

# Analysis of Functional Magnetic Resonance Imaging (fMRI) Brain Network – Dynamic Functional Connectivity

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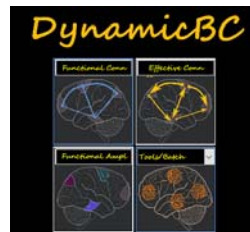
May 21, 2019

## Teaching Materials

- [http://www.ym.edu.tw/~cflu/CFLu\\_course\\_fMRIana.html](http://www.ym.edu.tw/~cflu/CFLu_course_fMRIana.html)
- **Week 13: Brain Network – Dynamic Functional Connectivity**
- <Handout> [Lesson13\\_slides.pdf](#)
- <Materials> [fMRIana13\\_materials.zip](#)

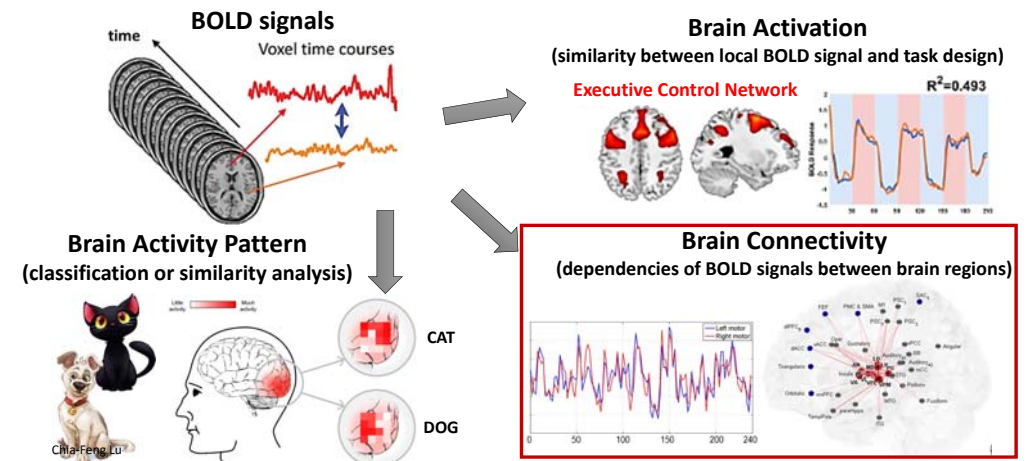
## Employed Software

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



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

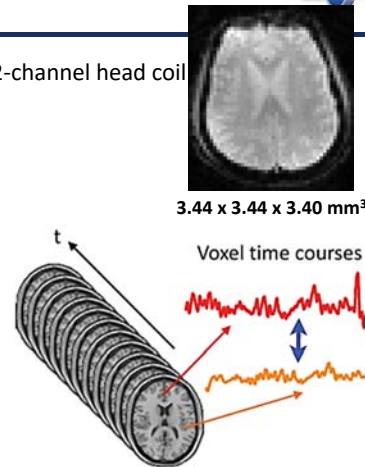
## fMRI Analysis



## 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 mm<sup>2</sup>
- Matrix size = 64 x 64
- Slice number = 40
- Volume number (**depends on experiment design**)



## Dynamic Functional Connectivity (dFC)

## Recommended Readings



- **Dynamic functional connectivity: Promise, issues, and interpretations.**
  - Hutchison et al. NeuroImage 2013.
- **Can sliding-window correlations reveal dynamic functional connectivity in resting-state fMRI?**
  - Hindriks et al. NeuroImage 2016.
- **Tracking Whole-Brain Connectivity Dynamics in the Resting State.**
  - Allen et al. Cerebral Cortex 2014.
- **Assessing dynamic brain graphs of time-varying connectivity in fMRI data: Application to healthy controls and patients with schizophrenia.**
  - Yu et al. NeuroImage 2015.

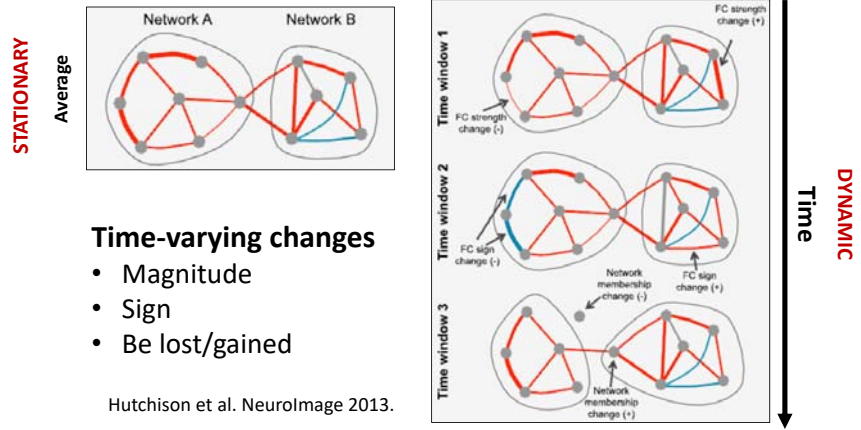
## Emerging evidence suggests...



