Principles of fMRI

Part I

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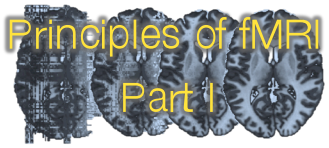
@fMRIstats

Analysis of fMRI Data

Functional MRI

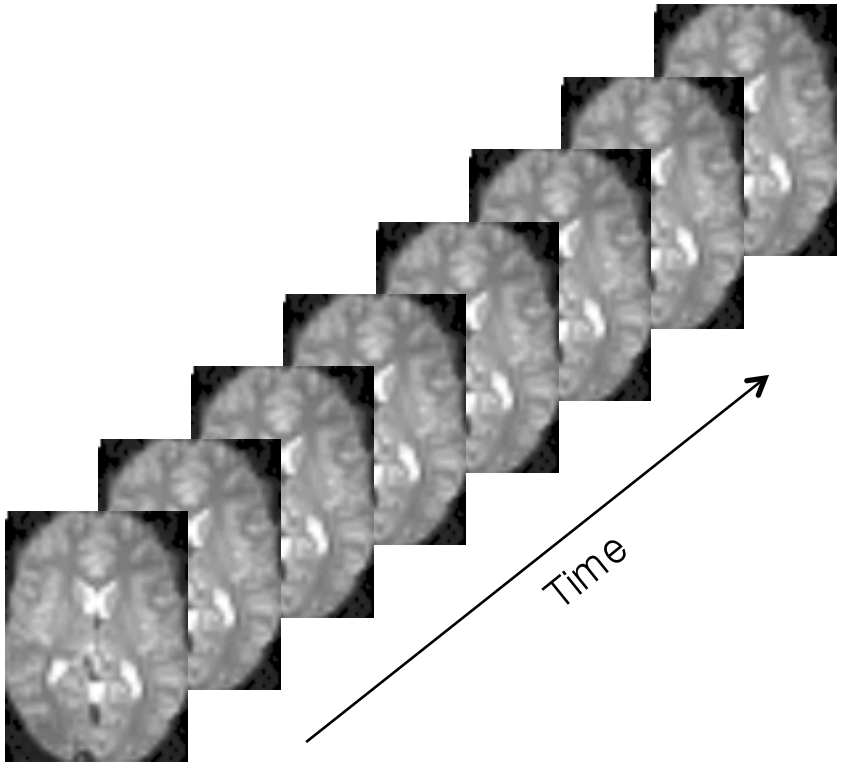


- Functional magnetic resonance imaging (fMRI) is a non-invasive technique for studying brain activity.

- During the course of an fMRI experiment, a series of brain images are acquired while the subject performs a set of tasks.

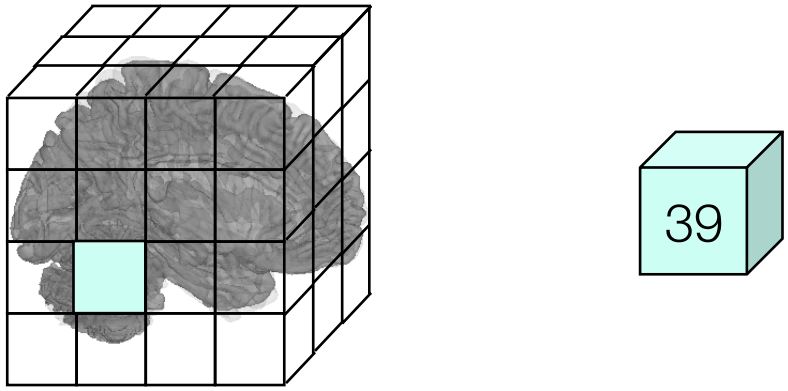
- Changes in the measured signal between individual images are used to make inferences regarding task-related activations in the brain.

