ANALYSIS APPROACHES PART TWO

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Encoding models

- Encoding model: a description of how experimental attributes relate to evoked brain activity. In other words, an encoding model makes a prediction of activity levels for different experimental conditions.
- But isn't that what a simple fMRI GLM does?
  - For example, a GLM with a face predictor and a house predictor
- Yes, but the key is generalization power: in order to be non-trivial, a model needs to appeal to a lower-level property that can generalize beyond faces and houses

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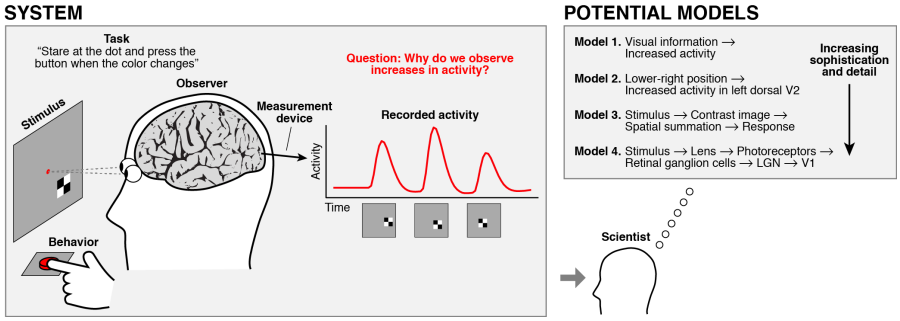
Building models is natural

Kay, *NeuroImage*, 2018

- Cognitive neuroscience is about linking experimental properties to neural activity
- Encoding models just make this explicit



The value of quantitative models

Kay, *NeuroImage*, 2018

- Models summarize data
- Models explain data
- Models predict data
  - Once you write down an actual quantitative model, it is falsifiable. (Word models aren't.)

Steps in building encoding models

Naselaris and Kay, *TICS*, 2015

Box 1. Steps in Building Encoding Models

- Design the experiment: typically, a large number of conditions are used to sample a variety of features, postponing commitment to the specific features that may be relevant to a given brain area.
- Collect the data: physiological responses are measured using multiple repetitions of each condition so that response variability (i.e., noise level) can be quantified.
- Select a model: the features hypothesized to be encoded in a given brain area are formally specified.
- Fit the model: free parameters of the model (e.g., weights in a linear model) are adjusted to best fit the data. This can entail ordinary least-squares estimation or regularized estimation procedures, such as ridge regression or the lasso.
- Summarize model parameters: parameters are summarized and compared across brain areas using simple metrics (e.g., mean or median) or more sophisticated methods (e.g., principal components analysis or model-based decoding). Reliability of parameter estimates is also assessed (e.g., by bootstrapping trials or subjects).
- Quantify model accuracy: to control for overfitting, model accuracy is assessed by cross-validating on new data (e.g., new trials, experimental conditions, or subjects). Accuracy is quantified as percent variance explained.
- Consider alternative models: the modeling procedure is repeated to determine whether the data might be better explained by a simpler or completely different model.

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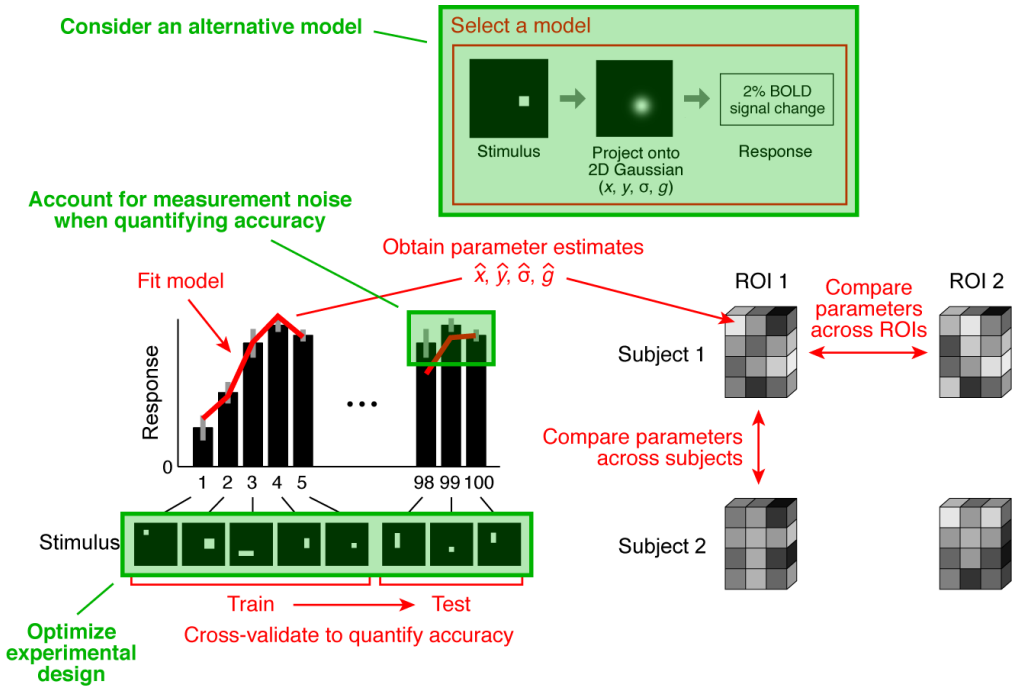

