Deformation-Invariant Sparse Coding

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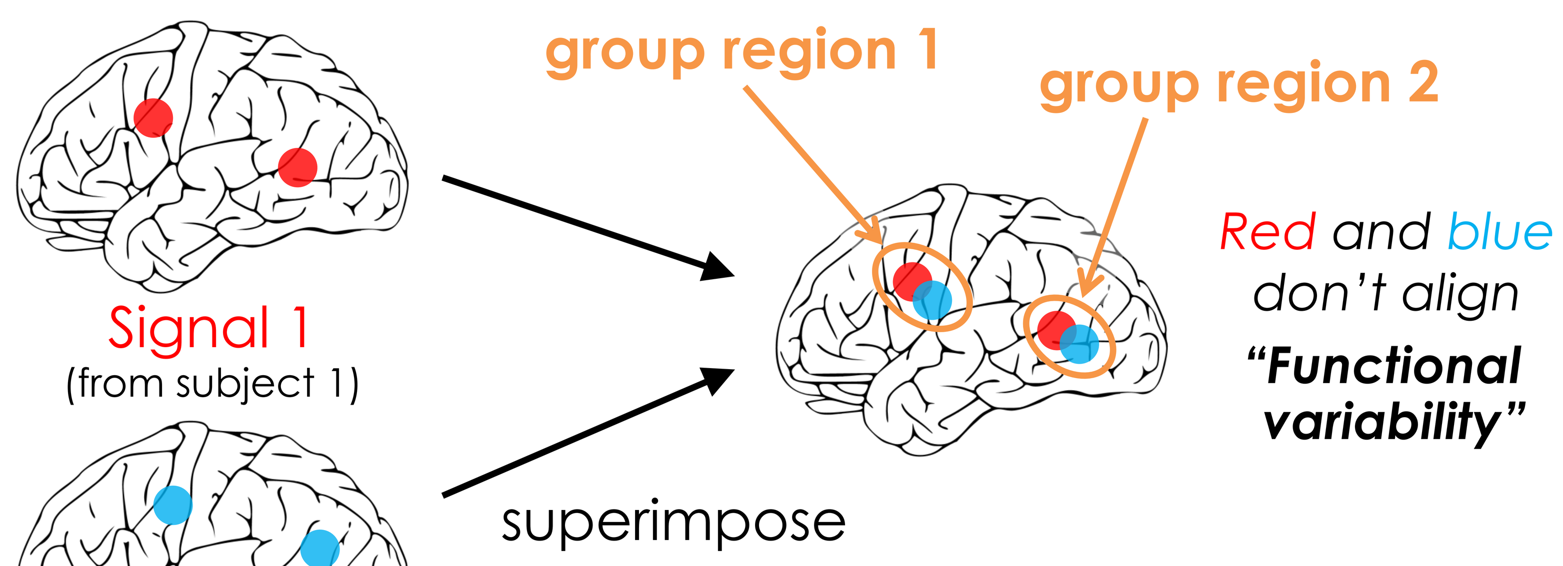
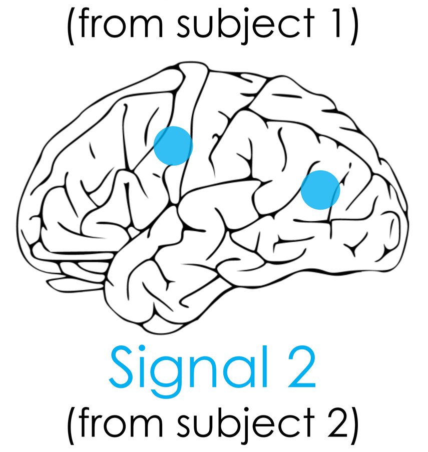
Motivation

How do we model population-level brain response to a given cognitive task such as reading sentences?

Challenge: Even if we pre-aligned brains (so everyone has the same brain), brain activations due to a cognitive task can vary in location in the normalized space!