fMRI



fMRI Data

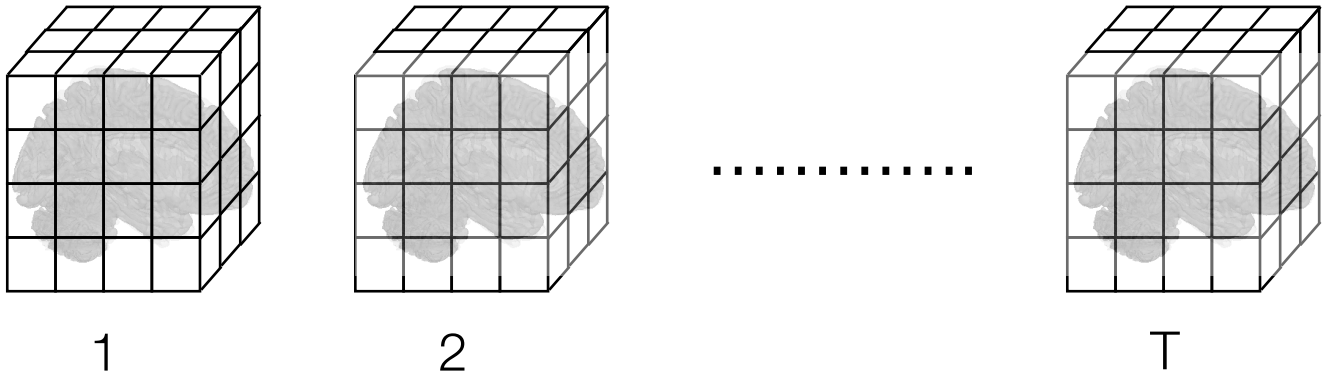
- Each image consists of ~100,000 'voxels' (cubic volumes that span the 3D space of the brain).



- Each voxel corresponds to a spatial location and has a number associated with it that represents its intensity.

