

MAPPING HUMAN CORTEX

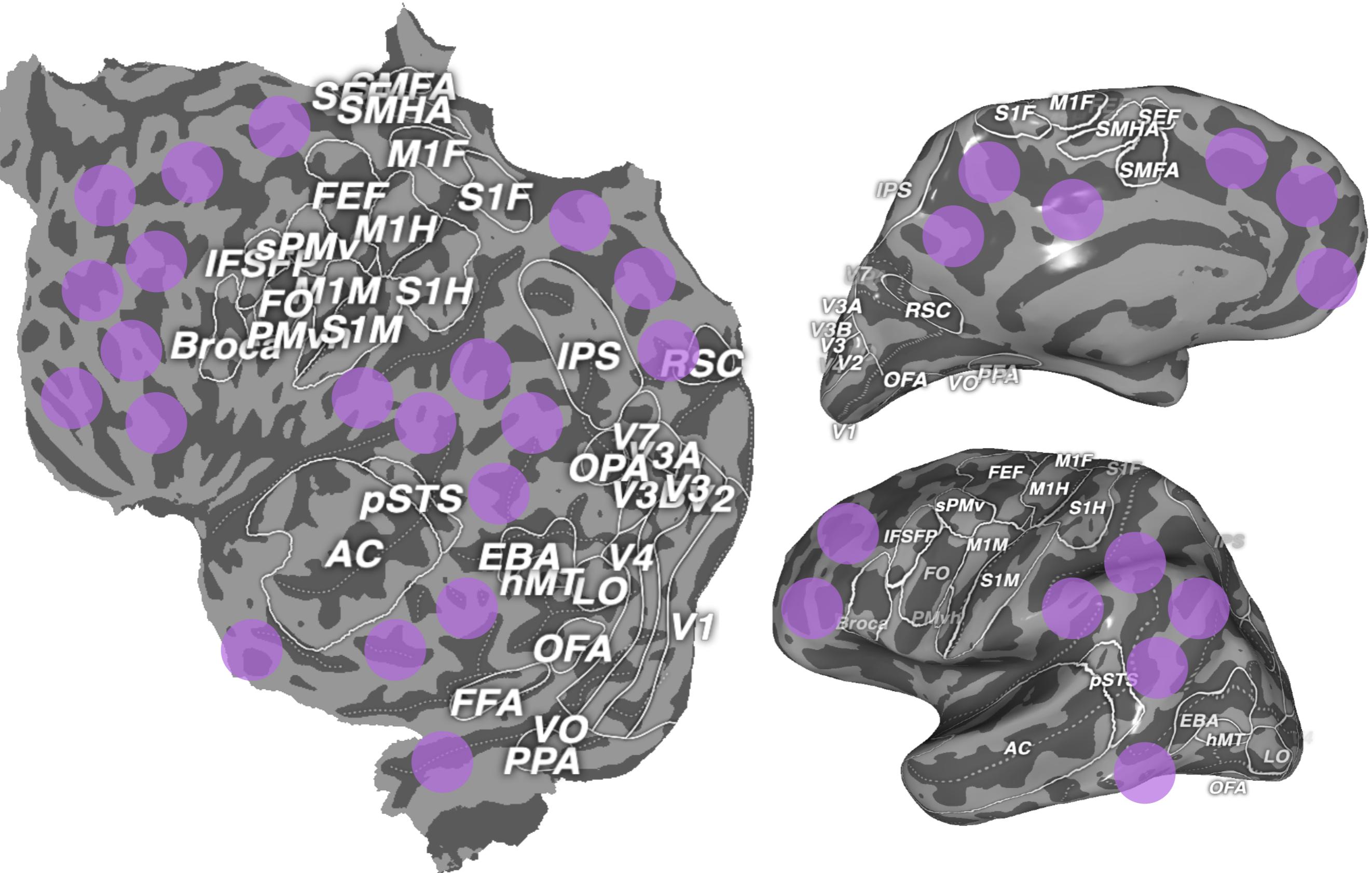
Prof. Alexander Huth

11.12.2020

HOMEWORKS

- * **Homework 3** (covering the somato-motor systems) will *actually* be posted before next class

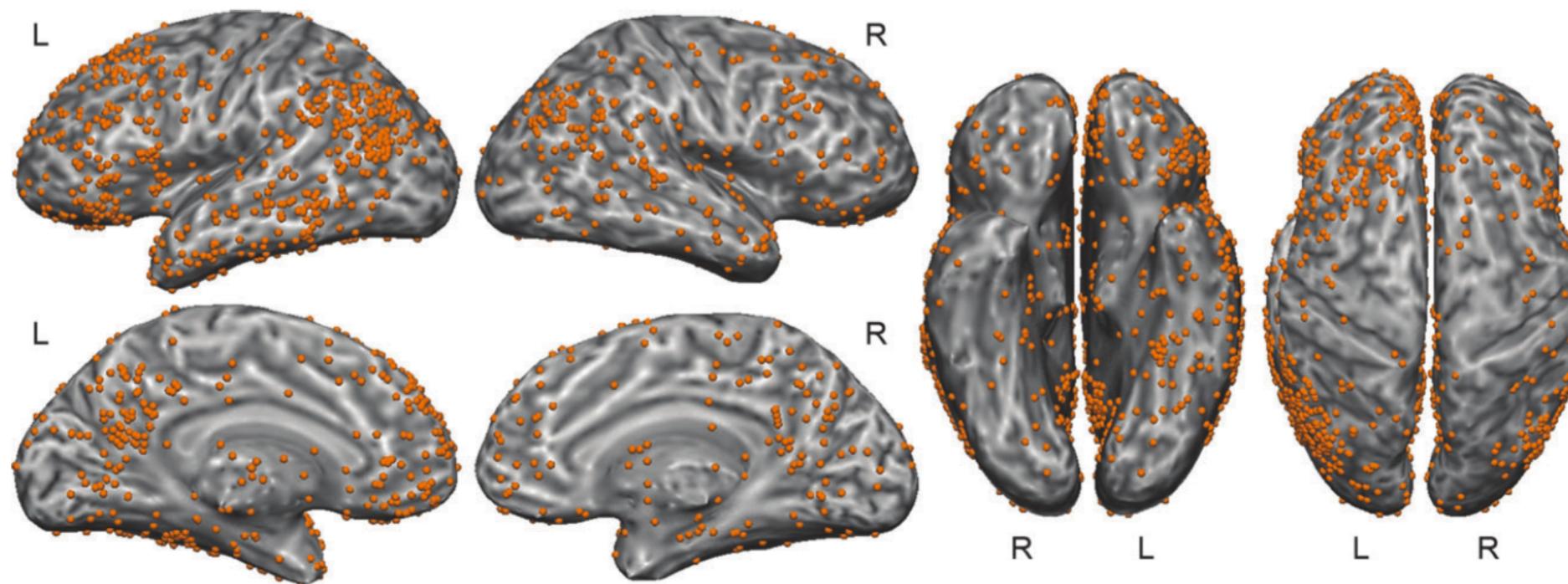
ASSOCIATION CORTEX



ASSOCIATION CORTEX

- * It's a name for all the bits of cortex that are *not* tied to a specific sensory modality or motor output
- * Many parts of association cortex are thought to be **multimodal**, i.e. represent information from multiple modalities
- * Association cortex is thought to be particularly important for **language understanding**