- *“The brain must dynamically integrate, coordinate, and respond to internal and external stimuli across multiple time scales.”*
  - Hutchison, 2013
- Functional connectivity averaged over the session (**STATIONARY**)
- V.S.**
- Changes of functional connectivity within the session (**DYNAMIC**)

**Presence & Pattern**

# General Concepts – dynamic graphs



## Time-varying changes

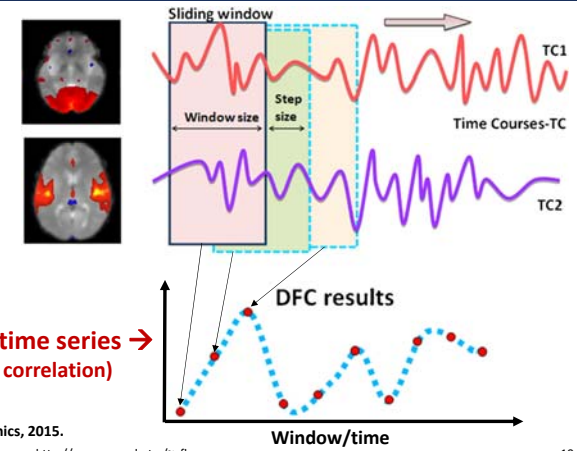
- Magnitude
- Sign
- Be lost/gained

Hutchison et al. NeuroImage 2013.

# General Concepts – time series

## Sliding window approach

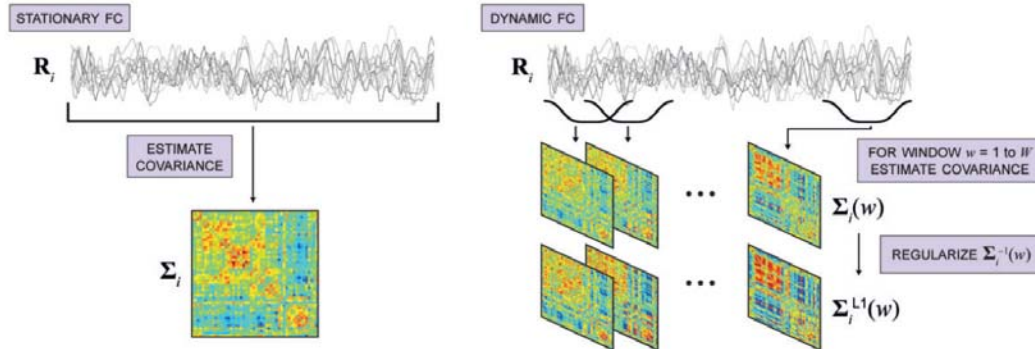
- Window size
- Step size



Akgun et al. Computerized Medical Imaging and Graphics, 2015.

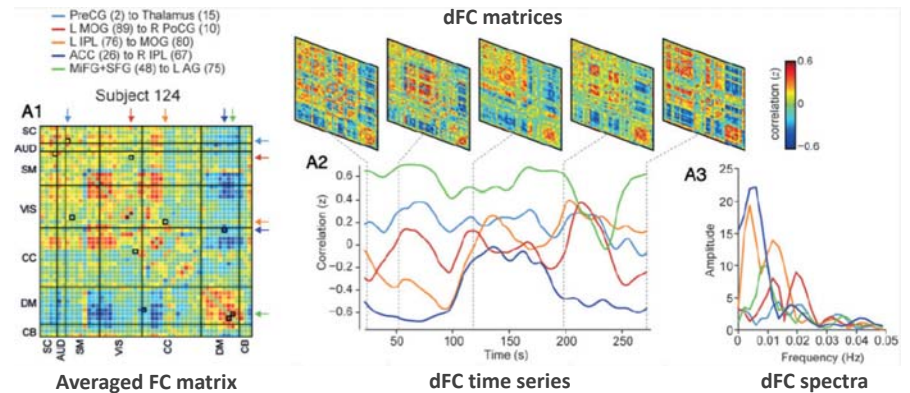
# General Concepts – dynamic connectivity maps

## ASSESSMENT OF FUNCTIONAL CONNECTIVITY (FC) BETWEEN ICNs



Allen et al. Cerebral Cortex 2014.

