

# Functional Connectivity & Network Analysis

Basic concepts and practical applications

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# Contents

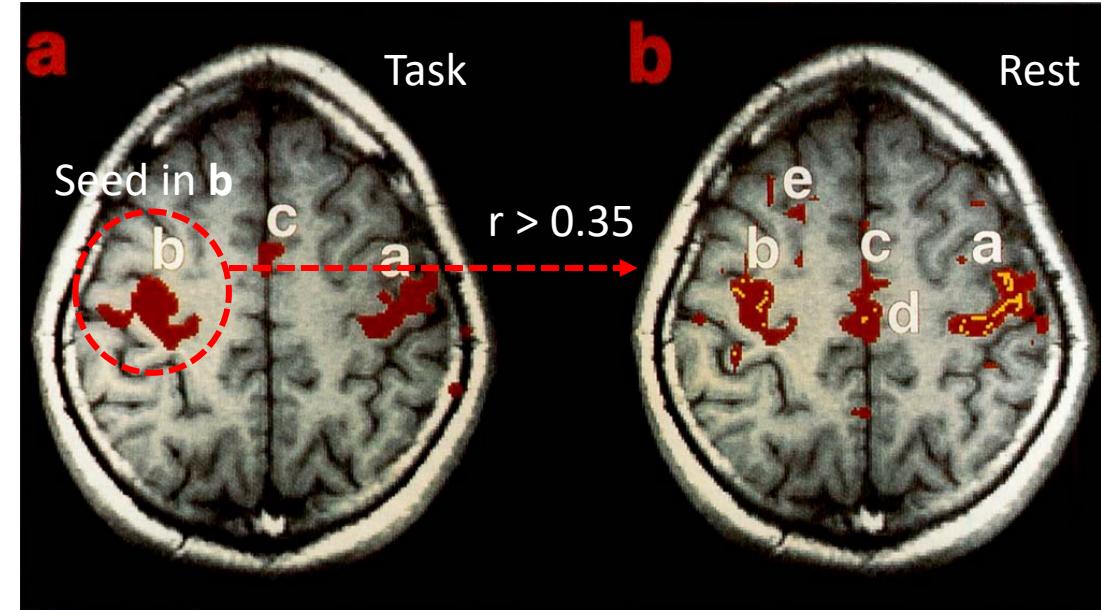
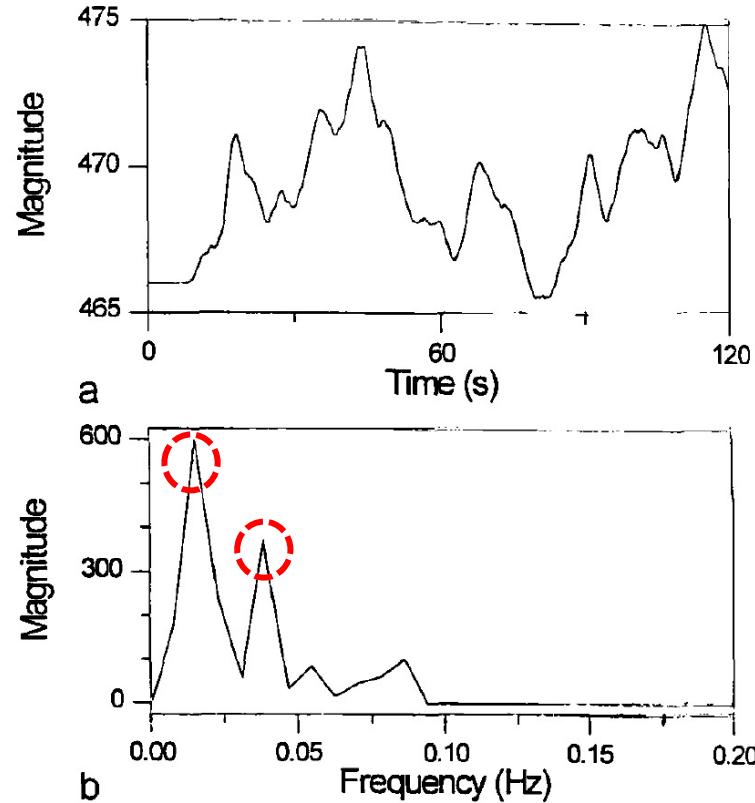
An introduction to the functional connectivity and network analysis

1. Functional connectivity: Overview
2. Functional connectivity: Practice
3. Network analysis: Overview
4. Network analysis: Practice



