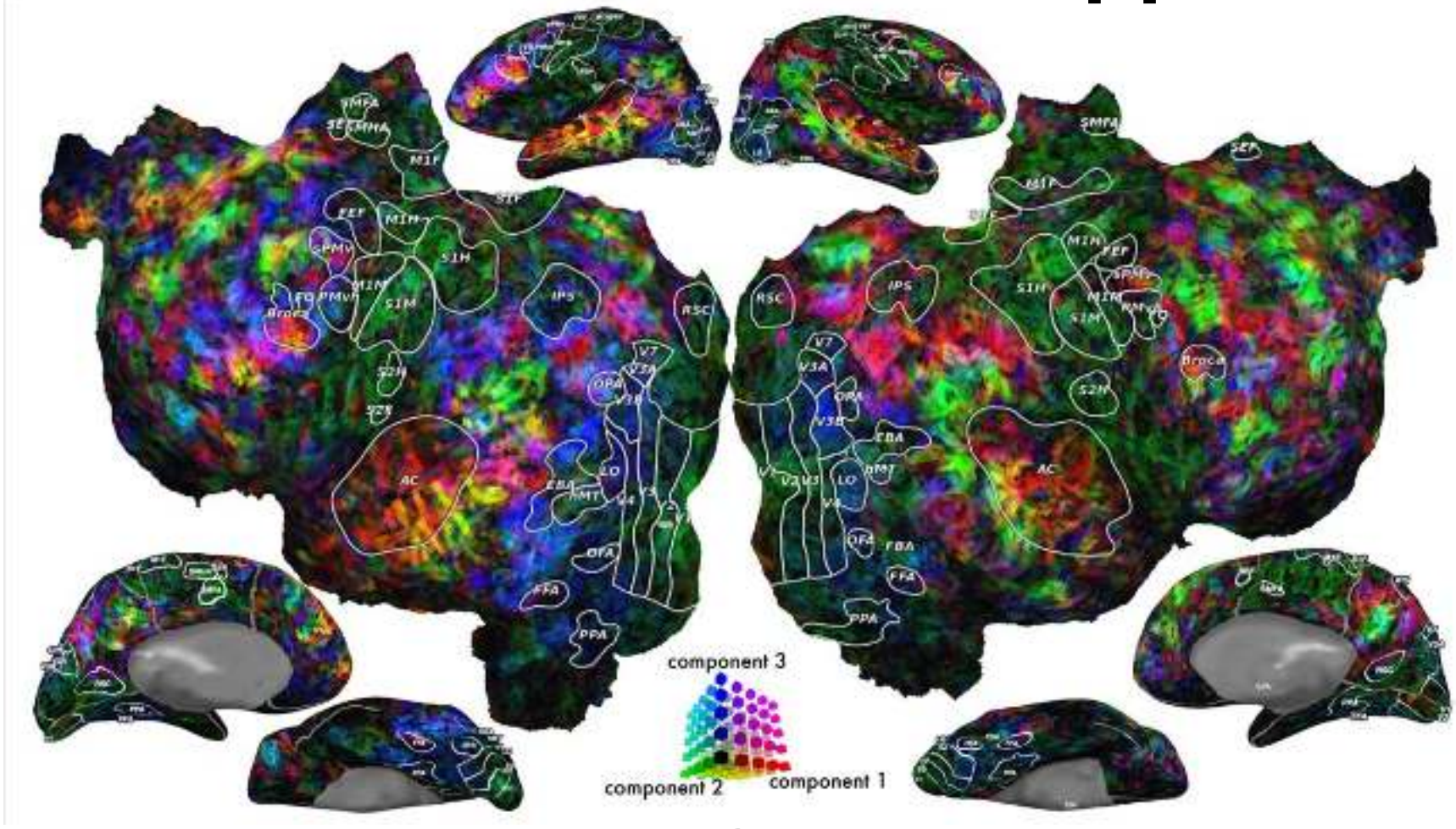
Non-invasive human brain measurement for AR /VR applications



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A brain-based AR/VR controller would be much more flexible and powerful than current methods

Emotiv inc.