# General Concepts – pattern of dFC



Allen et al. Cerebral Cortex 2014.



## Key/Open Questions

- What is the neural origin, mechanism, and function of dFC?
- What are the contributions to FC fluctuations from motion, physiological noise, and scanner noise?
- What are the optimal setups to measure dFC using fMRI?

➔ Interpretation & clinical application?

What is the neural origin, mechanism, and function of dFC?



## Basis of dFC

### • Reflecting anatomy and functions

- FC between bilateral homologues shows the least variability in connection over time, followed by the FC of nodes within sensory and motor networks.
- Higher-level regions showing greater FC variability tend to be involved in a greater range of functions and have a high degree of flexibility.

Gonzalez-Castillo et al., 2012.

What is the neural origin, mechanism, and function of dFC?



## Basis of dFC

### • Correlating with autonomic states

- The brainstem, thalamus, putamen, and dlPFC, was found to become more strongly coupled with the dACC during states of elevated HRV.

Chang et al., 2013.

What is the neural origin, mechanism, and function of dFC?



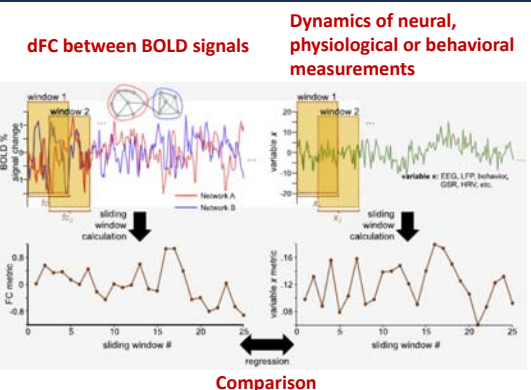
## Basis of dFC

### • Concurrent EEG measurements

- Fluctuations in the power of different frequencies of the EEG jointly contribute to the BOLD signals of resting-state networks.

### • Relationship with behavioral response

### • Modulation with conscious states



Mantini et al., 2007.



## dFC or noise?

- Variations of dFC
  - Low signal-to-noise ratio
  - Changing levels of non-neural noise (cardiac and respiratory processes and hardware instability)
  - Variations in the BOLD signal mean and variance over time



## Recommended parameters

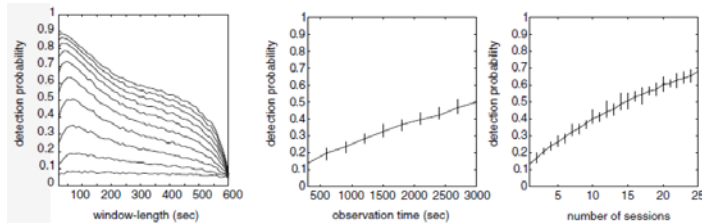
- Typical fMRI acquisitions for stationary FC
  - A single scan of approximately 5-10 min
  - A repetition time (TR) in the range of 2-3 s
  - Whole-brain coverage
- Correlation values within and between intrinsic connectivity networks stabilize within 4-5 min of data.

Van Dijk et al., 2010.



## Recommended parameters

- Empirically, **window sizes around 30-60s** have been noted to produce results in conventional acquisitions.



Hindriks et al. NeuroImage 2016.

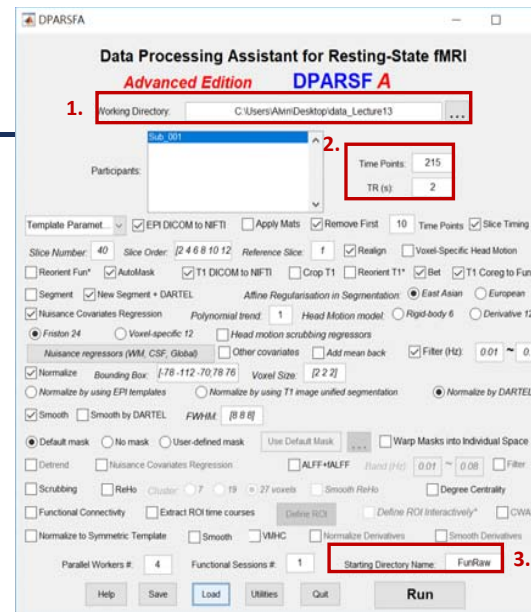
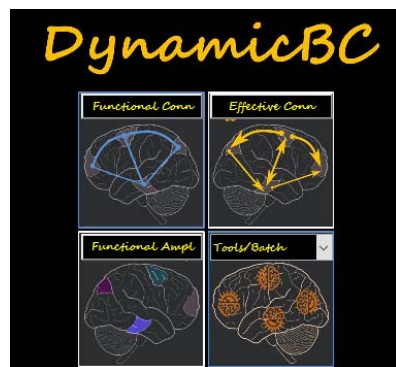
- Multi-scale approaches (**time-frequency analysis**) may provide an alternative solution.



