MAPPING HUMAN CORTEX

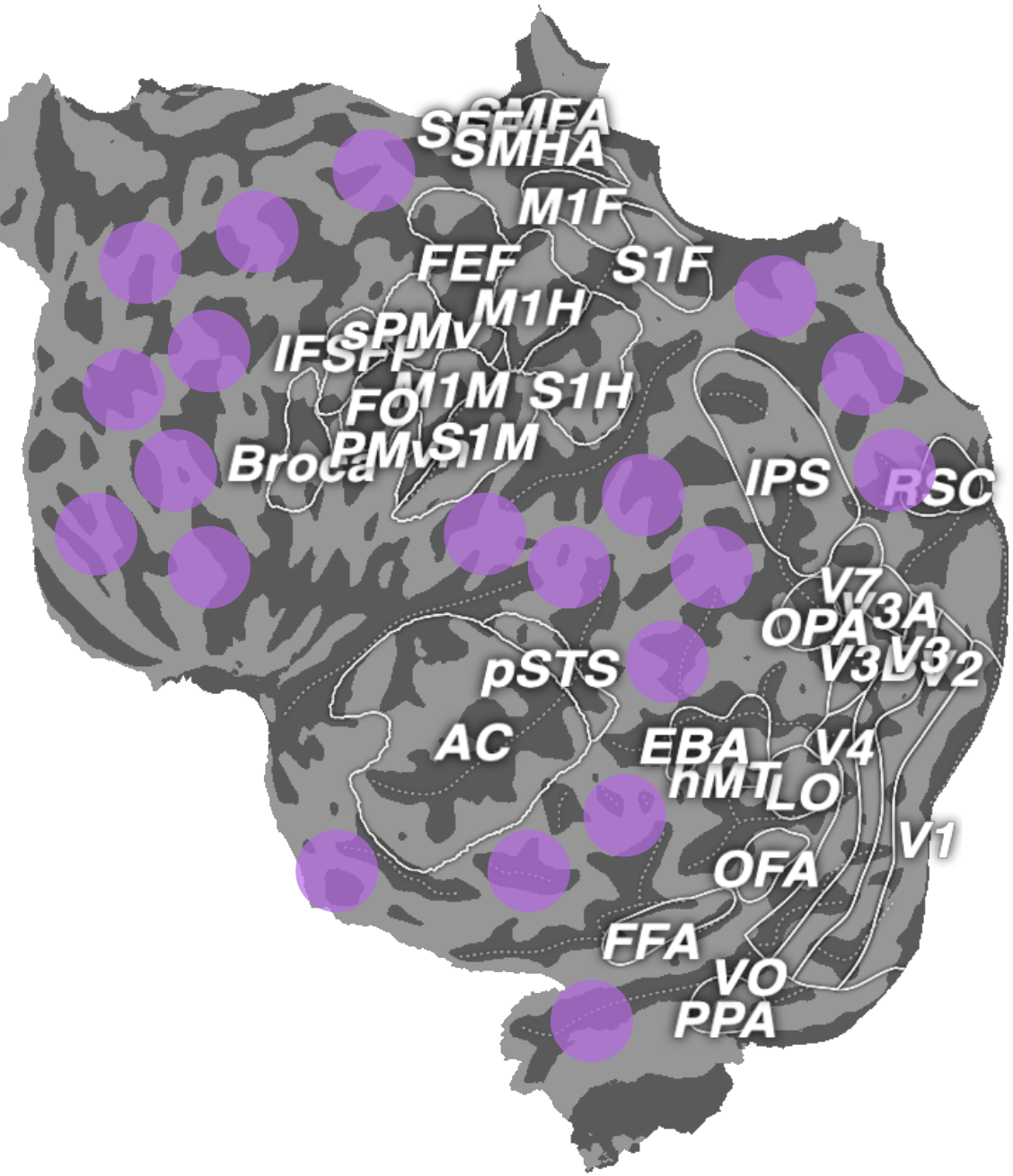
Prof. Alexander Huth

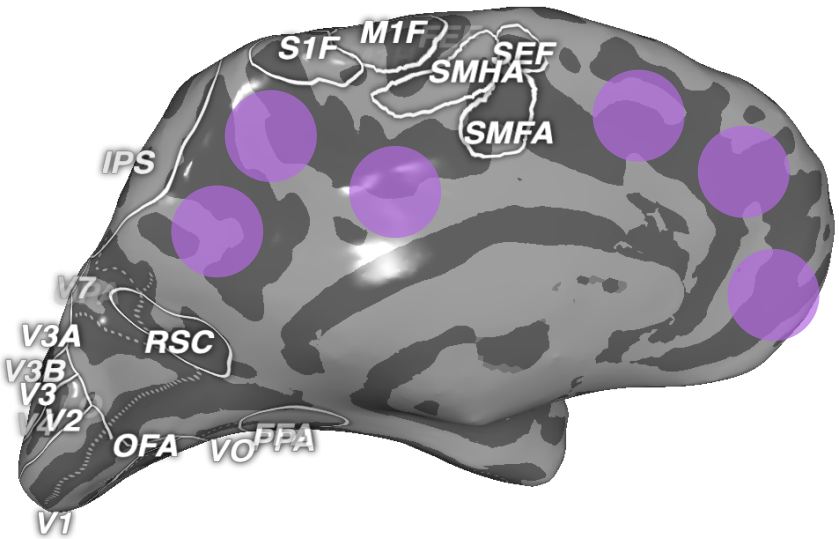
4.14.2021

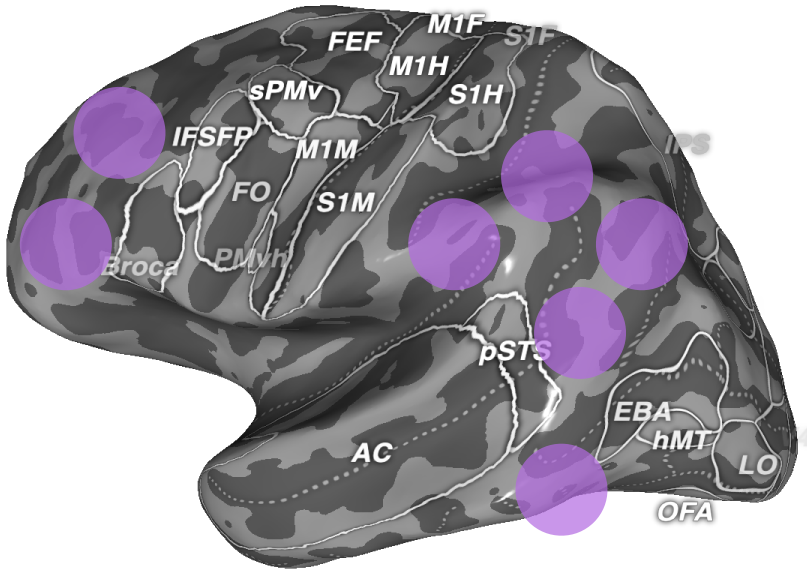
HOMEWORKS

* **Homework 3** (covering the somato-motor systems) is posted today!