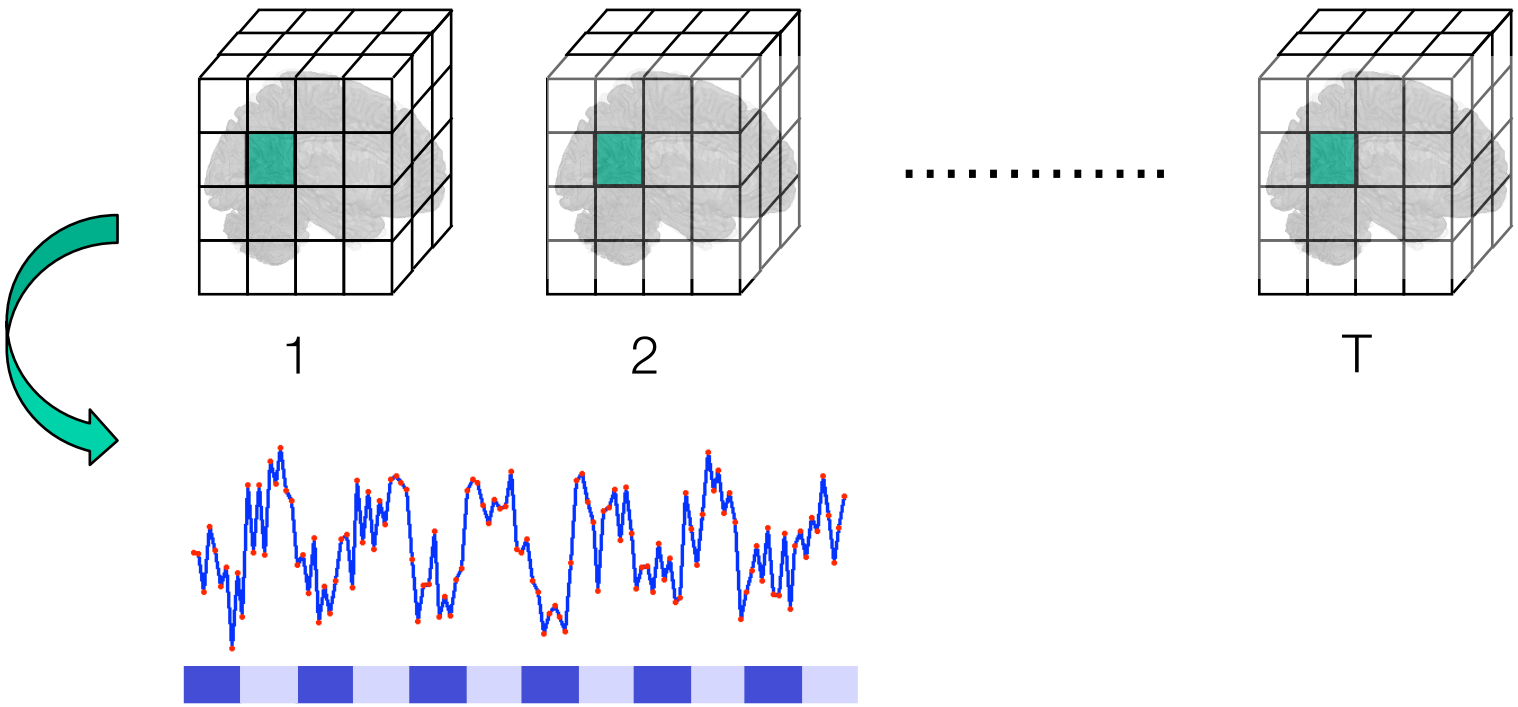
fMRI Data

- During the course of an experiment several hundred images are acquired (~ one every 2*s*).

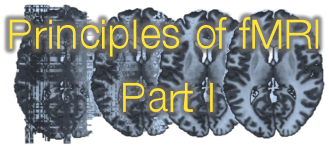


fMRI Data

- Tracking the intensity over time gives us a time series.



BOLD fMRI



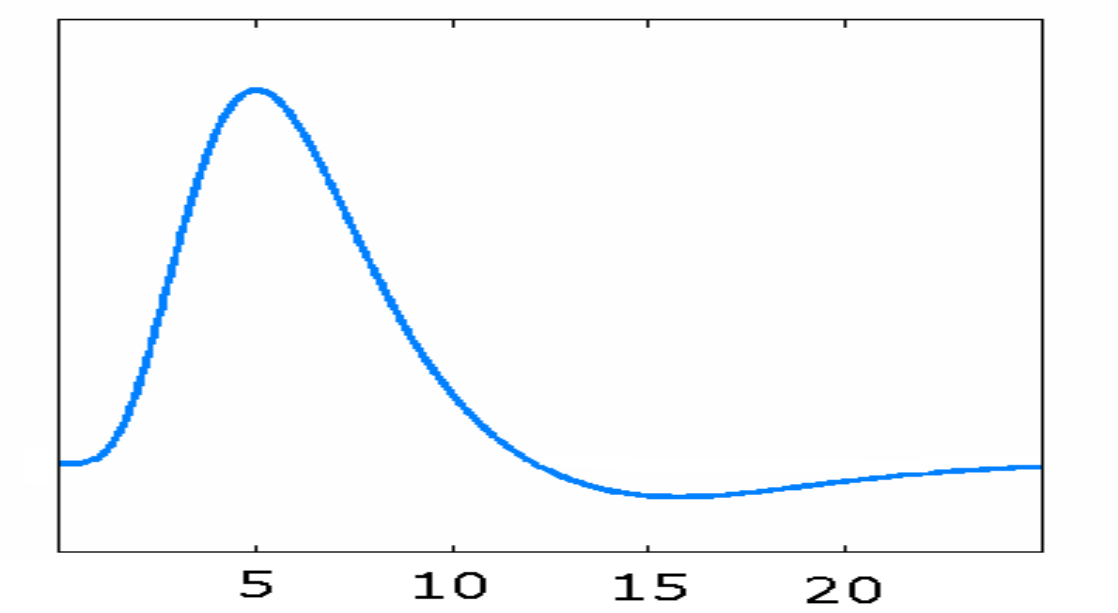
- The most common approach towards fMRI uses the Blood Oxygenation Level Dependent (BOLD) contrast.

- BOLD fMRI measures the ratio of oxygenated to deoxygenated hemoglobin in the blood.

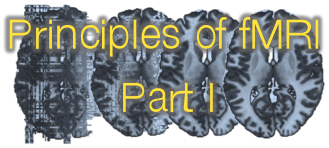
- It is important to note that BOLD fMRI doesn't measure neuronal activity directly, instead it measures the metabolic demands (oxygen consumption) of active neurons.

BOLD fMRI

- The hemodynamic response function (HRF) represents changes in the fMRI signal triggered by neuronal activity.