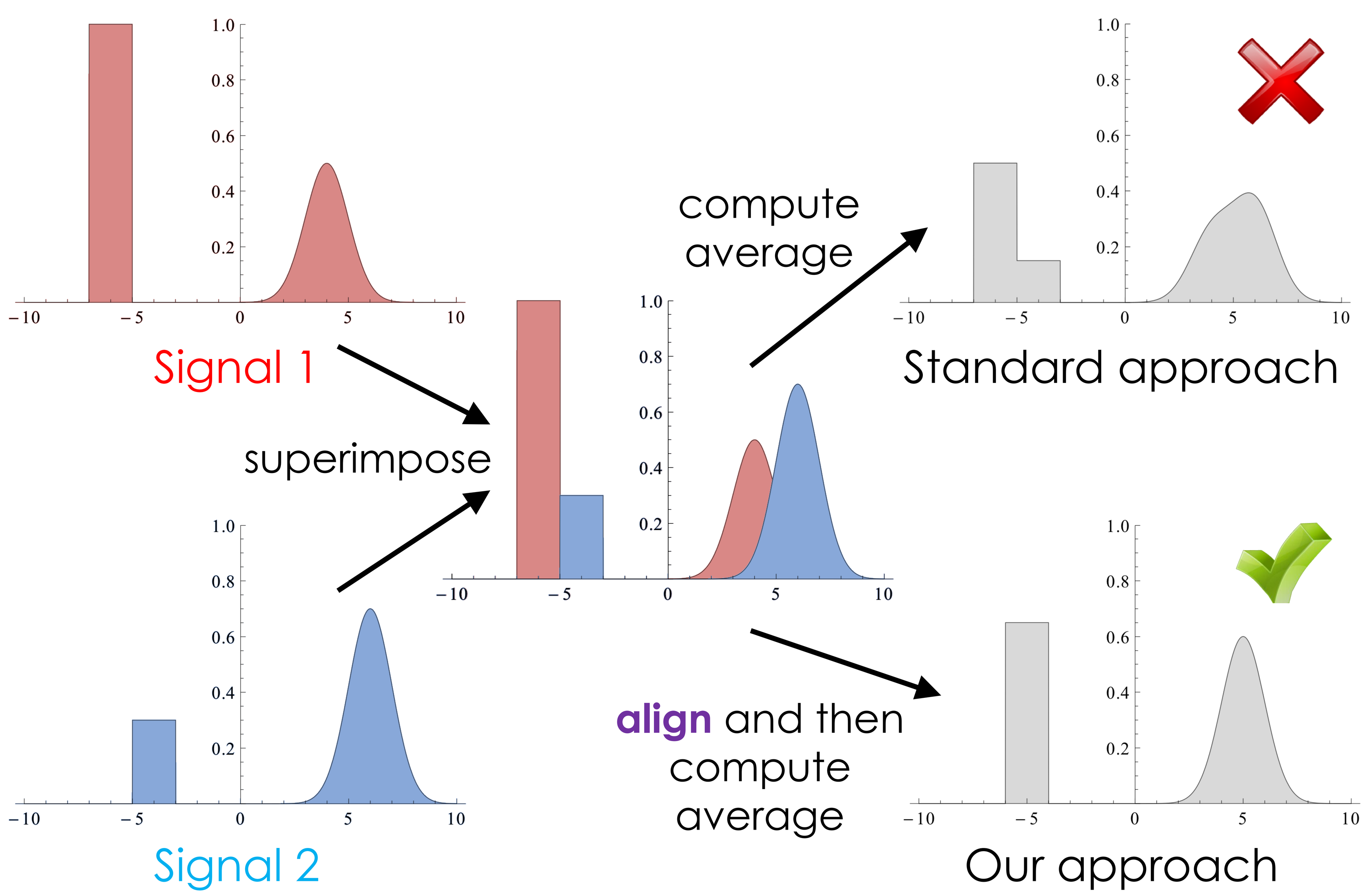




Goal: Find correspondences between different subjects' activation regions & find descriptions for each group region

