JOHNS HOPKINS BLOOMBERG SCHOOL of PUBLIC HEALTH

SMART JHSPH Biostatistics

Statistical Methods in functional MRI

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Module 1:
Introduction to fMRI

Brain Imaging

- In recent years there has been explosive interest in using imaging techniques to explore the inner workings of the human brain.
- Brain imaging data has found applications in a wide variety of fields, such as psychology, economics, political science, and statistics.
- In addition, it is central to several emerging fields, such as cognitive neuroscience, affective neuroscience, neuroeconomics, and more.

Brain Imaging

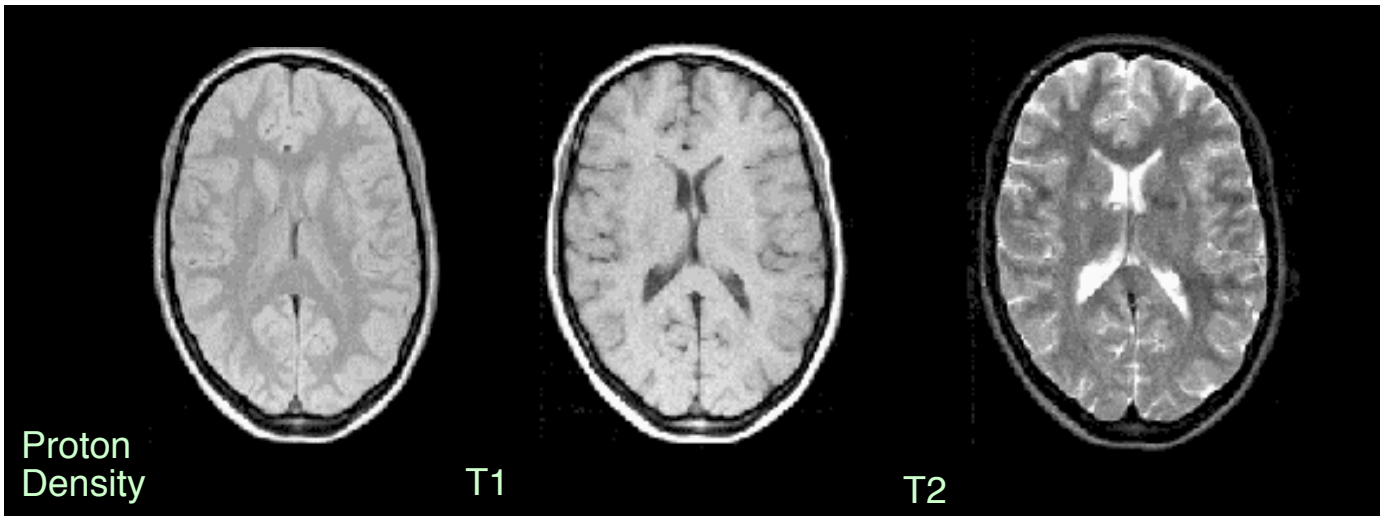
- Brain imaging can be separated into two major categories:
  - Structural brain imaging
  - Functional brain imaging
- There exist a number of different modalities for performing each category.

Structural Brain Imaging

- Structural brain imaging deals with the study of brain structure and the diagnosis of disease and injury.

- Modalities include:
  - computed axial tomography (CAT),
  - magnetic resonance imaging (MRI), and
  - positron emission tomography (PET).