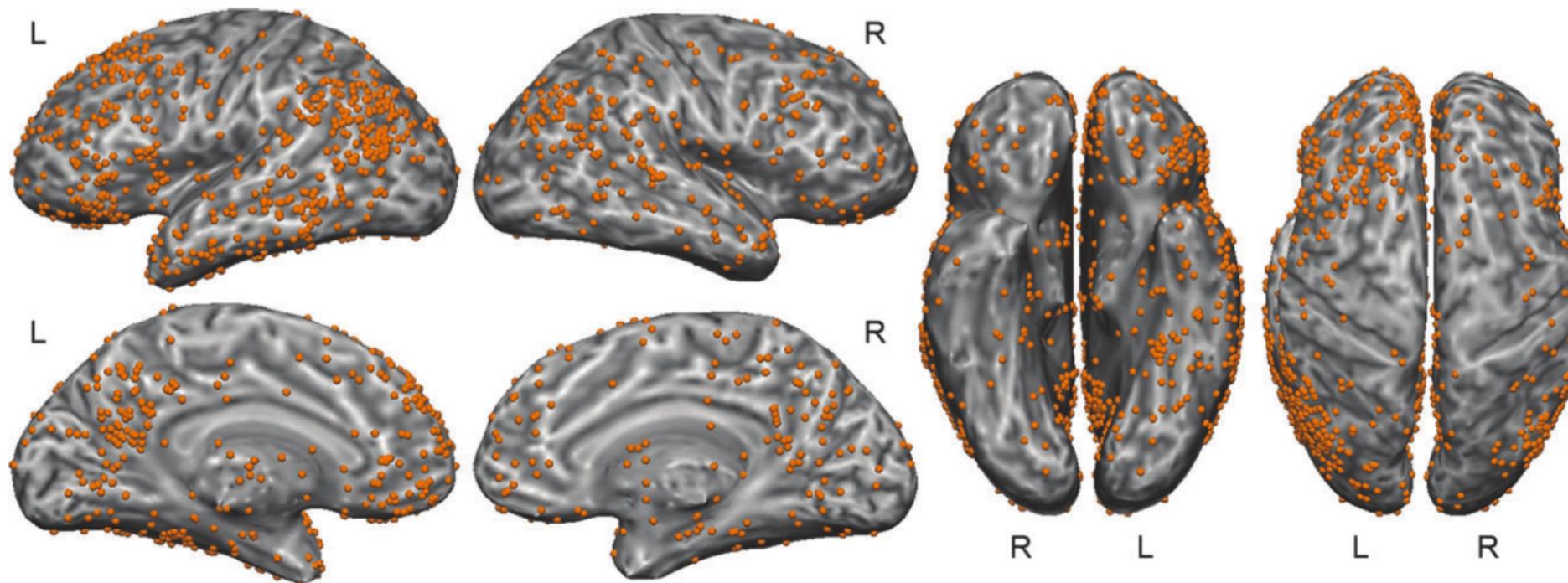
WHERE IS MEANING REPRESENTED?



From Binder et al.(2009)

- A meta-analysis of 100+ fMRI studies shows which parts of the brain respond when people need to process the **meaning or semantic content** of language

WHERE IS MEANING REPRESENTED?



From Binder et al.(2009)

- Do different parts of the brain represent different **categories** of words?

NATURAL LANGUAGE EXPERIMENT

Language fMRI data

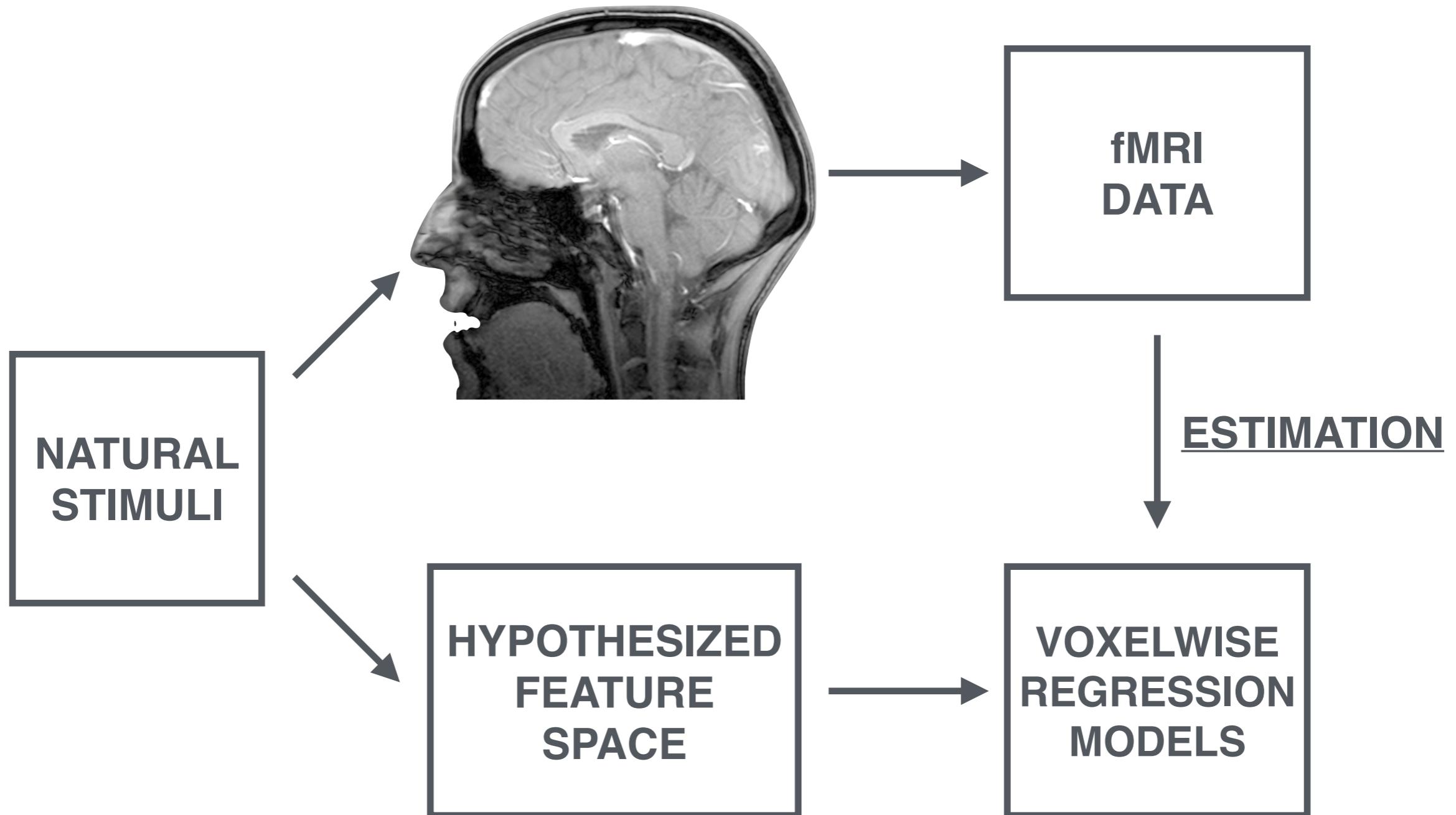
2.5h narrative stories from

The Moth Radio Hour



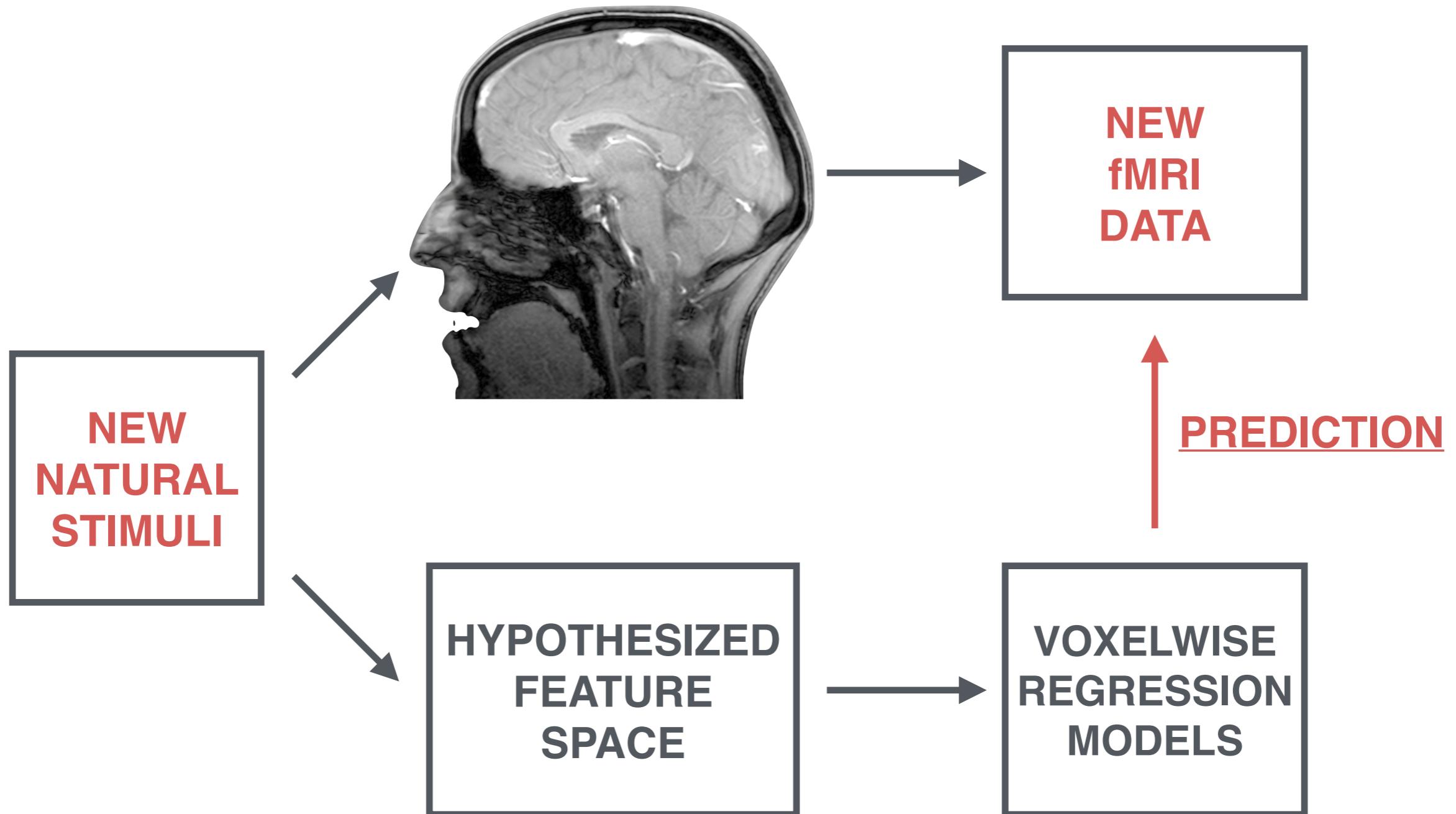
*"...she was removing photographs
from the walls and placing them in
little piles around the house..."*

