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Resting State fMRI

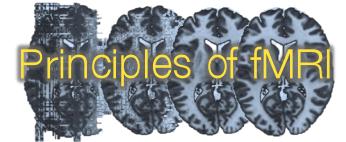
Resting State fMRI

- Clearly the brain is always active, even in the absence of an explicit task.
 - According to certain estimates, task-related changes in neuronal metabolism only account for about 5% of the brain's total energy consumption.
- Resting state fMRI (rfMRI) is a relatively new approach used to identify synchronous BOLD changes in multiple brain regions while subjects lie in the scanner but do not perform a task.

Resting State fMRI

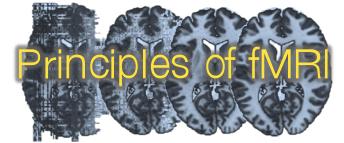
- In particular it has been shown that fluctuations in the **low-frequency** portion of the BOLD signal show strong correlations across spatially distant regions.
 - Thought to be caused by fluctuations in spontaneous neural activity.
 - The exact mechanisms remain unclear.
- Neuroscientists are increasingly interested in studying the correlation between spontaneous BOLD signal across the brain to learn about its intrinsic functional connectivity.

Resting State fMRI



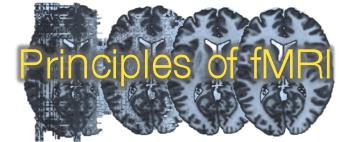
- Because of the lack of task, rfMRI is attractive as it removes the burden of experimental design, subject compliance, and training demands.
 - It is particularly attractive for studies of development and clinical populations.
- In addition, it is easy to ‘tack on’ a resting state scan when performing task-based experiments.
- For these reasons the amount of available resting state data has exploded.

Resting State Networks



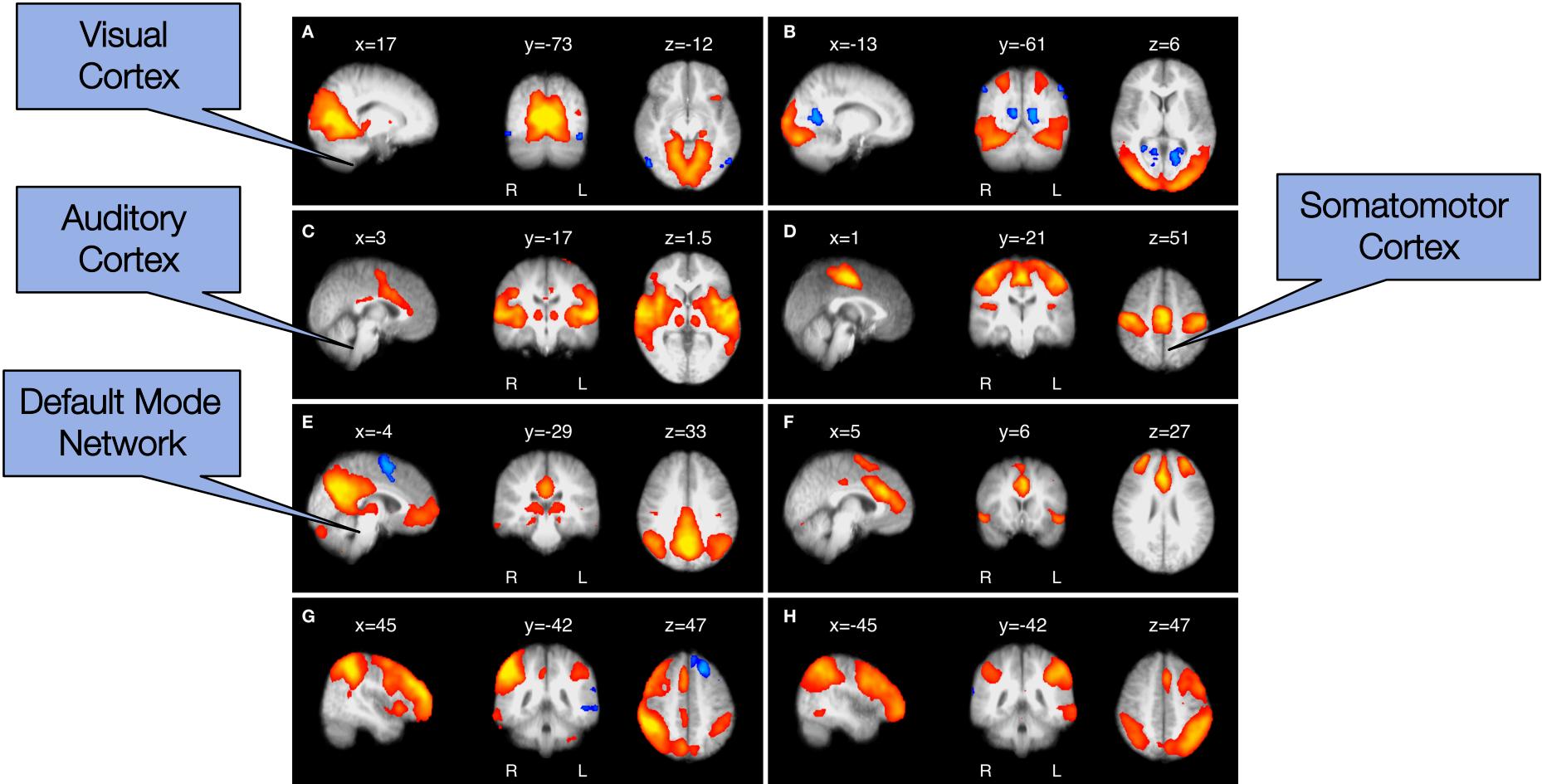
- Research has already revealed large-scale spatial patterns of coherent signal in the brain during rest, corresponding to functionally relevant resting-state networks (RSNs)
 - They are thought to reflect the neuronal baseline activity of the brain.
- A number of RSNs have been consistently observed both across groups of subjects and in repeated scanning sessions on the same subject.