ASSOCIATION CORTEX



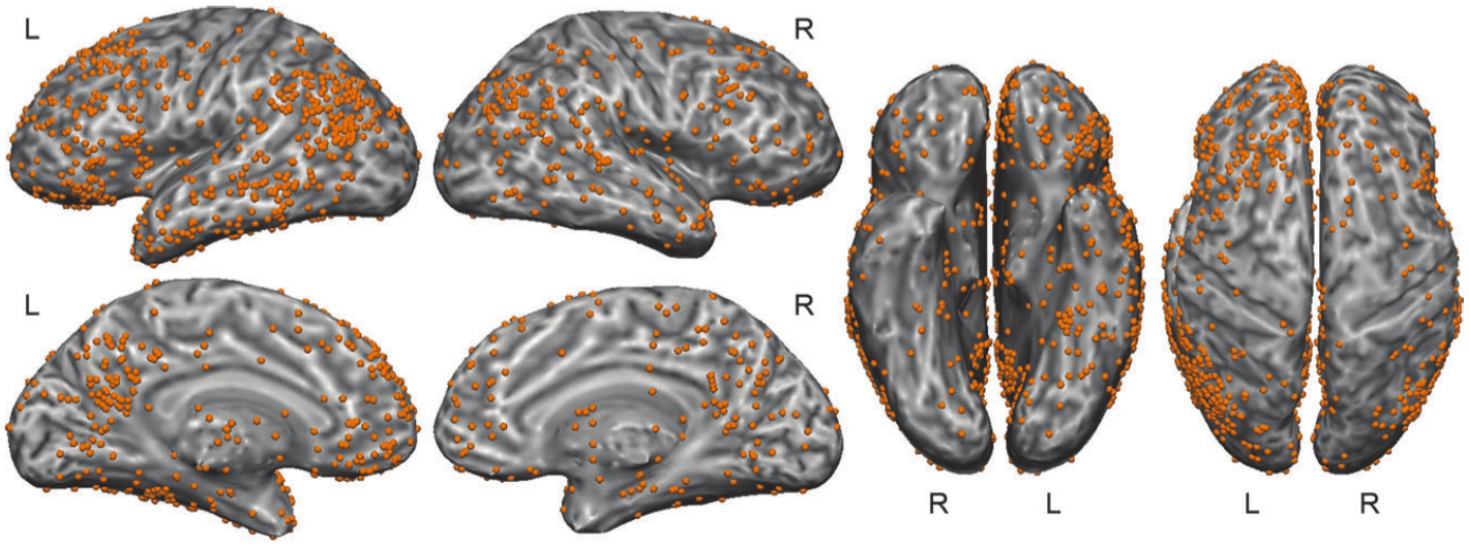




ASSOCIATION CORTEX

* 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**

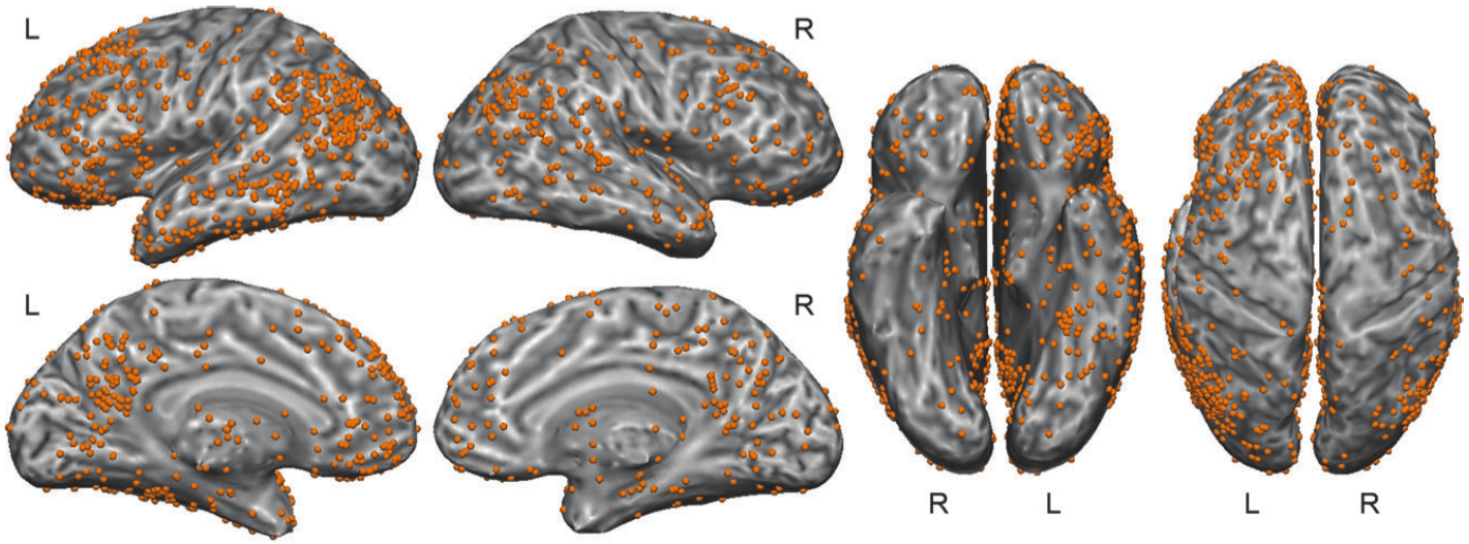
WHERE IS MEANING REPRESENTED?



