The geometry of human perception: RSA and multivariate models

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Overview

fMRI Background

- Nonparametric approaches: RSA
- Parametric approach: Multivariate linear model

Questions

- Defining the RSA null and alternative hypotheses
- Assumptions linking RSA to scientific conclusions
- Sensitivity to measurement and preprocessing choices

Proposed Projects

- Distribution-induced distance
- Parametric RSA

Representation similarity analysis (RSA)

- Framework for studying how mental objects are represented in the brain, via brain activity (measured by fMRI, EEG) or behavior
- Compare different brain regions or imaging modalities within a single subject, or compare multiple subjects
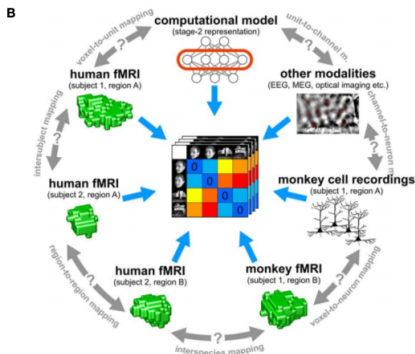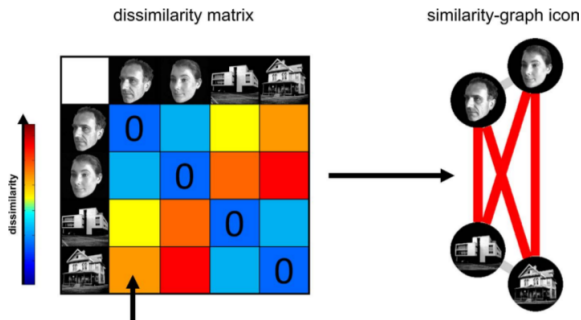
A typical RSA experiment

An experiment which demonstrates which regions of the brain differentiate between faces and objects.
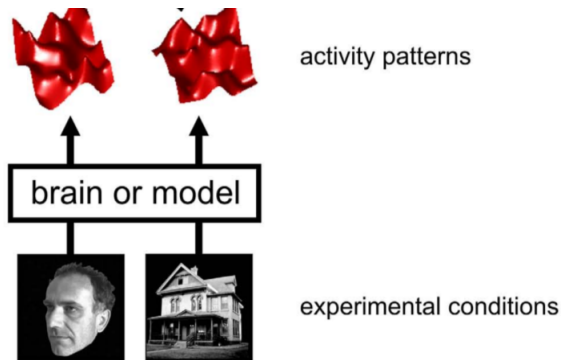
Step 1: Present the subject with visual stimuli: pictures of faces and houses. Record the subject's brain activity in the fMRI scanner.

A typical RSA experiment

Step 2a: Process the data, and represent the brain activity of the subject for the ith stimulus as a real vector y_i. Form matrix of distances between y_i and y_j, the *representation distance matrix* (RDM)

dissimilarity matrix

similarity-graph icon

Step 2b: Assess statistical significance of distances to form similarity graph

A typical RSA experiment

Step 3: Compare similarity graphs between different brain regions.
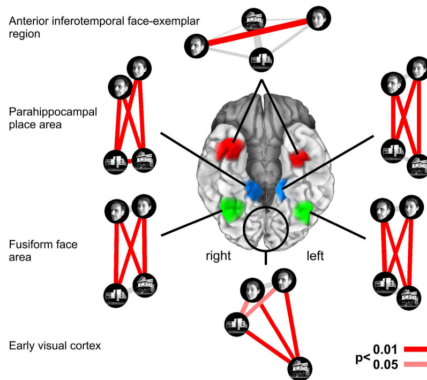
Step 4: Draw scientific conclusions. (Step 5: Profit!!..?)

Comparison to parametric approach

- RSA is a "nonparametric" approach, because stimuli are treated as discrete classes

- In contrast, one could consider presenting stimuli which are parameterized

- Example: present the subject with gratings of varying orientation. Orientation x is parameter
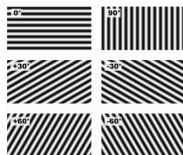
Example of parametric approach: natural images

Stage 1: model estimation
Estimate a receptive-field model for each voxel

Images

Receptive-field model for one voxel
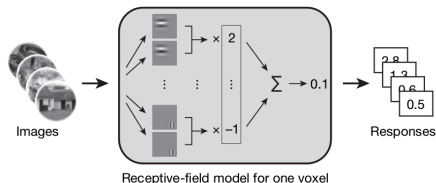
Responses

- Kay et al (2008) parameterize natural images using *Gabor filters*
- Let x_i be the vector of 10000 Gabor filter coefficients for a natural image. Let y_i be the vector of 20000 individual voxel responses.
- Kay fits a model of the form

$$y_i = B^T x_i + \epsilon_i$$

where B is a 10000 x 20000 coefficient matrix, and ϵ_i is vector-valued noise with covariance Σ