# What is functional connectivity?

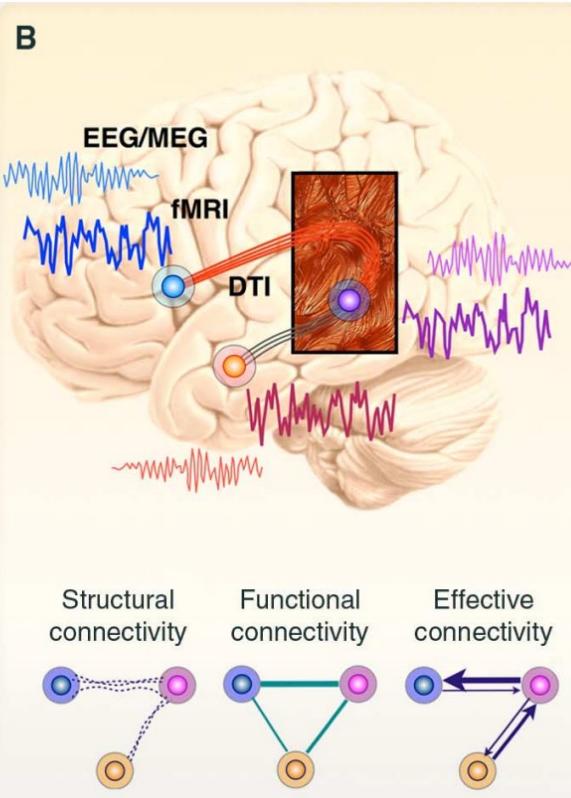
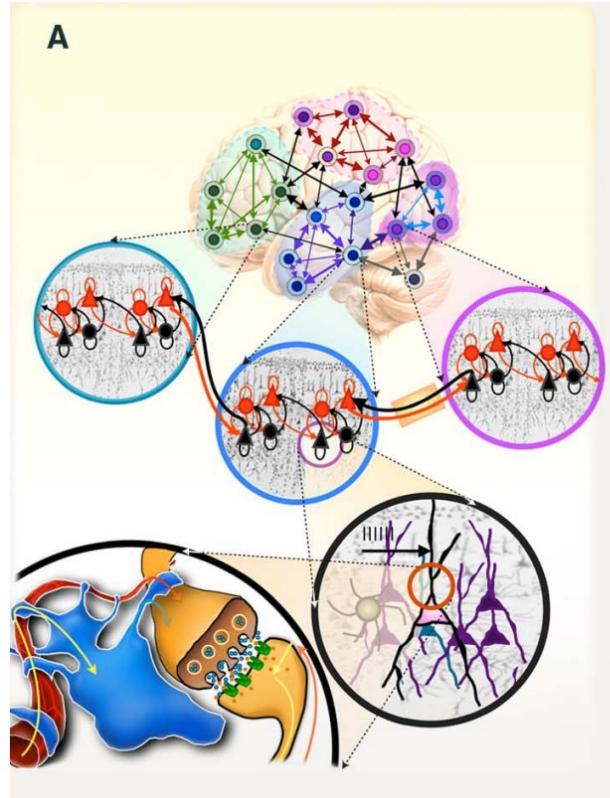
Low-frequency fluctuation seems to be a manifestation of neurophysiological “connection”.



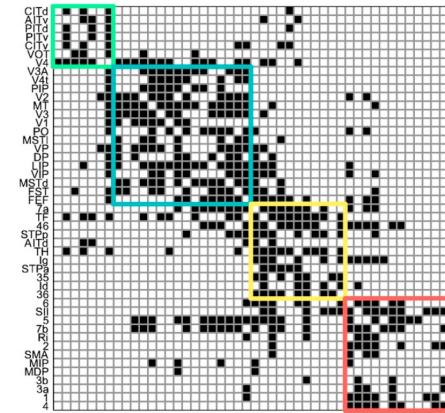
Biswal et al., 1995



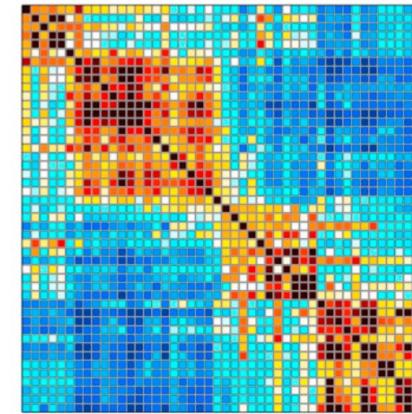
# What is functional connectivity?