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

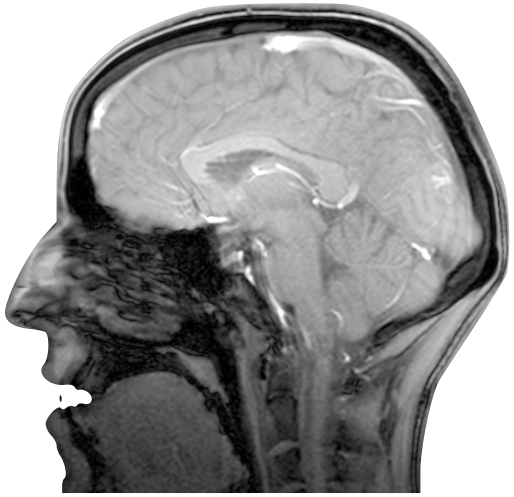
Language fMRI data

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…"

Huth, de Heer, Griffiths, Theunissen, & Gallant. *Nature* (2016)

VOXELWISE MODELING



NATURAL STIMULI

fMRI DATA

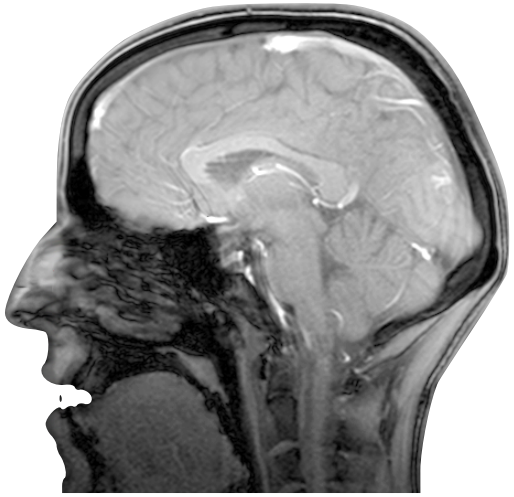
ESTIMATION

HYPOTHESIZED FEATURE SPACE

VOXELWISE REGRESSION MODELS

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

VOXELWISE MODELING



NEW NATURAL STIMULI

HYPOTHESIZED FEATURE SPACE

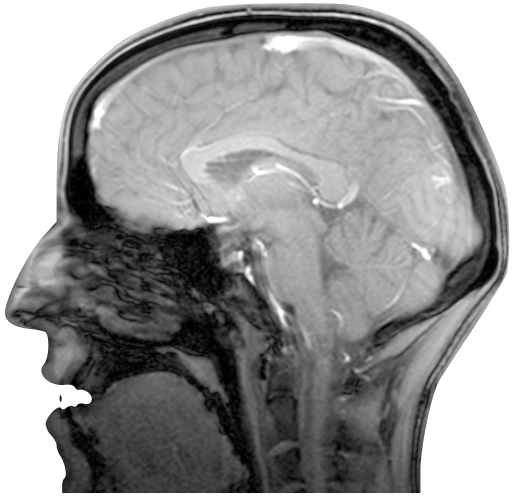
VOXELWISE REGRESSION MODELS

PREDICTION

NEW fMRI DATA

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

VOXELWISE MODELING



NEW NATURAL STIMULI

NEW fMRI DATA

PREDICTION

HYPOTHESIZED FEATURE SPACE

VOXELWISE REGRESSION MODELS

INTERPRETATION

VOXELWISE MODELING

BASIC WORD-LEVEL MODEL:

each voxel responds (some amount) to **each word**

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

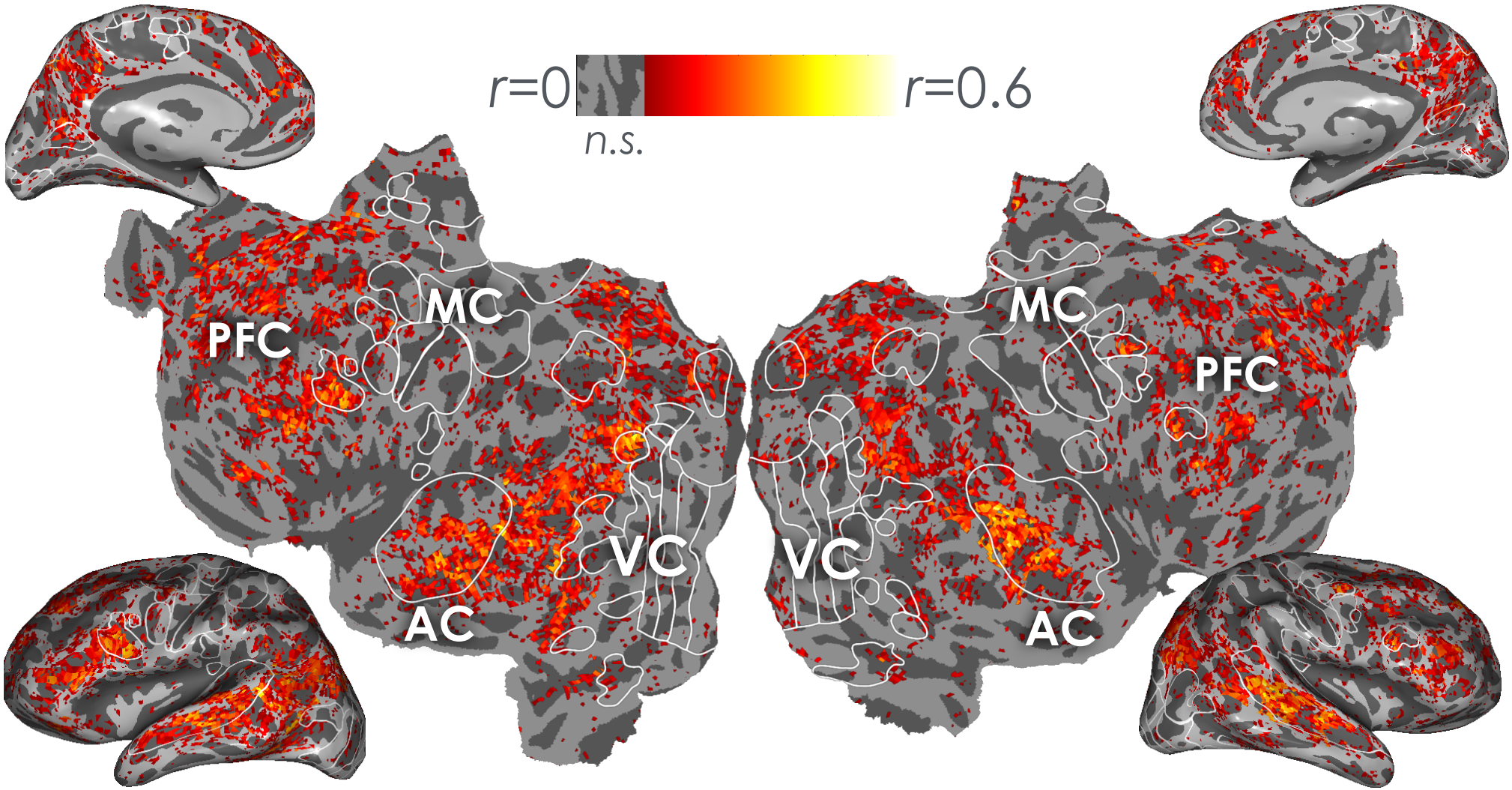
$$\beta \sim \mathcal{N}(0, I)$$

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

likelihood prior

Nunez-Elizalde, Huth, & Gallant, *Neuroimage* (2019)

WORD MODEL PERFORMANCE: MEDIOCRE



SEMANTIC PRIOR

IMPROVED WORD-LEVEL MODEL:

Similar responses to words with similar meanings

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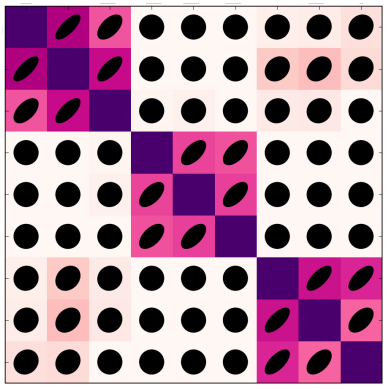


Nunez-Elizalde, Huth, & Gallant, *Neuroimage* (2019)

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

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

word embedding matrix

"target" words:

…
difficult
…
husband
…
potato
…
remember
…

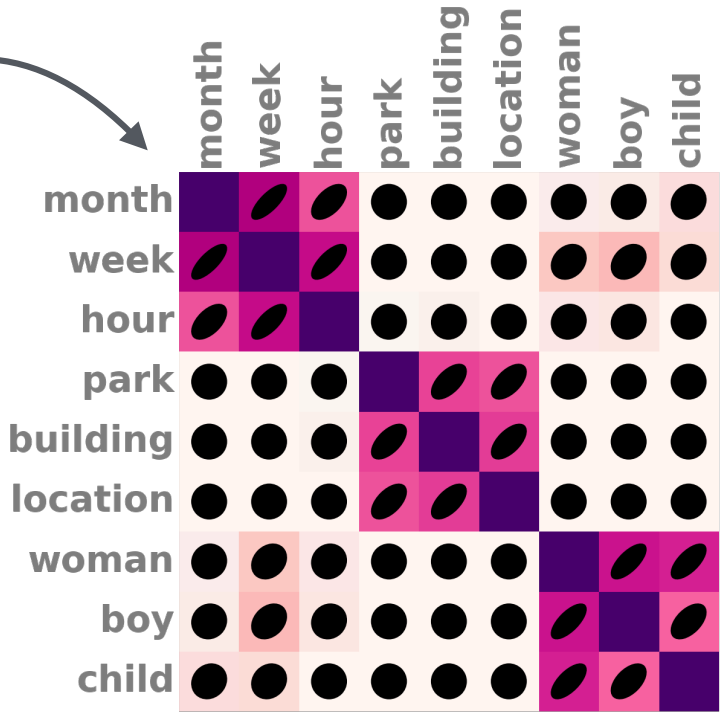
Huth et al., *Nature* (2016)

SEMANTIC PRIOR

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

word embedding matrix

$$E^\top E$$



Huth et al., *Nature* (2016)

