Resting State fMRI

Hanning Su

Resting State fMRI

- Our brains are always active, even in the absence of any explicit task.

- Resting state fMRI (rfMRI) is a relatively new approach used to identify synchronous BOLD in multiple brain regions while subjects lie in the scanner but do not perform a task.

[handwritten annotations: "5%", "95%", "change", "Group level differences → diagnosis for individuals."]

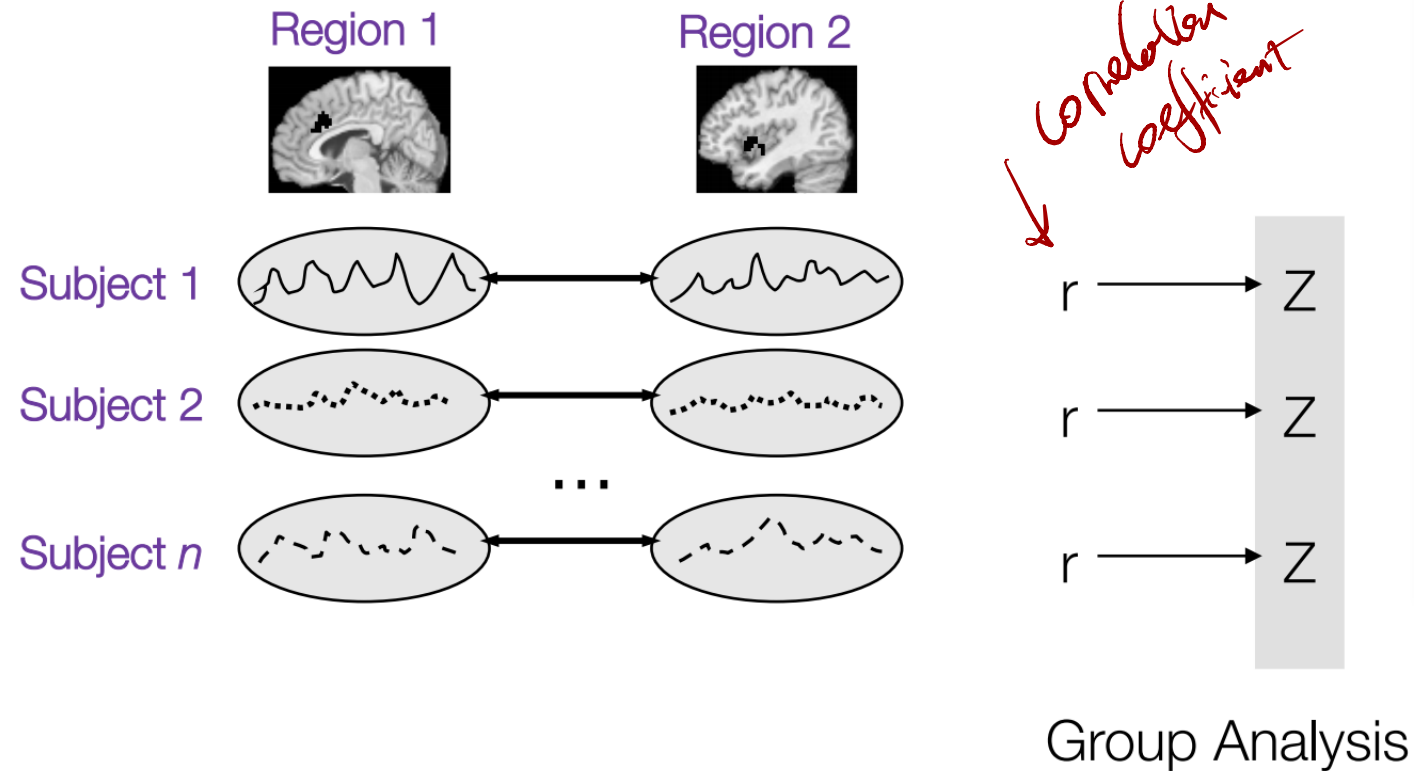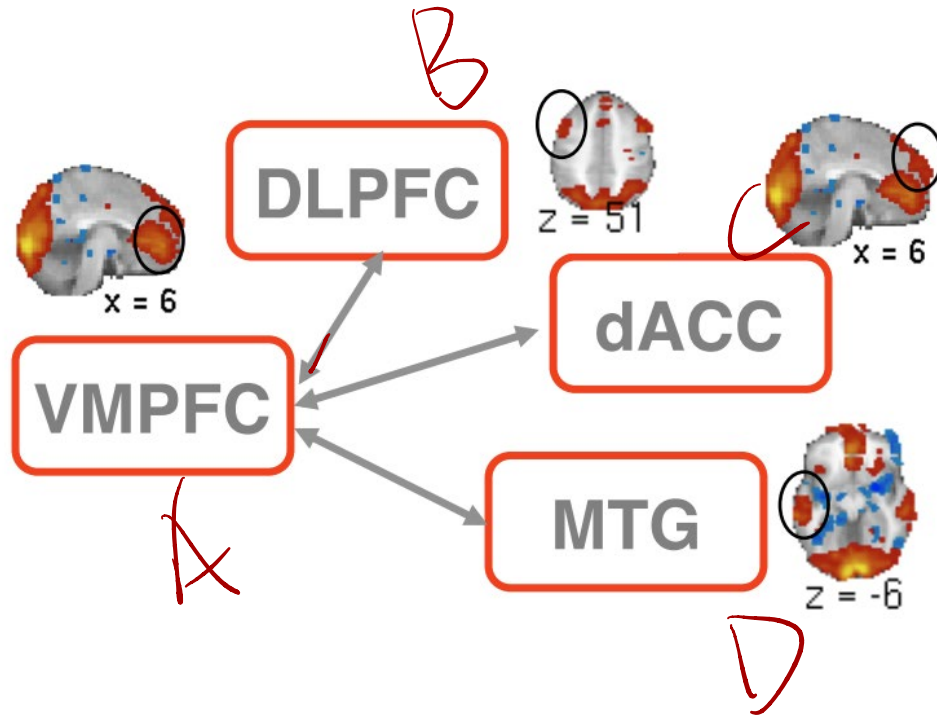# Resting State fMRI