## DynamicBC Toolbox

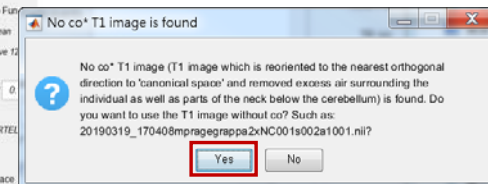
# DynamicBC Toolbox

- Dynamic brain connectome (DynamicBC) analysis toolbox
  - Dynamic Functional Connectivity (d-FC)
  - Dynamic Effective Connectivity (d-EC)
- Dynamic analysis strategies
  - Sliding window analysis (Bivariate Pearson correlation and Granger causality)
  - Time varying parameter regression method (Flexible Least Squares)



## Step 1: Data Preprocessing using DPABI

Takes 10~20 minutes for each subject



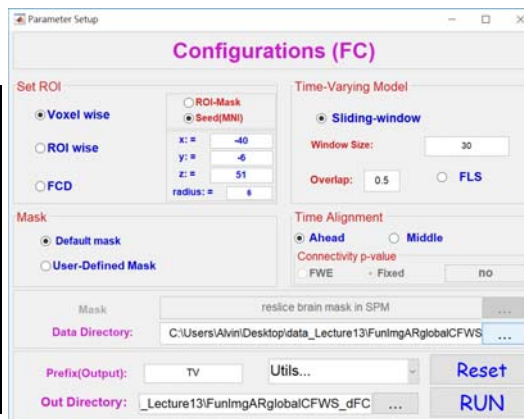
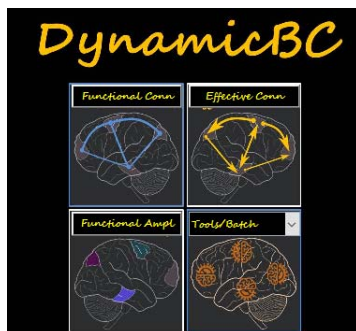
DPARSF\_advanced\_pipeline\_dFC.mat

<https://youtu.be/5Pdrwi5Z5Xc>

# Step 2: Setup dFC parameters

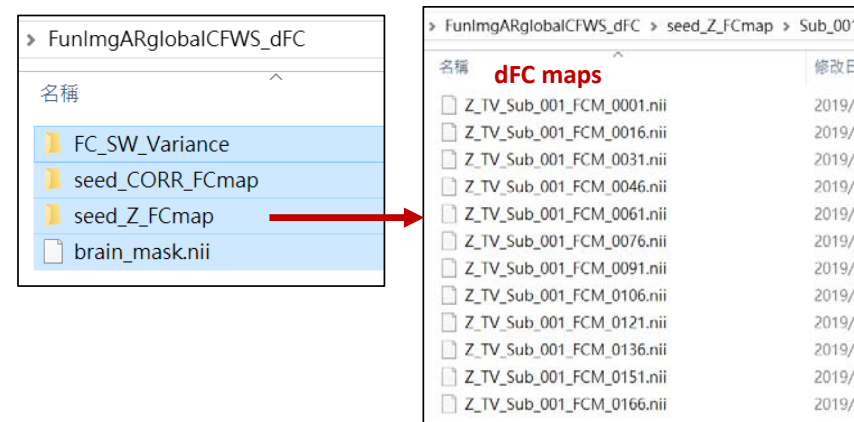
Include DynamicBC2.2\_20181112 path and key in **DynamicBC** in MATLAB command window

