Analysis of Functional Magnetic Resonance Imaging (fMRI)

Brain Network – Independent Component Analysis

盧家鋒 Chia-Feng Lu, Ph.D.

Laboratory of Neuroimage Biomarker Analysis,
Department of Biomedical Imaging and Radiological Sciences,
National Yang-Ming University
alvin4016@ym.edu.tw

April 23, 2019

Teaching Materials

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

- ***Week 10: Brain Network – Independent Component Analysis***
- ＜***Handout***＞*Lesson10_slides.pdf*

  ＜***Materials***＞*fMRIana10_materials.zip*

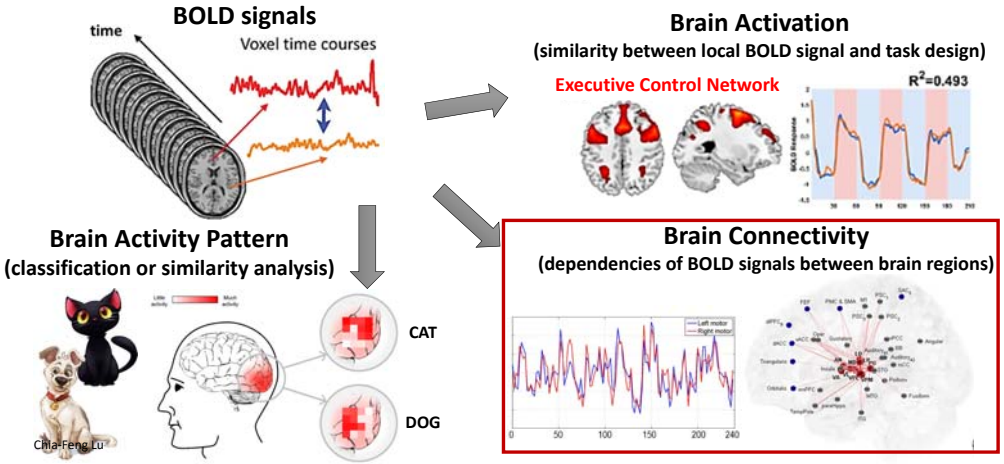
Employed Software

- **MRIcro**
  - https://people.cas.sc.edu/rorden/mricro/mricro.html#Installation
  - https://www.mccauslandcenter.sc.edu/crnl/mricro
- **Group ICA of fMRI Toolbox (GIFT)**
  - http://mialab.mrn.org/software/gift/

MIALAB
MEDICAL IMAGE ANALYSIS LAB

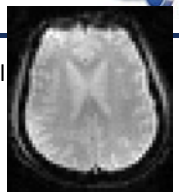
[Caution]
- **File name\path contains Chinese character or space may cause error!**
- **Do not download GtiHub version of GroupICAT v4.0b (incomplete package).**

fMRI Analysis

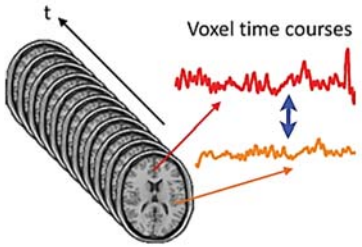


fMRI Protocol

- 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 mm^2
- Matrix size = 64 x 64
- Slice number = 40
- Volume number **(depends on experiment design)**



3.44 x 3.44 x 3.40 mm^3

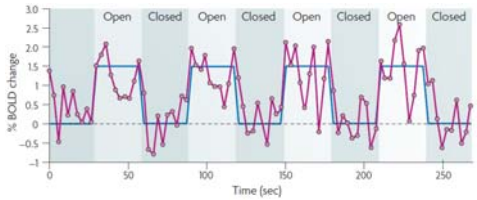


ICA of fMRI

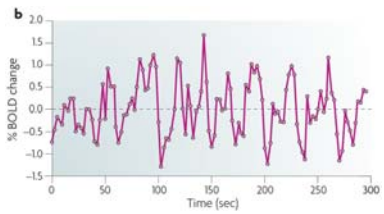
Independent Component Analysis (ICA)

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.