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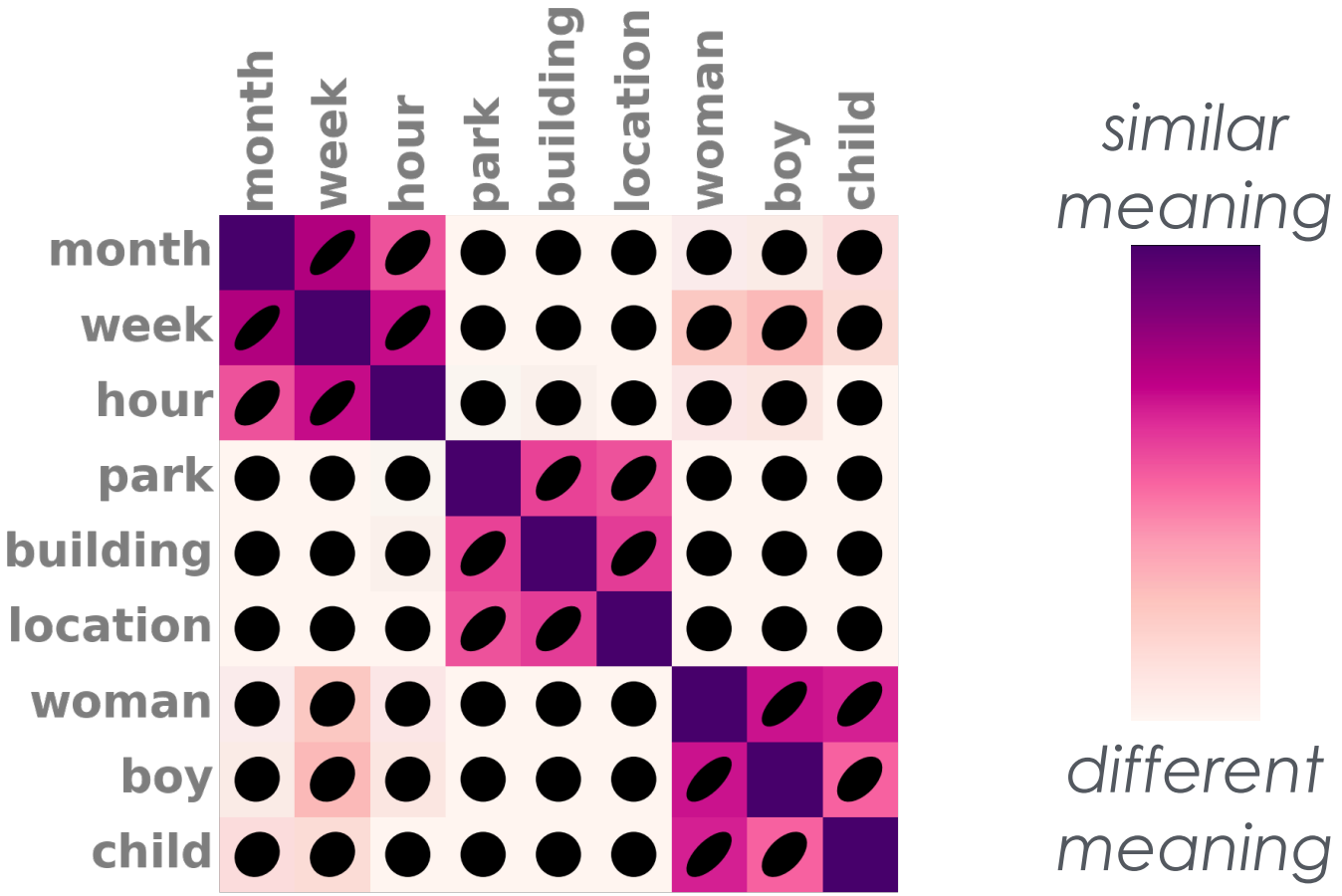