VOXELWISE MODELING



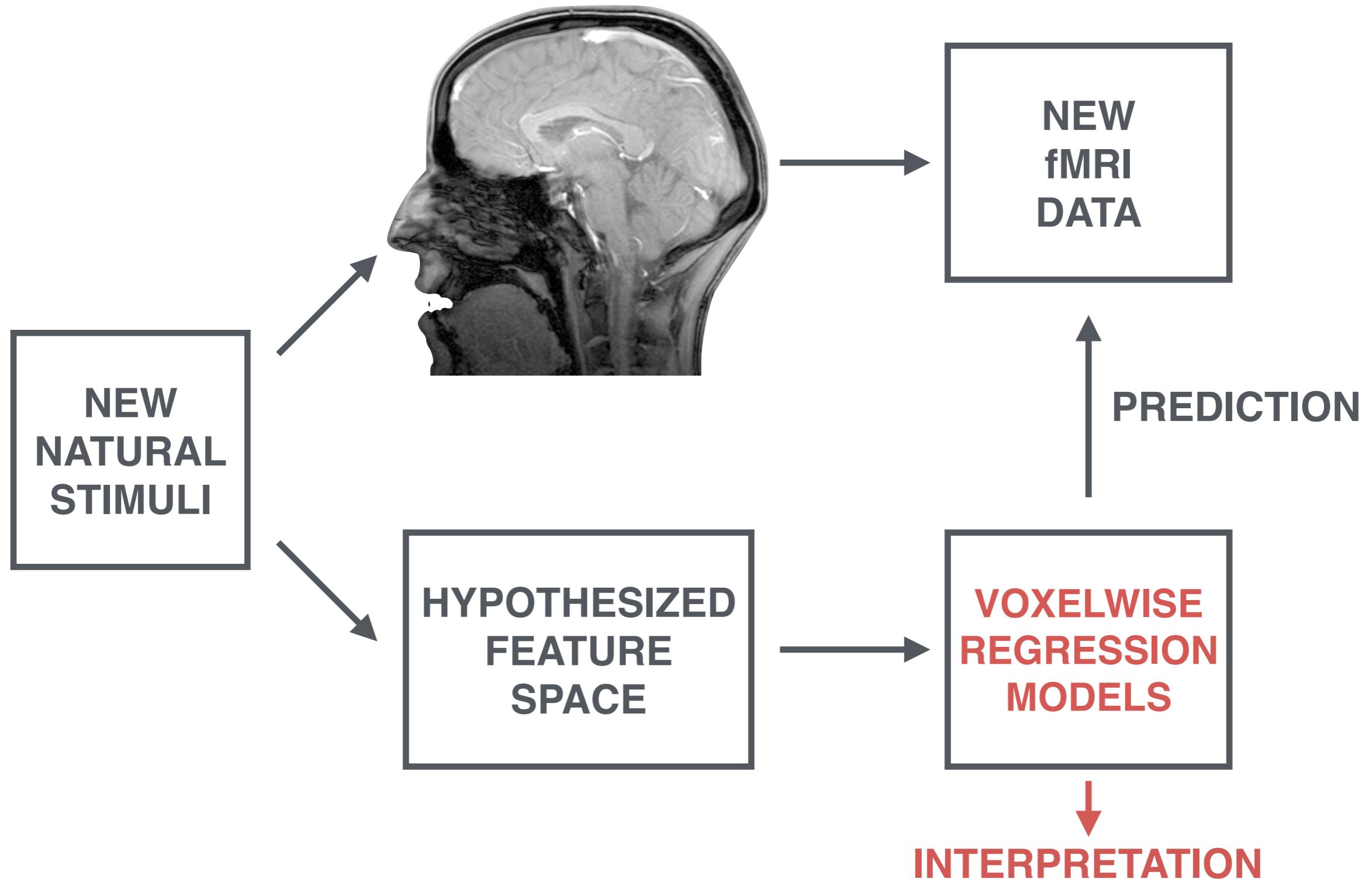
Kay et al. *Nature* (2008), Naselaris *Neuron* (2009), Nishimoto *Current Biology* (2011),
Huth *Neuron* (2012), Huth *Nature* (2016), etc.

VOXELWISE MODELING



Kay et al. *Nature* (2008), Naselaris *Neuron* (2009), Nishimoto *Current Biology* (2011),
Huth *Neuron* (2012), Huth *Nature* (2016), etc.

VOXELWISE MODELING



VOXELWISE MODELING

BASIC WORD-LEVEL MODEL:

each voxel responds (some amount) to each word

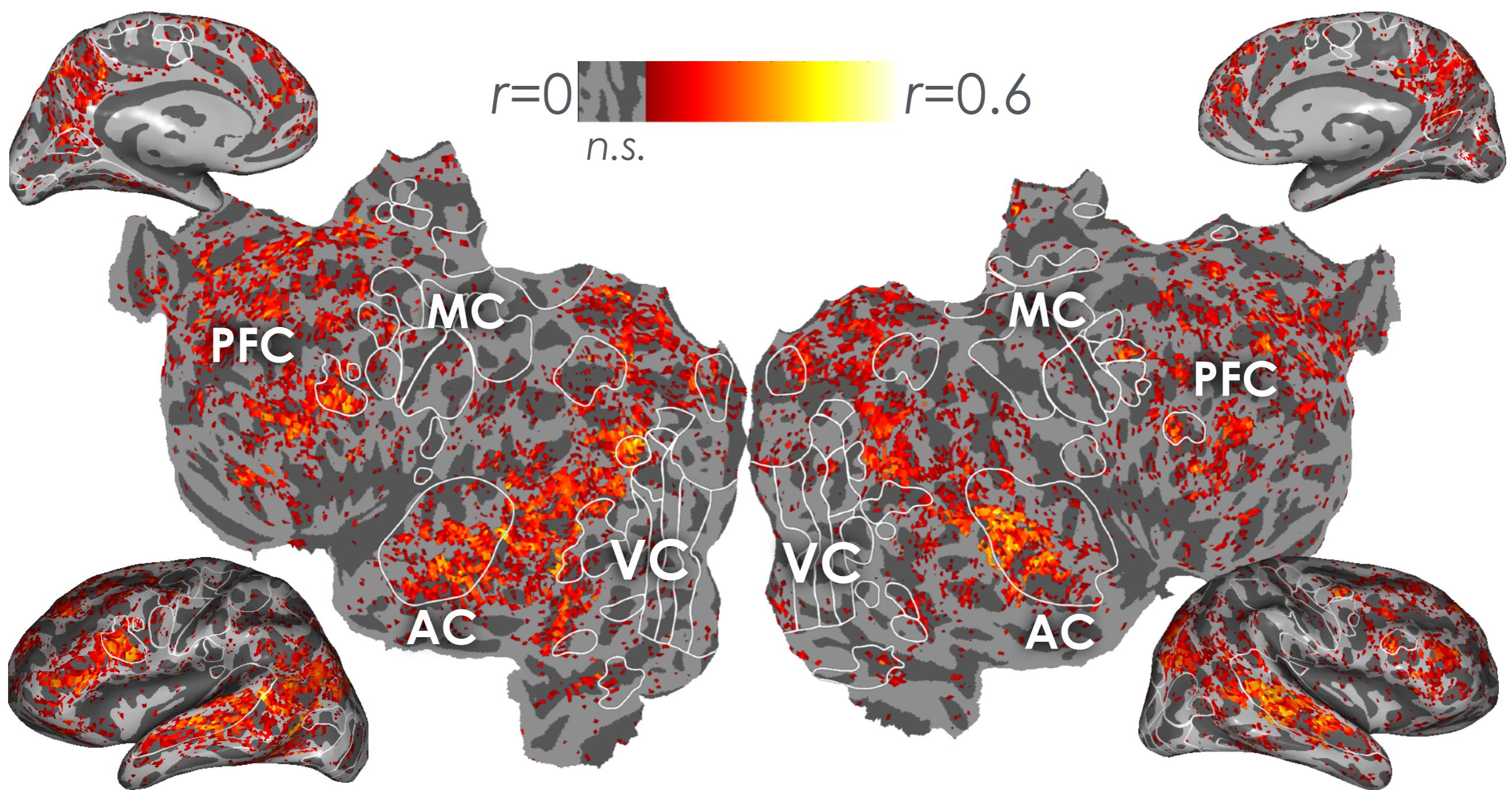
$$R_i(t) = \sum_{j=1}^N \beta_{ij} W_j(t)$$