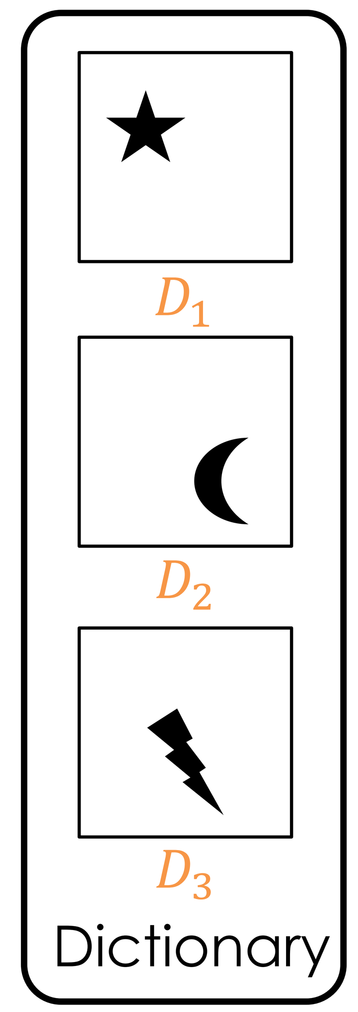
Toy Example

Want to recover box and Gaussian bump



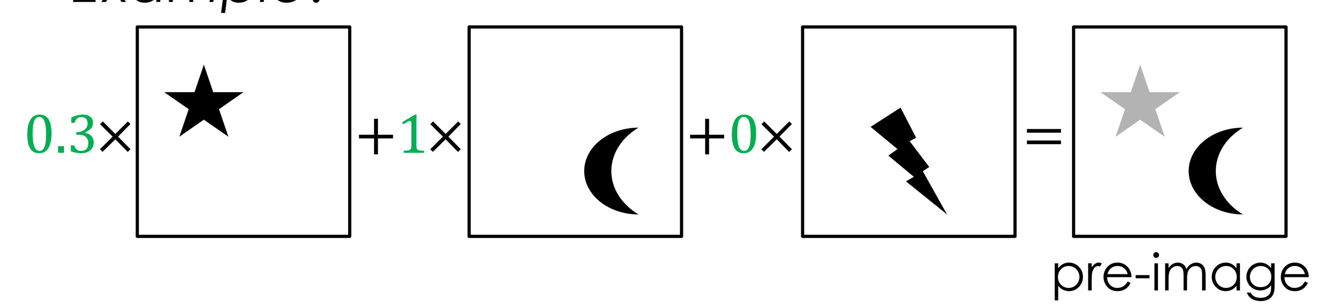
Model

Generative process for signal $n = 1, \ldots, N$:

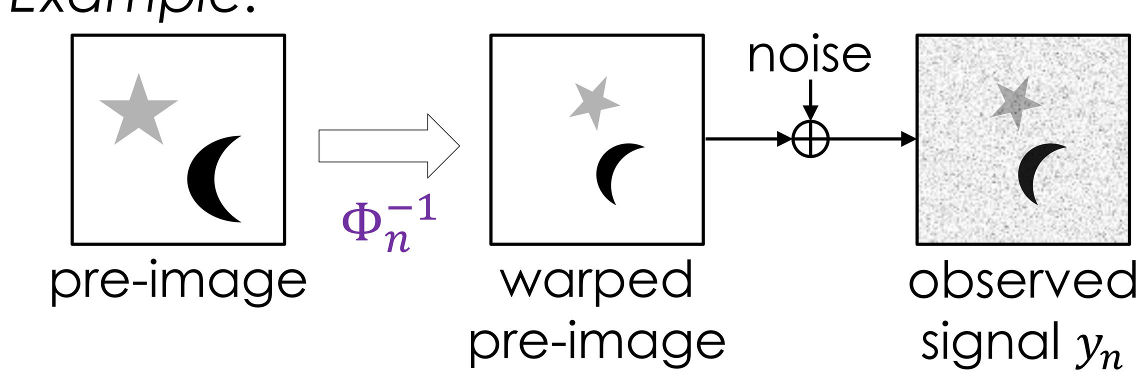


Encode each group region as a dictionary element!

1. Choose weights for each dictionary element
   Example: $w_n = (0.3,1,0)$
2. Form a weighted sum of dictionary elements
   Example:



3. Warp pre-image and add Gaussian noise
   Example:

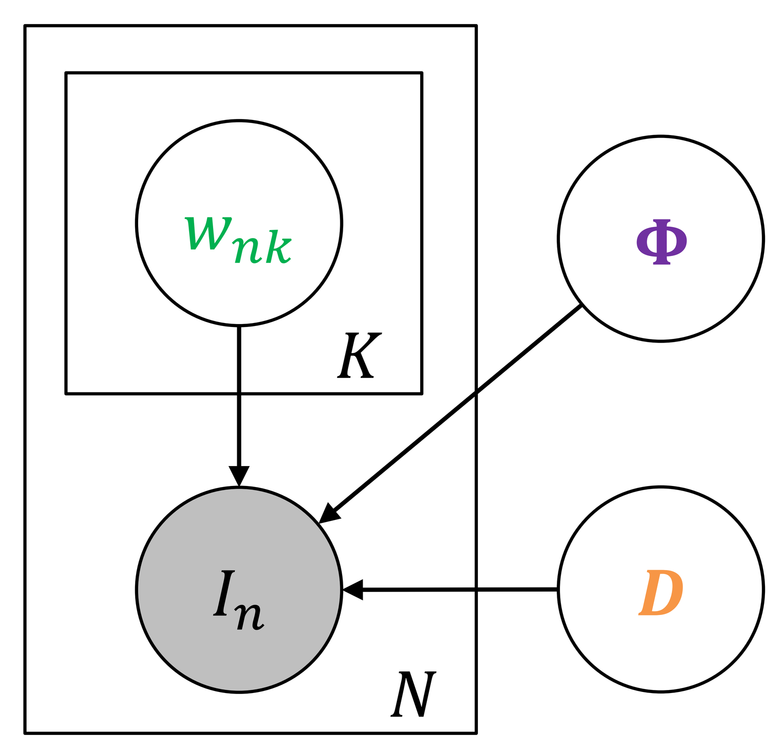


$$y_n = \left(\sum_{k=1}^{K} w_{nk} D_k \right) \circ \Phi_n^{-1} + \text{noise}$$

w_n sparse, no deformations → **sparse coding**

Choice of Priors

- Weights w_n: **sparse**
- Deformations Φ_n: exploit **existing image alignment algorithms**
  → *recovery dictionary elements up to small deformation*
- Dictionary elements D: **sparse**, **smooth**, **localized**, **diverse**



Graphical model

Goal: Find dictionary & deformations maximizing $p(D, \Phi | y)$
→*use EM-like inference algorithm (iterate between updating weights, deformations, dictionary)*

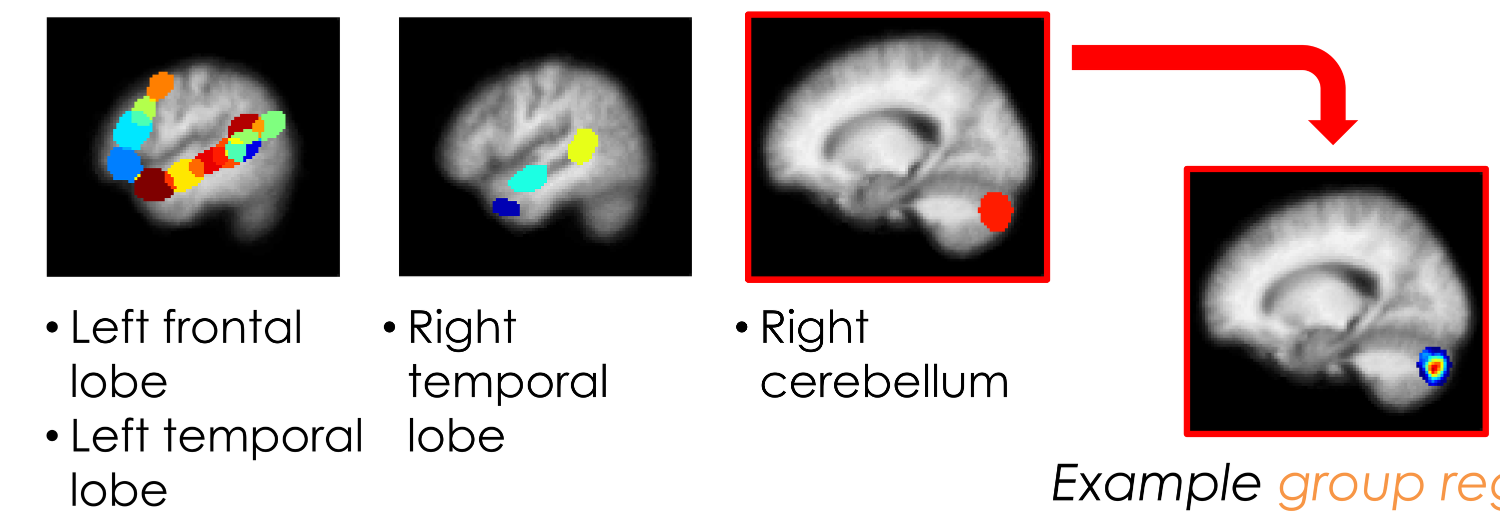
Results

Language processing data:

- Substantial functional variability!
- 82 subjects reading sentences vs. non-words
- Observed signals y_n are t-statistic images from standard fMRI preprocessing
  → *higher intensity at voxel implies higher statistical significance for language processing at that voxel*

1. Estimated group regions → agree with known literature

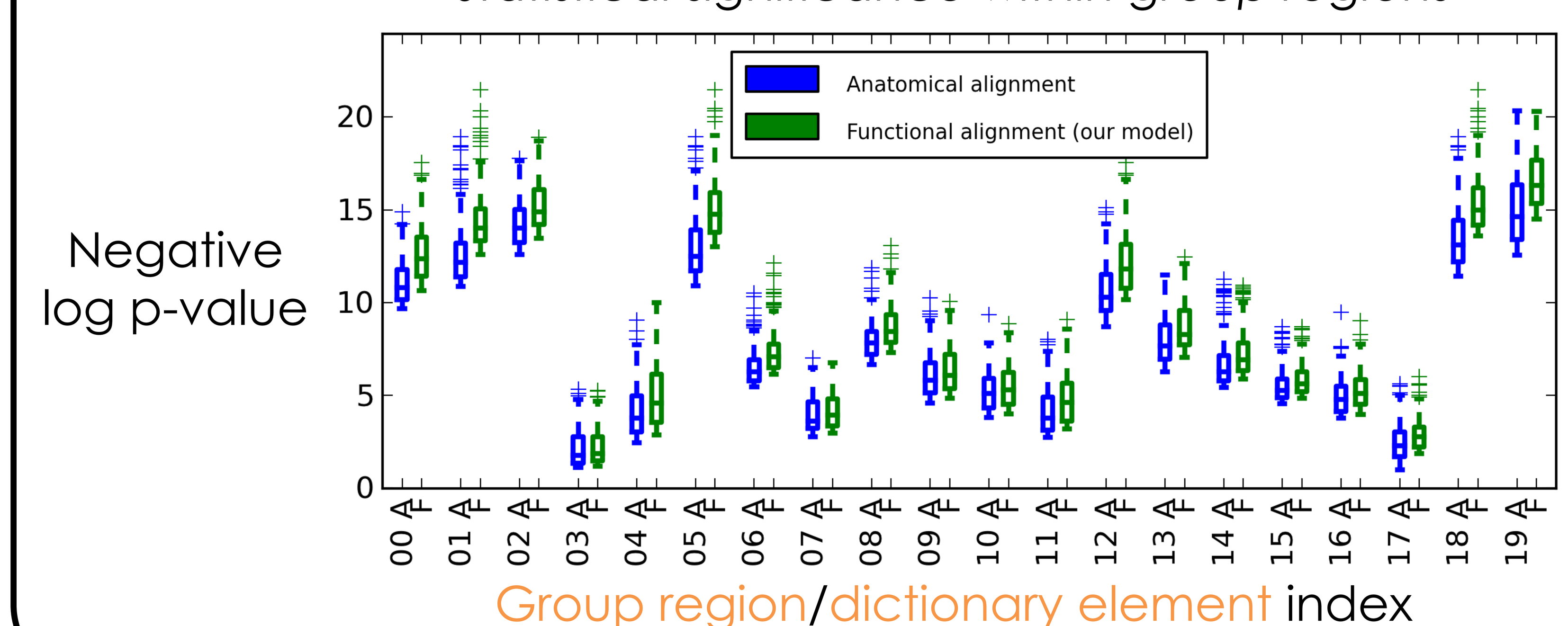
Spatial support of group regions (in different colors)



Example group region/ dictionary element

2. Estimated deformations → more robust group effects

Statistical significance within group regions



Contributions

- Extended sparse coding to handle deformations
  - Uses existing image alignment algorithms as subroutine
  - Can be interpreted as aligning a group with images with spatially adaptive intensity equalization
- Applied model to functional neuroimaging data

This work is supported by the following grants: NSF IIS/CRCNS 0904625, NSF CAREER 0642971, NIH NCRR NAC P41-RR13218, NIH NEI 5R01EY1345