Pattern-information fMRI

stimulus decoding, computational-model testing, columnar sensitivity

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Overview

Part A: Pattern-information fMRI

- **Neuroscientific motivation**
- **Insights on object vision**

Part B: Recent studies from my lab

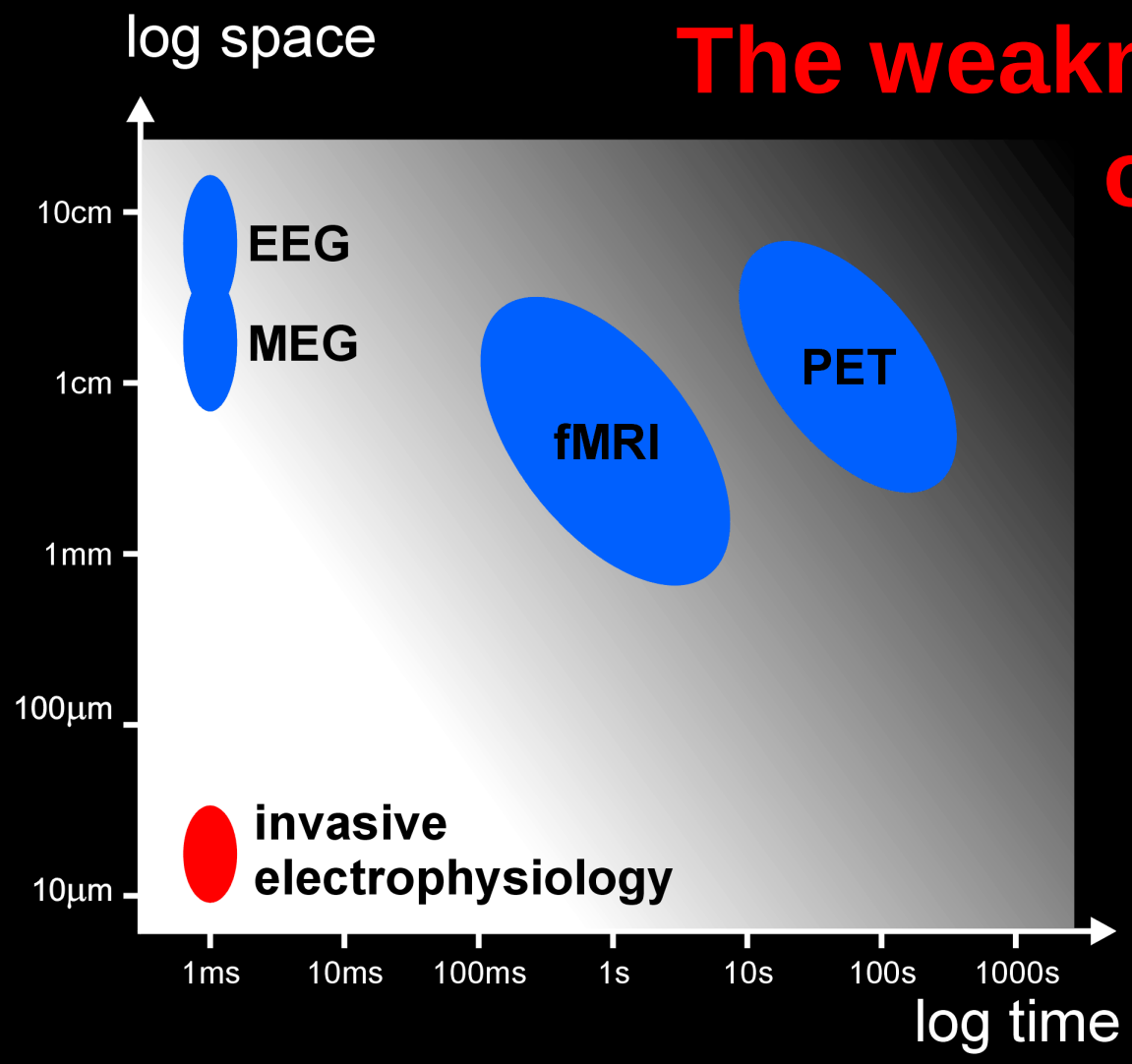
- **Columnar sensitivity?**
  Origins of V1 orientation signals in fMRI
- **Individually unique object representations**

Part A: Learning objectives

1. Why fMRI?
2. Why pattern-information fMRI?
3. Why decode fMRI?
4. Why test encoding models with fMRI?
5. Why should your analysis be at once data and hypothesis-driven?

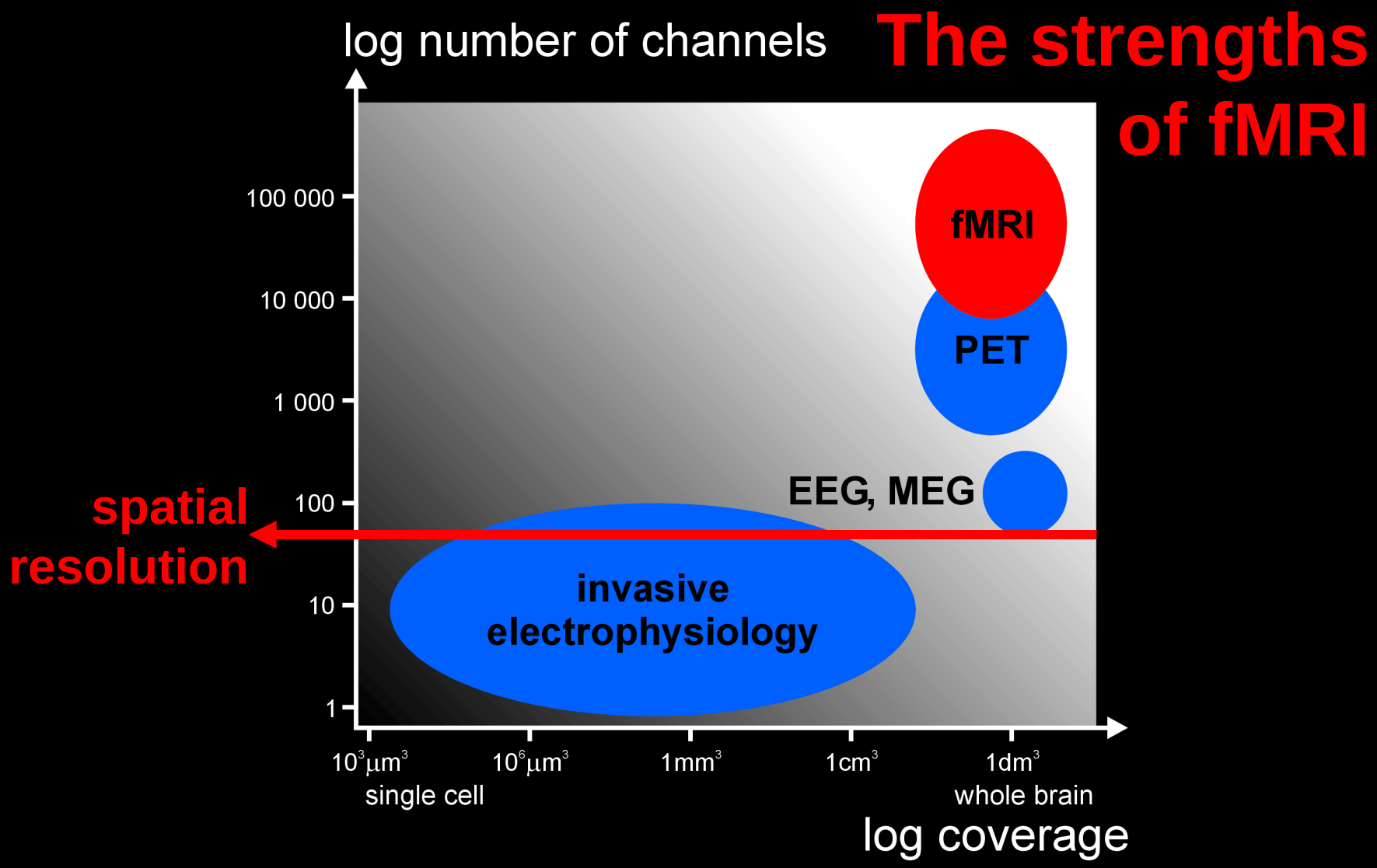
1 Why fMRI?