Resting State Networks



- RSNs are localized to grey matter, and are thought to reflect functional systems 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

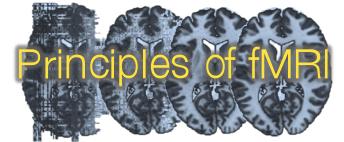


Eight of the most common and consistent RSNs identified by ICA.



Cole et al. 2010

Low Frequency Fluctuations

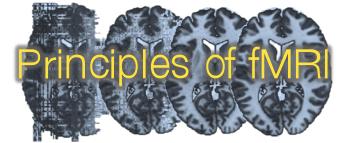


- rfMRI is based on studying low-frequency BOLD fluctuations.
- Functionally relevant, spontaneous BOLD oscillations have been found in the lower frequency ranges (0.01–0.08 Hz).
- This is separable from respiratory (0.1–0.5 Hz) and cardiovascular (0.6–1.2 Hz) signal frequencies.

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



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

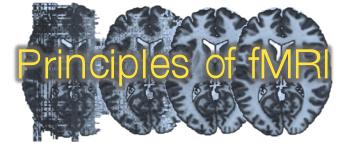
Pre-processing

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

Analysis

- Many traditional approaches towards analyzing fMRI data (e.g., the GLM) are not relevant for resting state data 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 tailored to rfMRI, such as amplitude of low frequency fluctuations (ALFF), fractional ALFF (fALFF), and regional homogeneity (ReHo).

Controversies



- In the past few years, there has been increased attention given to observed anti-correlations between RSNs.
 - Anti-correlations between the components of the default-mode and attention networks have been consistently observed.
- However, recently there has been a lot of debate about these findings.
 - It is thought that global signal regression will induce a bias towards finding anti-correlations between RSNs.

- 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.
 - Experiments do not need to be synchronized.
- This has led to large data sharing initiatives (e.g. 1000 Functional Connectomes Project).