## Calculate dFC maps

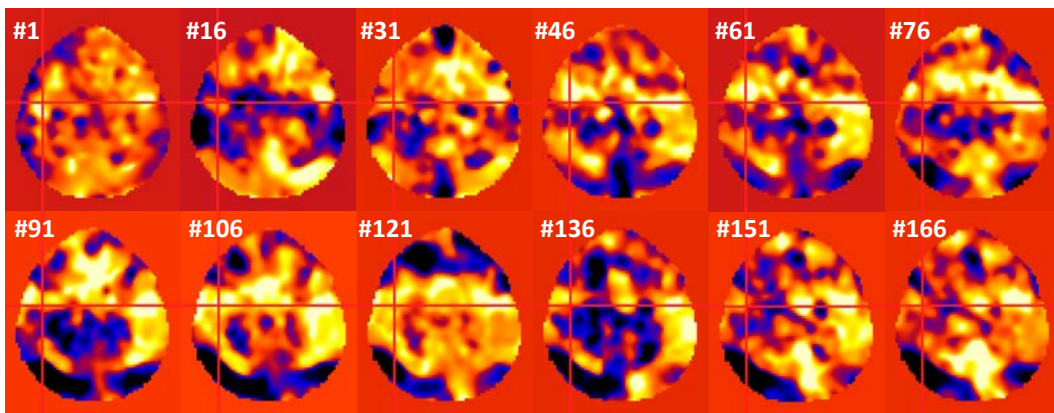


Keyin **parpool** in command window before running the analysis.

# Step 3: Review Results



## Step 3: Review Results dFC maps



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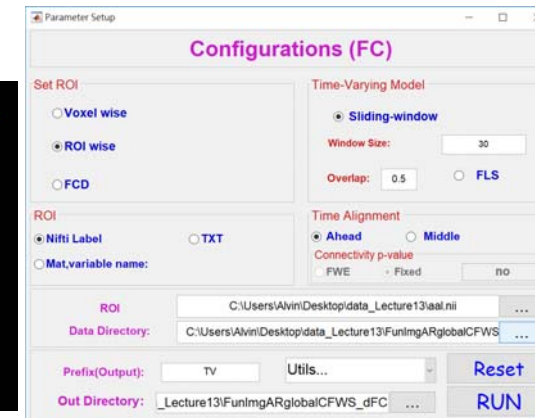
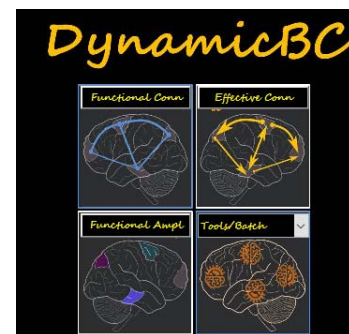
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## Step 2: Setup dFC parameters

Include DynamicBC2.2 20181112 path and key in **DynamicBC** in MATLAB command window

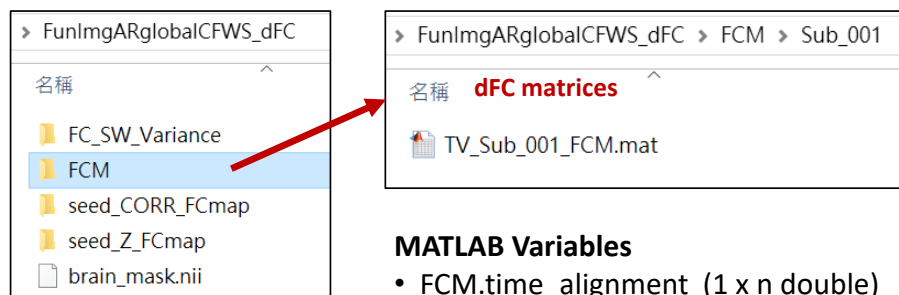
### Calculate dFC matrices



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Keyin **parpool** in command window before running the analysis. 26

## Step 3: Review Results



### MATLAB Variables

- FCM.time\_alignment (1 x n double)
- FCM.Matrix (n x 1 cell)
- FCM.Variance (n x n double)