Spatial and temporal resolution

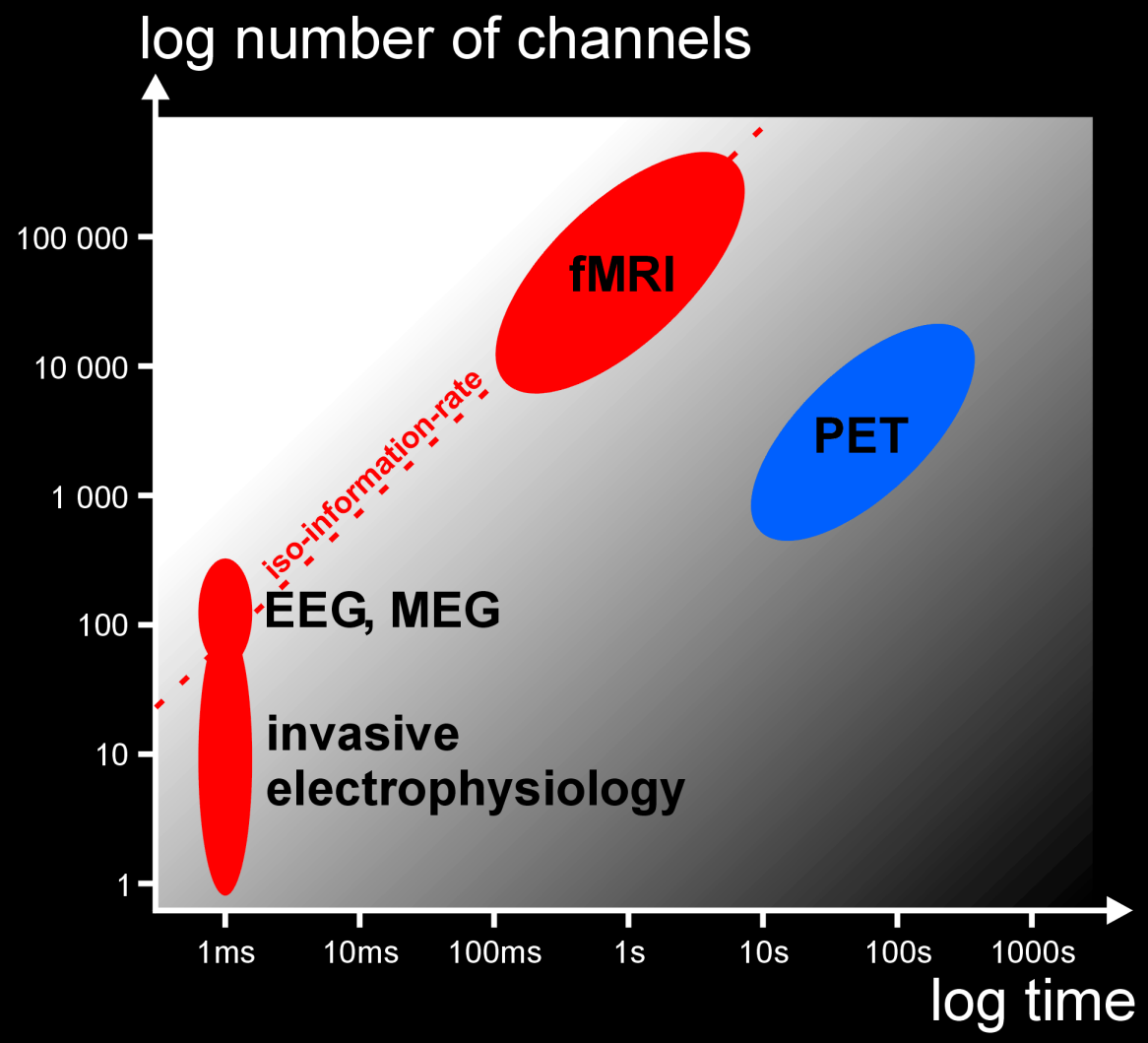


The weaknesses of fMRI

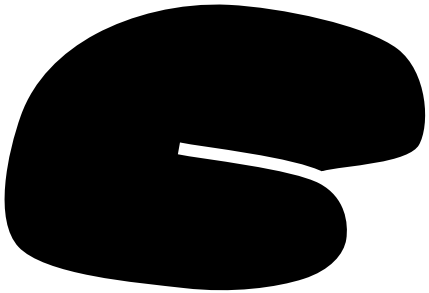
Number of channels and coverage



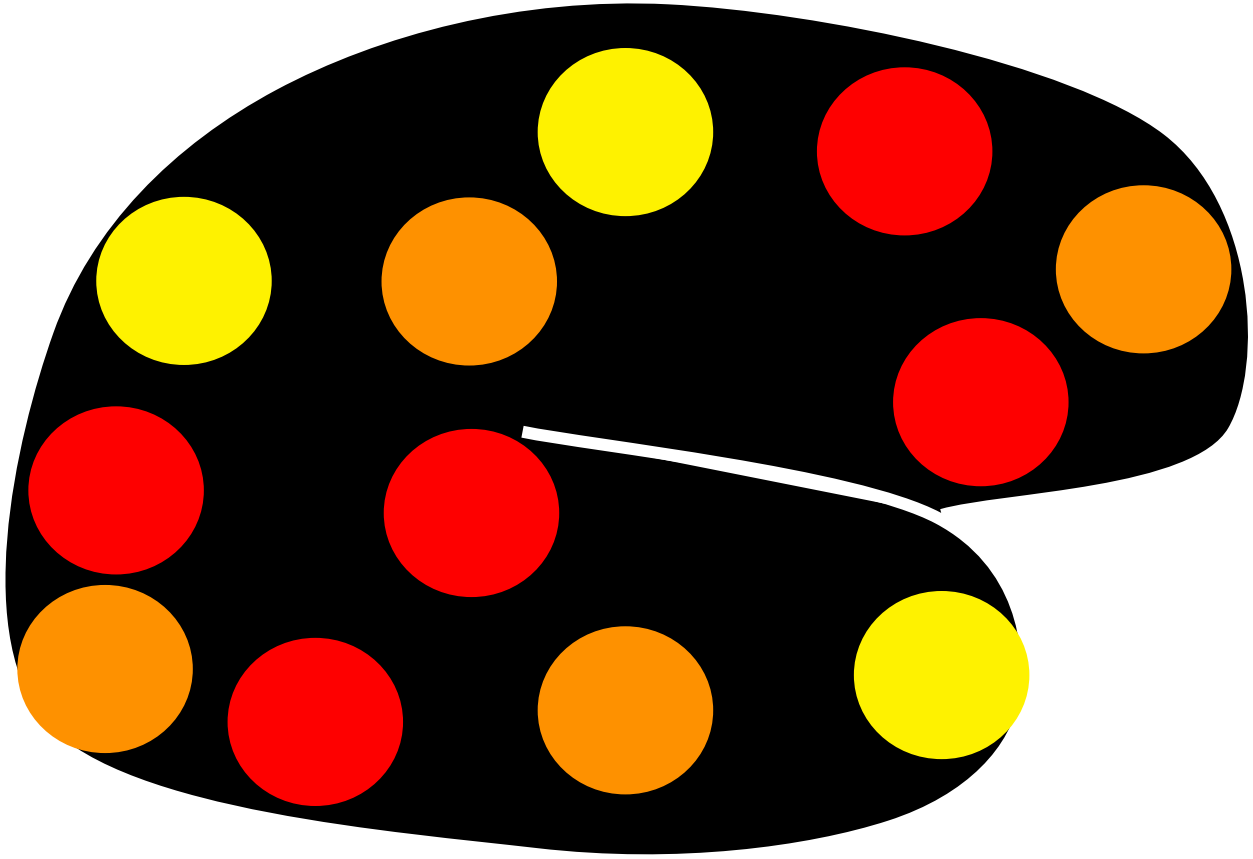
Similar information rates



2 Why pattern-information fMRI?

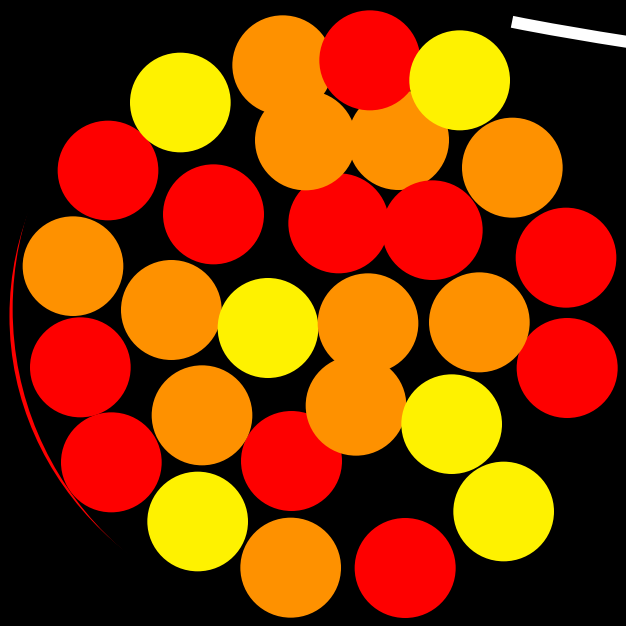


Activation analysis



activation ➔ "involvement" in cognitive function

Pattern-information analysis

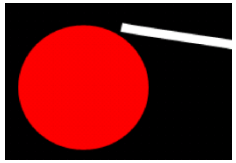


information →
"representational content"

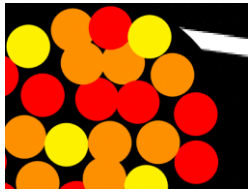
Filling the explanatory gap

level of description

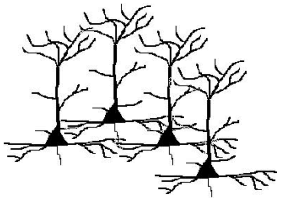
whole brain

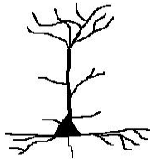


functional regional
("activation")