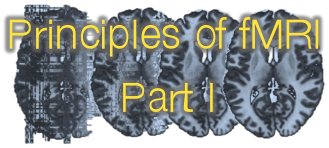
fMRI Data



- fMRI data analysis is a massive data problem.
  - Each brain volume consists of ~100,000 voxel measurements.
  - Each experiment consists of hundreds of brain volumes.
  - Each experiment may be repeated for multiple subjects (e.g.,10–40) to facilitate population inference.

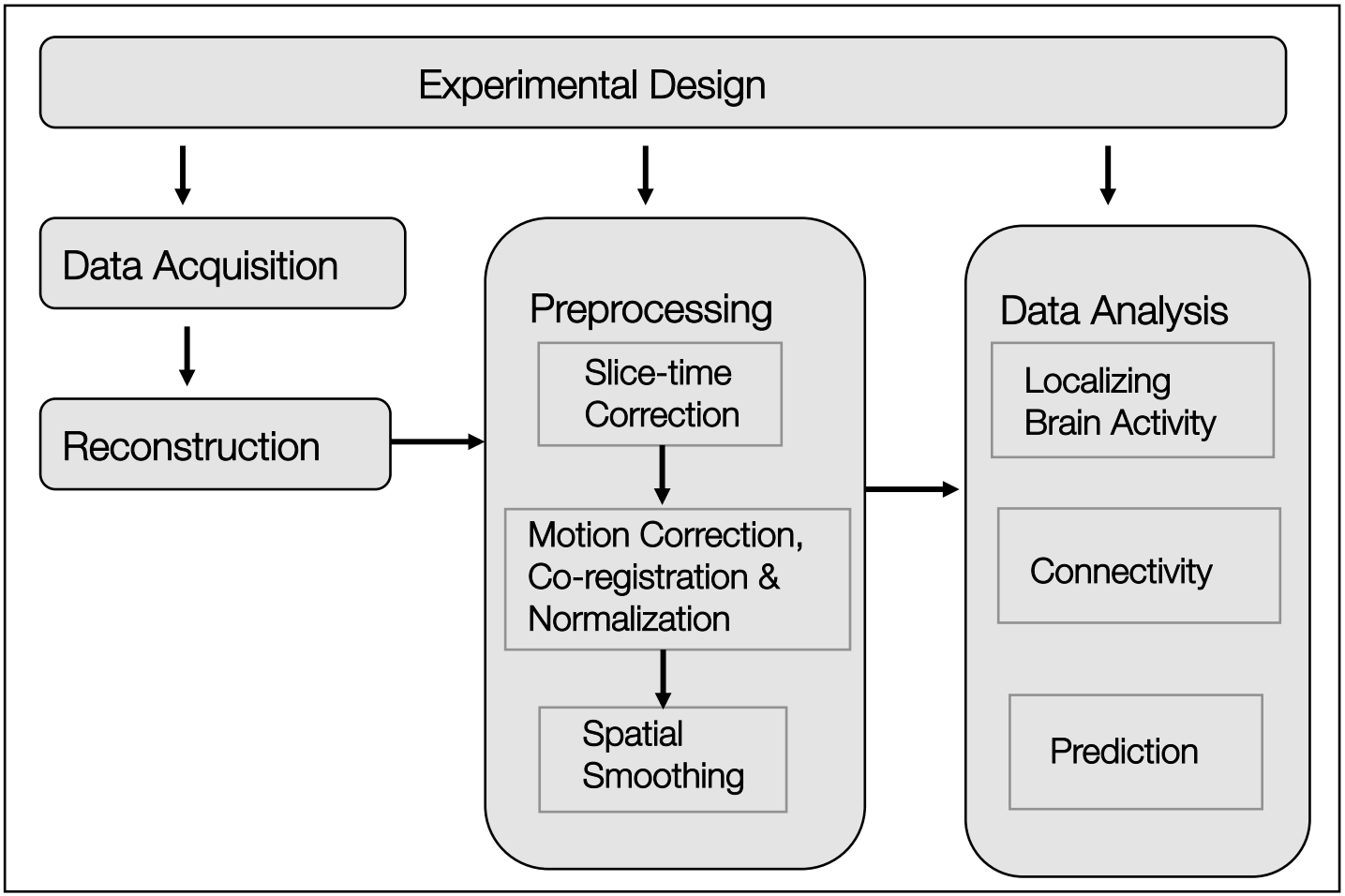
- The total amount of data that needs to be analyzed is staggering.