Brain decoding is limited by both brain measurements and brain models

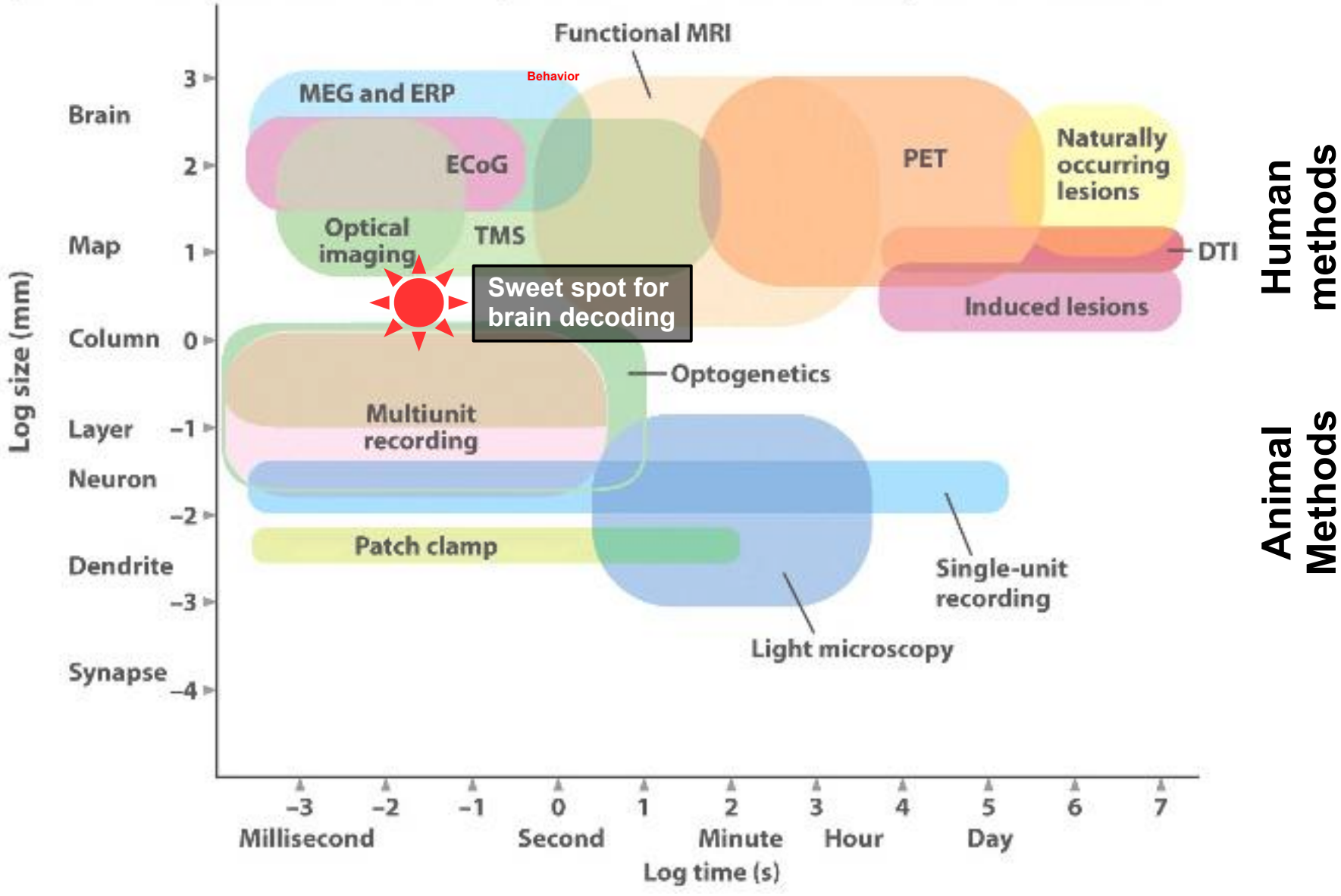
Source

Channel
(Measurement)

Destination
(Model)

$$I(X;Y)=\sum_{y\in Y}\sum_{x\in X}p(x,y)\log\left(\frac{p(x,y)}{p(x)\,p(y)}\right)$$

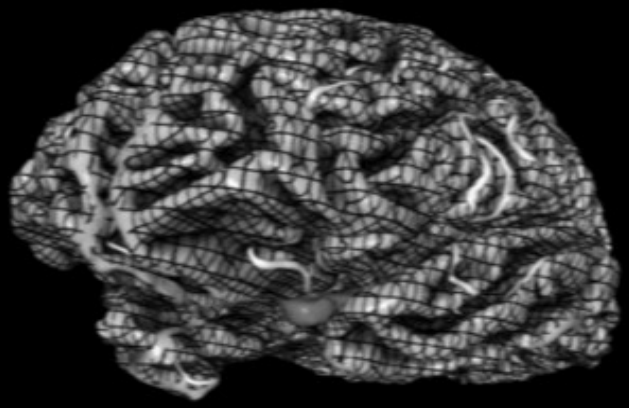
No current portable, non-invasive brain imaging method is broadly useful for brain decoding



Non-invasive measurement devices
are limited in space or time
EEG
fNIRS
MEG
fMRI

The best current method for recovering functional brain information is magnetic resonance imaging (MRI)