regional
population code



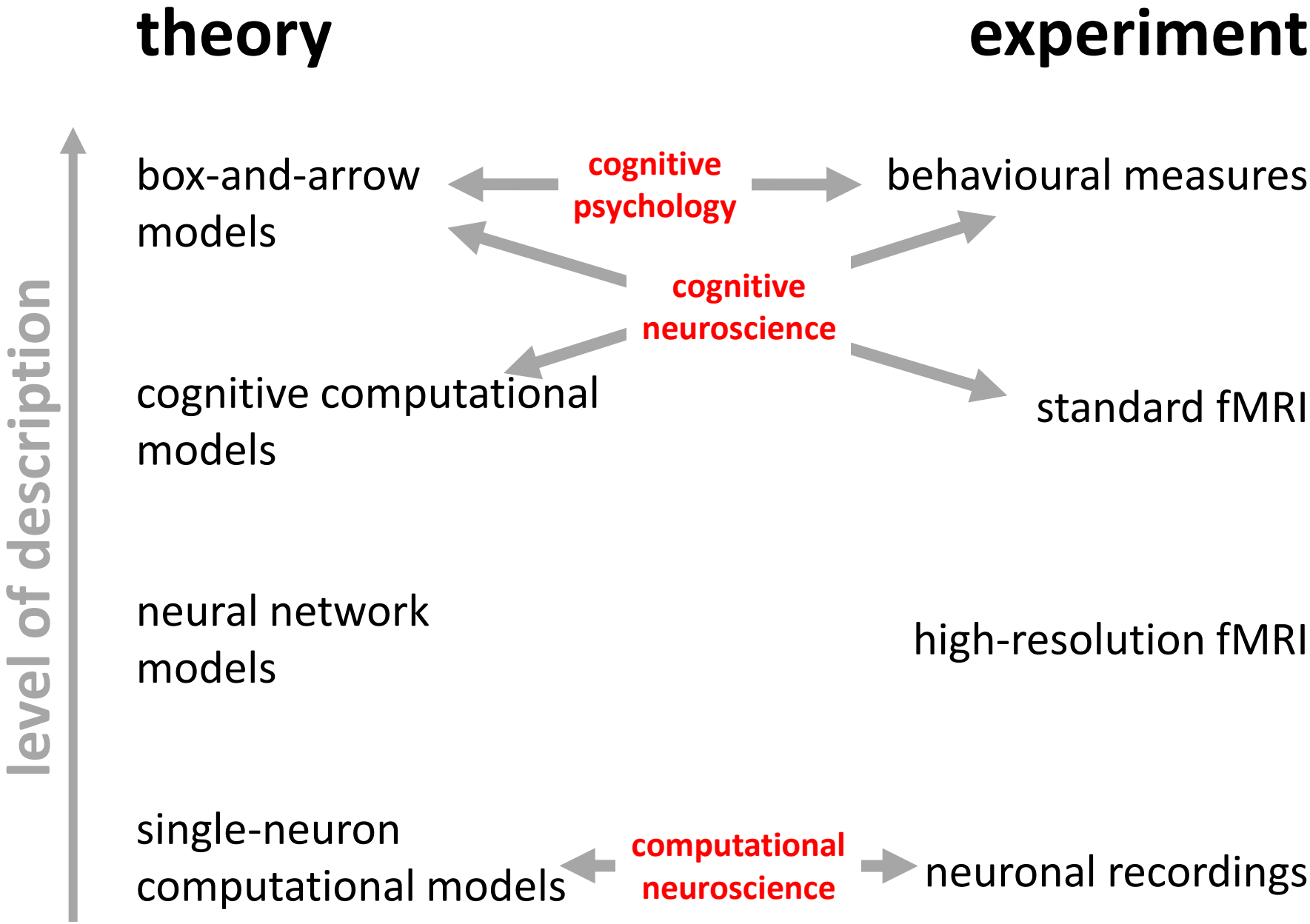


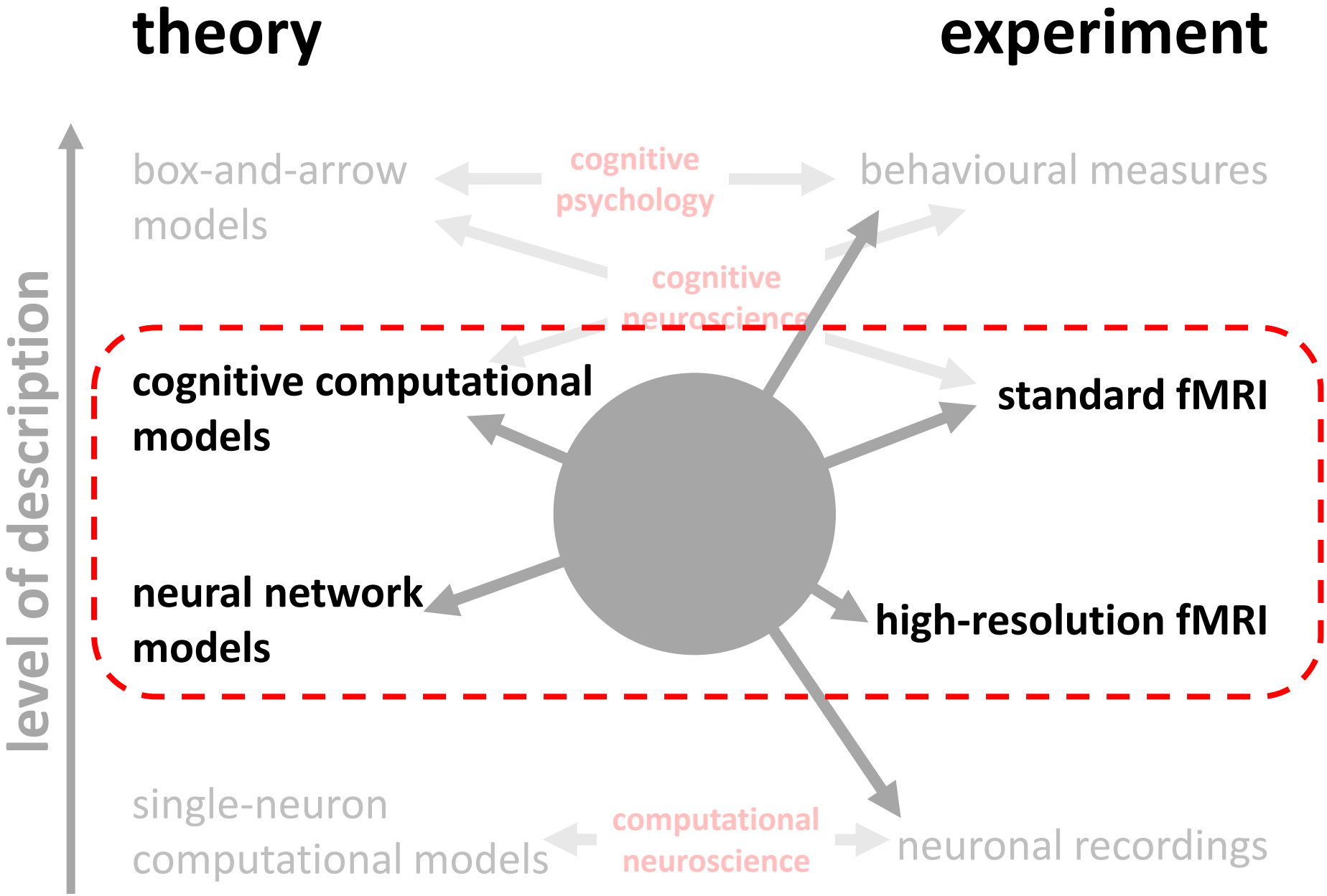
single-cell
("selectivity")

functional imaging
Haxby et al. (2001), **Cox** & Savoy (2003), **Carlson** et al. (2003), **Kamitani** & Tong (2005), **Kriegeskorte** et al. (2004, 2006, 2007, 2008), **Haynes** & Rees (2005, 2006), **Aguirre** (2007)

cell recording
Op de Beeck et al. (2001), **Hung** et al. (2005), **Sereno** & Lehky (2006), **Kiani** et al. (2007)