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Many possible attributes (features)

- Low-level sensory attributes
- High-level sensory attributes
- Attention/task attributes
- Semantic attributes
- Etc.

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Population Receptive Field (pRF)

- This is just a special case of encoding models.
  - Specifically, the attribute that is thought to be related to the response is visual space.

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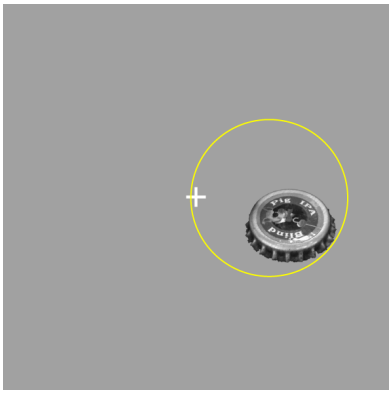
Population Receptive Field (pRF)

- **Receptive field** – region of the visual field within which a visual stimulus elicits a response from a neuron
- **Population receptive field** – concept of the receptive field applied to a voxel (population of neurons)



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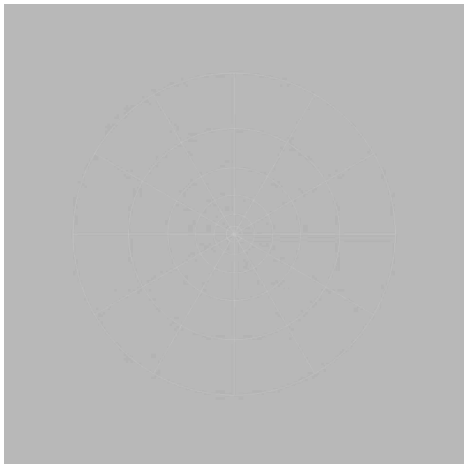
A real-world example



Kay, Weiner, Grill-Spector, *Curr Bio*, 2015

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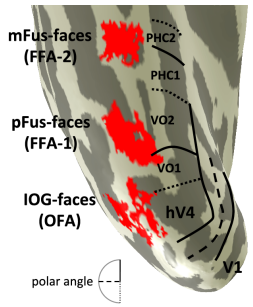
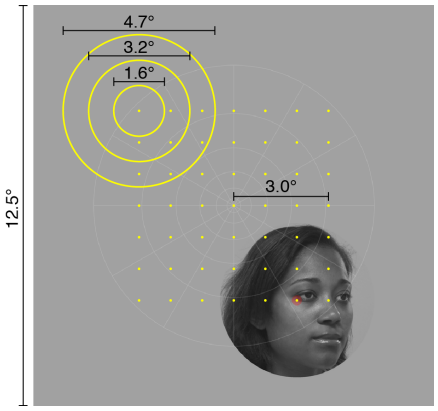
A real-world example

- Systematically vary position and size of the face
- 3 T, 2 mm, TR 2 s
- Functional localizers



Weiner and Grill-Spector, 2012



Kay, Weiner, Grill-Spector, *Curr Bio*, 2015

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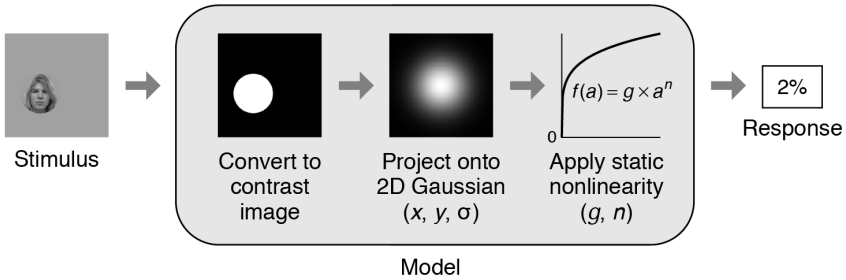
pRF estimation