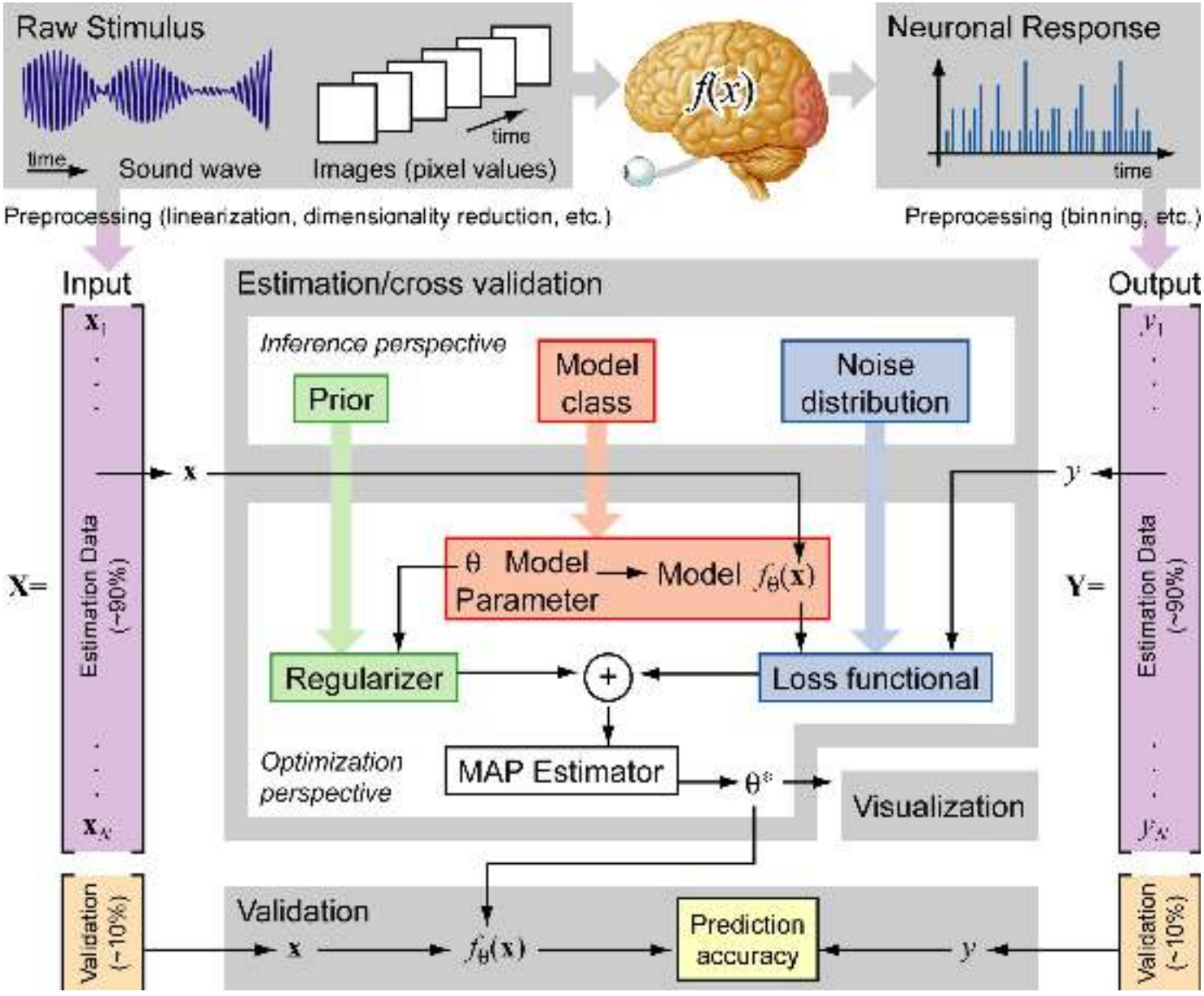
REST



Less activity **Average activity** **More activity**

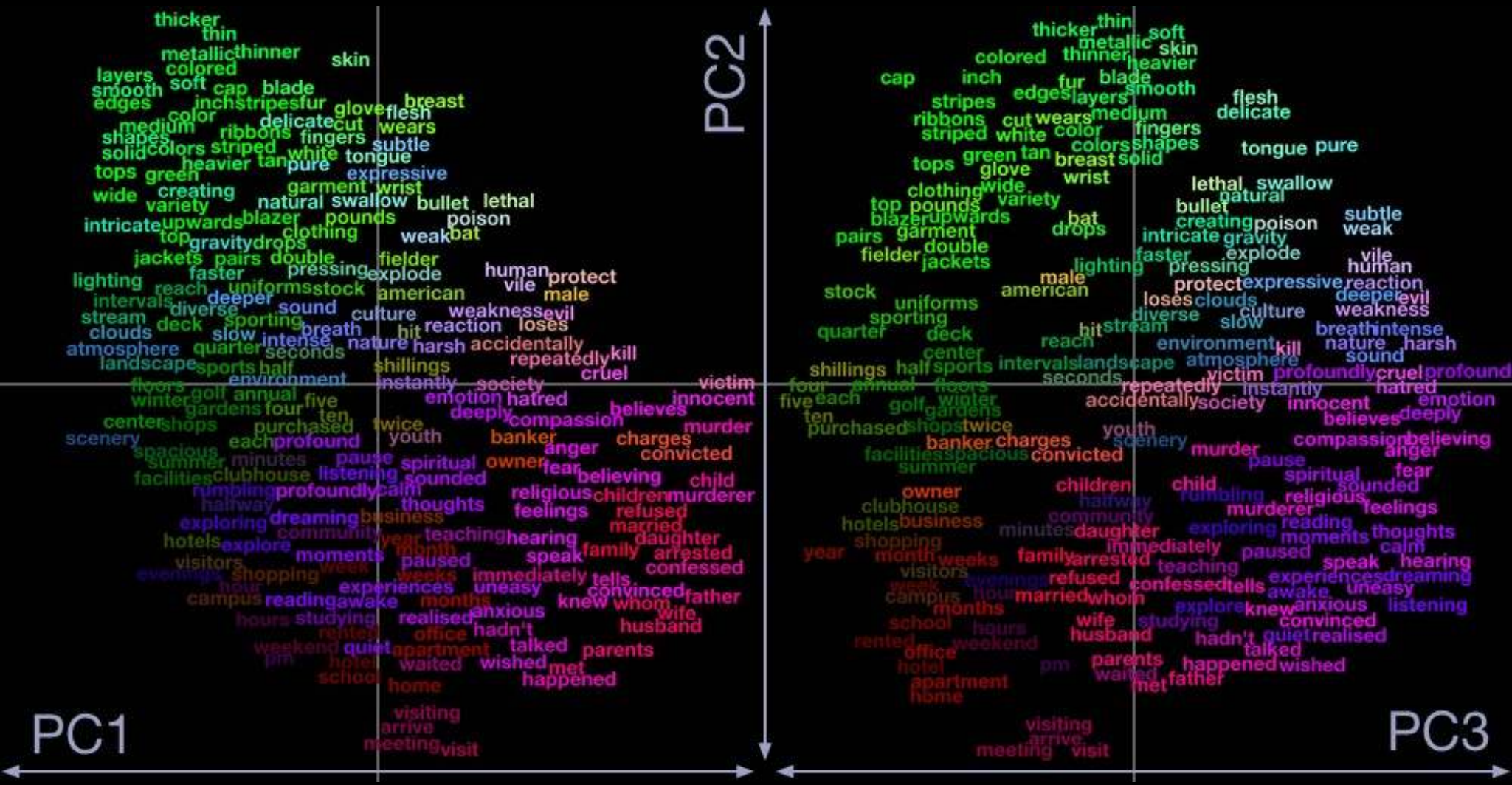
Nunez-Elizalde & Gallant, *unpublished*

Modeling these data is essentially a multiple-regression problem that can be solved using many different methods