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 (**ICA**; McKeown et al., HBM 1998; Calhoun et al., HBM 2001)

Independent Component Analysis (ICA)

A cocktail-party problem

Speaker 1 Speaker 2 Speaker 3

Microphone 1: $x_1(t) = 0.7s_1(t) + 0.2s_2(t) + 0.1s_3(t)$

Microphone 2: $x_2(t) = 0.3s_1(t) + 0.4s_2(t) + 0.3s_3(t)$

Microphone 3: $x_3(t) = 0.1s_1(t) + 0.2s_2(t) + 0.7s_3(t)$

Blind Source Separation

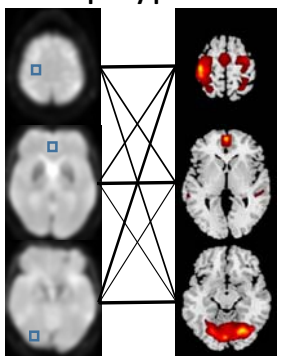
$$\begin{bmatrix} x_1(t) \\ x_2(t) \\ \vdots \\ x_m(t) \end{bmatrix} = \mathbf{A} \begin{bmatrix} s_1(t) \\ s_2(t) \\ \vdots \\ s_k(t) \end{bmatrix}$$

A is the mixing matrix.

Number of microphones ≥ number of speakers

Spatial ICA of fMRI

A cocktail-party problem



Motor Network

Default Mode Network

Visual Network

Number of voxels ≥ number of networks

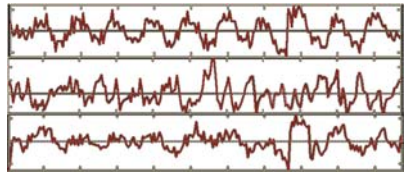
Blind Source Separation

X = AS

Measurements (fMRI data)

Sources (Maximally spatially independent network)

Mixing matrix (time courses of the sources)

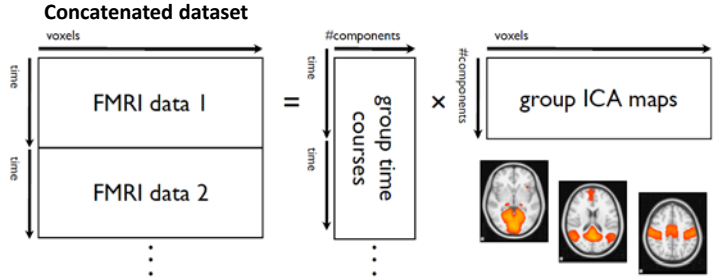


ICA Types

- For fMRI data, temporal and spatial ICA are possible, but spatial ICA is by far the most common approach.
- **Spatial ICA** – Independent components are estimated by maximizing independence in space (spatially independent).
- **Temporal ICA** – Independent components are estimated by maximizing independence in time.

Group-wise ICA

- Group analysis of fMRI is important to study specific conditions within or between groups of subjects.



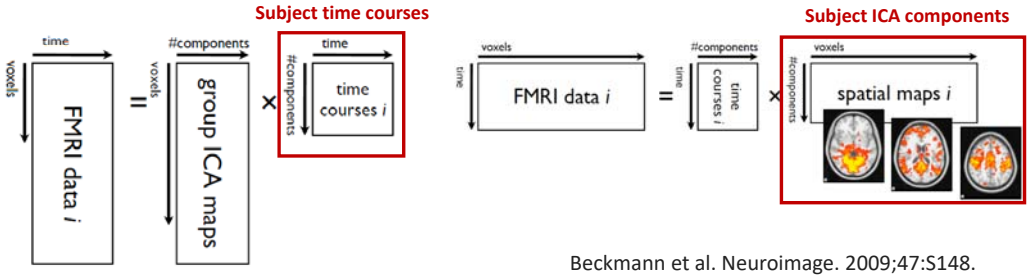
Beckmann et al. Neuroimage. 2009;47:S148.

Reconstructed Subject ICA

- Dual Regression

Using the group-level spatial maps as a set of spatial regressors in a GLM, to find temporal dynamics associated with each group-level map.

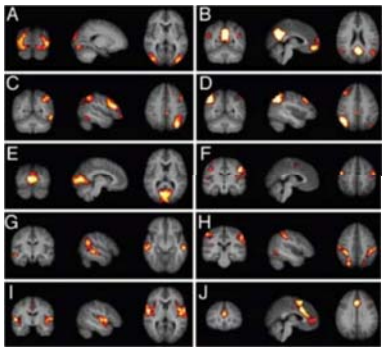
Using these time courses as a set of temporal regressors in a GLM, to find subject specific maps (still associated with the group-level spatial maps).