Kriegeskorte & Kreiman, Eds. (in press)


theory
experiment
level of description
box-and-arrow models
cognitive psychology
behavioural measures
cognitive neuroscience
cognitive computational models
standard fMRI
neural network models
high-resolution fMRI
single-neuron computational models
computational neuroscience
neuronal recordings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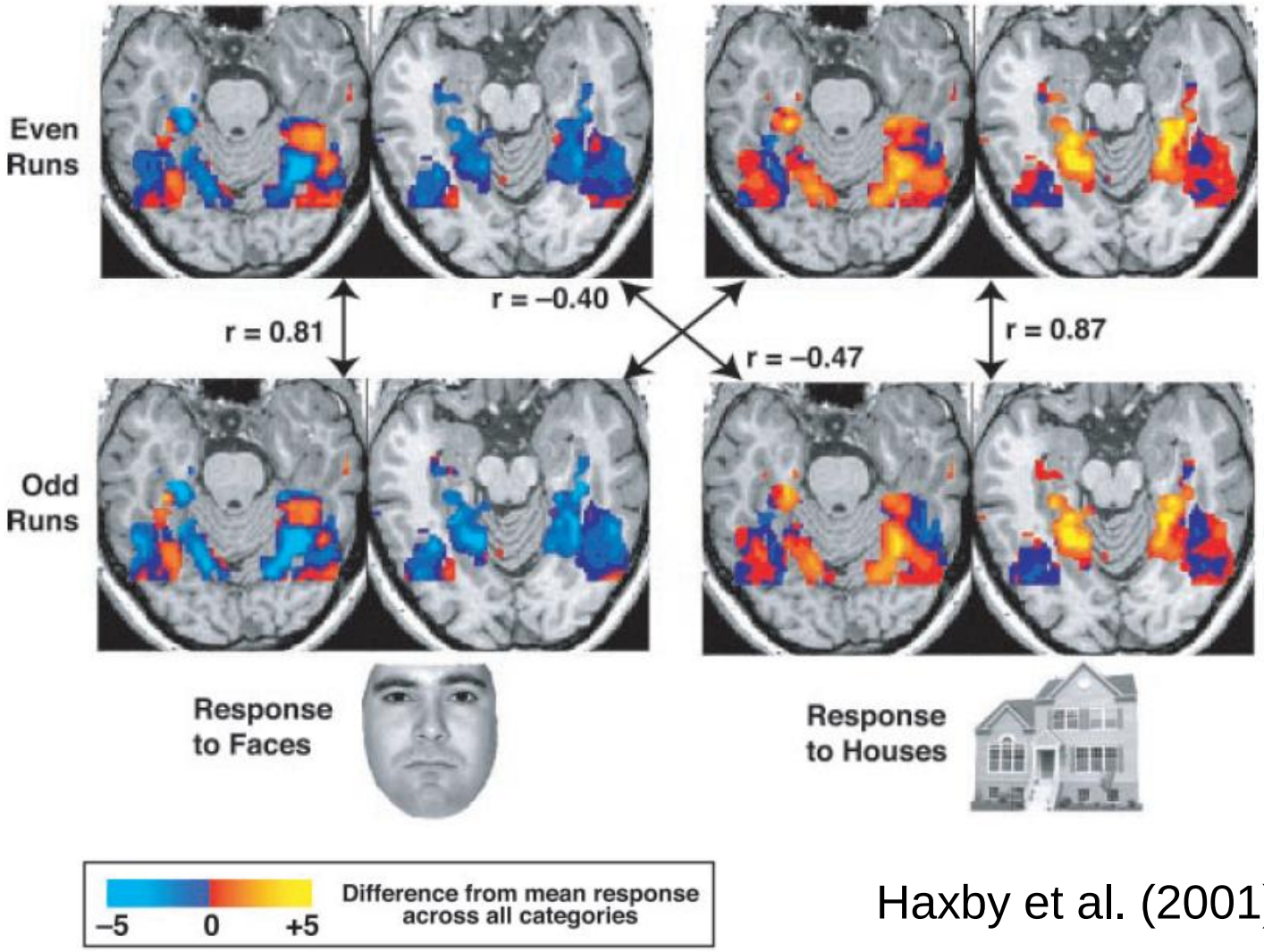
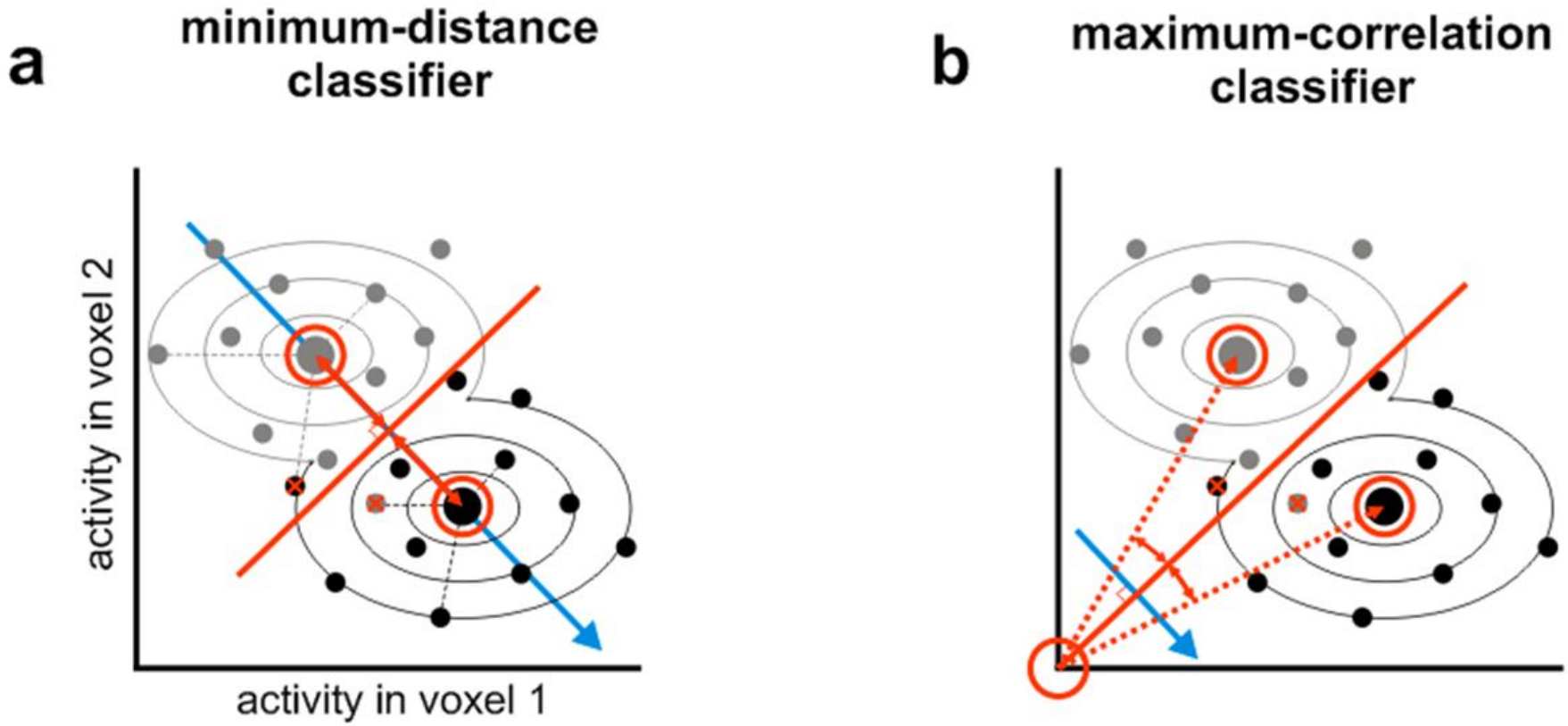
3 Why decode fMRI?