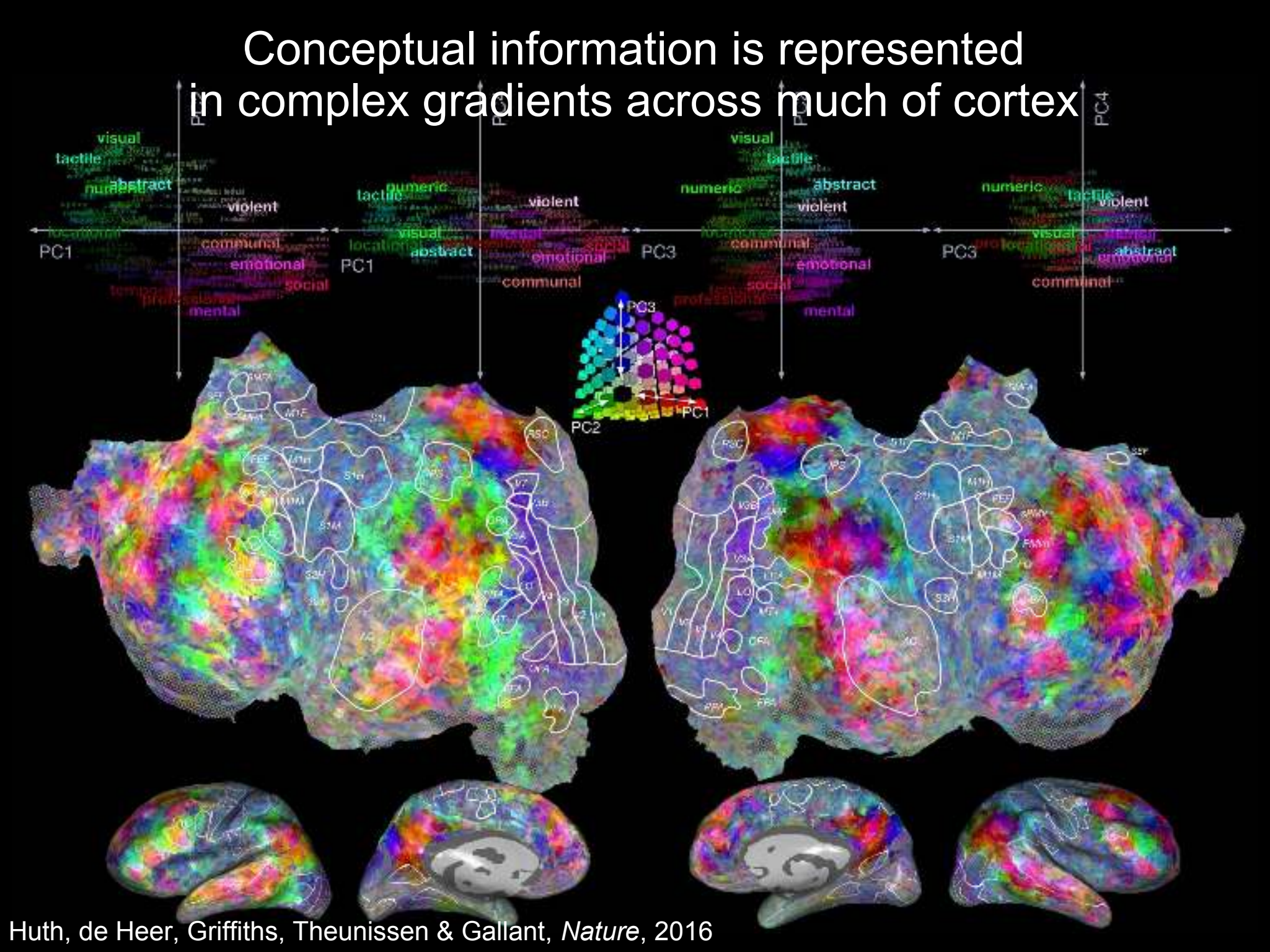
Wu, David & Gallant, 2006

Individuals share a common conceptual space



Huth, de Heer, Griffiths, Theunissen & Gallant, *Nature*, 2016

Conceptual information is represented in complex gradients across much of cortex



Huth, de Heer, Griffiths, Theunissen & Gallant, *Nature*, 2016

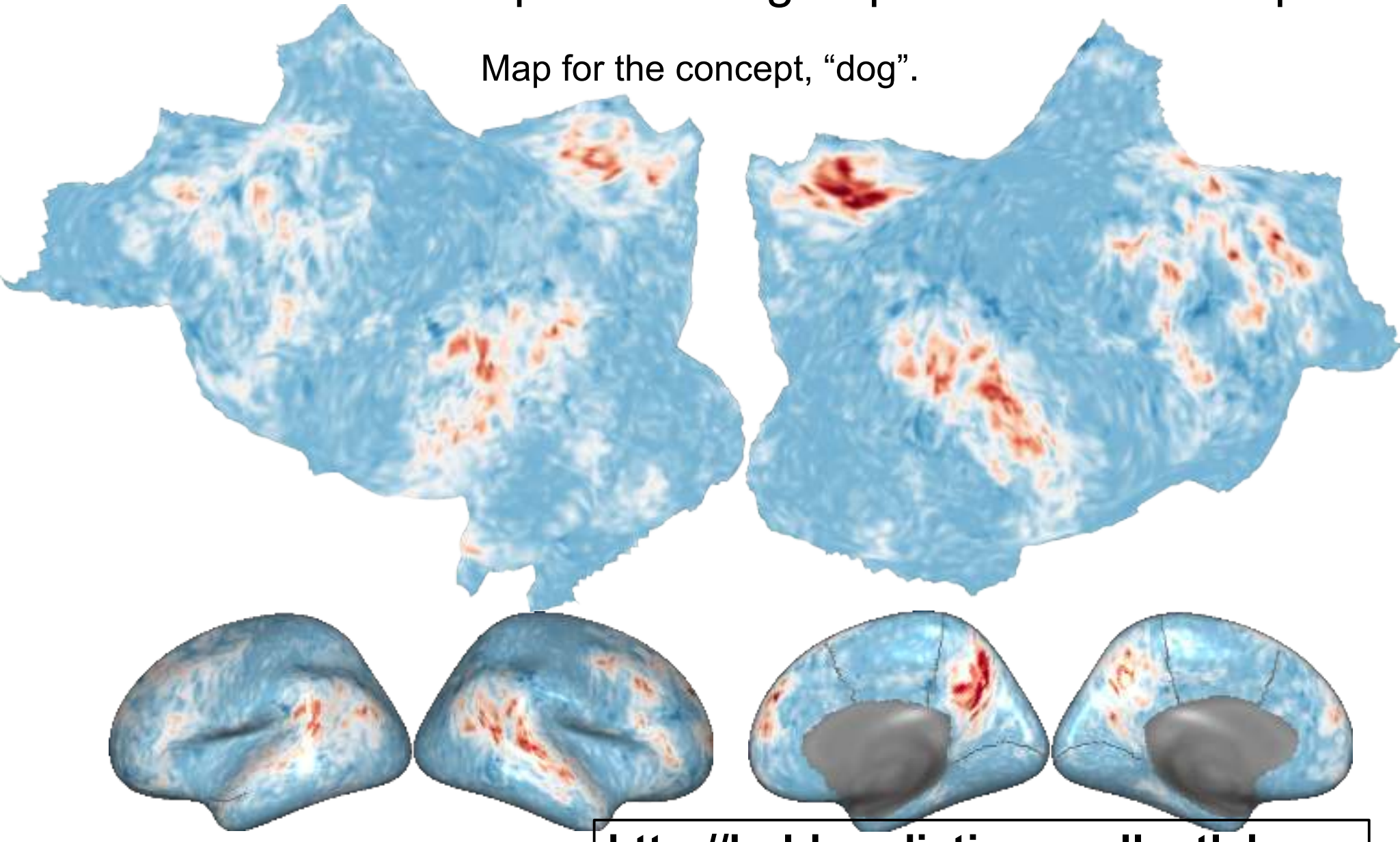
You can inspect these data yourself using our online, interactive brain viewer

http://gallantlab.org/huth2016

Huth, de Heer, Griffiths, Theunissen & Gallant, *Nature*, 2016

Each concept is represented at multiple locations and each location represents a group of related concepts

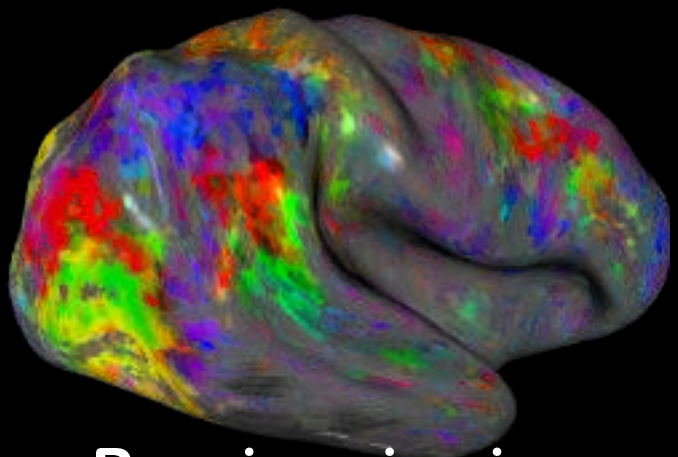
Map for the concept, “dog”.