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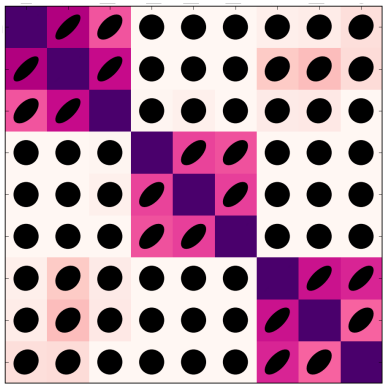
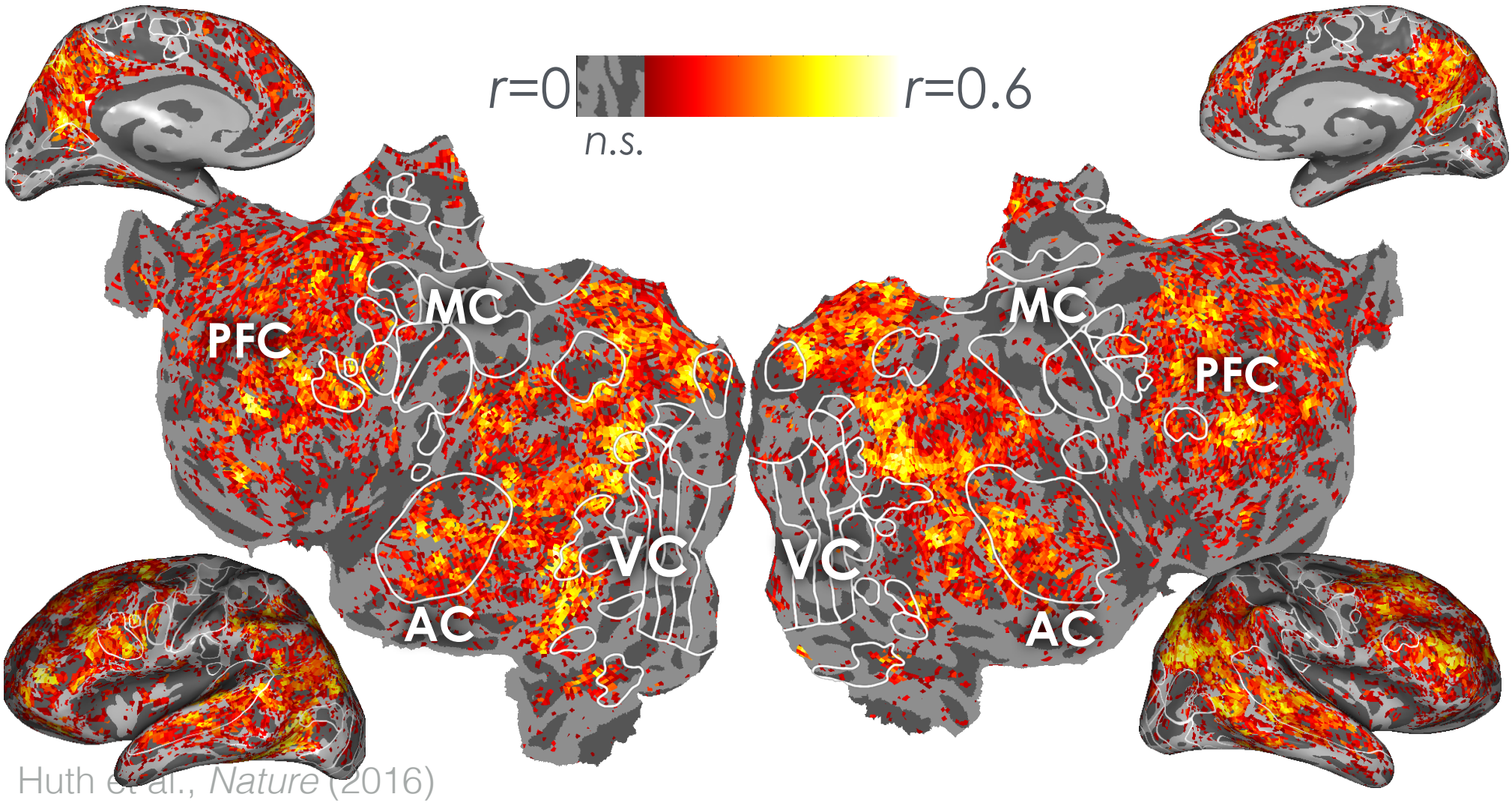


Nunez-Elizalde, Huth, & Gallant, *Neuroimage* (2019)

SEMANTIC MODEL PERFORMANCE: GOOD



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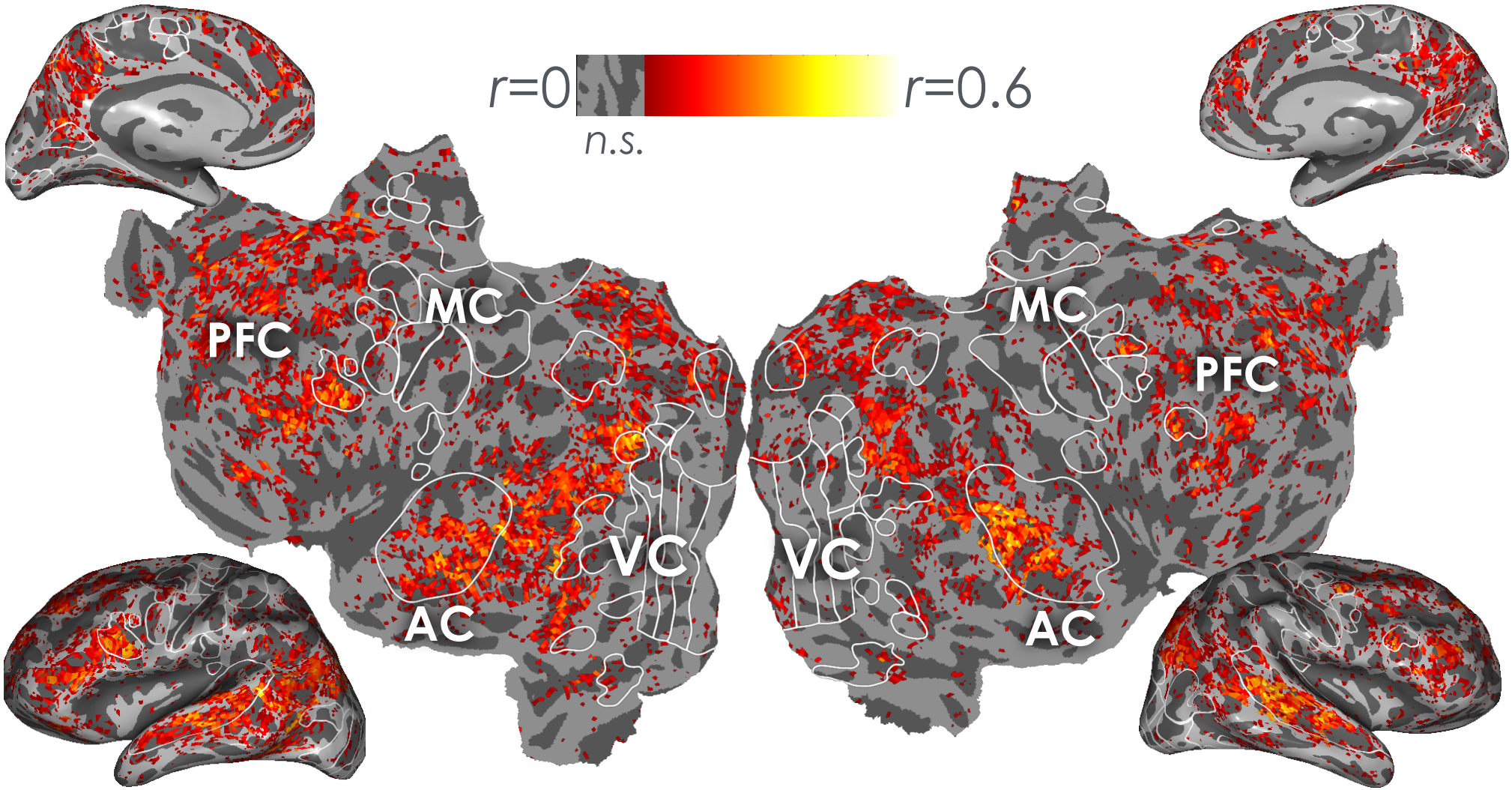
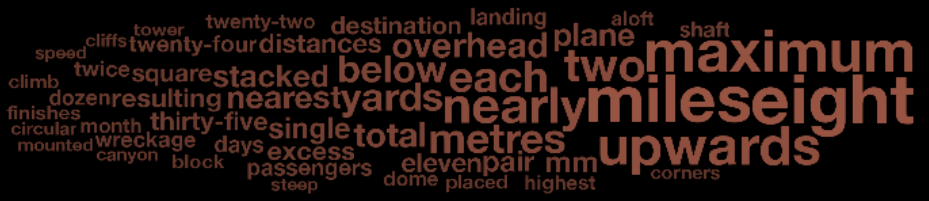
WORD MODEL PERFORMANCE: MEDIOCRE