Beckmann et al. Neuroimage. 2009;47:S148.

Independent Components of rs-fMRI

A. parts of visual cortex
B. default mode network
C & D. left and right memory function
E. visual cortex
F. sensorimotor cortex
G. occipitotemporal pathway (ventral stream)
H. superior parietal cortex
I. auditory cortex
J. executive control & working memory



Consistent resting-state networks across healthy subjects. PNAS 2006, 103 37): 13848-13853.
(cited for more than 3200 times)

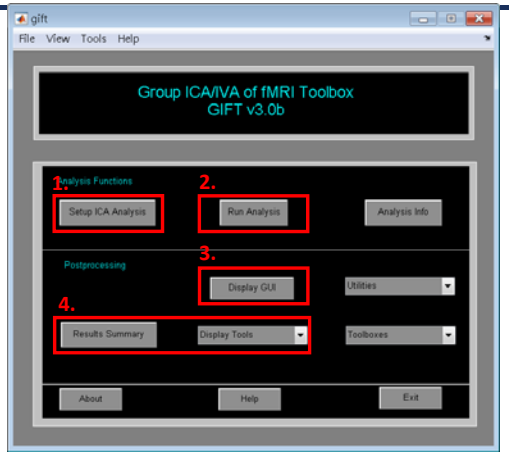
GIFT Toolbox

Group ICA of fMRI Toolbox (GIFT)

Group ICA Of fMRI Toolbox (GIFT)

Include GroupICATv4.0b path and key in gift in MATLAB command window

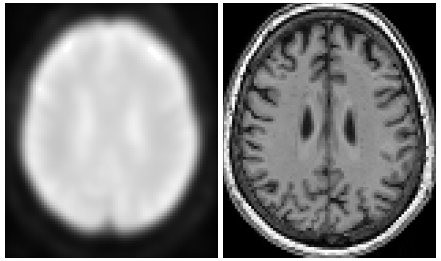
- GIFT is a MATLAB toolbox which implements multiple algorithms for independent component analysis and blind source separation of group (and single subject) functional magnetic resonance imaging data.



http://mialab.mrn.org/software/gift/

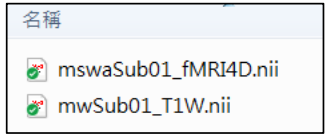
Data Organization

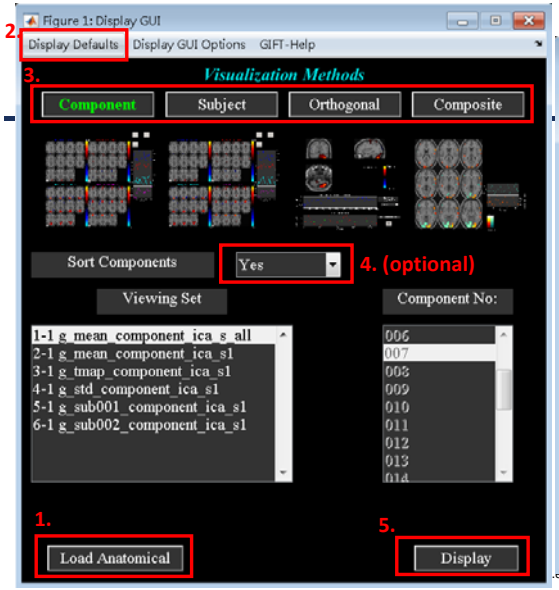
- Before using GIFT toolbox, you have to finish the fMRI preprocessing (e.g., slice timing, realignment, normalization, smoothing, **and bias correction**)