“Decoding” stimuli from brain responses



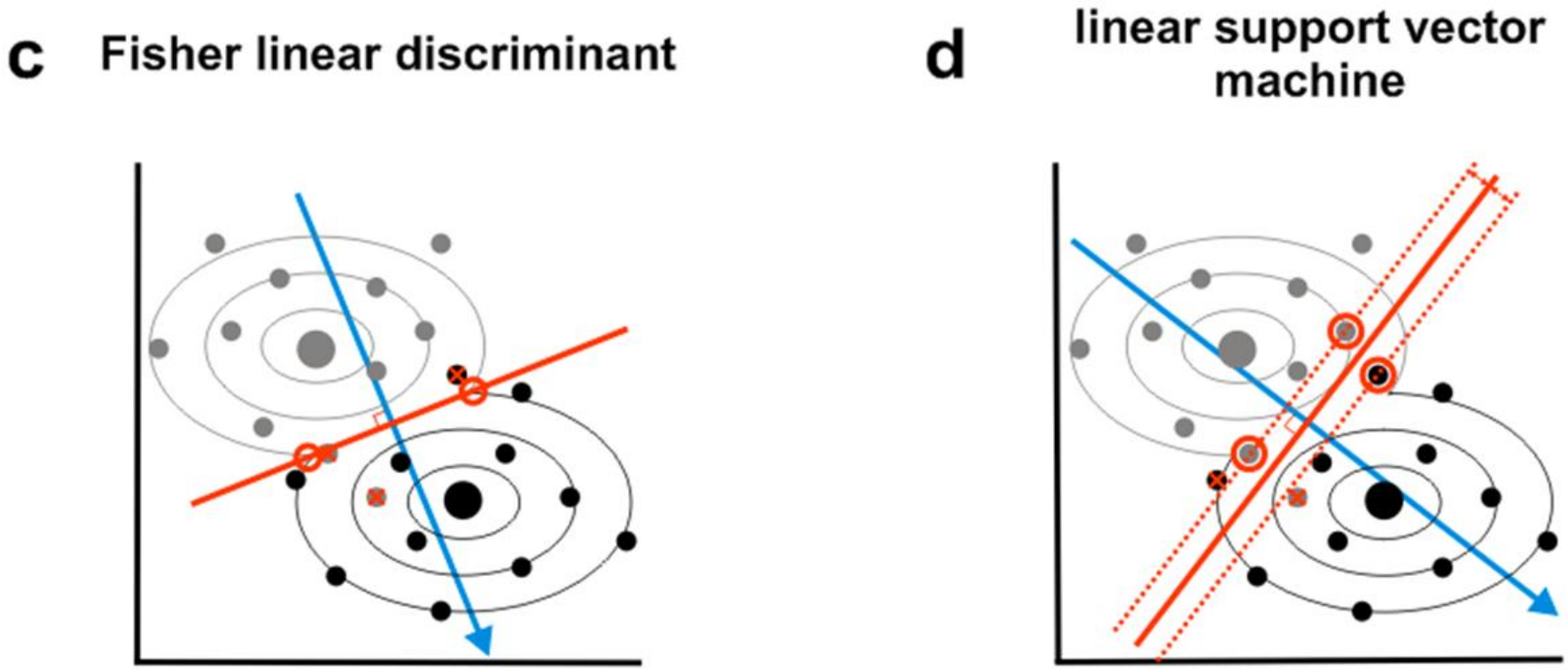
Haxby et al. (2001)

Linear pattern-classifier analysis



Kriegeskorte & Kreiman (2011) *Understanding visual population codes*. MIT Press.

Linear pattern-classifier analysis



Kriegeskorte & Kreiman (2011) *Understanding visual population codes*. MIT Press.

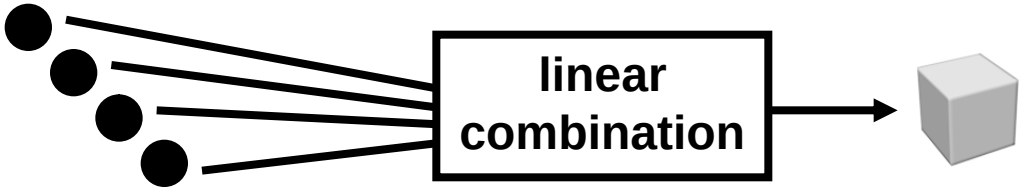
Nonlinear classifiers?