- In particular it has been shown that fluctuations in the low-frequency portion of the BOLD signal show strong correlations across spatially distant regions, for unclear mechanism.

- Neuroscientists are increasingly interested in studying the correlation between spontaneous BOLD signal across the brain to learn about its intrinsic functional connectivity.

- Remark: functional connectivity is ..

Functional Connectivity

1. It is undirected association between two or more fMRI time series. Association between fMRI time series and physiological time series such as heart rate process could also be explored.

2. It makes statements about the structure of relationships among brain regions

3. Usually, it makes no assumptions about the underlying biology.

Functional Connectivity (example and analysis)

Group Analysis

Resting State fMRI

- Because of the lack of task, rfMRI is attractive as it removes the burden of experimental design, subject compliance, and training demands

- In addition, it is easy to 'tack on' a resting state scan when performing task-based experiments (relatively easy additional work).

- For these reasons the amount of available resting state data has exploded.
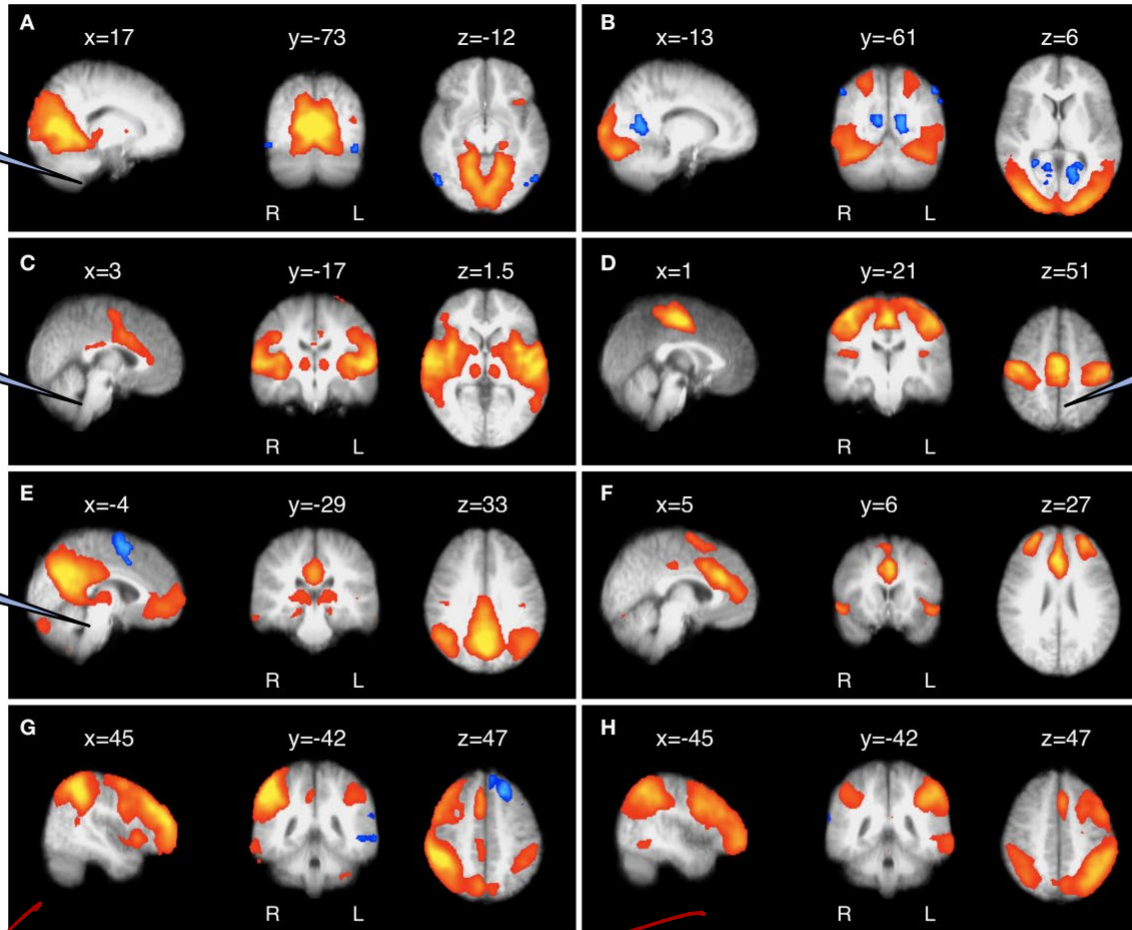
Resting State Networks