$\beta \sim \mathcal{N}(0, I)$

$$\hat{\beta} = \operatorname{argmax}_{\beta} P(R|\beta, W)P(\beta)$$

likelihood prior

WORD MODEL PERFORMANCE: MEDIOCRE



SEMANTIC PRIOR

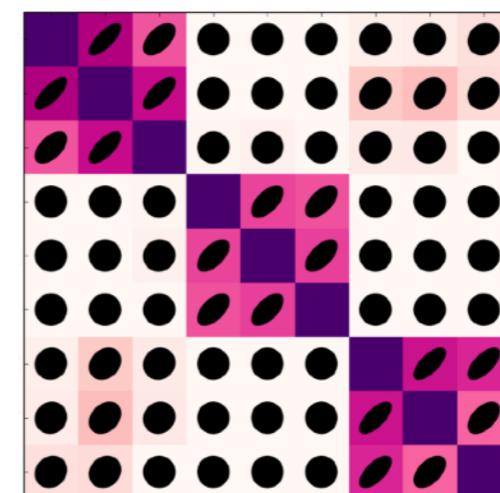
IMPROVED WORD-LEVEL MODEL:

Similar responses to words with similar meanings

$$\hat{\beta} = \operatorname{argmax}_{\beta} P(R|\beta, W)P(\beta)$$

likelihood **prior**

$$\beta \sim \mathcal{N}(0,$$



SEMANTIC PRIOR

Distributional hypothesis:

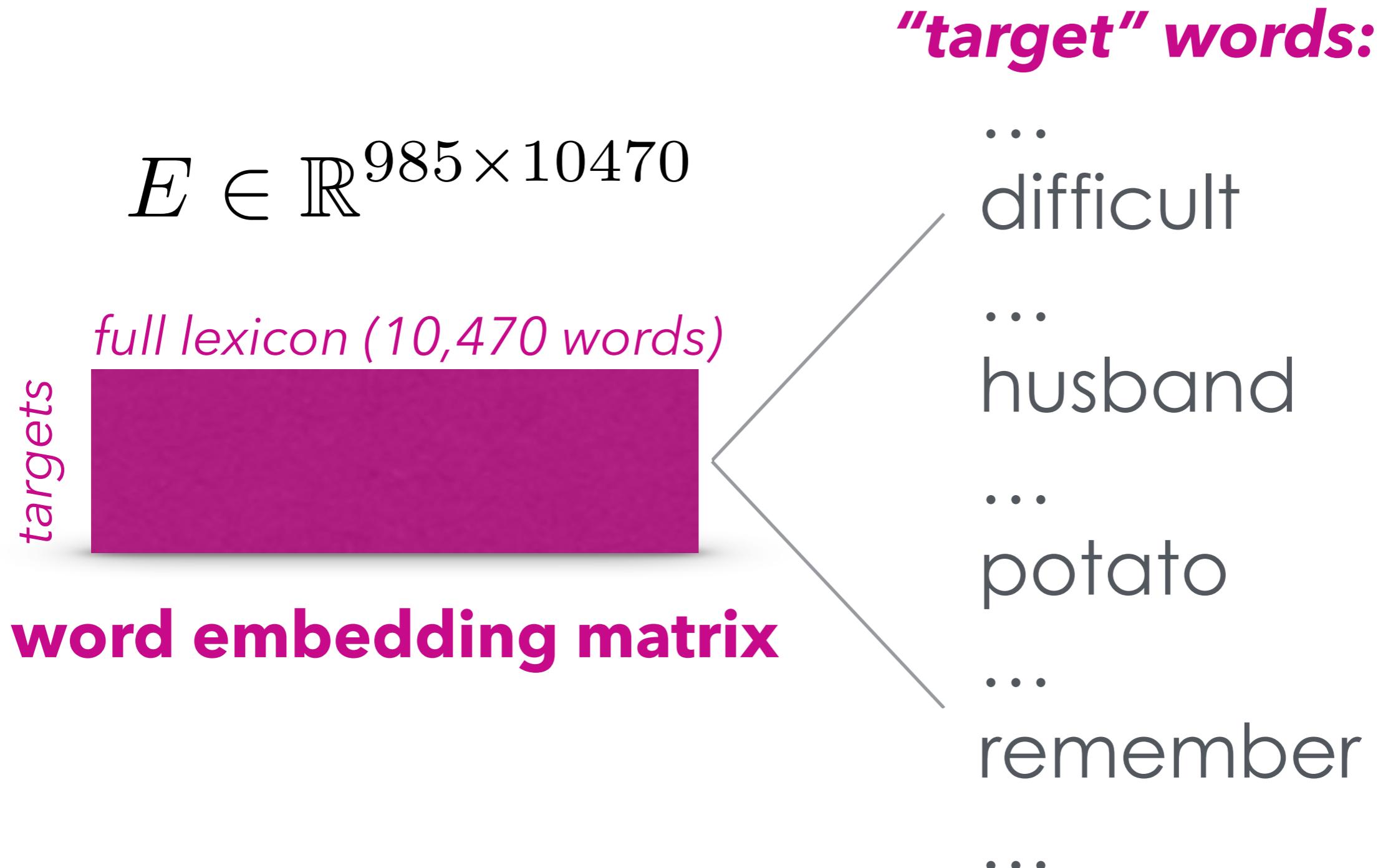
“You shall know a word by
the company it keeps,”

J. R. Firth (1954)



*Word meaning can be **measured** by looking
at patterns of “co-occurrence”, or the similarity
of contexts in which words occur!*