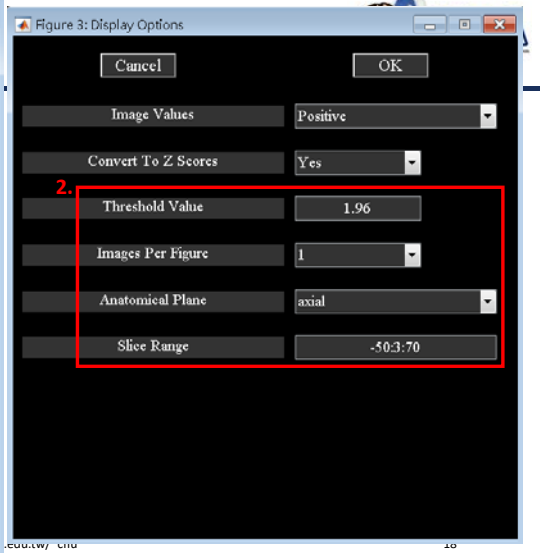


fMRI for 10-block motor tasking

Preprocessed msw*.nii data
mw*.nii data



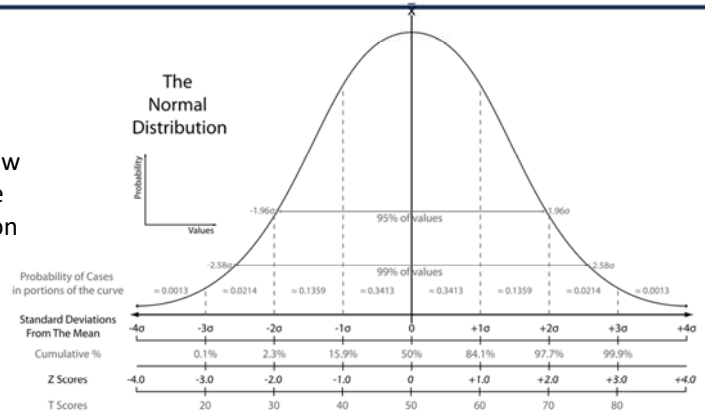




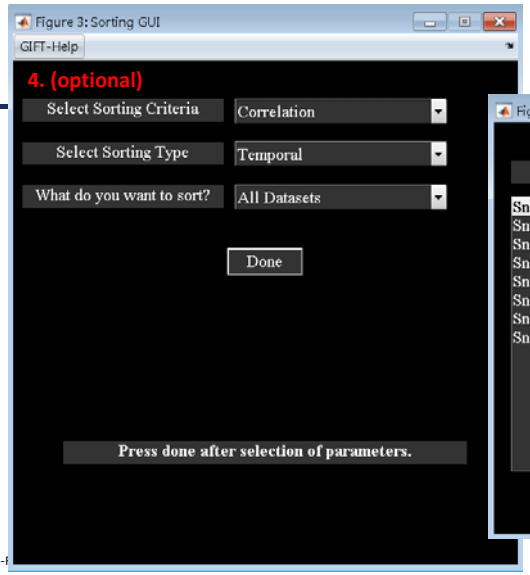
Z Score

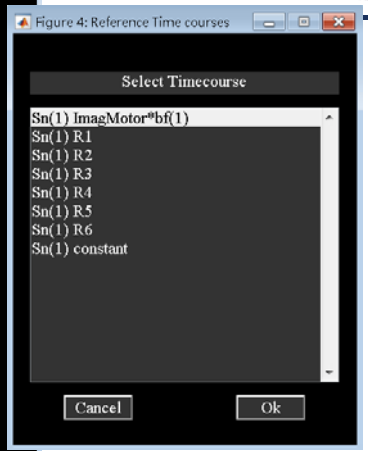
Z score is calculated by subtracting the population mean from an individual raw score and then dividing the difference by the population standard deviation.