MODEL INTERPRETATION

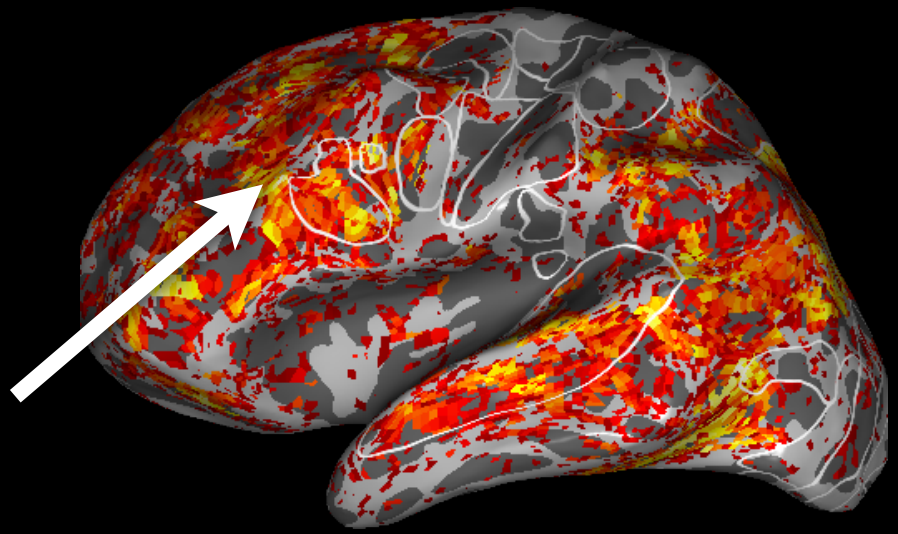
What information is represented in each voxel?