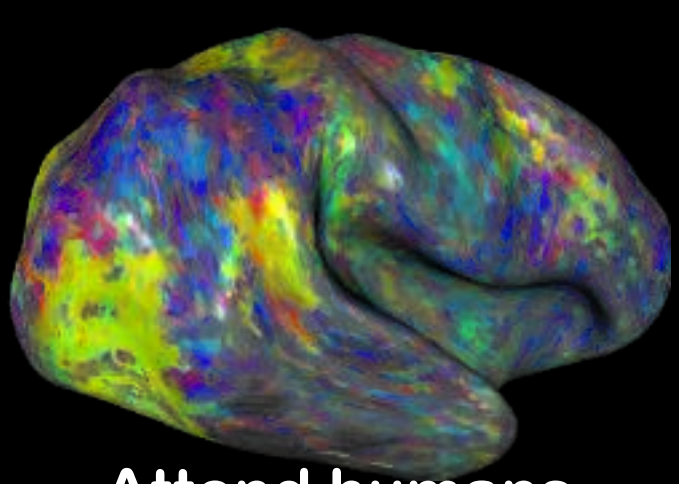
http://boldpredictions.gallantlab.org

Wehbe, Imamoglu, Huth & Gallant, *unpublished*

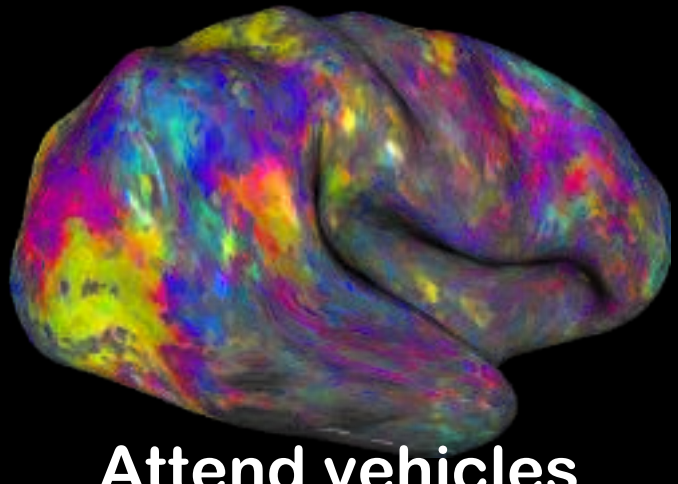
Attention changes the flow of information through the brain and so changes conceptual maps