MRI

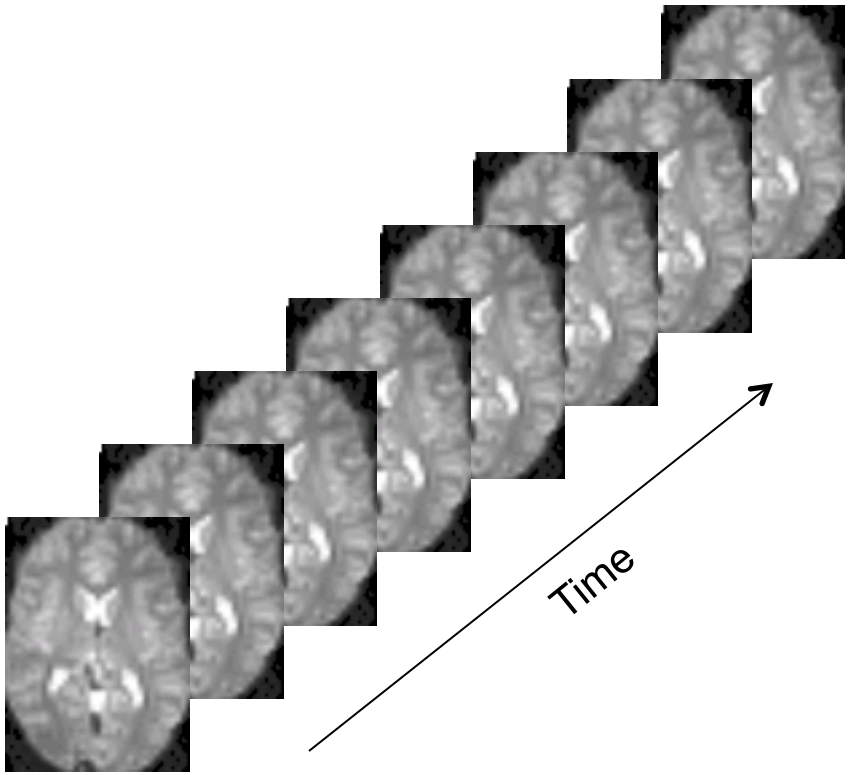


Functional Brain Imaging

- Functional brain imaging can be used to study both cognitive and affective processes.

- Modalities include:
  - positron emission tomography (PET),
  - functional magnetic resonance imaging (fMRI),
  - electroencephalography (EEG), and
  - magnetoencephalography (MEG).

fMRI



Properties

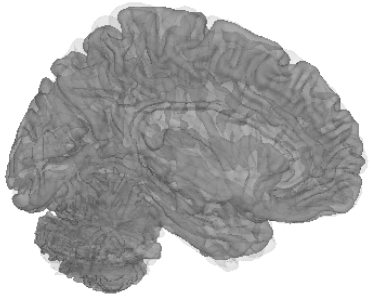
- Each functional imaging modality provides a different type of measurement of the brain.
- They also have their own pros and cons with regards to spatial resolution, temporal resolution and invasiveness.
- Functional MRI provides a nice balance between these properties and has become the dominant functional imaging modality in the past decade.

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 Data

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



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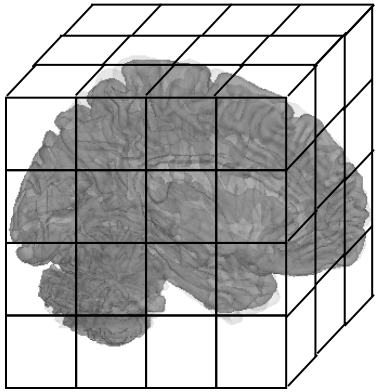