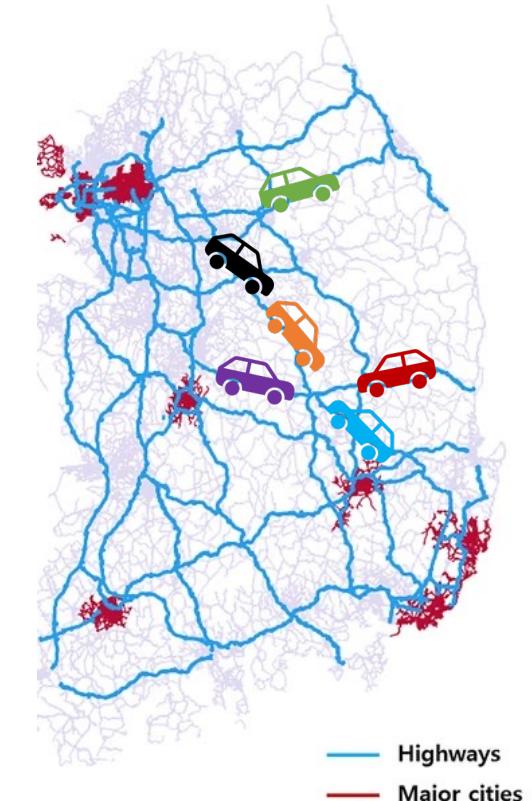
## Structural connectivity



## Functional connectivity

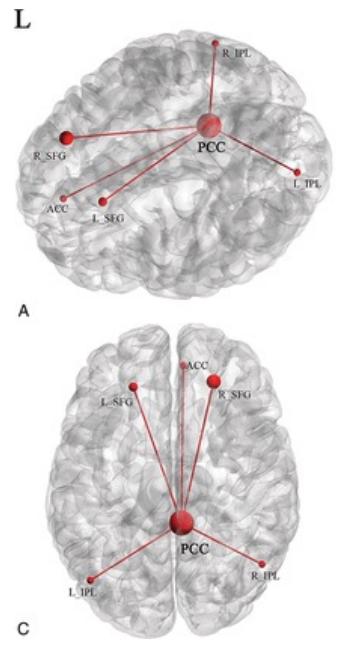


Rubinov & Sporns, 2013

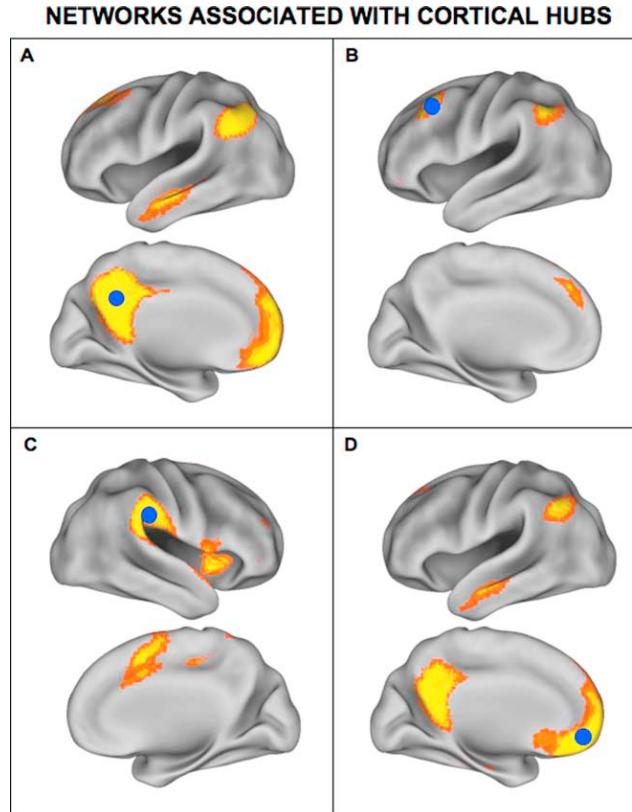


# How to calculate functional connectivity?

## Seed-based correlation

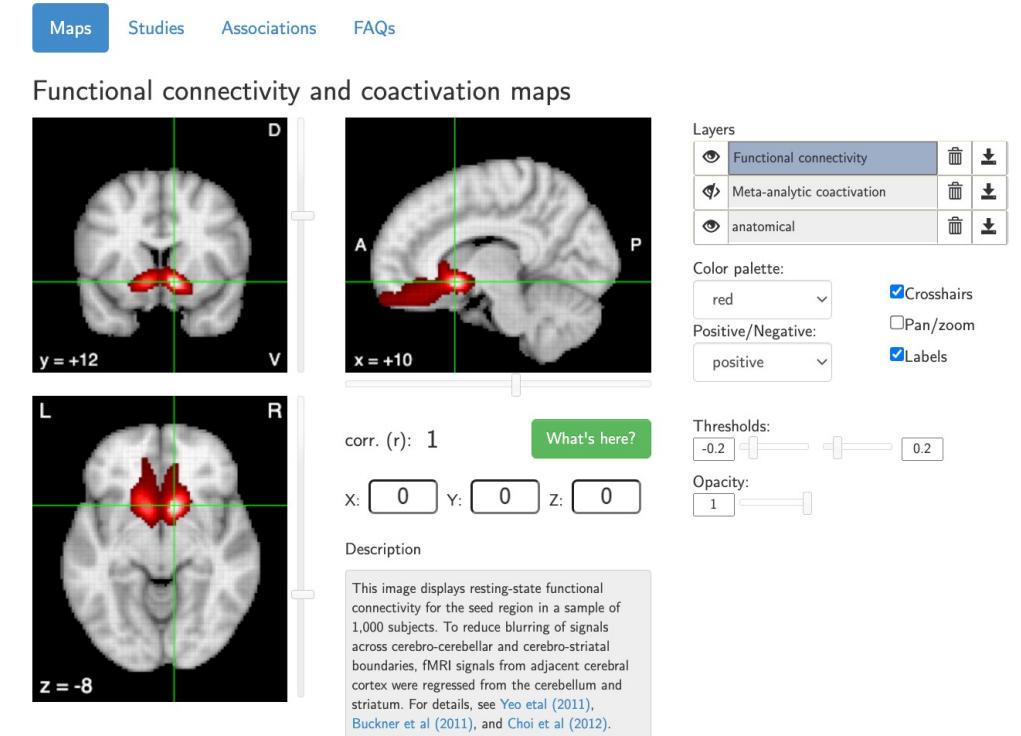


Wang et al., 2018



Buckner et al., 2009

Data for coordinates: 10 12 -8

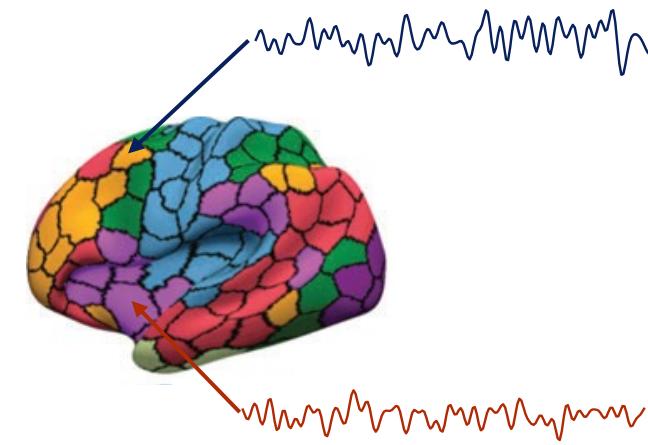


[https://neurosynth.org/locations/10\\_12\\_-8\\_6/](https://neurosynth.org/locations/10_12_-8_6/)