SEMANTIC PRIOR



SEMANTIC PRIOR

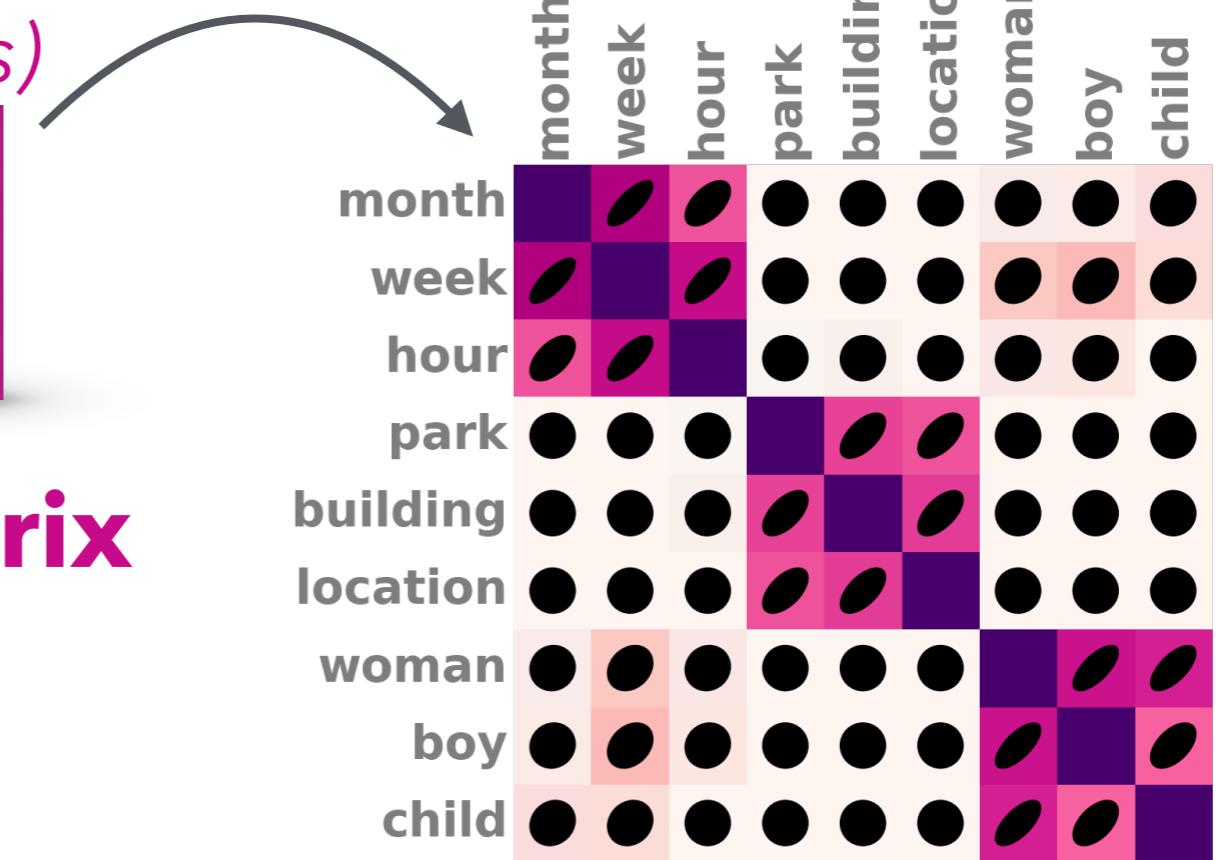
$$E \in \mathbb{R}^{985 \times 10470}$$

$$E^\top E$$

targets

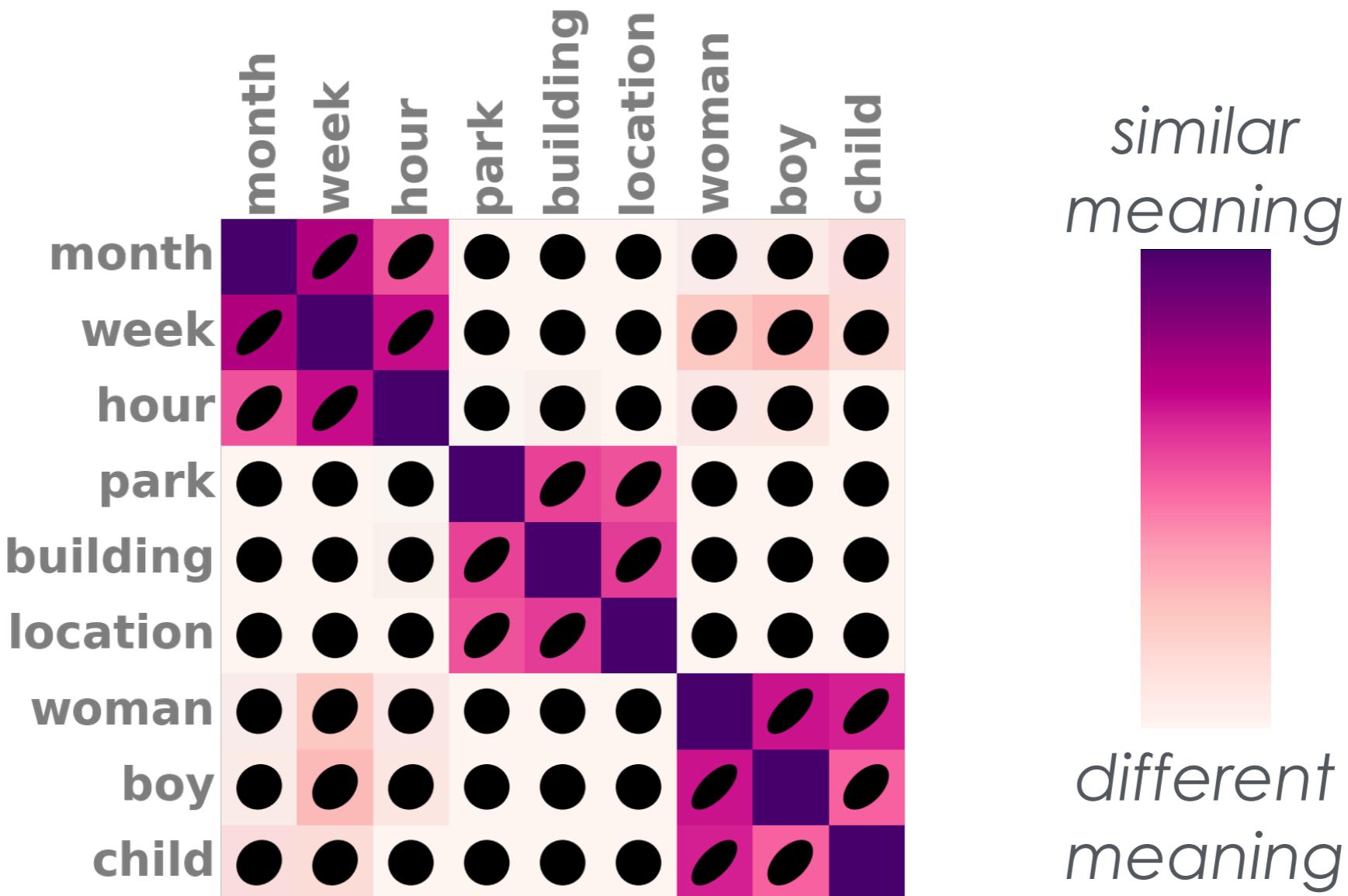


word embedding matrix



SEMANTIC PRIOR IMPROVED WORD-LEVEL MODEL:

Similar responses to words with similar meanings



SEMANTIC PRIOR

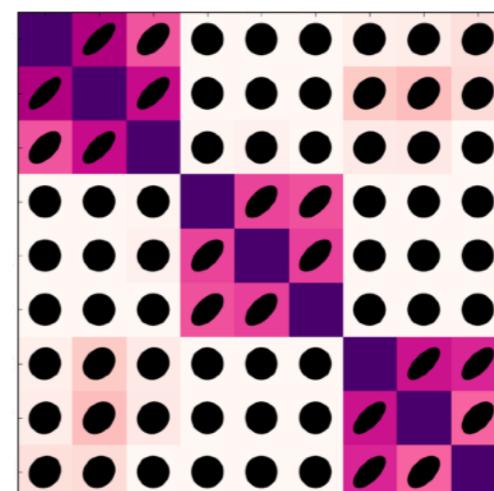
IMPROVED WORD-LEVEL MODEL:

Similar responses to words with similar meanings

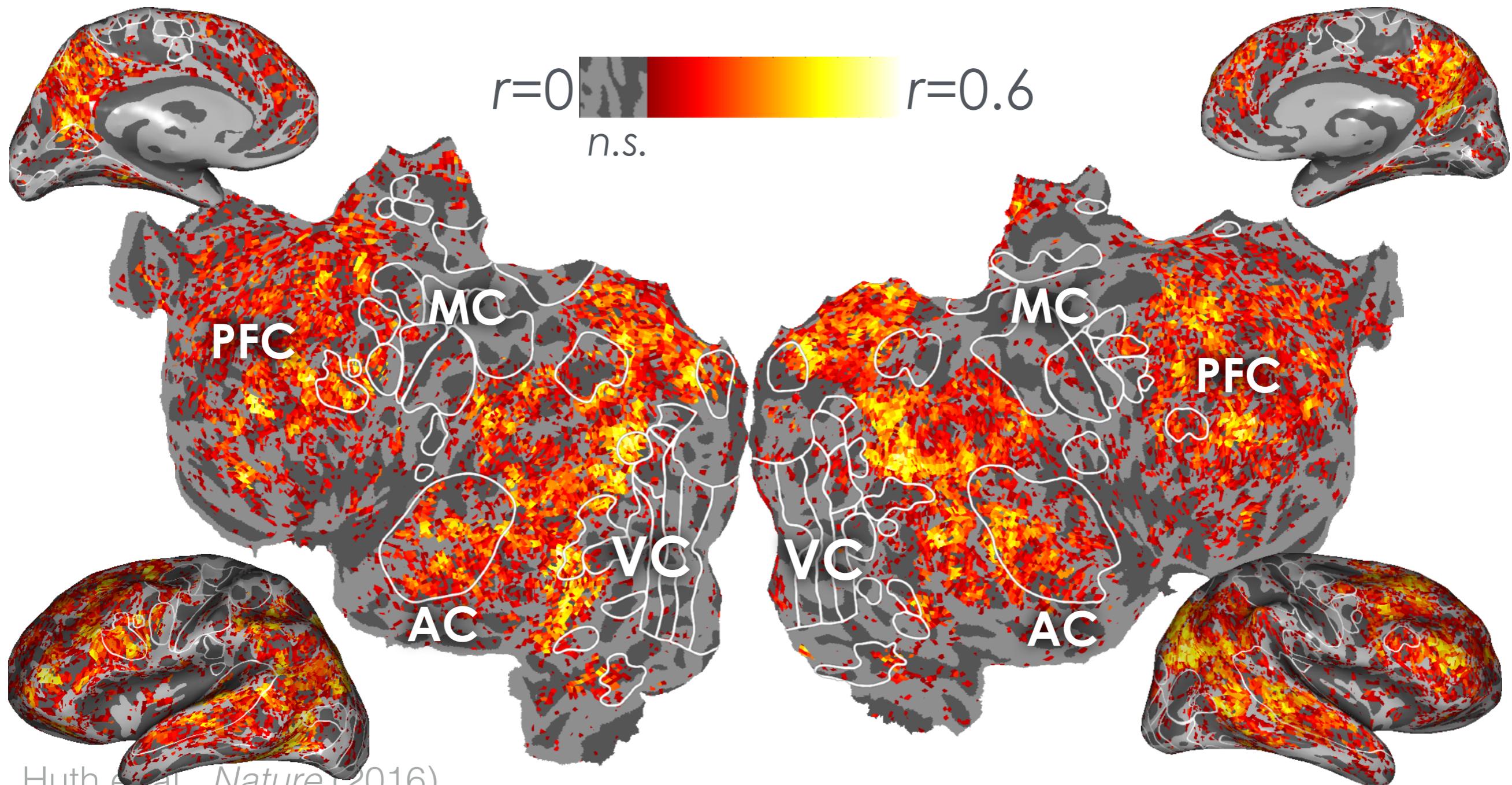
$$\hat{\beta} = \operatorname{argmax}_{\beta} P(R|\beta, W)P(\beta)$$