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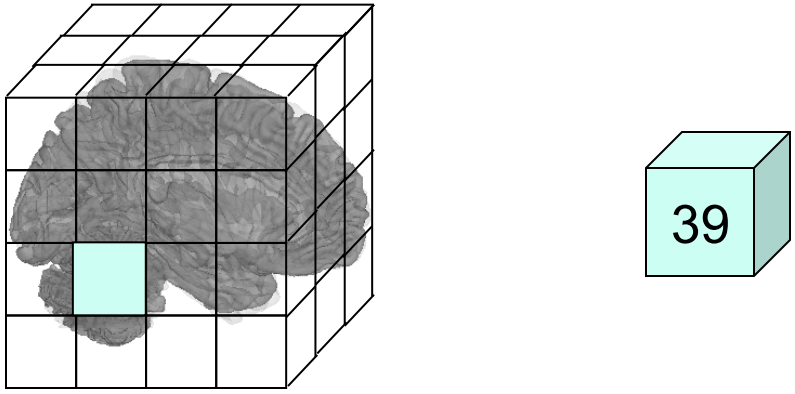
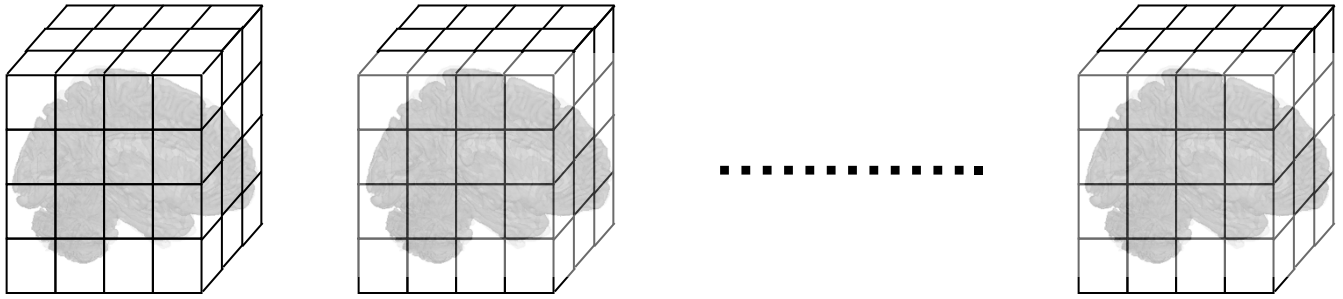


- Each voxel corresponds to a spatial location and has a number associated with it that represents its intensity.