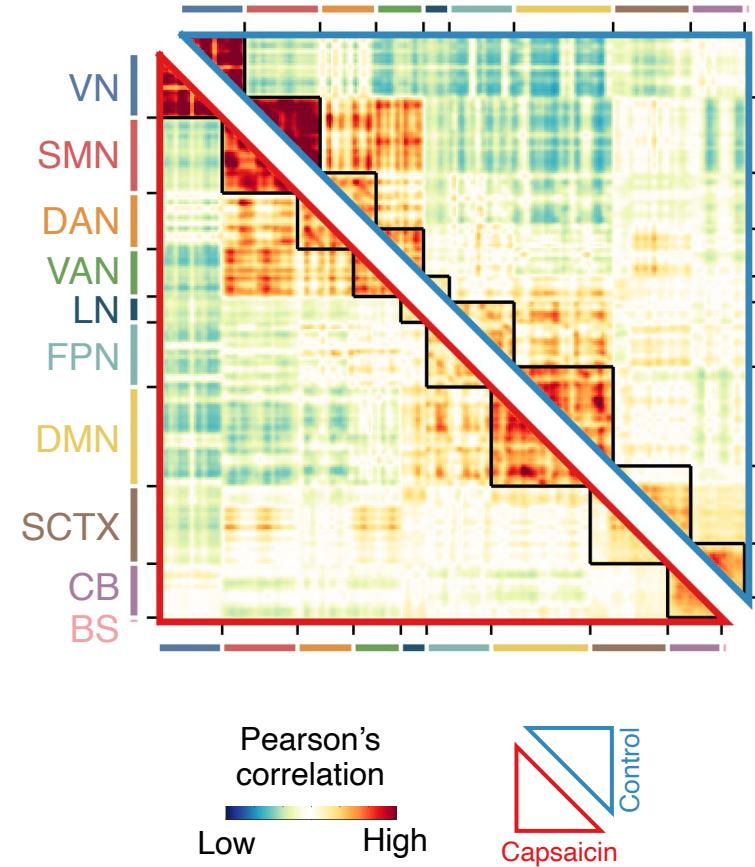


# How to calculate functional connectivity?

## Parcellation-based correlation

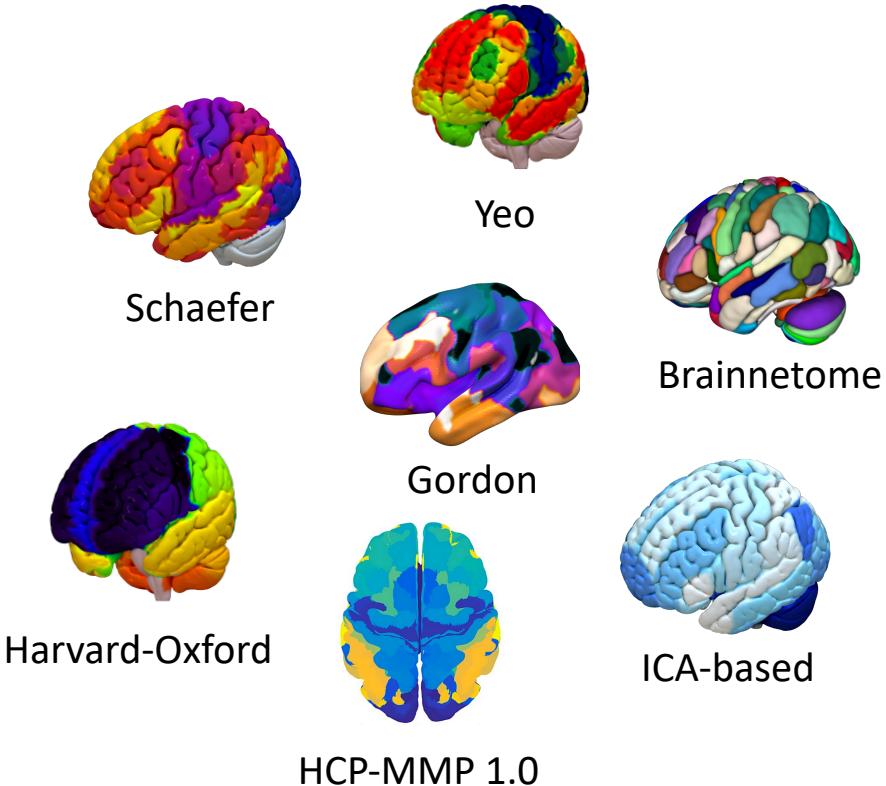


Average signals  
within each ROI



# How to calculate functional connectivity?

## Parcellation



<https://www.lead-dbs.org/helpsupport/knowledge-base/atlasresources/cortical-atlas-parcellations-mni-space/>