likelihood **prior**

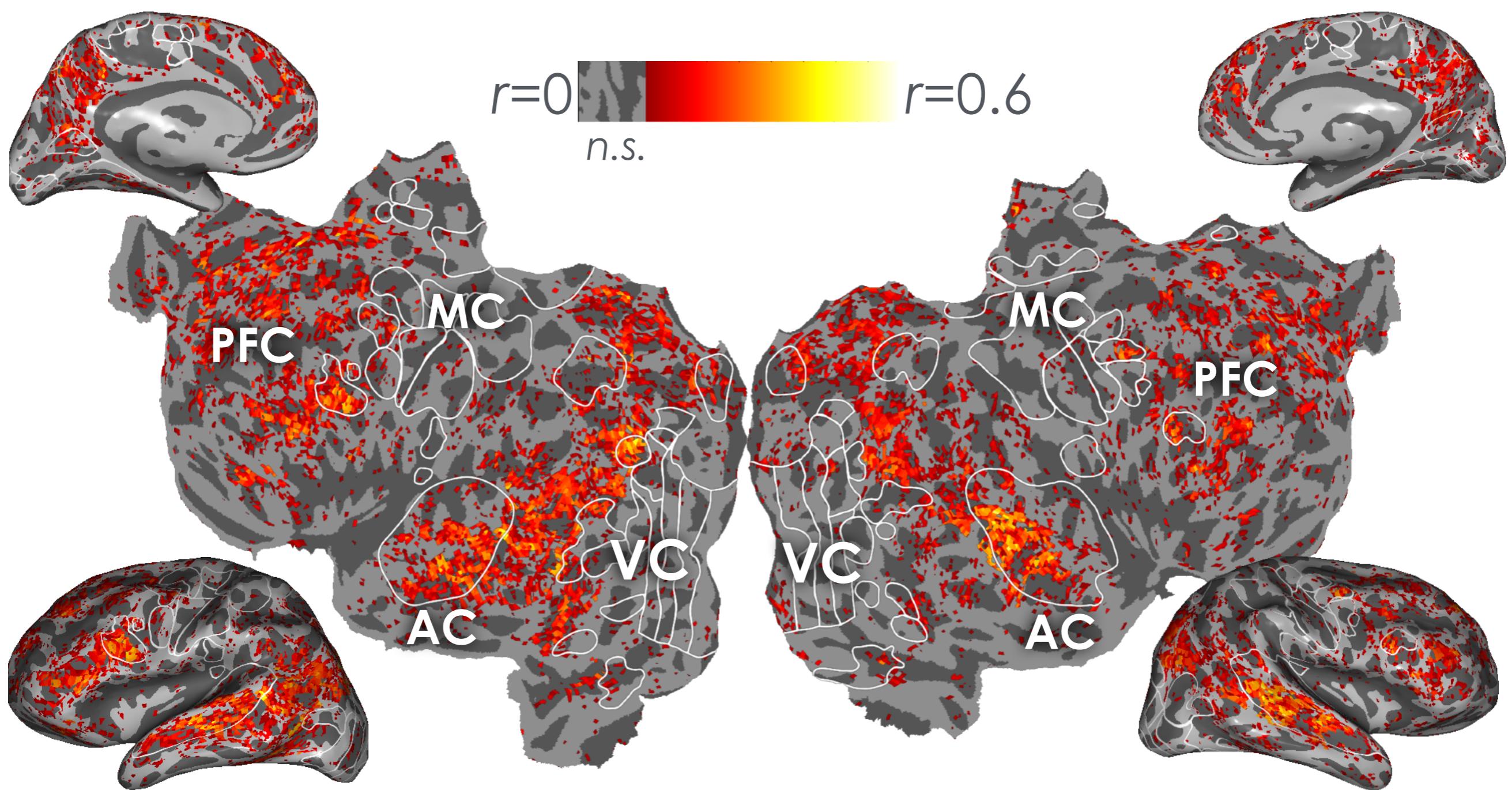
$$\beta \sim \mathcal{N}(0,$$



SEMANTIC MODEL PERFORMANCE: GOOD



WORD MODEL PERFORMANCE: MEDIOCRE



MODEL INTERPRETATION

*What information is represented
in each voxel?*

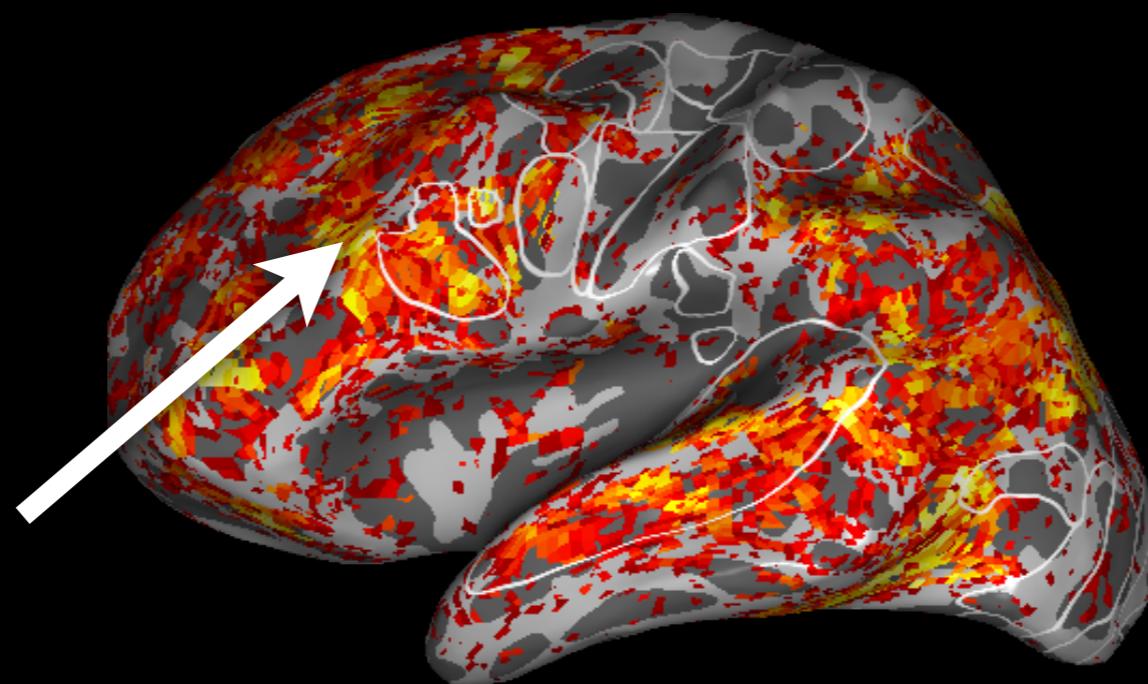
MODEL INTERPRETATION

emotions bible behaved thoroughly
advice counselor politician taught community
opinion political intellectual sir reasoned humor scientist kindly
politics religious singer biology dislike people's discussed
fellow appreciated culture educated arrogant rightly pope
encourage chaplain response colleagues offended polite moral recognize
argue enthusiasm remark understand

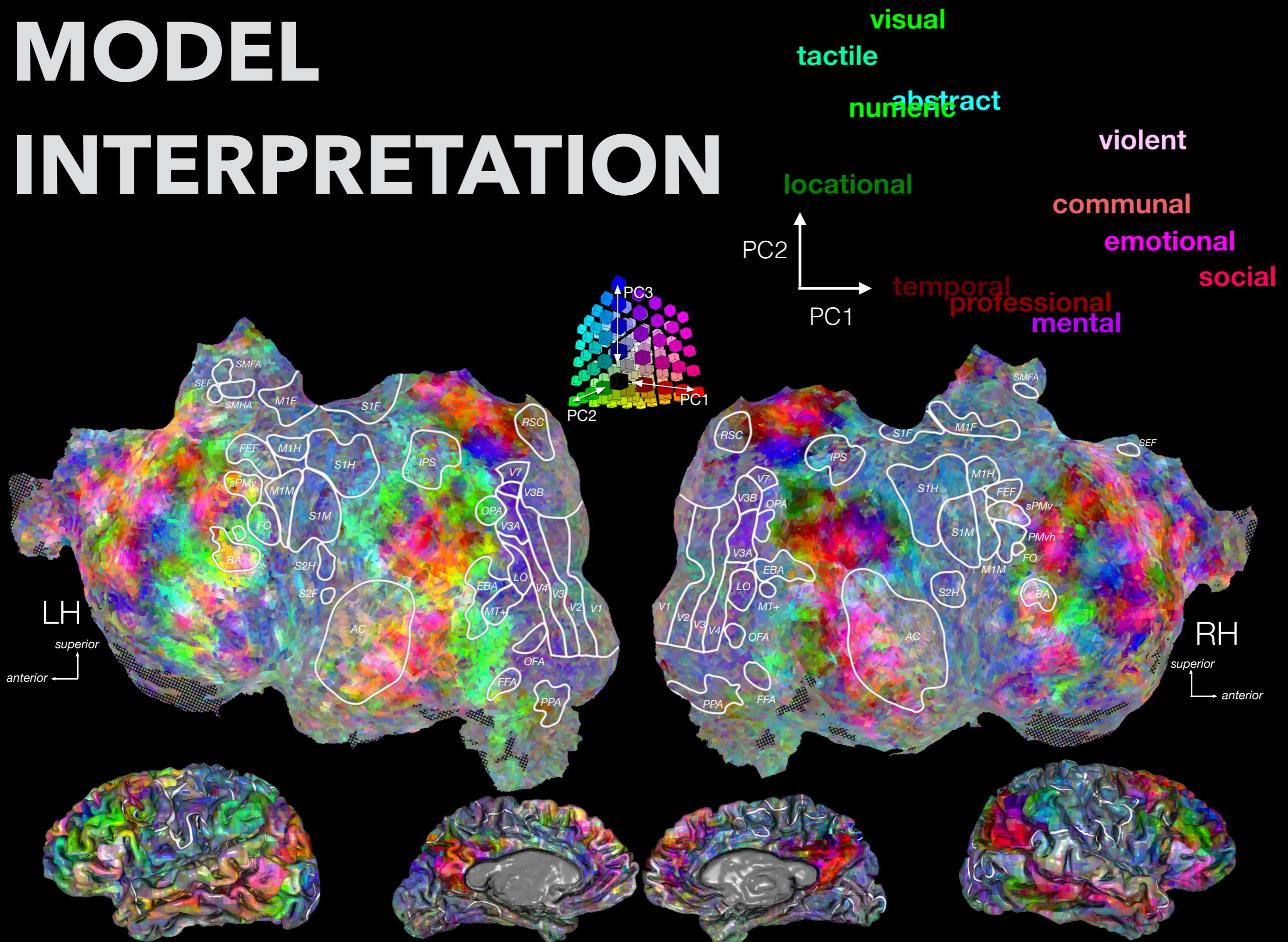
speed cliffs tower twenty-two destination landing aloft shaft
climb twice square stacked below each two maximum
dozen resulting nearest yards nearly miles eight
finishes circular month thirty-five single total metres upwards
mounted wreckage days excess passengers eleven pair mm
canyon block dome placed highest corners