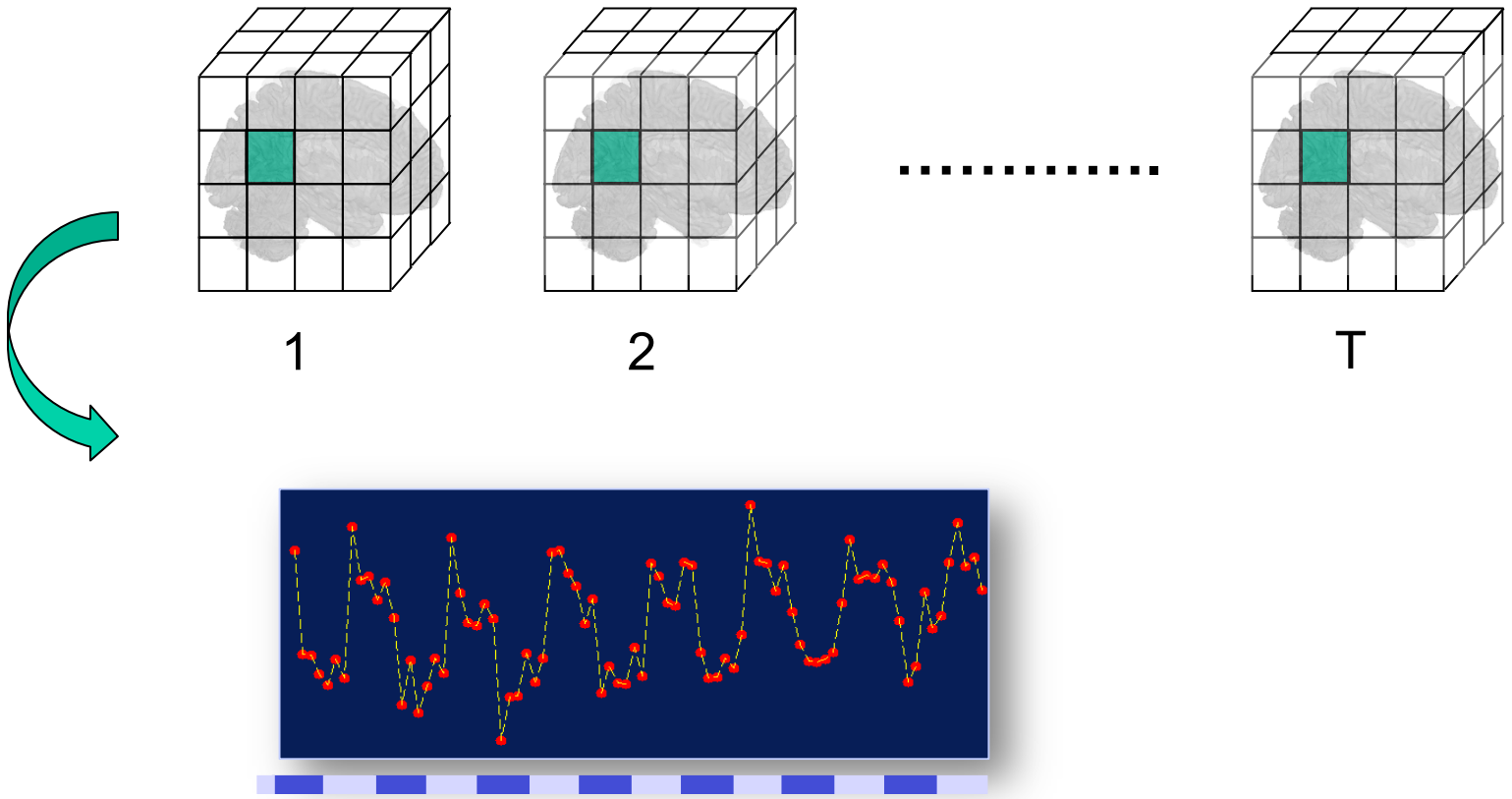
fMRI Data

- 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

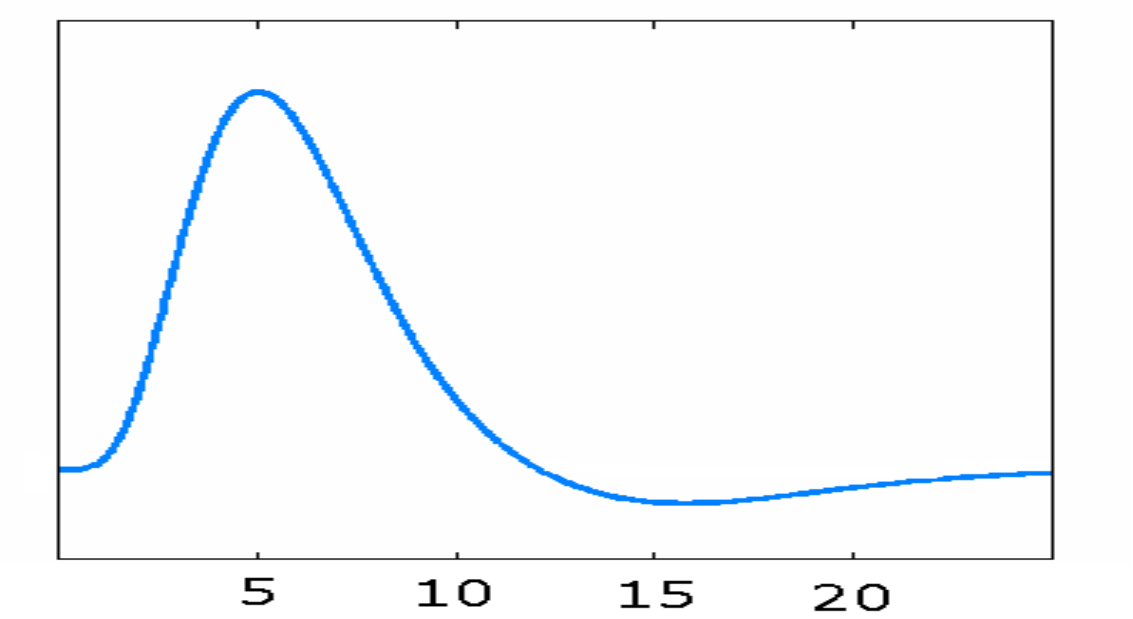
- The most common approach towards fMRI uses the Blood Oxygenation Level Dependent (BOLD) contrast.