$$z = \frac{x - \mu}{\sigma}$$

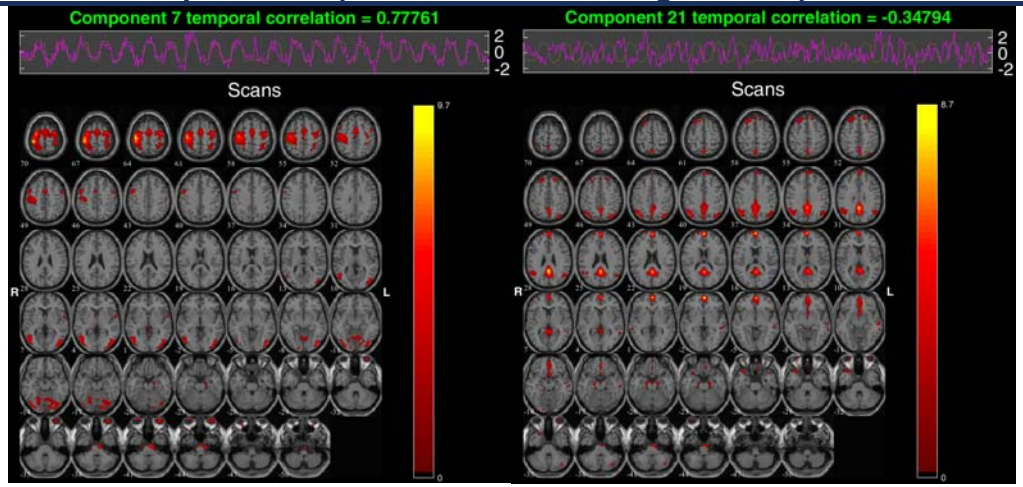


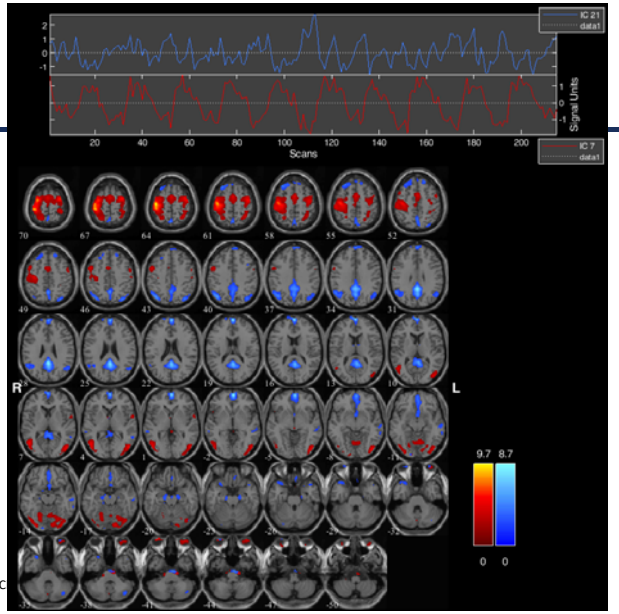
https://en.wikipedia.org/wiki/Standard_score





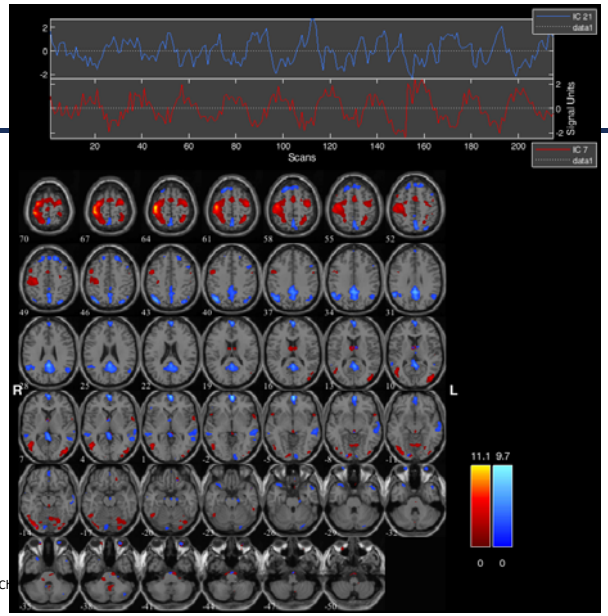
Component Display
with temporal sort (correlation with design matrix)