Algorithm	Boundary mapping	Clustering or factorization
<b>Markers</b>		
<b>Local</b> Histology-based: <ul style="list-style-type: none"><li>Cytoarchitecture</li><li>Receptors</li><li>Myelin</li></ul> MRI-based: <ul style="list-style-type: none"><li>Myelin</li><li>Meta-analytic activation modelling</li></ul>	Border detection in cortex based on cytoarchitecture 	Clustering of amygdala voxels based on their activation in behavioural paradigms 
<b>Global</b> MRI-based: <ul style="list-style-type: none"><li>Resting-state functional connectivity</li><li>Meta-analytic connectivity modelling</li><li>Diffusion tractography</li><li>Structural covariance</li></ul>	Boundary mapping of resting-state functional connectivity of cerebral cortex 	Clustering of cerebral cortex based on resting-state functional connectivity 

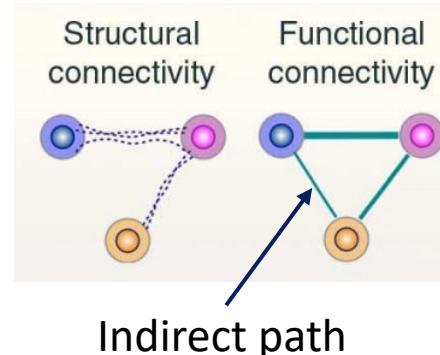
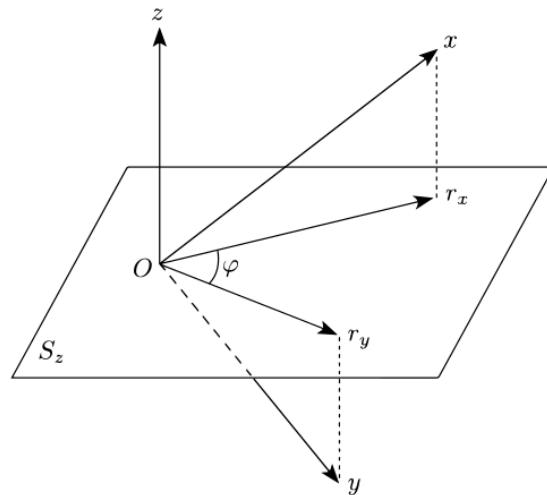
Eickhoff et al., 2018



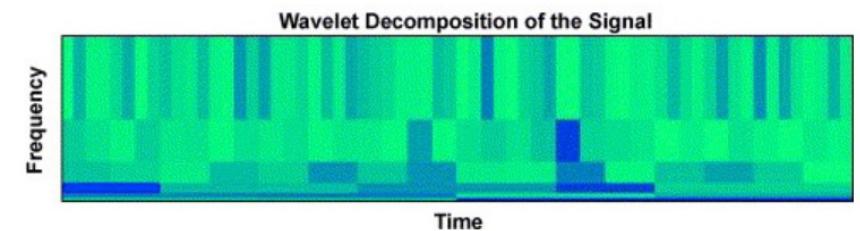
# How to calculate functional connectivity?

What else?

