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

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## Course Arrangement

PART I
- REST toolbox http://restfmri.net/forum/index.php?q=rest
- ReHo, ALFF, fALFF, Statistics

PART II
- REST toolbox
- Functional connectivity (seed-based, atlas-based)
- FC strength mapping



## Course Arrangement

PART III
- Large-scale network analysis
- Graph theory: topological properties (degree, strength, efficiency, clustering…)

PART IV
- Dynamic functional connectivity



## Dynamic functional connectivity (dFC)

# Recommended Reading

**1. Dynamic functional connectivity: Promise, issues, and interpretations.**
- Hutchison et al. NeuroImage 2013.

**2. Can sliding-window correlations reveal dynamic functional connectivity in resting-state fMRI?**
- Hindriks et al. NeuroImage 2016.

**3. Tracking Whole-Brain Connectivity Dynamics in the Resting State.**
- Allen et al. Cerebral Cortex 2014.

**4. 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.**

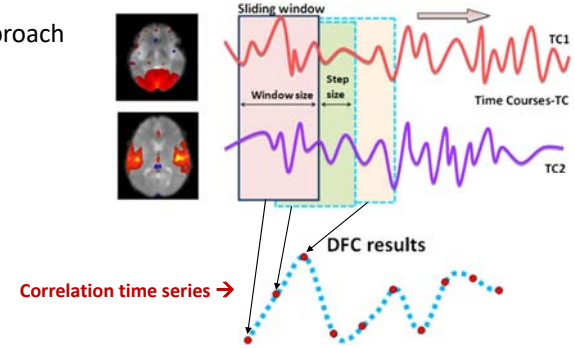
Changes of functional connectivity within the session **(DYNAMIC)**

**Presence & Pattern**



# General Concepts – time series

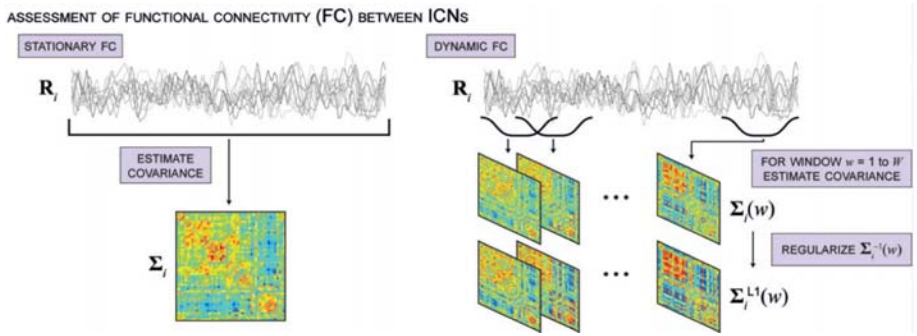
Sliding window approach
- Window size
- Step size




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

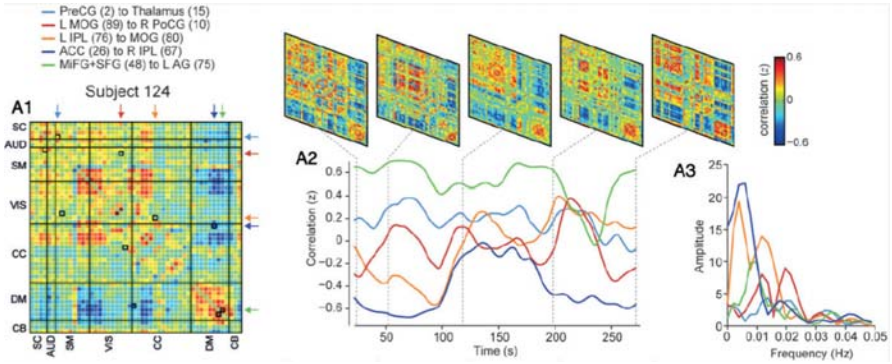


# General Concepts – connectivity maps




Allen et al. Cerebral Cortex 2014.

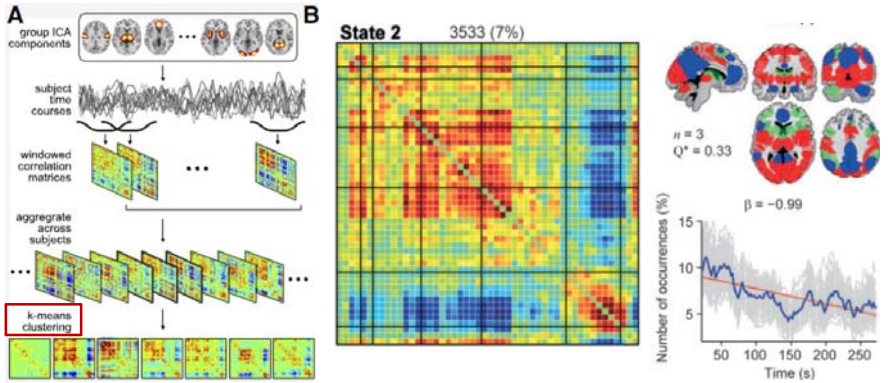
# General Concepts – pattern of dFC




Allen et al. Cerebral Cortex 2014.



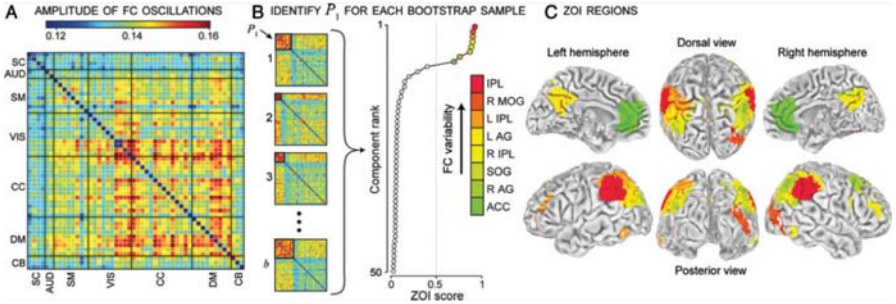
# General Concepts – pattern of dFC




Hutchison et al. NeuroImage 2013; Allen et al. Cerebral Cortex 2014.