- Research has already revealed large-scale spatial patterns of coherent signal in the brain during rest, corresponding to functionally relevant resting-state networks (RSNs), which are thought to reflect neuronal baseline activity of the brain.

- A number of RSNs have been consistently observed both across groups of subjects and in repeated scanning sessions on the same subject.

- Picture:

Eight of the most common and consistent RSNs identified by ICA.

Visual Cortex

Auditory Cortex

Default Mode Network

Somatomotor Cortex

(disorder vs normal controls)

attention Network.

No ROI

Cole et al. 2010

Resting State Networks

- RSNs are localized to grey matter, and are thought to reflect supporting core perceptual and cognitive processes

- Regions that are co-activated during active tasks also show resting state connectivity.

- **Brain regions with similar functionality tend to express similar patterns of spontaneous BOLD activation.**

- Sometimes subsets of RSNs appear to be either up or down-regulated during specific cognitive tasks.

Resting State Networks

- Recall: Grey Matter:
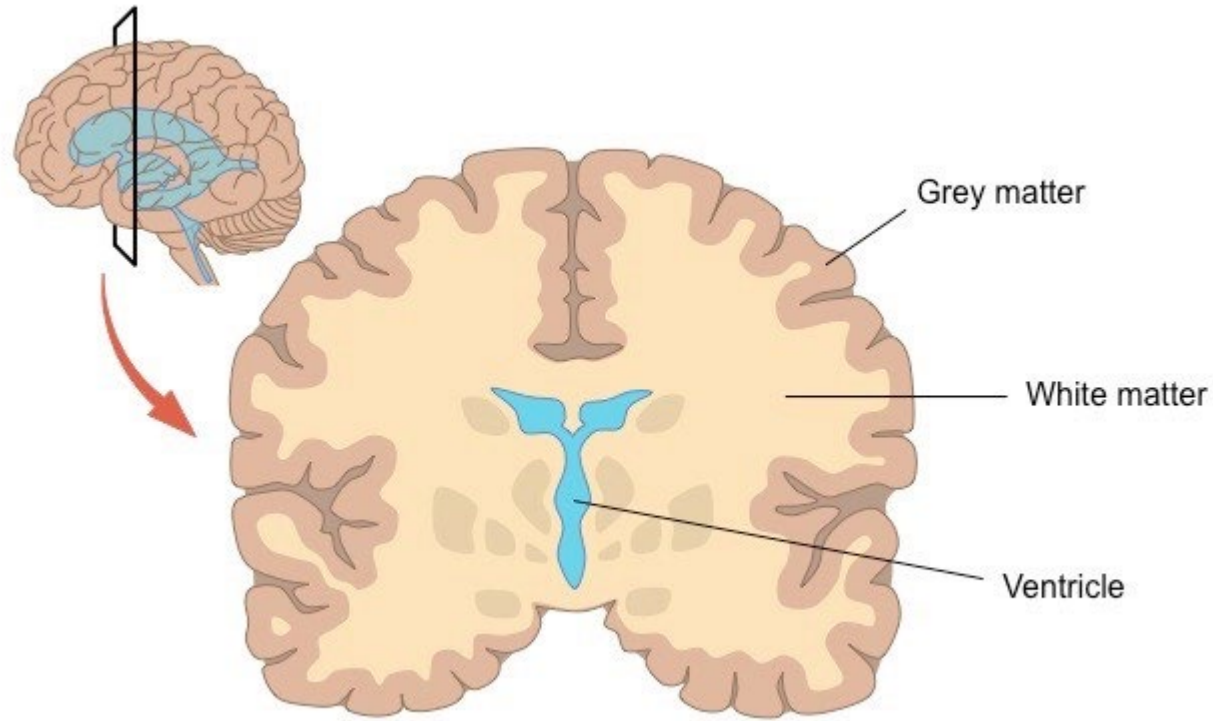
Low Frequency Fluctuations