- Partial correlation



- Wavelet coherence

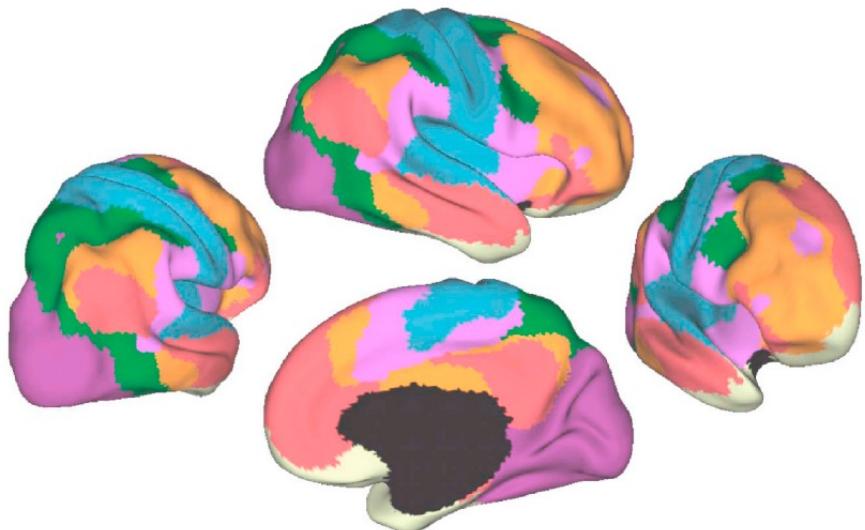


Bullmore et al., 2004



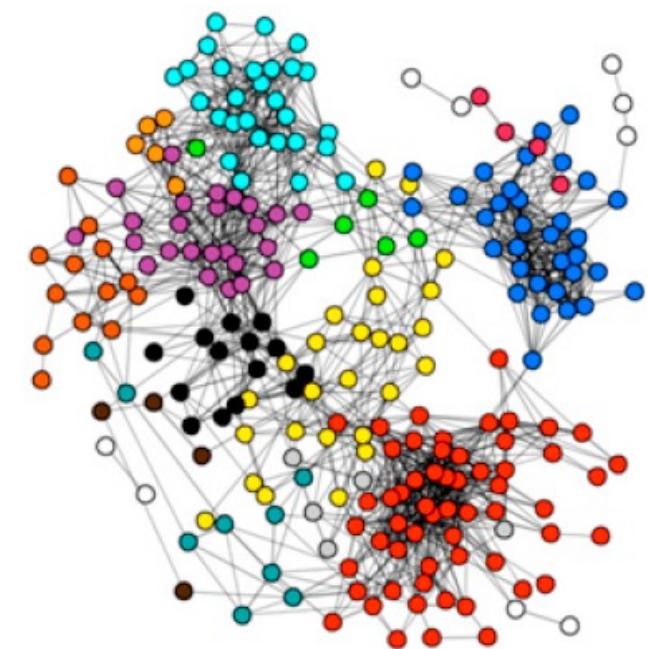
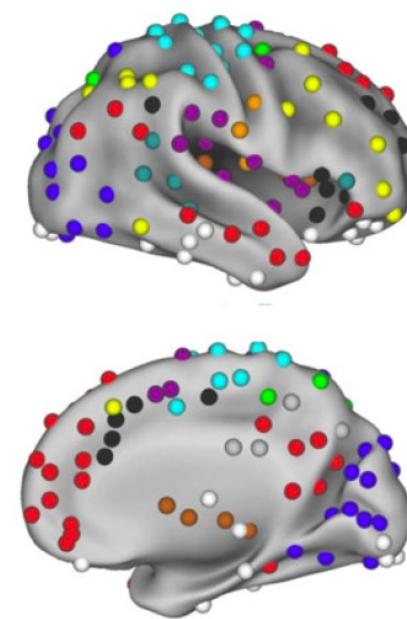
# Why functional connectivity is important?

Functional architecture of brain – e.g., Resting state network



- Purple (Visual)
- Blue (Somatomotor)
- Green (Dorsal Attention)
- Violet (Ventral Attention)
- Cream (Limbic)
- Orange (Frontoparietal)
- Red (Default)

Yeo et al., 2011

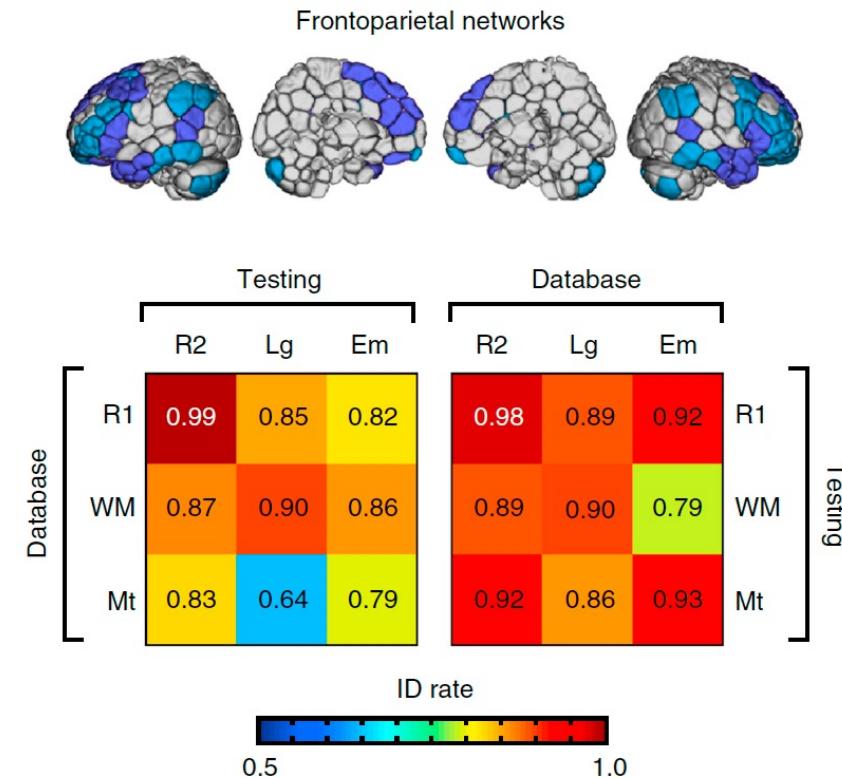
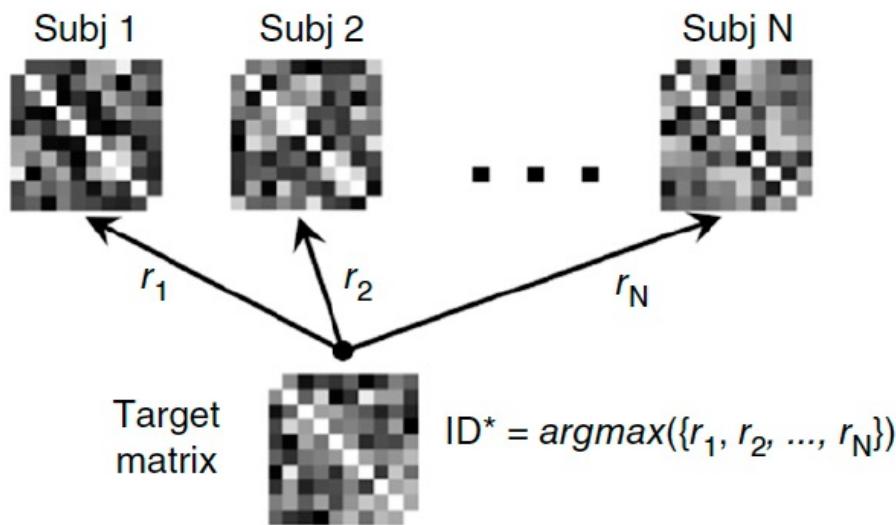