- The encoding model:



Kay et al., *J. Neurophys.*, 2013

Also see:
Dumoulin and Wandell, *NeuroImage*, 2008

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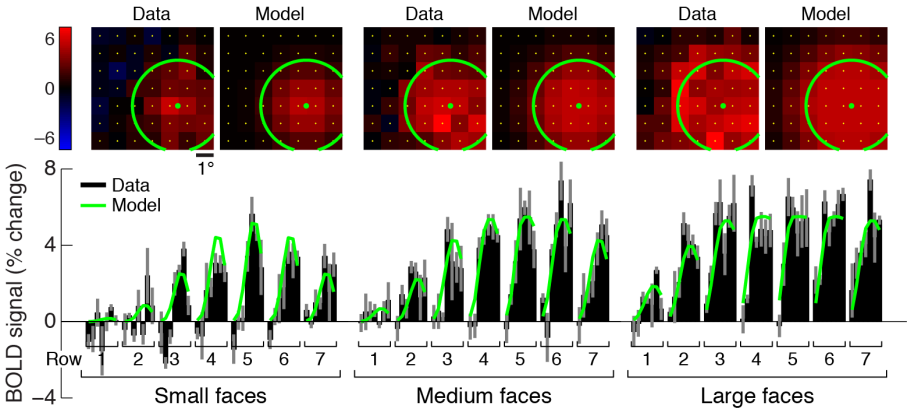
pRF estimation

• Example voxel (IOG, left hemisphere):



Kay, Weiner, Grill-Spector, *Curr Bio*, 2015

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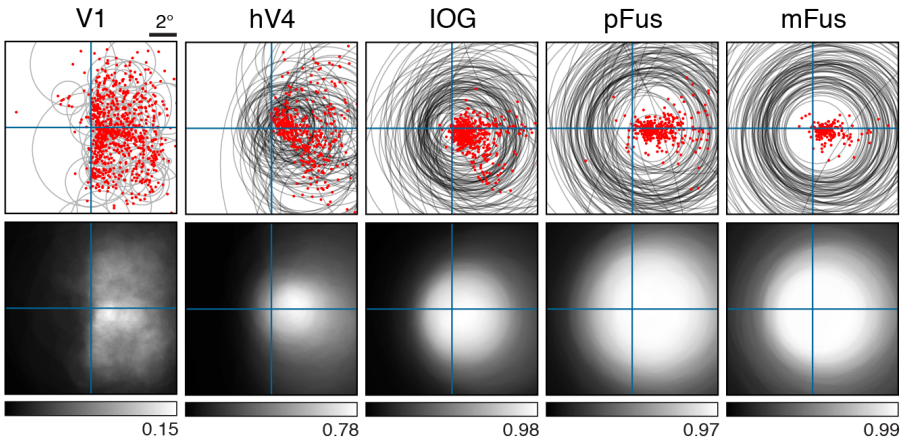
Face regions exhibit foveal bias, large pRFs



Kay, Weiner, Grill-Spector, *Curr Bio*, 2015

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Encoding-model approach: a summary

- Approach: "formally relate experimental attributes to the observed BOLD response"
  - (This is arguably a natural scientific endeavor)
- pRF is just a special case of encoding models
- Typically, models of individual units are built (hence, the approach is univariate in nature).
  - (But one can approach the approach multivariately (c.f. CCA))

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How to actually build models

- A number of interesting issues to deal with:
  - Noise ceiling
  - Experimental design (stimulus sampling)
  - Model selection
  - Cross-validation schemes
  - Local minima
  - Computational time for model fitting
  - Model interpretation
- See 'Bonus Lecture: Model Mechanics'
- Additional resources at http://cvnlab.net

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How do the approaches fit together?

- Encoding: "Given that the experiment is this, what do I expect the response to be?"
- Decoding: "Given that the response is this, what do I expect the experiment to be?"

A metaphorical way to consider the approaches:

- Subtraction is a poor-man's encoding model
  [univariate]
- MVPA is a fancy decoding-based approach for essentially performing subtraction
  [typically multivariate but can be univariate]
- RSA is a method that assesses how responses vary across many experimental conditions
  [typically multivariate but can be univariate]
- Encoding models is an approach that formally tries to predict responses
  [typically univariate but can be multivariate]

also see Naselaris et al., *NeuroImage*, 2011

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