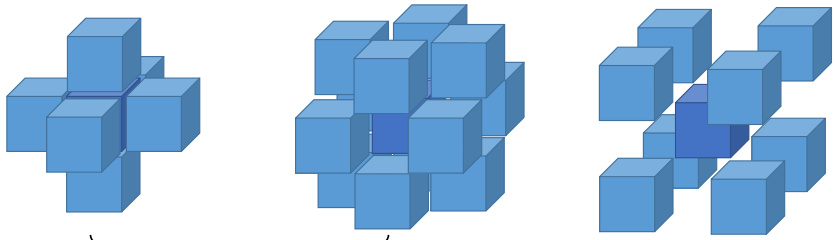
$$W = \frac{12 \times 0}{9(125 - 5)} = 0$$ ➔ **Total disagreement**

Neighbors & Cluster size



(3 by 3 cube)

Surface connected (6) **Edge connected (12)** **Corner connected (8)**



6+1= 7-voxel cluster

6+12+1= 19-voxel cluster

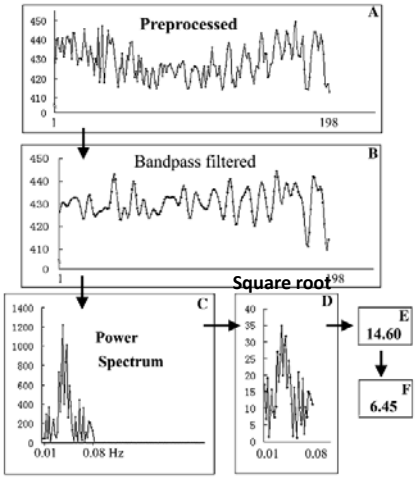
6+12+8+1= 27-voxel cluster

What does ALFF represent?

- Regional activation (regional activity during resting state) measured by the amplitude of low frequency fluctuation (ALFF).
- Regional spontaneous neural activity
  - **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.**
  - ALFF is higher in grey matter than in white matter (Biswal et al., 1995).
- 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 flowchart



BOLD time series for a given voxel

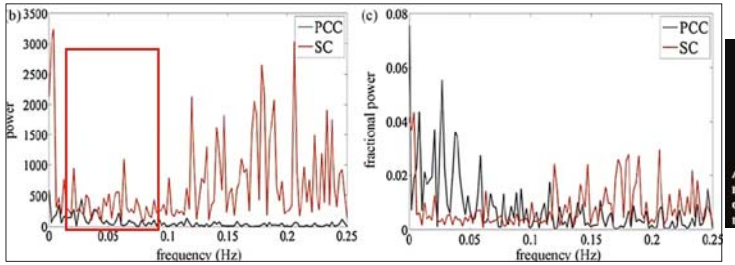
ALFF = Average over 0.01~0.08 Hz

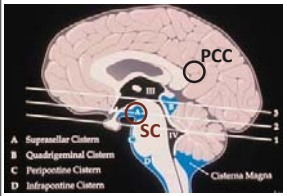
Standardized by divided the ALFF by global mean

Zang et al., Brain & Development 2007

Fractional ALFF (fALFF)

- The ALFF is 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.





Zou et al., J Neurosci Methods 2008

DPABI Toolbox

Introduction and Usage

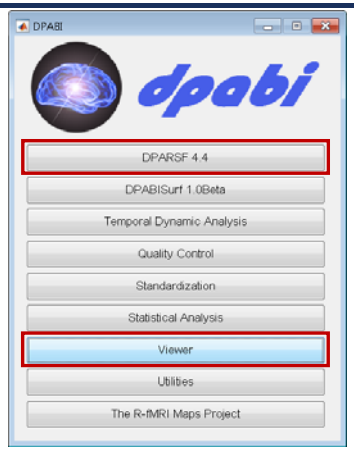
Related Publications

Chao-Gan Yan, et al.