Lower response

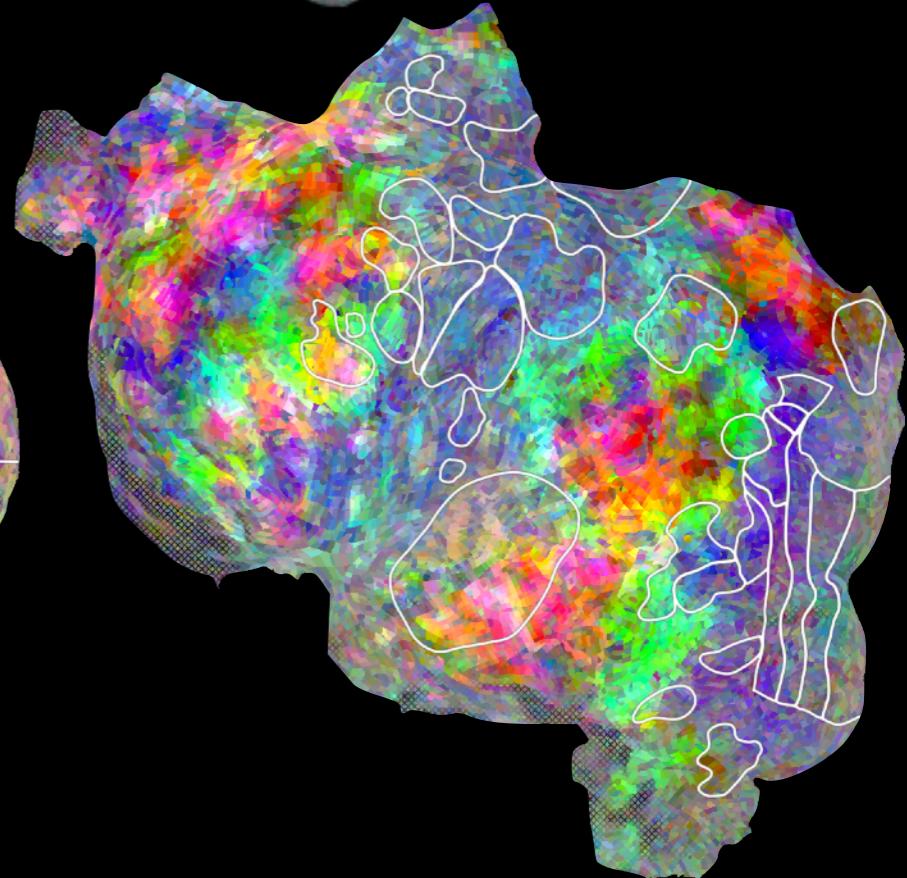
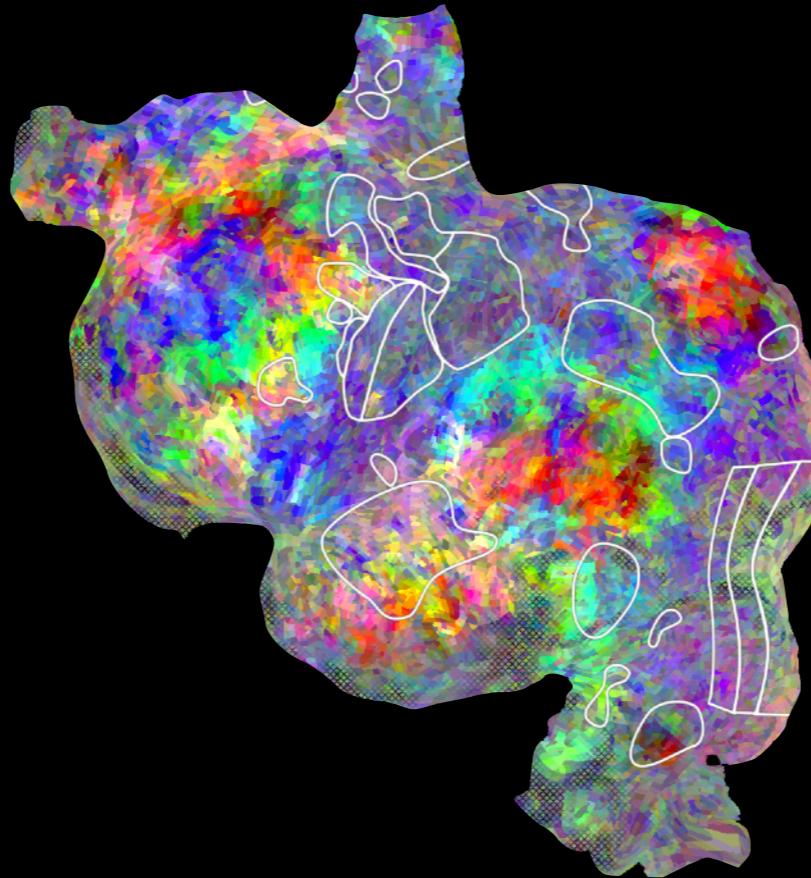
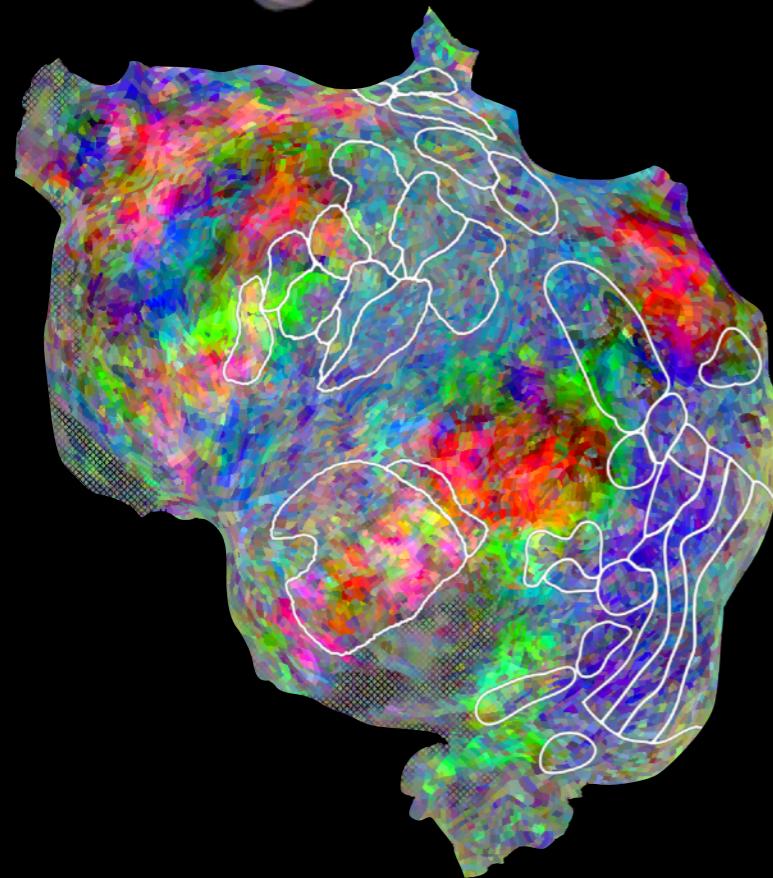
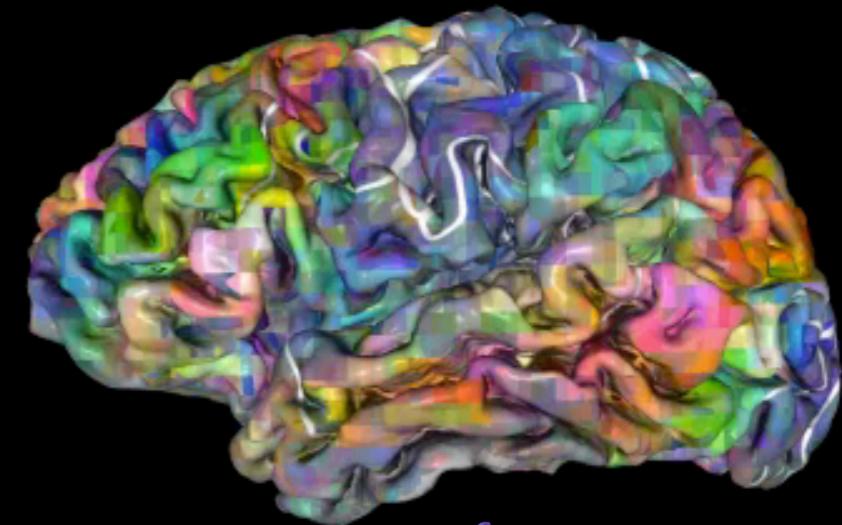
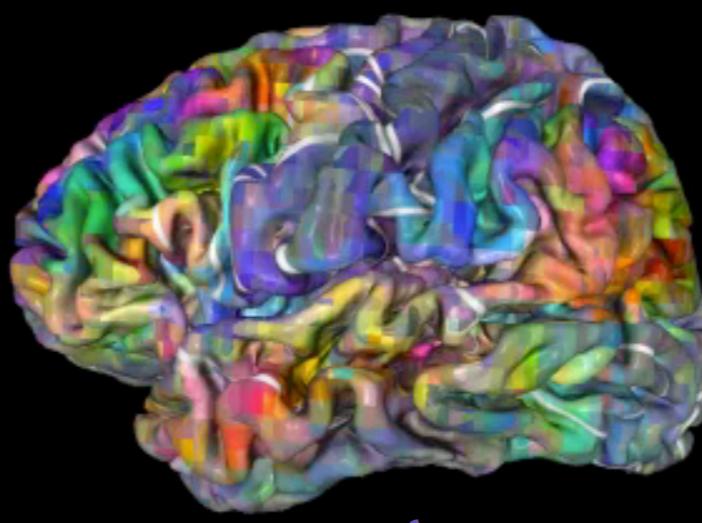
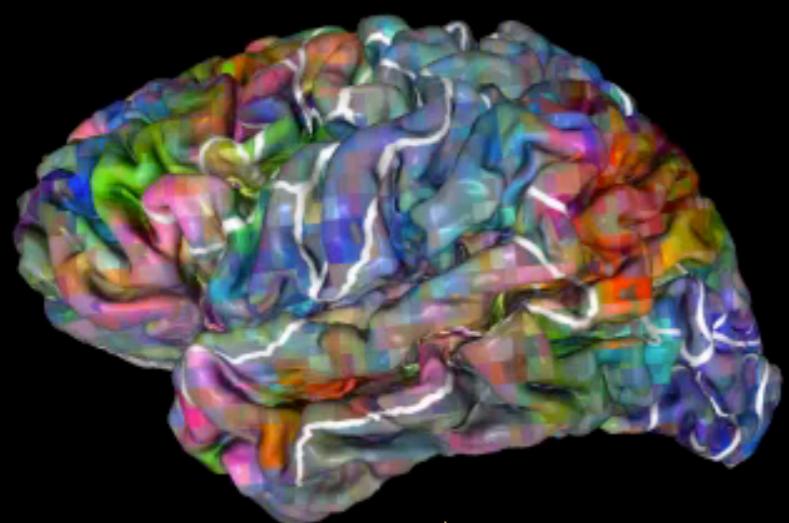
Higher response



MODEL INTERPRETATION



MAPS ARE CONSISTENT ACROSS SUBJECTS



UNTIL

NEXT

TIME