Statistical Analysis



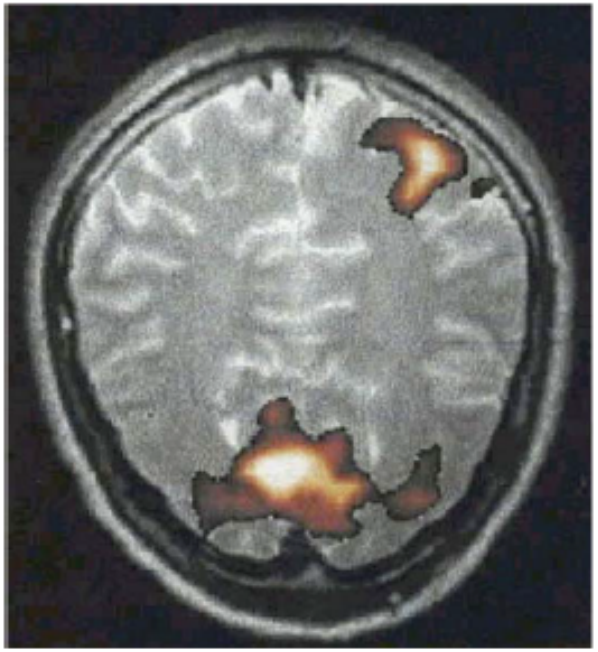
- The statistical analysis of fMRI data is challenging.
  - It is a massive data problem.
  - The signal of interest is relatively weak.
  - The data exhibits a complicated temporal and spatial noise structure.