MODEL INTERPRETATION

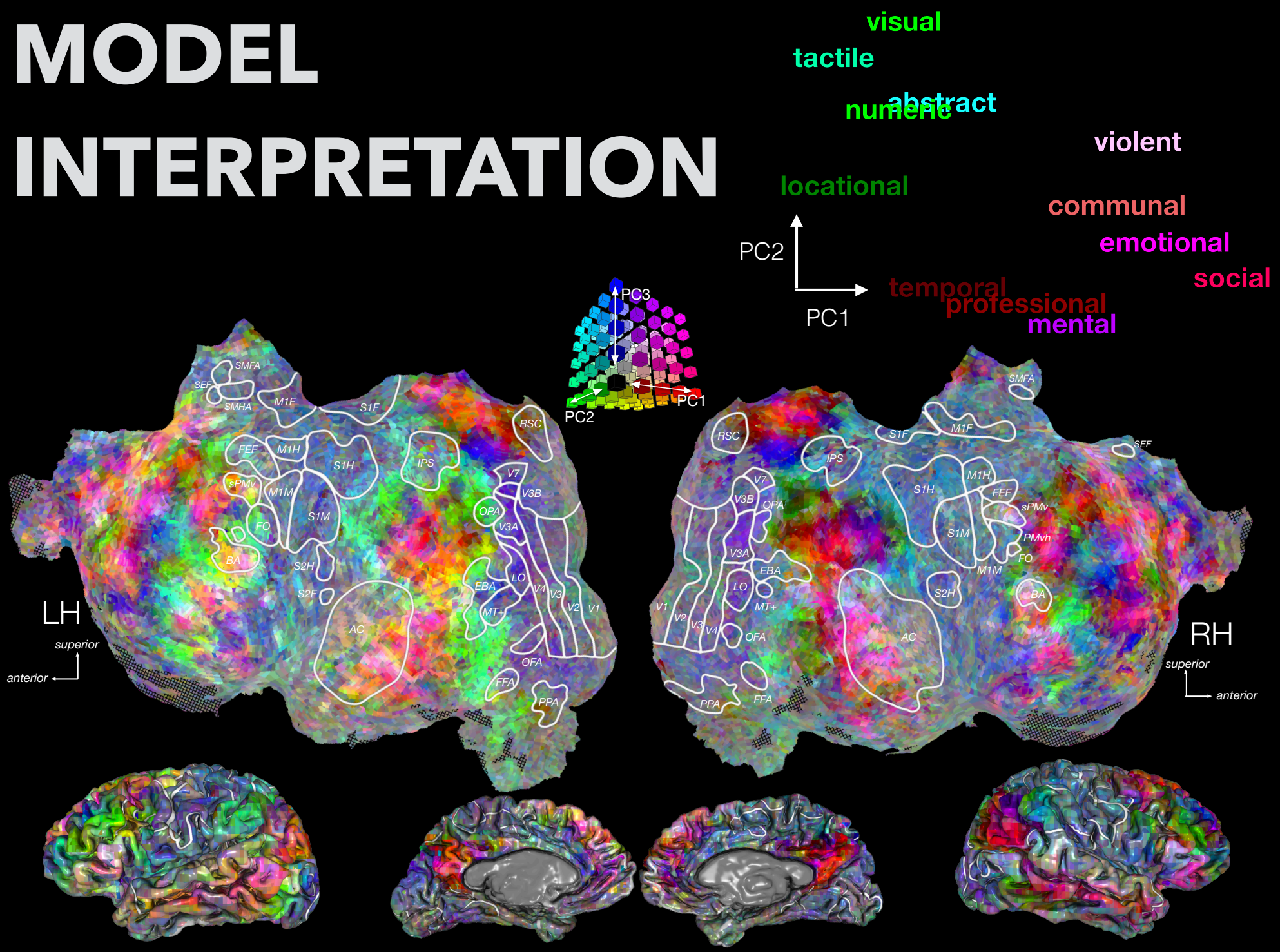


Lower response

Higher response



MODEL INTERPRETATION



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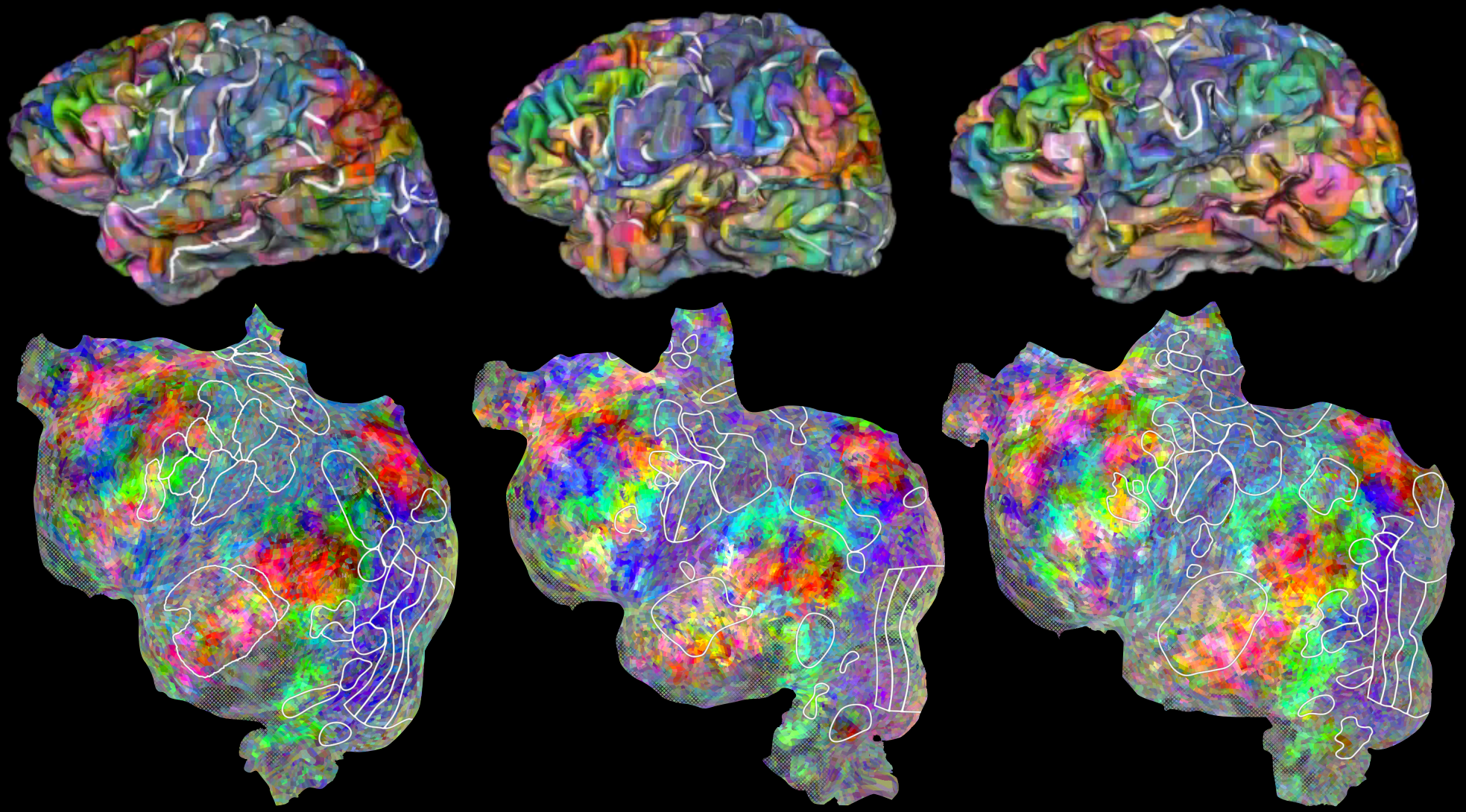
MAPS ARE CONSISTENT ACROSS SUBJECTS



UNTIL

NEXT

TIME