- 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

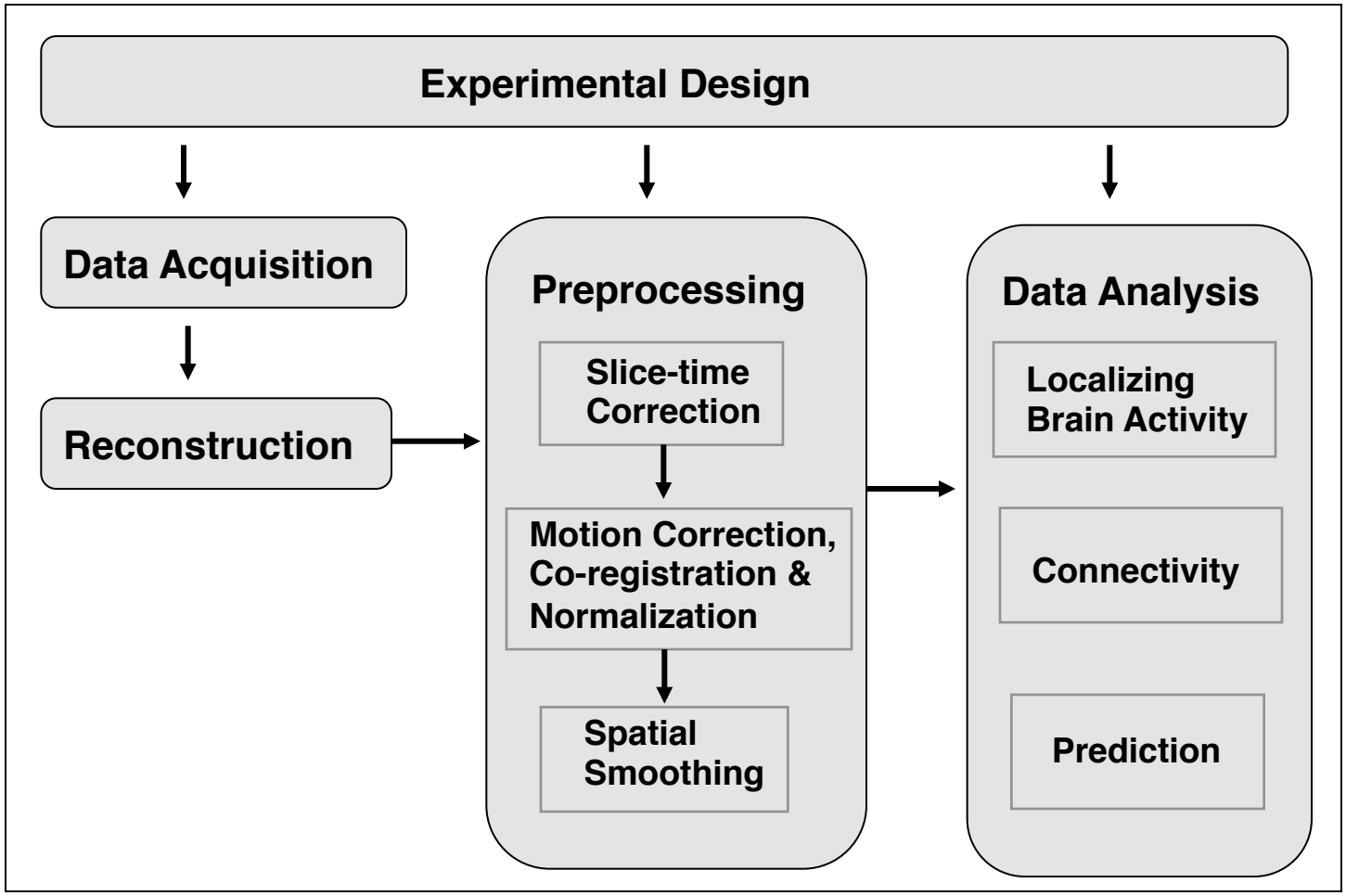
- fMRI data analysis is a massive data problem.
  - Each brain volume consists of ~100,000 voxel measurements.
  - Each experiment consists of hundreds of brain volumes.
  - Each experiment may be repeated for multiple subjects (e.g.,10–40) to facilitate population inference.