- **DPABI**: Data Processing & Analysis for (resting-state) Brain Imaging, Neuroinformatics 2016 **(more than 300 citations)**
- **DPARSF**: a MATLAB toolbox for" pipeline" data analysis of resting-state fMRI, Frontiers in systems neuroscience, 2010 **(more than 1700 citations)**

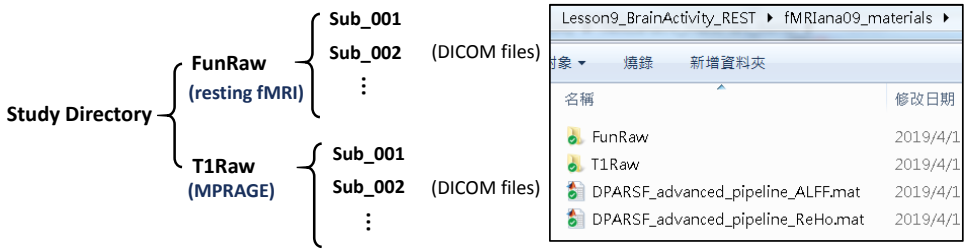
DPABI

- DPABI is evolving from DPARSF, which is based on SPM.
  - **fMRI preprocessing pipeline** (slice timing, realign, segment, normalize, and smooth).
  - **rs-fMRI analyses** (ALFF/fALFF, ReHo, degree centrality, and functional connectivity)
- Online videos
  - http://rfmri.org/WebinarCourse_20160125



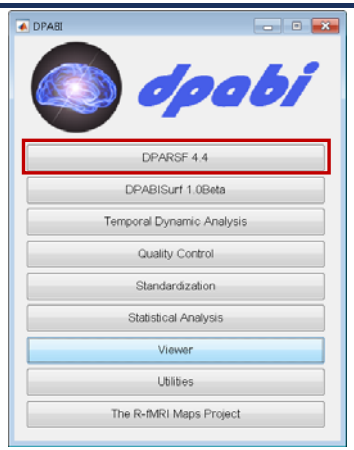
Step 1: Data Organization

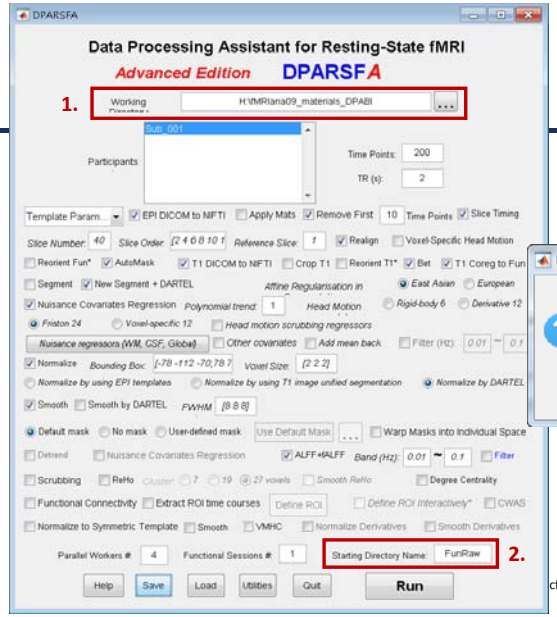
- Before using DPABI toolbox, you have to organize subject data by the following way,



Step 2: Pipeline Setup

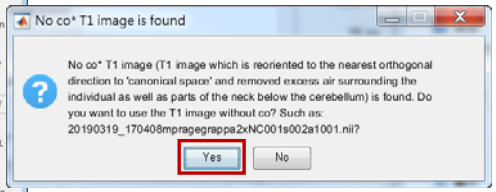
Include DPABI_V4.0_190305 path and key in **dpabi** in MATLAB command window