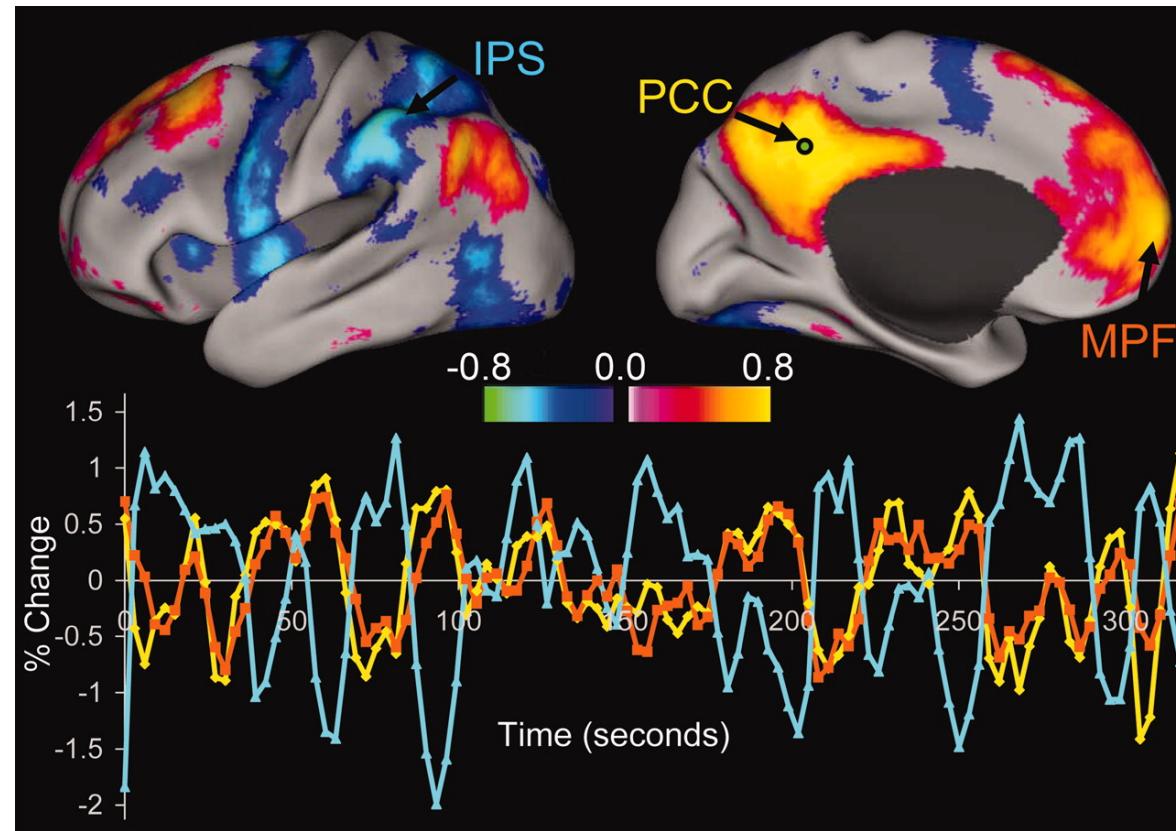
End of Module



@fMRIstats

Seed Analysis

- The most common approach to explore functional connectivity within the brain is to use **seed-based correlation analysis**.
- Seed analysis is based on the a priori selection of a seed region from which time series data are extracted, and connectivity is calculated as the correlation between the time series from the seed and all other voxels in the brain.

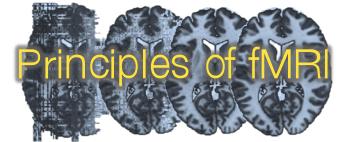


Intrinsic correlations between a seed region in the PCC and all other voxels in the brain for a single subject during resting fixation.



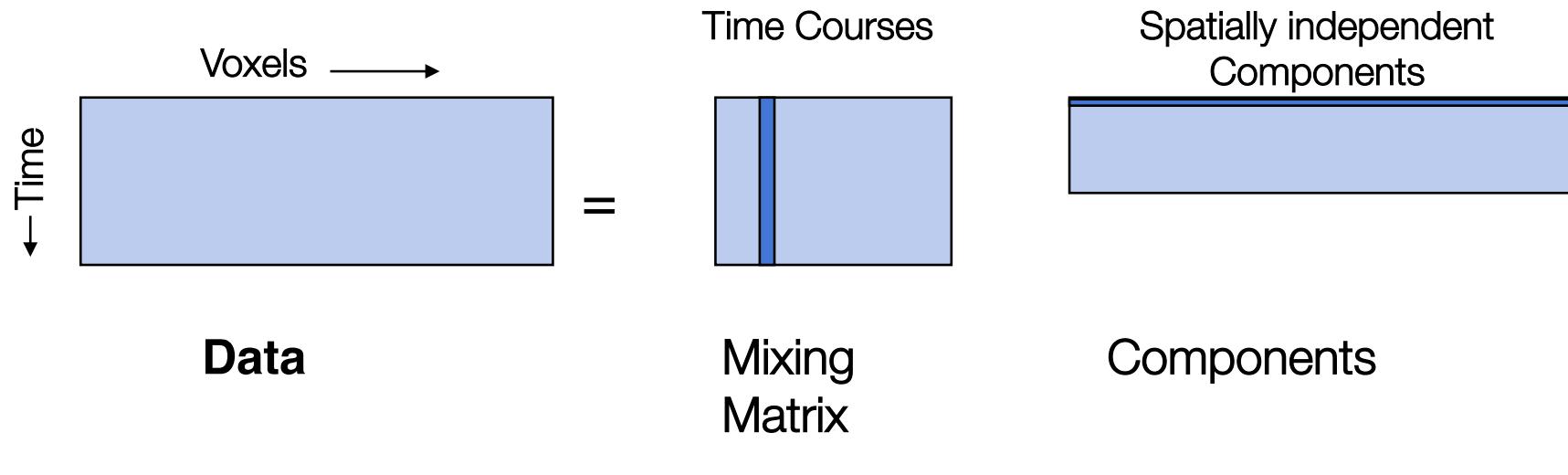
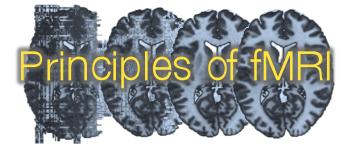
Fox et al. 2005