Data Processing Pipeline



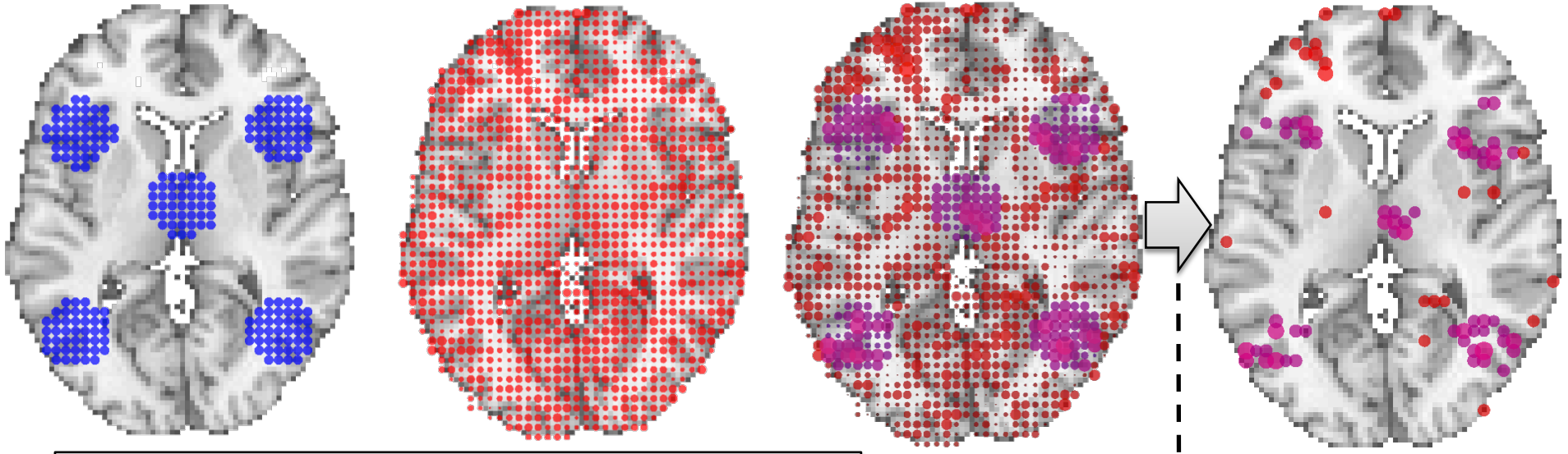
Localization

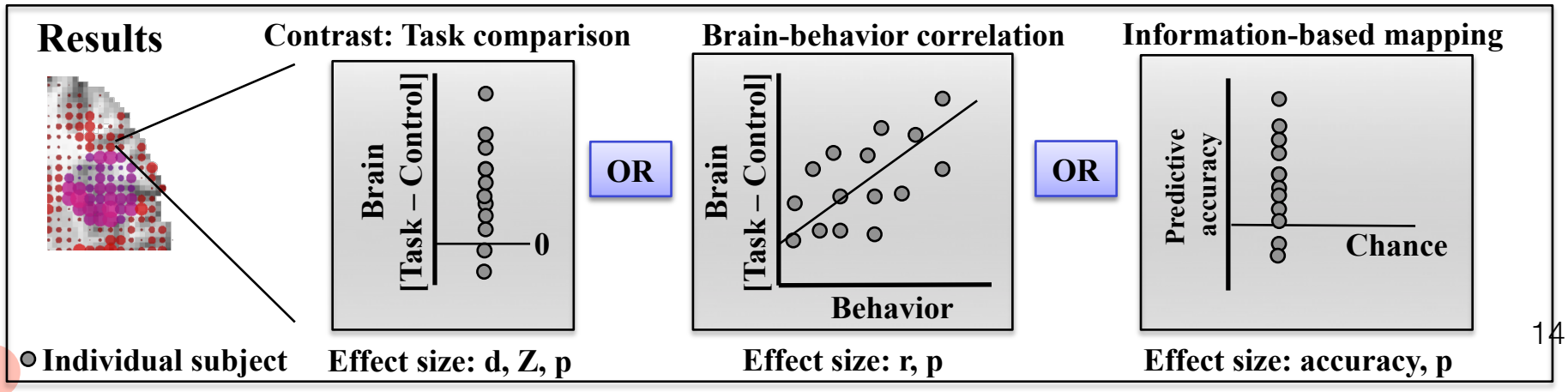
- Determine which regions of the brain are active during a specific task.



Lindquist (2008)

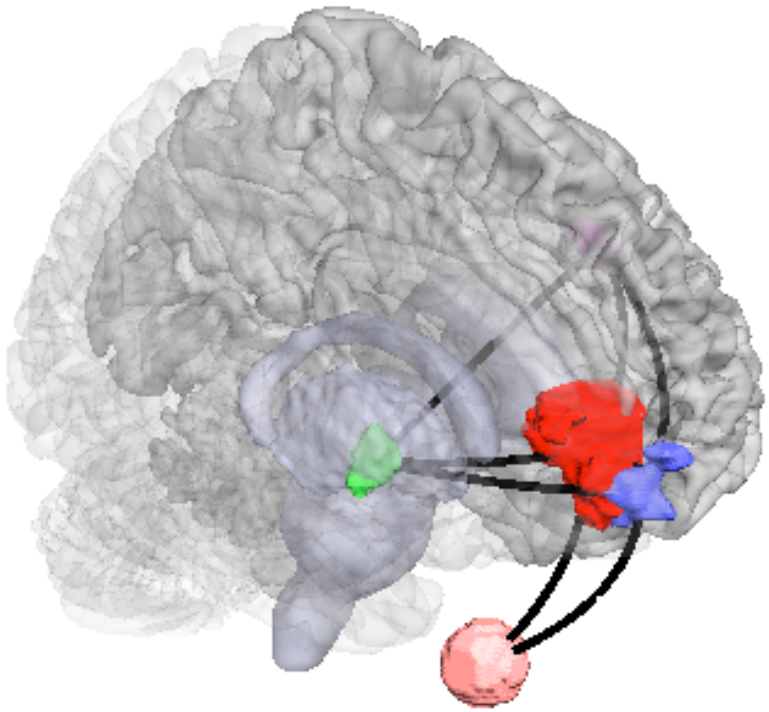
Varieties of Localization: Brain Mapping





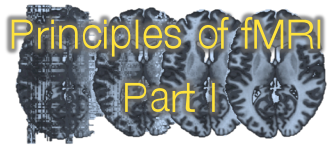
Connectivity

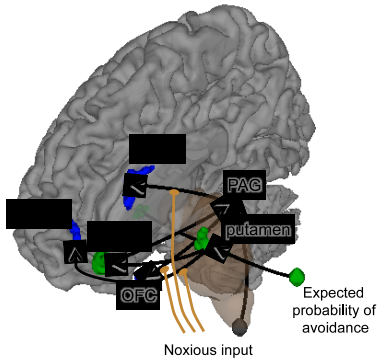
- Determine how different brain regions are connected with one another.