Step 2: Pipeline Setup

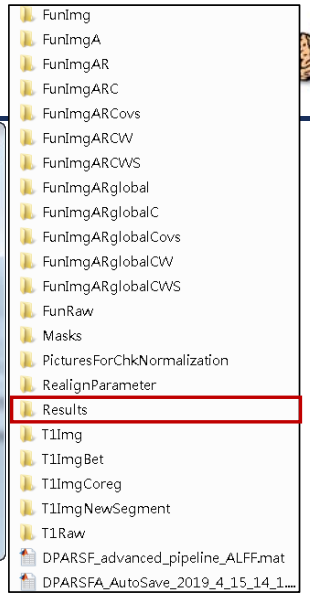
Takes 10~20 minutes for each subject



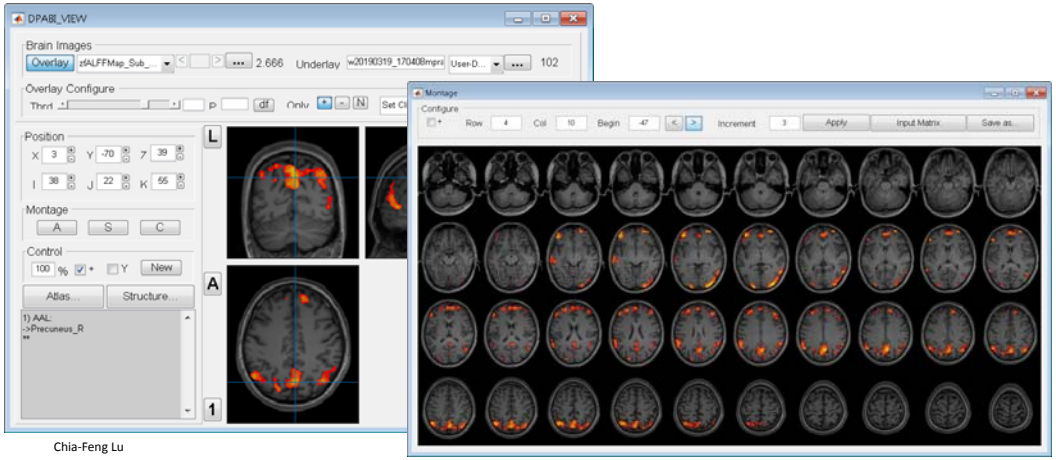
DPARSF_advanced_pipeline_ALFF.mat
DPARSF_advanced_pipeline_ReHo.mat
(Data should not be smoothed before ReHo)

Step 3: Review Results

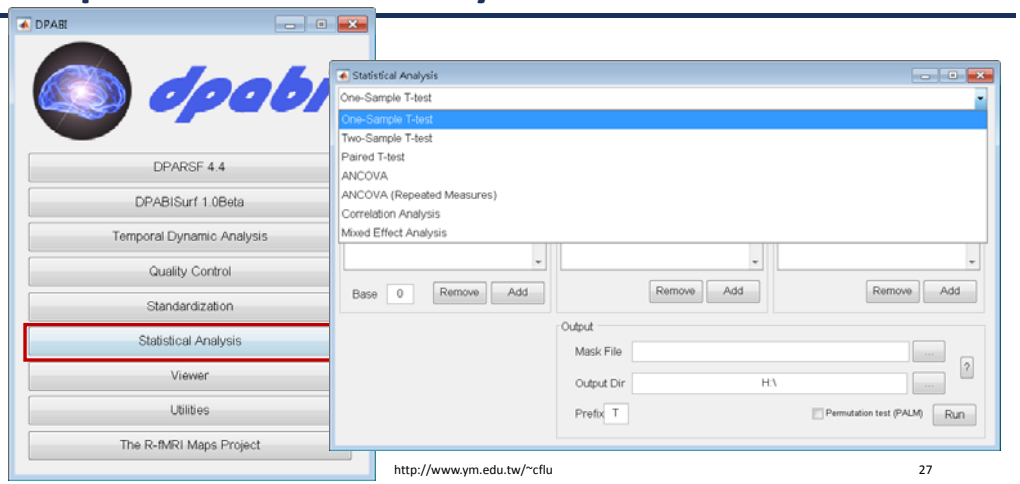
Congratulations, the running of DPARSFA is done!!! :)



Step 3: Review Results



Step 4: Statistical Analysis



Common Errors When using DPABI

- No Chinese character or space is allowed in the file path.
- Please install parallel computing toolbox in MATLAB (e.g., R2019a didn't install this toolbox by default).
- For MAC OS, FreeSurfer is demanded for perform BET process.

THE END

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Teaching Materials: http://www.ym.edu.tw/~cflu/CFLu_course_fMRIana.html