Composite Display

<GIFT mean maps>



Composite Display

<sub001 maps>

Network Summary

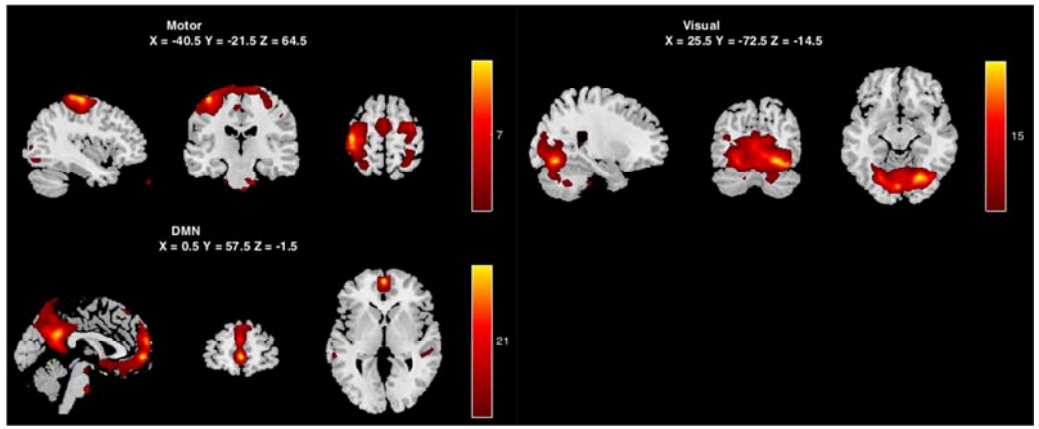
- Create an **IC_network_summary.html**

Contents

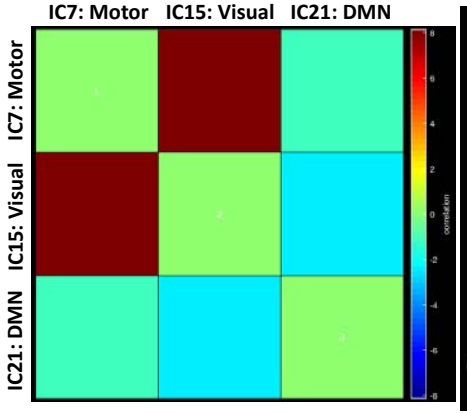
- Rendering: Multiple components are rendered on surface of a 'standard' brain
- FNC correlations: Correlations are visualized in a matrix plot
- Connectogram view - FNC correlations are shown using bezier curves and thumbnails of spatial maps are shown in a circle. Components within the same network are shown in the same color.
- Multiple components are displayed in a composite plot. Orthogonal slices are shown.
- Stacked ortho slices are shown for each component in the network. Title shows component numbers plotted from top to bottom

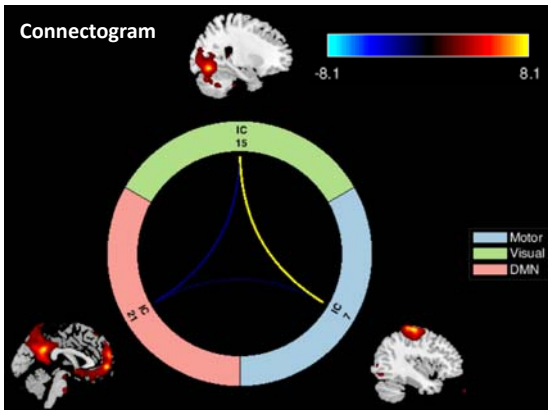
fMRIana10_materials\NetworkSummary\IC_network_summary.html

Network Summary



Functional Network Connectivity (FNC)/ Connectogram





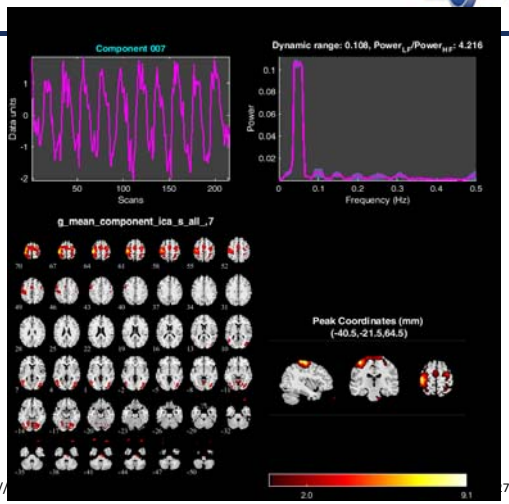
Results Summary

- Create an **icatb_gica_html_report.html**

Contents

- Group ICA Parameters
- ICASSO Plots
- Mean Components
- Spectral Summary
- Temporal Stats On Beta Weights
- Kurtosis of timecourses and spatial maps
- FNC correlations
- FNC metrics of component spatial maps

fMRIana10_materials\g_gica_results\ icatb_gica_html_report.html



THE END

alvin4016@ym.edu.tw

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