Passive viewing



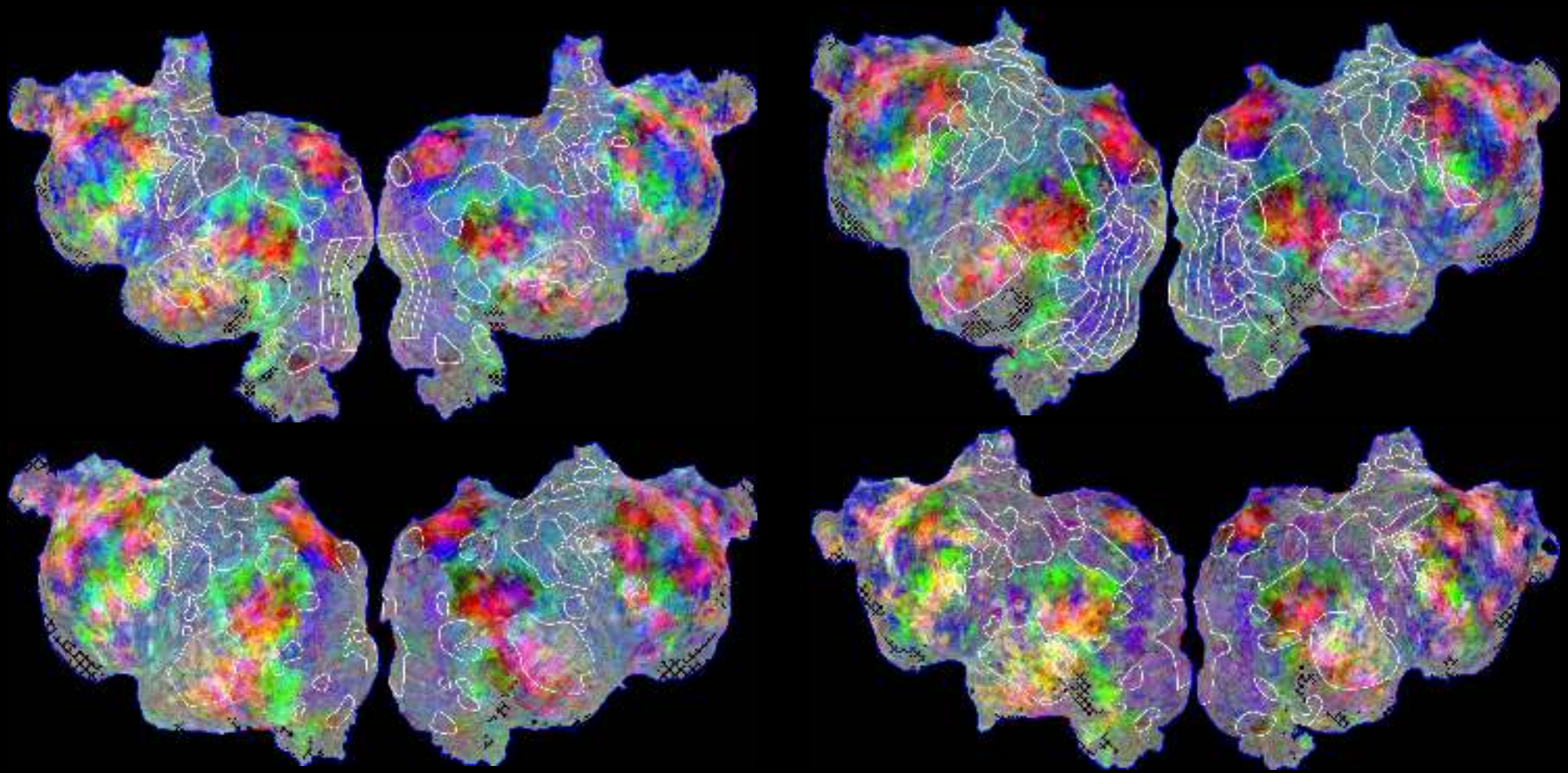
Attend humans



Attend vehicles

Cukur, Nishimoto, Huth & Gallant, *Nat. Neuro.*, 2013

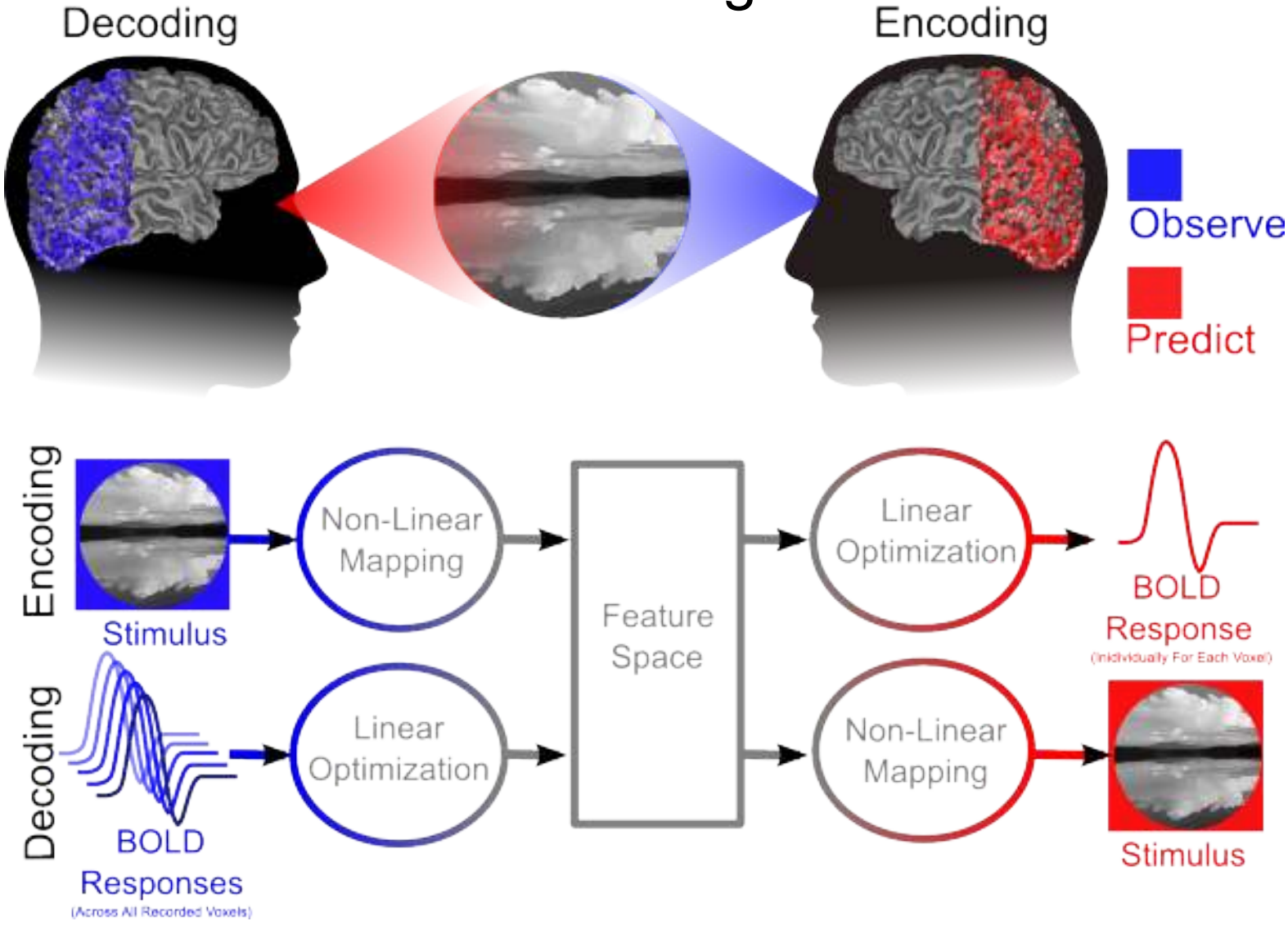
Conceptual maps from different individuals are similar but not identical



Huth, de Heer, Griffiths, Theunissen & Gallant, *Nature*, 2016

(Preliminary data slide redacted)

Any encoding model can be converted into a decoding model



$$P(f(S)|R) \propto P(R|f(S))\,P(f(S))$$

Decoding structural information from early visual areas

Image

Reconstruction

Naselaris, Kay, Prenger, Oliver and Gallant, *Neuron*, 2009

Decoding scene categories and contents from higher-order visual areas

Image	Likely Scene	Likely Objects	Image	Likely Scene	Likely Objects
	land animals few people food	man woman person head animal		urban areas large crowds	sky car building road people
	sporting event large crowds few people	athlete people man woman person		fields fenced areas large crowds	grass trees fence field ground
	signs/text	text sign washbowl beverage background		food	food fruit vegetables vegetable container

Stansbury, Naselaris and Gallant, *Neuron*, 2013

Decoding structural information from early visual areas

Nishimoto, Vu, Naselaris et al, *Current Biology*, 2011; Bilenko, Savage & Gallant, *unpublished*