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

Statistical Analysis

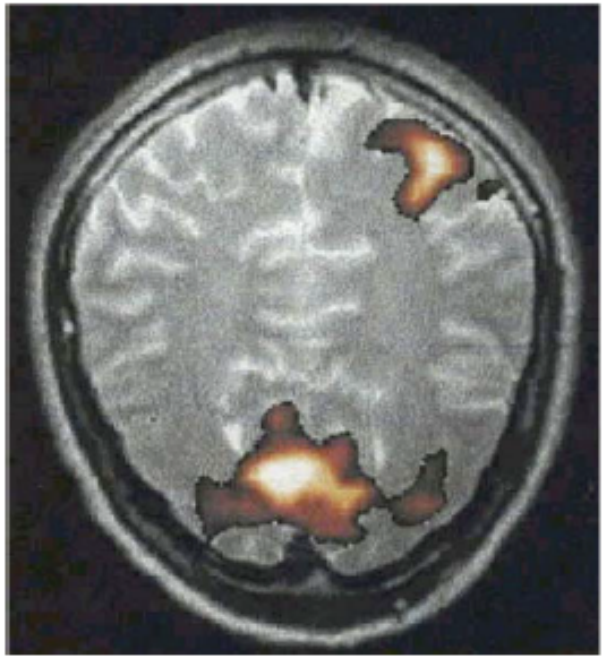
- The statistical analysis of fMRI data is challenging.
  - It is a massive data problem.
  - The signal of interest is relatively weak.
  - The data exhibits a complicated temporal and spatial noise structure.

Data Processing Pipeline



Localization

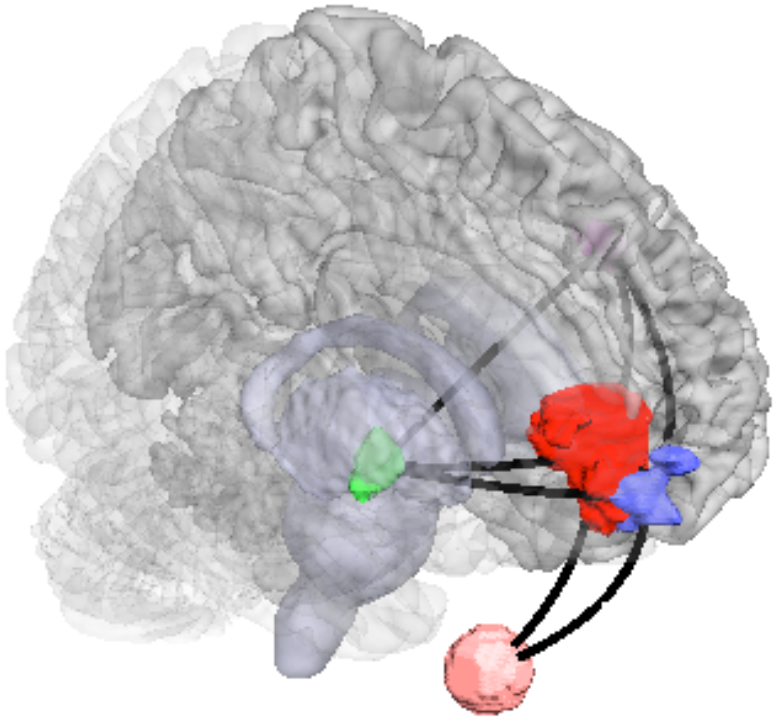
- Determine which regions of the brain are active during a specific task.