- rfMRI is based on studying low-frequency BOLD fluctuations.

- Functionally relevant, spontaneous BOLD oscillations have been found in the lower frequency ranges (0.01-0.08 Hz).

- This is separable from respiratory (related to breathing) (0.1-0.5 Hz) and cardiovascular (related to heart and blood vessels) (0.6-1.2 Hz) signal frequencies.

rfMRI

- Typical resting experiments are of the order of 5-10 minutes, though the identification of an optimal duration of a resting fMRI session and the possible need for multiple sessions remains and open issue.

- In addition, there is no consensus as to whether data should be collected while subjects are asleep or awake, and with eyes open or closed. (Need to further refine the definition of "resting".)

⊛ depending on your interest.

Pre-processing

- Pre-processing of rfMRI data typically follows the same pipeline applied to standard task-related BOLD fMRI.

- However, there are a few important differences:

- 1. High pass temporal filtering applied to task fMRI data may be overly aggressive with respect to removing some of the relevant frequency information

- 2. Often the data is band-pass filtered at (0.01-0.08 Hz)

Pre-processing

- It has been shown that non-neuronal physiological signals may interfere with resting state BOLD data.

- Removing of confounding signals, such as respiratory or cardiovascular noise considerably improves the quality of data attributed to neural activity.

- It has therefore become common practice in rfMRI research to monitor such signals, and retrospectively correct for their confounding effects post-acquisition.

Pre-processing

- In addition the global mean signal, at least six motion parameters, the cerebrospinal fluid (CSF), and the white matter signals are also commonly removed as nuissace variables to reduce the effects of head motion and non-neuronal BOLD fluctuations.

- However, the removal of the global signal is particularly controversial.

Analysis

task → y

- Many traditional approaches towards analyzing fMRI data (e.g. GLM) are not relevant for resting date due to the inherent lack of task.

- Instead more exploratory methods like seed analysis and independent components analysis (ICA) are popular.

- There also exist specific methods.. (not going into details here)

Analysis

Early work = [Biswal — 1995]
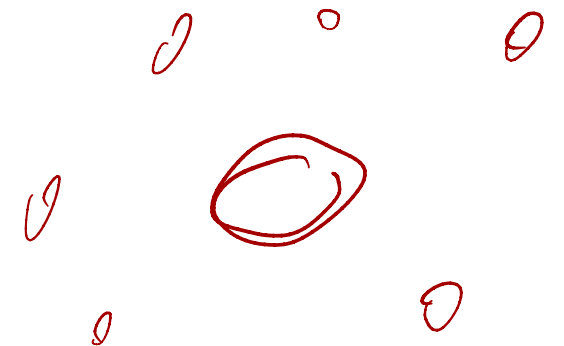
- Seed Analysis: *Hypothesis driven*

- In this analysis, the cross-correlation is computed between the time course from predetermined region (seed regions) and all other voxels. *Two techniques used*

  Any python package?

- ~~IDC~~: *ICA*

- It is a family of techniques used to extract independent signals from some source signal.

aspects of Resting State

Controversies

- In the past few years, there has been increased attention given to observed anti-correlations between RSNs.

  - The interpretation could be that the human brain is intrinsically organized into dynamic, anti-correlated functional networks.

- However, recently there has been lots of debate about these findings.

- The anticorrelation could be the result of bias introduced from removing global variations in the BOLD signal.

  - Global variations of the BOLD signal are often considered nuisance effects and are commonly removed using a general linear model (GLM) technique.

Benefits

- There is a growing subfield around the acquisition and analysis of rfMRI data.

- One of the primary benefits with rfMRI is the ability to compare data across labs.

- This has let to large data sharing initiatives (e.g. 1000 Functional Connectomes Project).

HCp