# General Concepts – presence of dFC

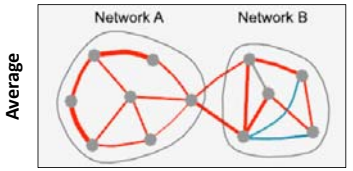



ZOI: zone of instability

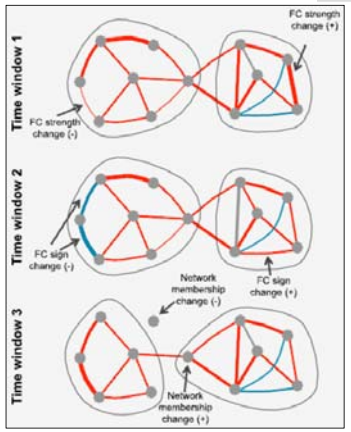
Allen et al. Cerebral Cortex 2014.



# General Concepts – dynamic graphs




Time-varying changes
- Magnitude
- Sign
- Be lost/gained




Hutchison et al. NeuroImage 2013.

# 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?
- What are the statistical pitfalls in the assessment of dFC?

➔ Interpretation & clinical application?





# 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.

- 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.

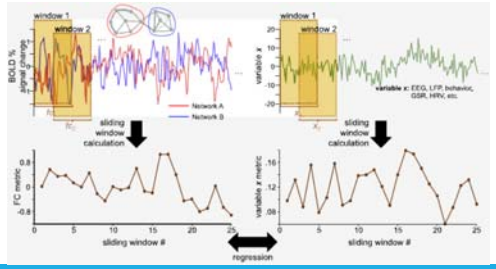
Chang et al., 2013.





# 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. Mantini et al., 2007.
- Relationship with behavioral response
- Modulation with conscious states




Hutchison et al. NeuroImage 2013.





# 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

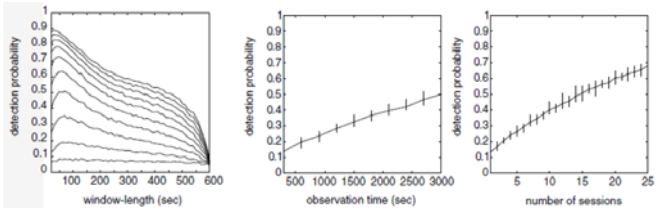
- Typical fMRI acquisitions for stationary FC
  - A single scan of approximately 5-10 min
  - A repetition time (TR) in the range of 2-3 s
  - Whole-brain coverage
- Correlation values within and between intrinsic connectivity networks stabilize within 4-5 min of data. Van Dijk et al., 2010.





# Recommended parameters

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




Hindriks et al. NeuroImage 2016.

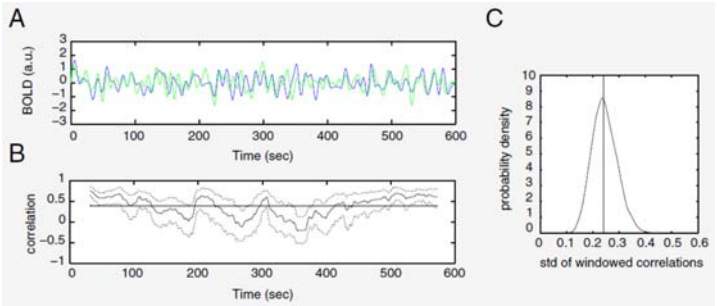
- Multi-scale approaches (time-frequency analysis) may provide an alternative solution.





# Statistical methods

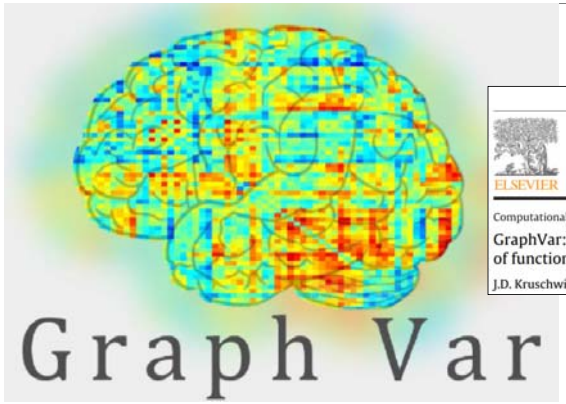
- H0: stationary FC vs. H1: dynamic FC
- Approaches: bootstrap and permutation tests




Hindriks et al. NeuroImage 2016.



# GUI for dFC analysis





Journal of Neuroscience Methods 245 (2015) 107–115
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Journal of Neuroscience Methods
journal homepage: www.elsevier.com/locate/jneumeth
Computational Neuroscience
GraphVar: A user-friendly toolbox for comprehensive graph analyses of functional brain connectivity
J.D. Kruschwitz, D. List, L. Waller, M. Rubinov, H. Walter

**Set Path**
**>> start_GraphVar**

# 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
3. **IBASPM 64-bit**
   - http://www.ym.edu.tw/~cflu/software/Ibaspm_64.zip
4. **Brain Connectivity Toolbox/Network Based Statistic Toolbox**
   - https://sites.google.com/site/bctnet/
5. **Dynamic brain connectome analysis toolbox**
   - http://restfmri.net/forum/index.php
6. **GraphVar**
   - http://www.rfmri.org/graphvar



**Thanks for your attention : )**