Power et al., 2011



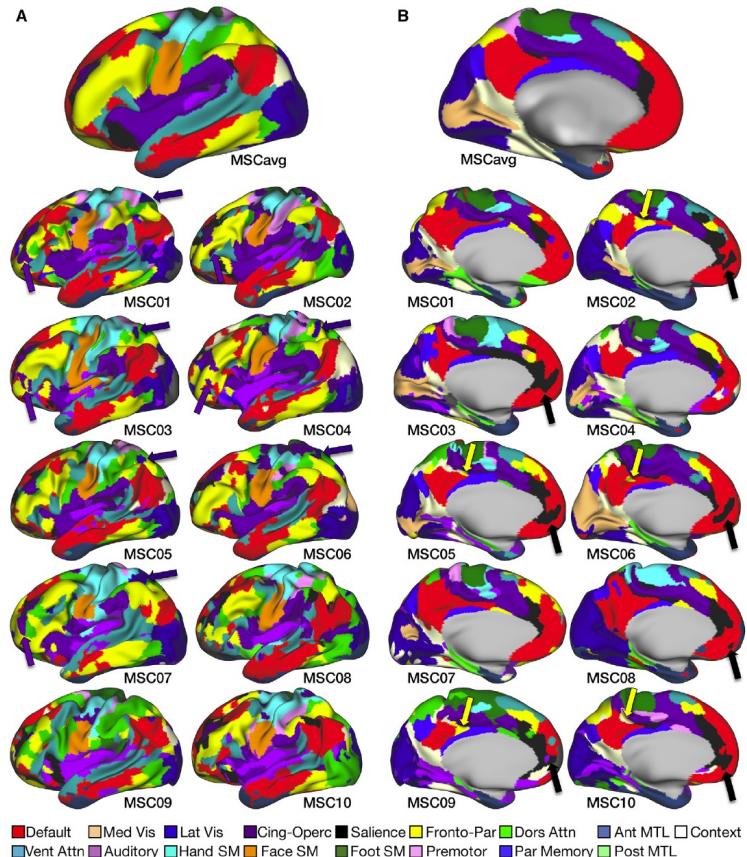
# Why functional connectivity is important?

## Individual differences



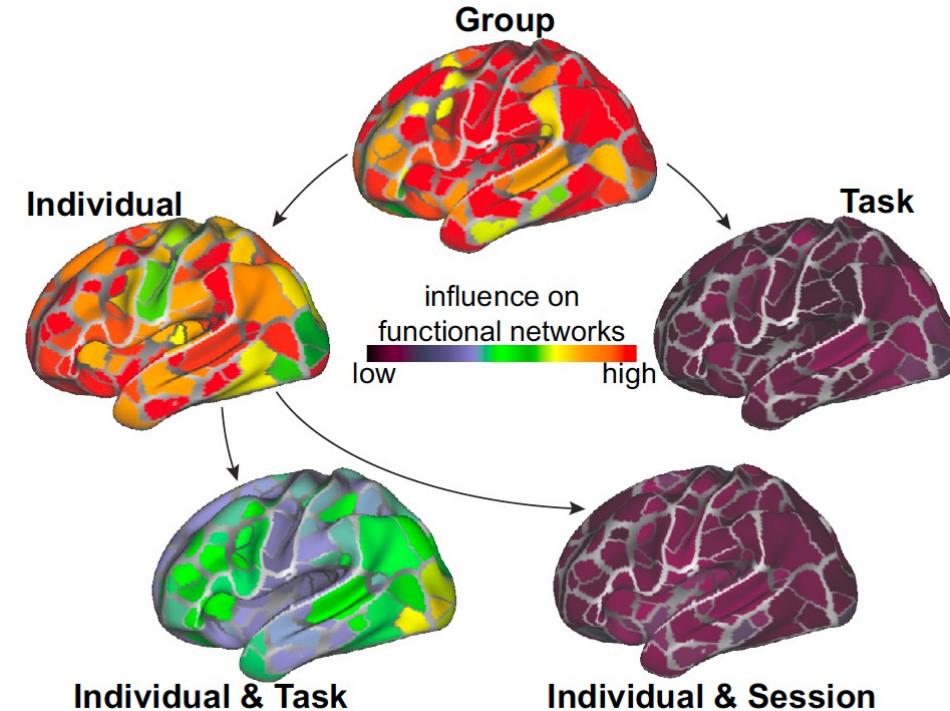
# Why functional connectivity is important?