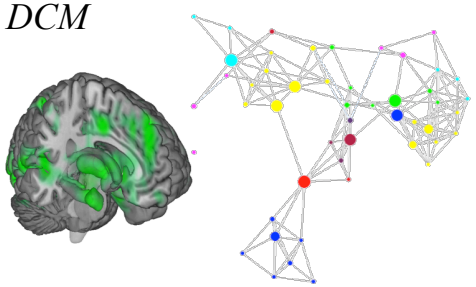
Cribben et al. (2012)

Varieties of Connectivity

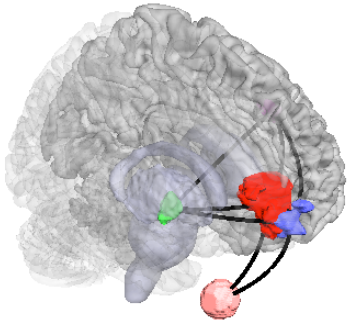




Roy et al. 2014 DCM



Wager et al. 2015 graphical model



Cribben et al. 2012 time-varying Graphical LASSO

Functional connectivity

-'Seed'-based (two regions)
-Psychophysiological interactions

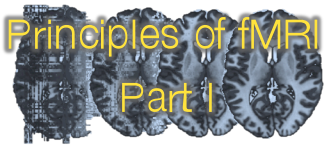
Effective connectivity

-Path analysis, mediation
-Granger 'causality'
-Dynamic causal modeling (DCM)

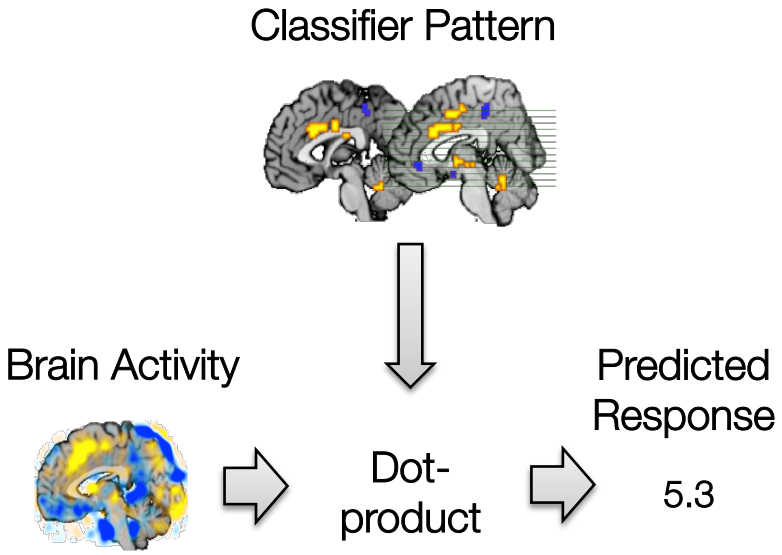
Multivariate connectivity

-Independent/principal components
-Graphical models

Prediction



- Use a person's brain activity to predict their perceptions, behavior, or health status.



Wager et al. (2013): Pain

Emerging applications

- Alzheimer's disease
- Depression (e.g., Craddock et al. 2009)
- Chronic pain (e.g., Baliki et al. 2012)
- Anxiety (e.g., Doehrmann et al. 2013; Siegle et al. 2006)
- Parkinson's disease
- Drug abuse (Whelan et al. 2014)
- Acute pain (e.g., Wager et al. 2013)
- Emotion (Kassam et al. 2011; Kragel et al. 2014; Wager et al. 2015)

End of Module

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