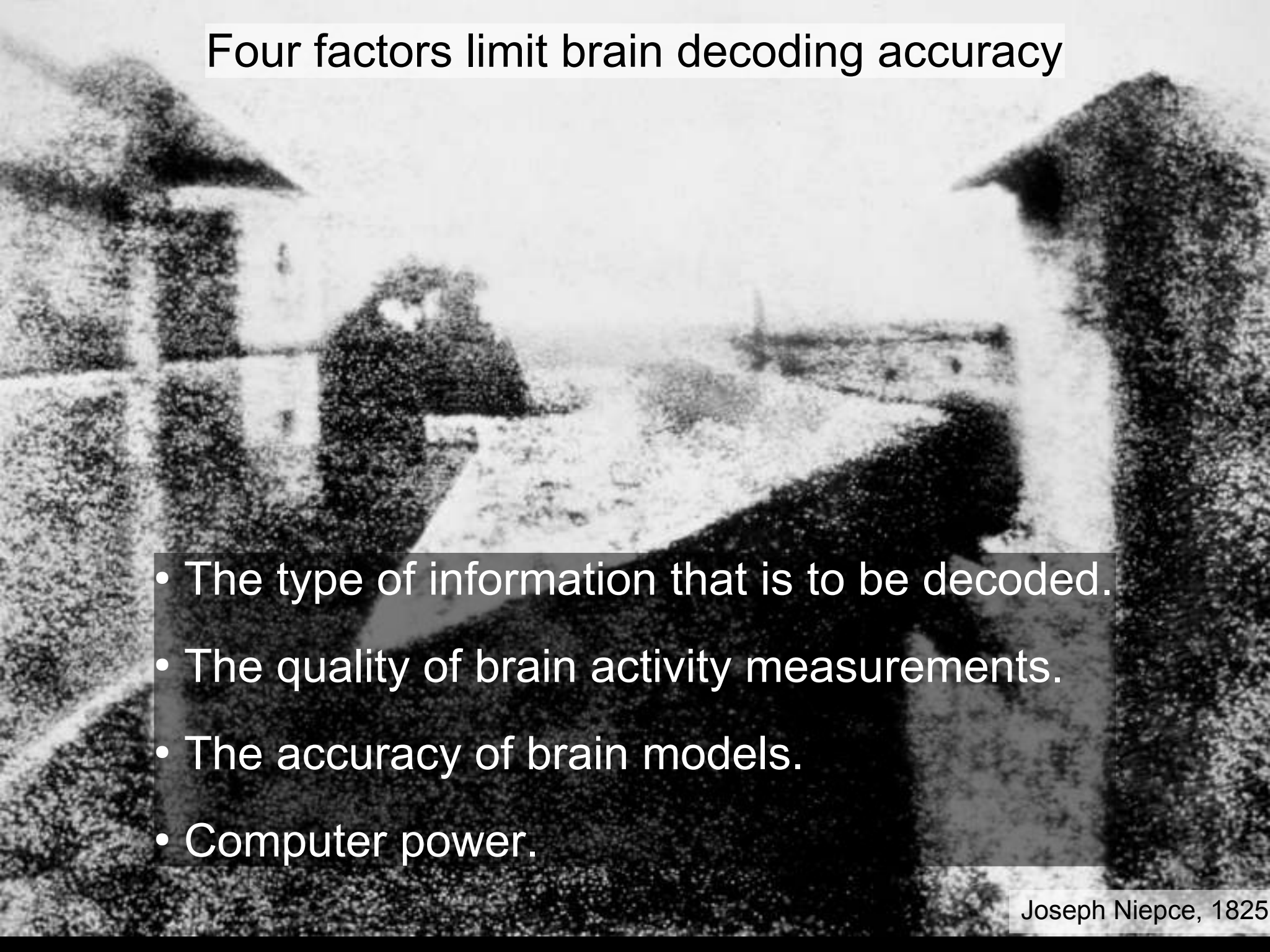
Decoding semantic categories from higher-order visual areas

Presented movie

Decoded concepts

Huth et al., *Front. Comp. Bio.*, 2016

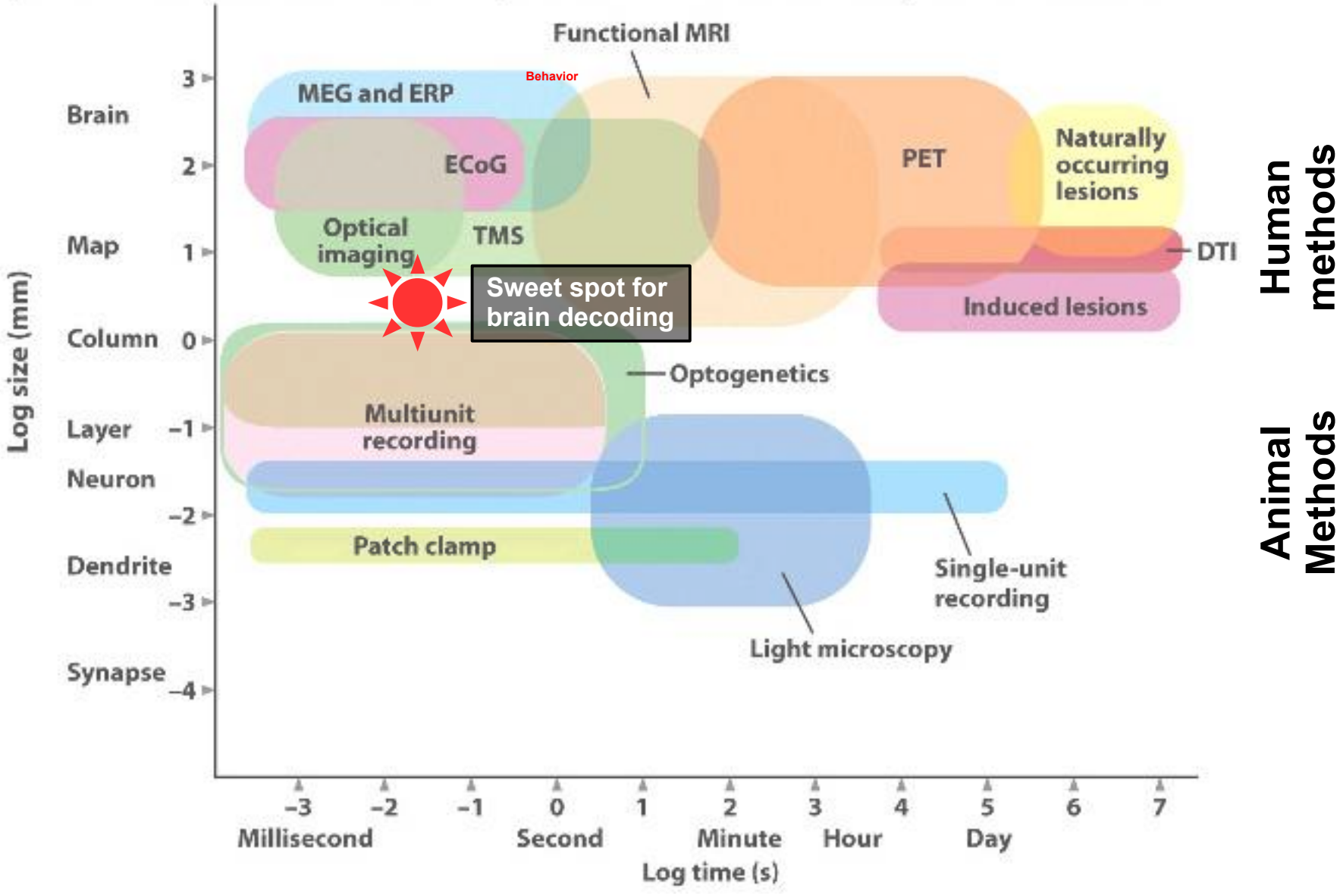
Four factors limit brain decoding accuracy



- The type of information that is to be decoded.
- The quality of brain activity measurements.
- The accuracy of brain models.
- Computer power.