- Nonlinear decoding typically doesn't generalise as well in fMRI (Misaki et al. 2010).
- Linearly decodable information can be considered "explicit" in the code.

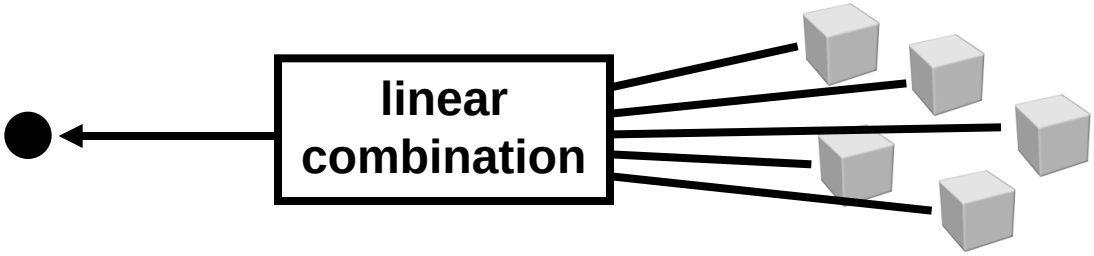
Decoding or encoding?

stimulus

response



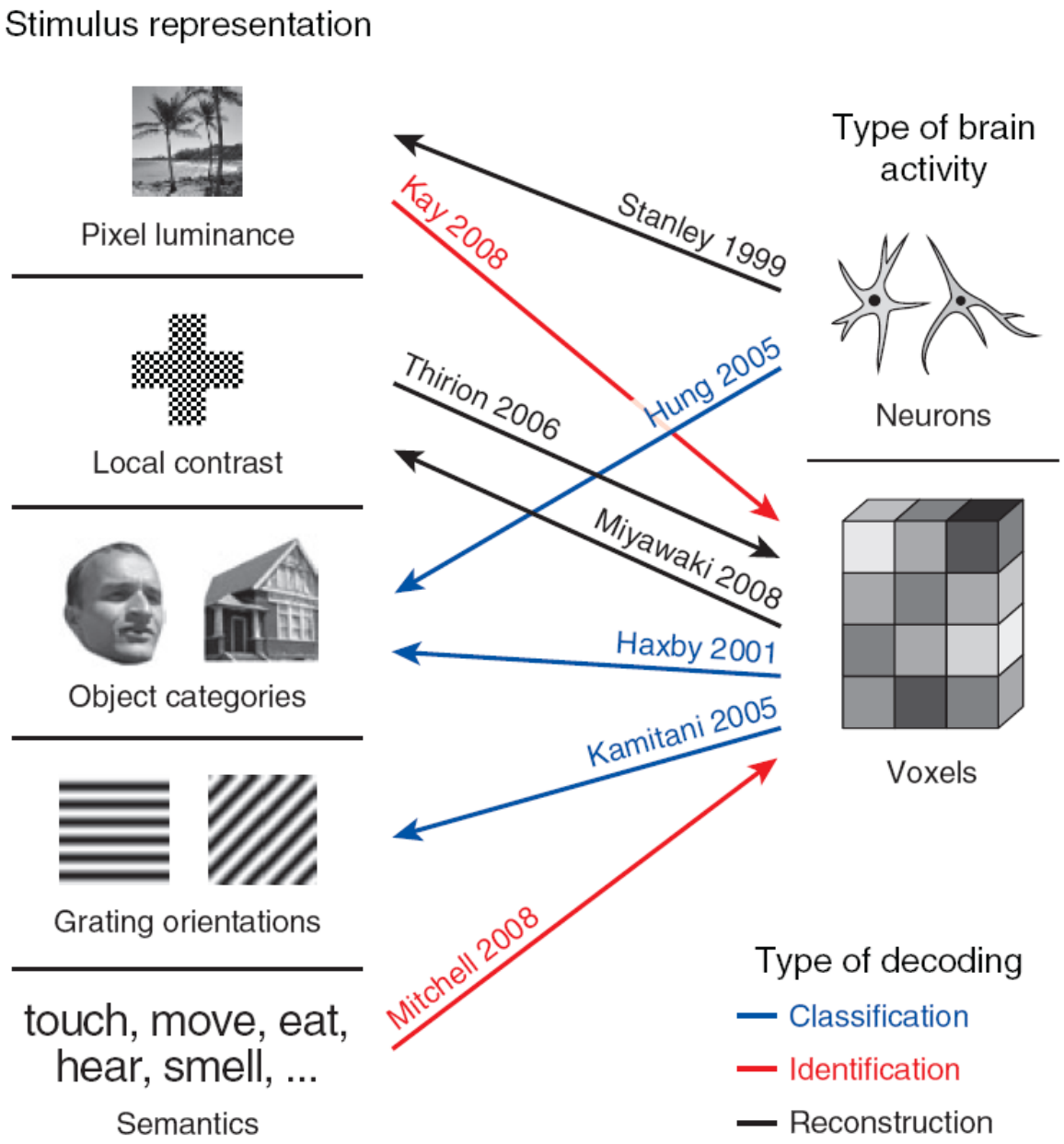
univariate
activation
analysis



multivariate
pattern-information
analysis

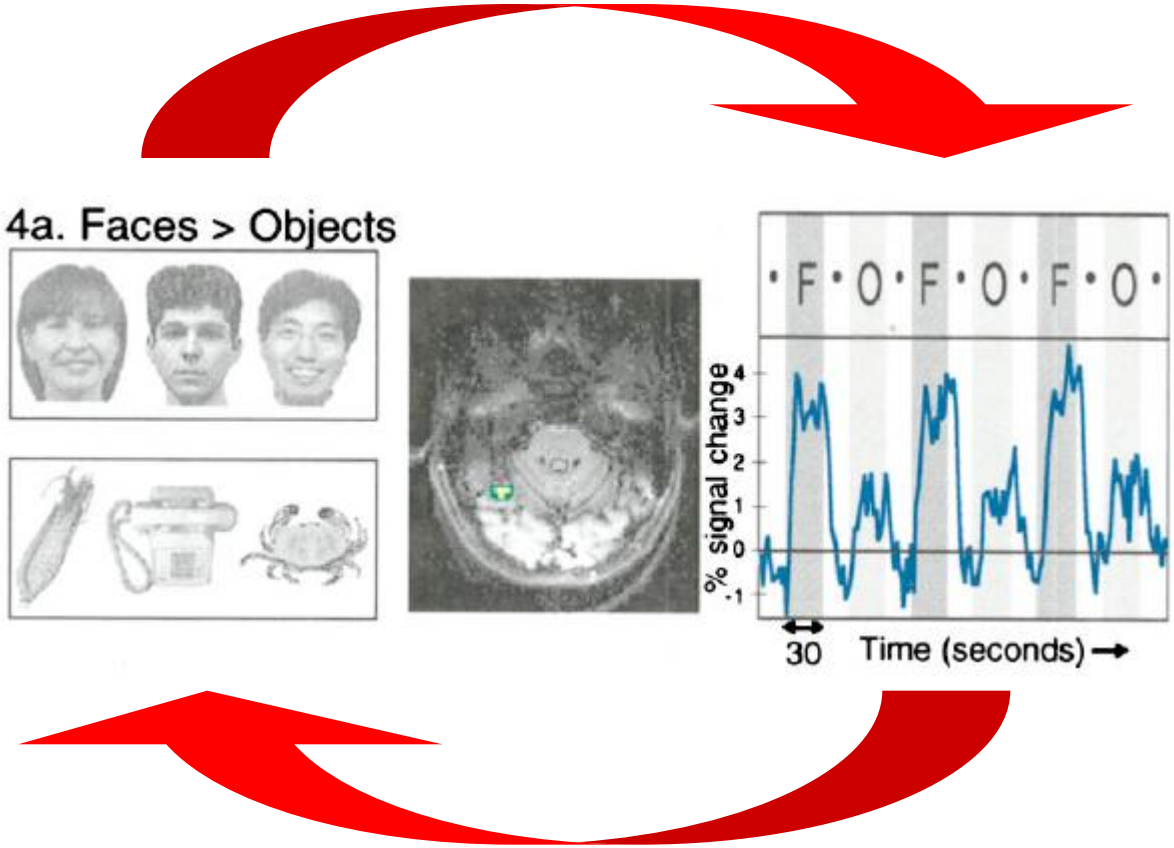
“decoding”, “prediction” ← spin

substance