## Individual differences



Gordon et al., 2017

Variance in human functional brain networks attributable to:

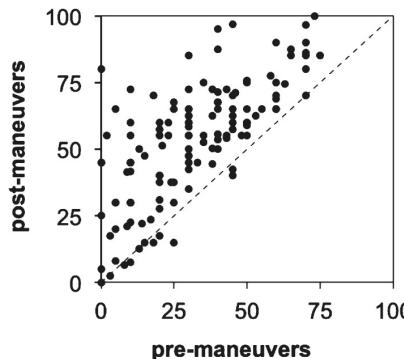
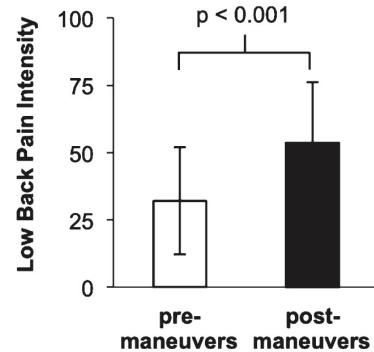


Gratton et al., 2018

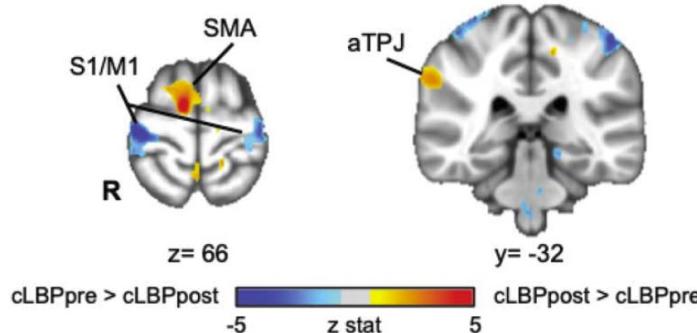


# Why functional connectivity is important?

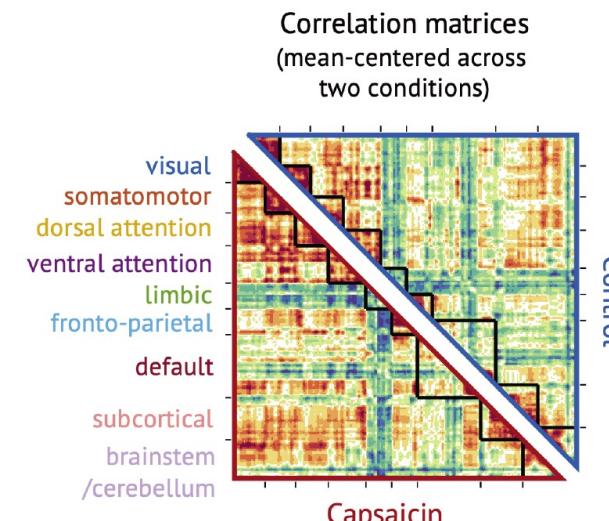
## Task-induced changes of neural dynamics



## B S1<sub>back</sub> connectivity: cLBP<sub>post</sub> versus cLBP<sub>pre</sub>

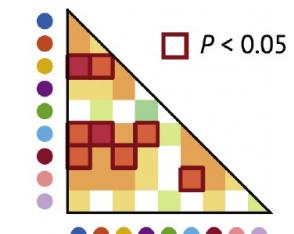


Kim et al., 2019



Lee et al., 2021

## Capsaicin vs. Control

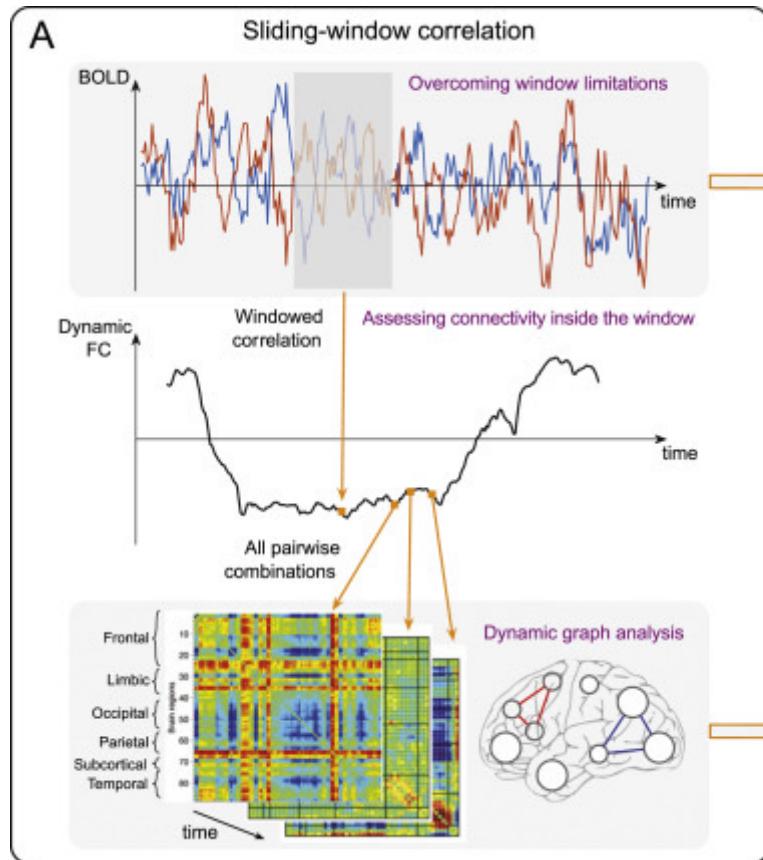


- Low  $r$  High
- Visual (VN)
  - Somatomotor (SMN)
  - Dorsal attention (DAN)
  - Ventral attention (VAN)
  - Limbic (LN)
  - Fronto-parietal (FPN)
  - Default mode (DMN)
  - Subcortical regions (SCTX)
  - Brainstem/cerebellum (BS/CB)



# Dynamic functional connectivity

## Time-varying changes of brain functional connectivity



Preti et al., 2017

Window type (length, volatility)  
Time-frequency analysis (phase synchrony)