ICA



- Independent Components Analysis (ICA) is often used to analyze fMRI data.
- Because it provides a method to blindly separate the data into spatially independent components, it does not require the specification of a stimulus function.
- The hope is that the spatial components will correspond to RSNs.

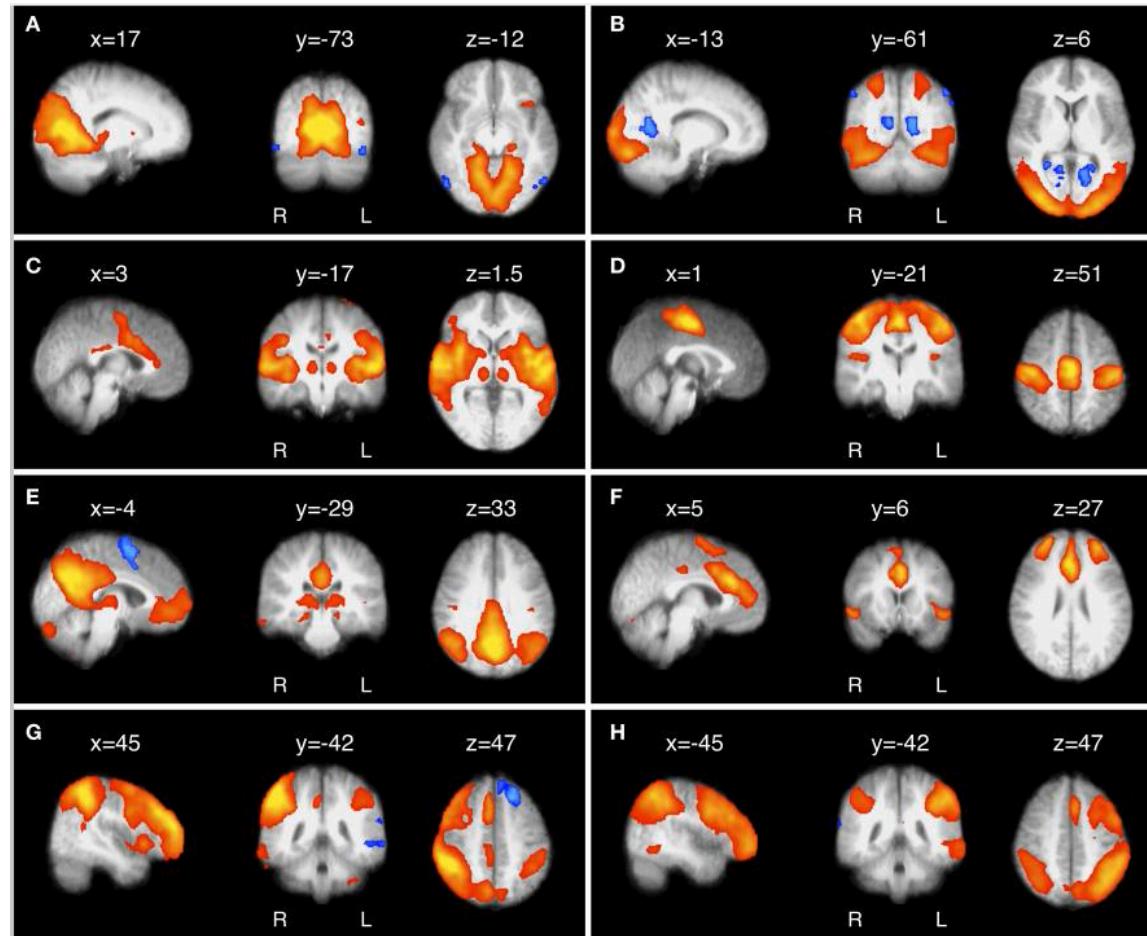
Overview



$$\mathbf{X} = \mathbf{AS}$$



Resting State Networks



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Cole et al. 2010