Lindquist (2008)

Connectivity

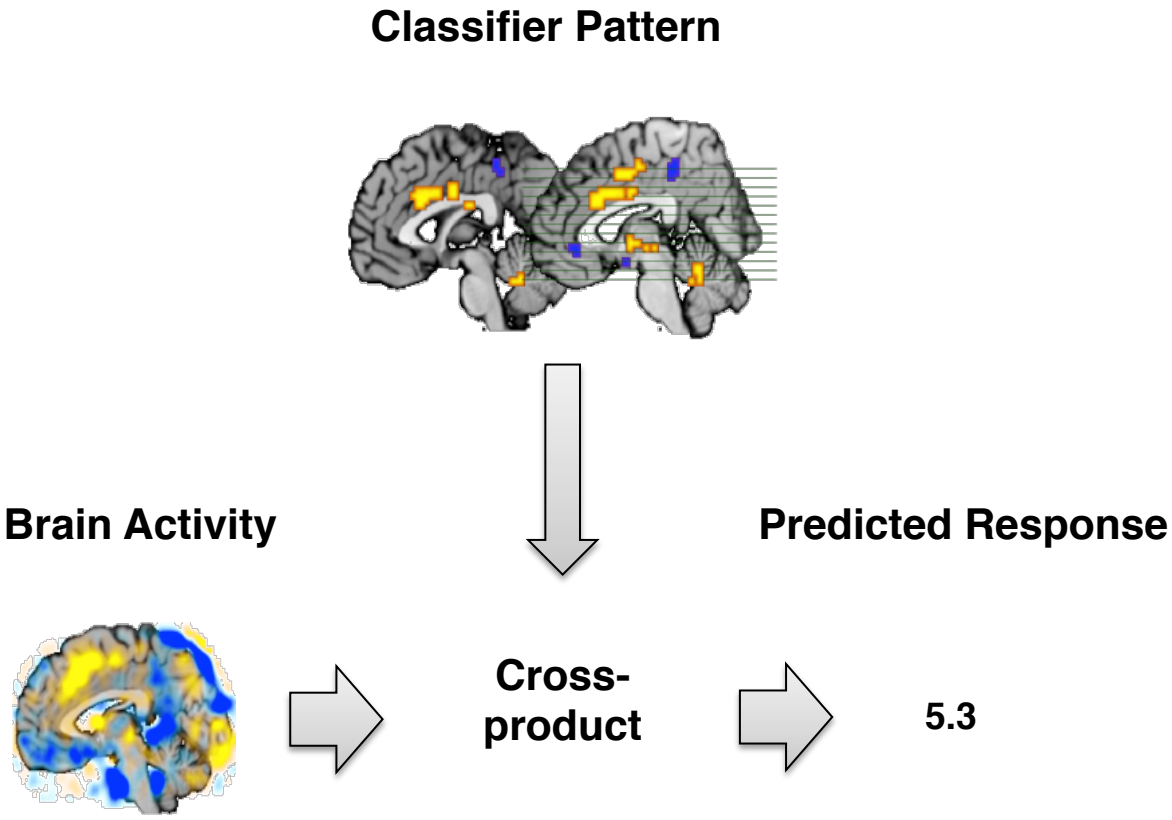
- Determine how different brain regions are connected with one another.



Cribben et al. (2012)

Prediction

- Use a person's brain activity to predict their response or disease status.



Wager et al. (2013)

End of Module

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