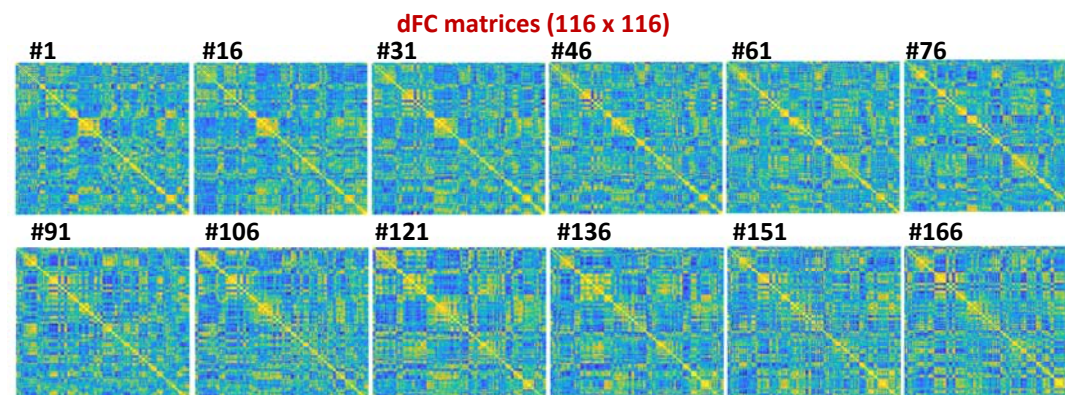
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## Step 3: Review Results

```
for i=1:12
    figure,imagesc(FCM.Matrix{i})
end
```

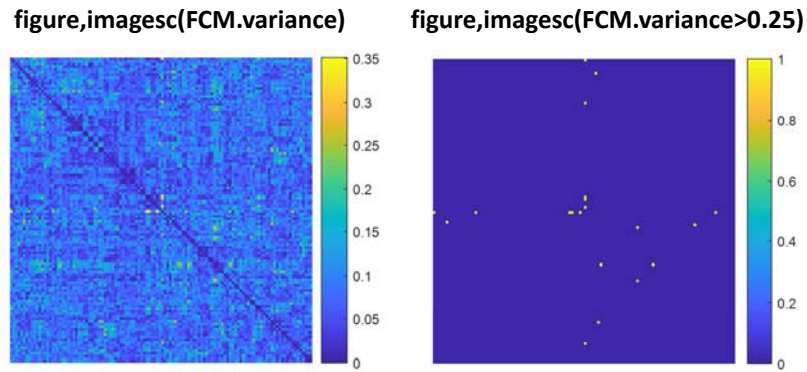


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## Step 3: Review Results



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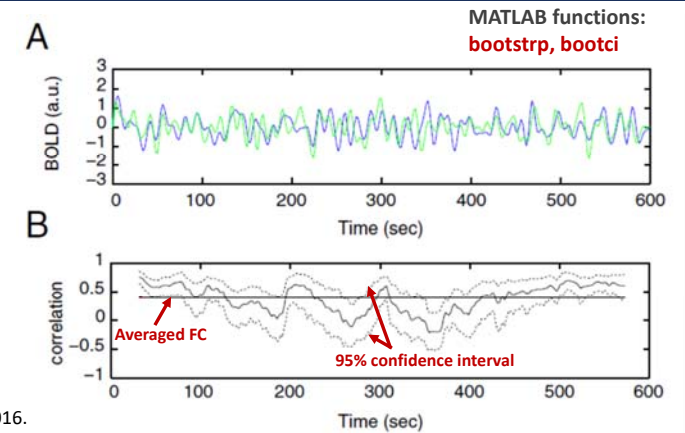
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## Statistical methods

- **H0: stationary FC**  
**H1: dynamic FC between brain regions**
- Bootstrap procedure (sample with replacement)

Hindriks et al. NeuroImage 2016.

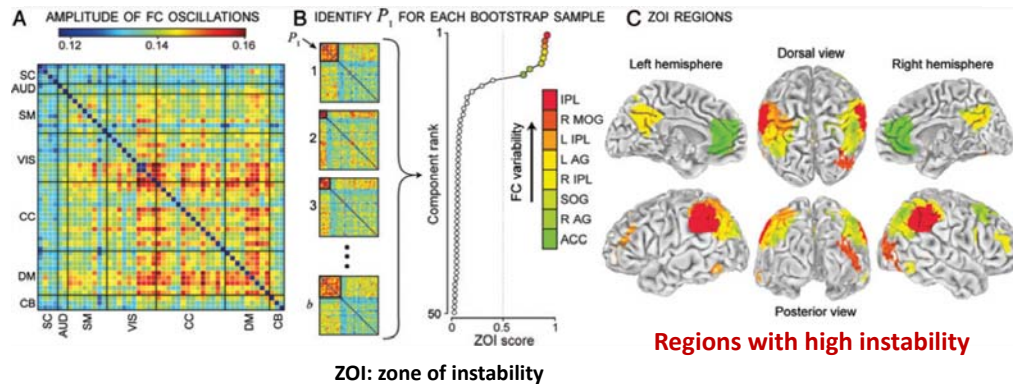
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## Variability of dFC



Allen et al. Cerebral Cortex 2014.

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# THE END

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