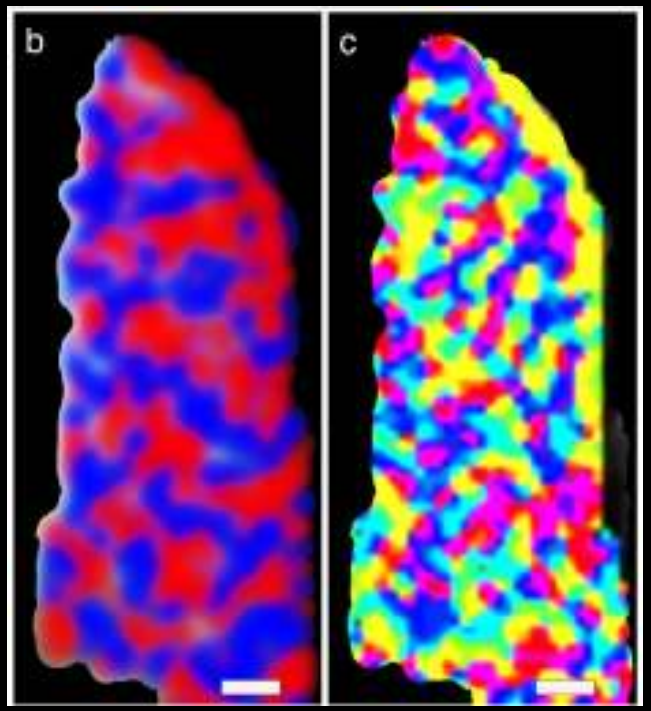
Joseph Niepce, 1825

The resolution of current non-invasive neuroimaging is still fairly low, relative to invasive methods

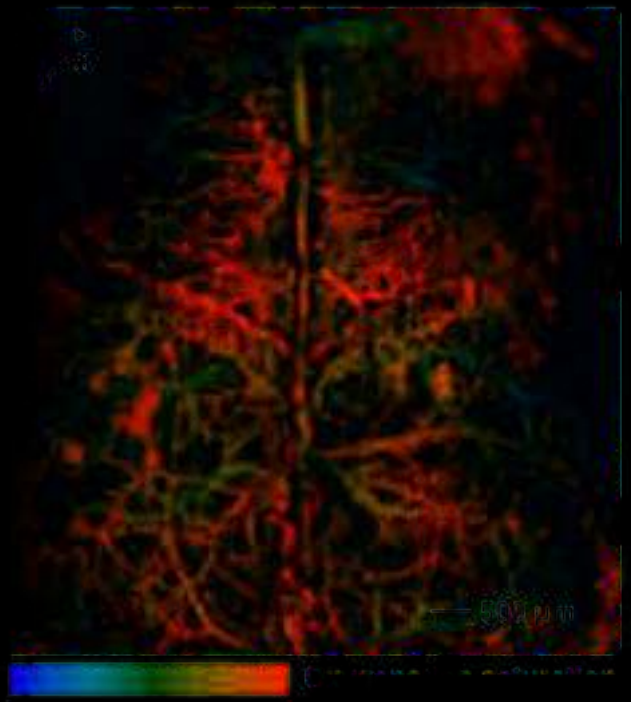


Many groups are developing new methods for improving non-invasive functional brain imaging

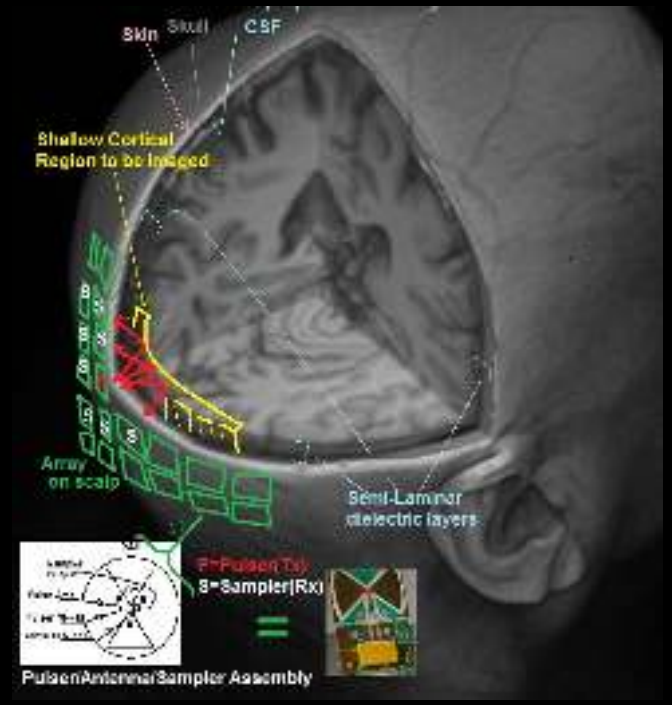
High-resolution fMRI



Acoustic-optical approaches



Picopulse imaging



Berkeley high resolution MRI project

- Develop f/MRI to achieve 100-500 micron resolution for imaging of the cerebral cortex.
- Design new radiofrequency coil arrays that maximize SNR in the cerebral cortex.
- Design new pulse sequences and image reconstruction methods optimized for cortical imaging.
- Develop susceptibility tensor imaging for cortical tractography.
- In collaboration with Siemens, Miki Lustig (Berkeley), Chunli Liu (Berkeley), Larry Wald (Martinos), Kaiwin Setsompop (Martinos) and others.

(Preliminary data slide redacted)

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This work was supported by NEI, NIMH, NSF, ONR and IARPA