from Kay & Gallant (2009)

“Predicting” brain responses from stimuli



Kanwisher et al. (1997)

Potential title claims

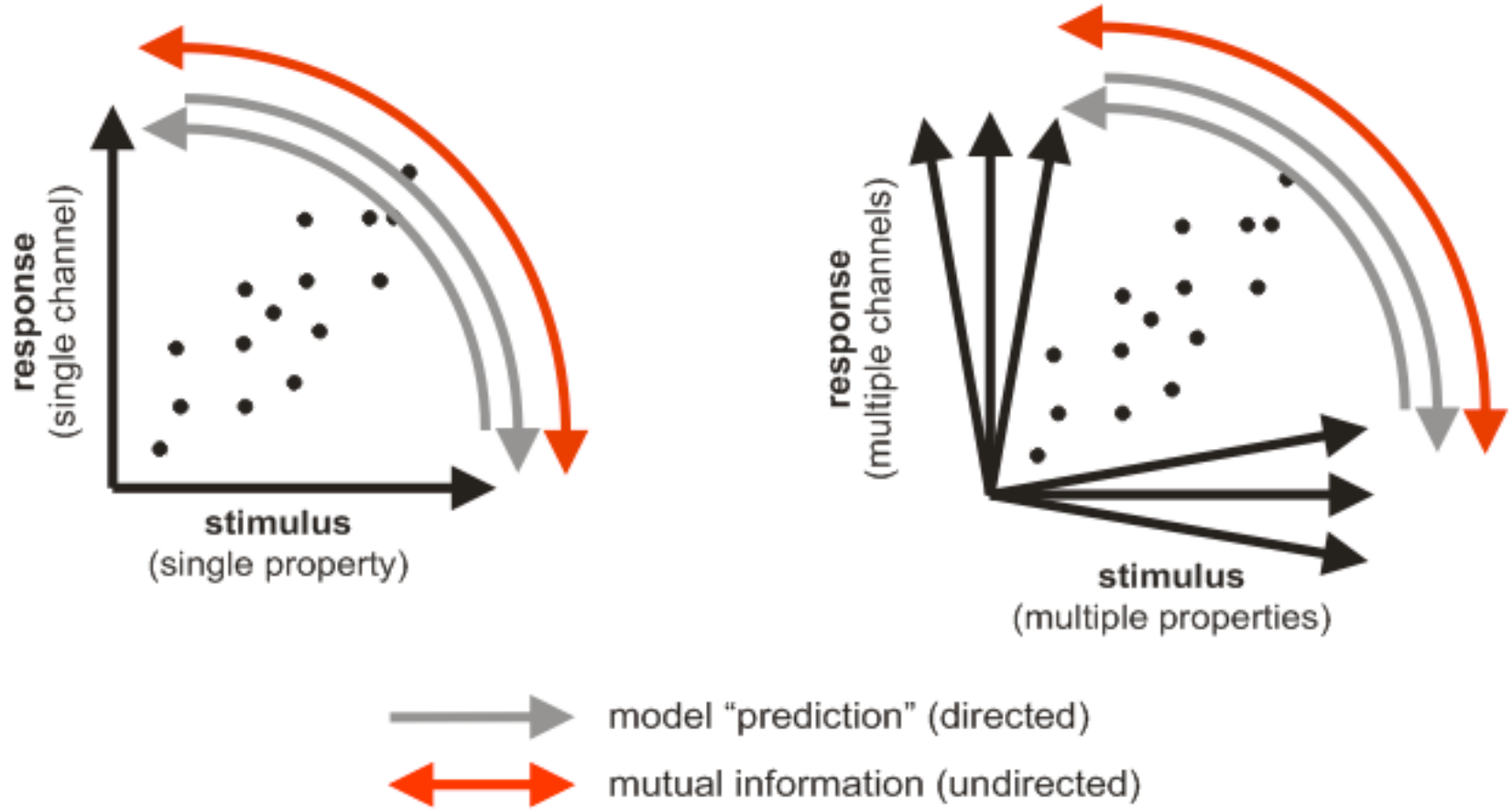
Fusiform region responds more strongly to visual faces than objects. *Neuroreport*, 1997.

The fusiform face area: a module in human extrastriate cortex specialized for face perception. *J Neurosci*, 1997.

Brain reading: Predicting face percepts from fusiform activity. *Science*, 1997.

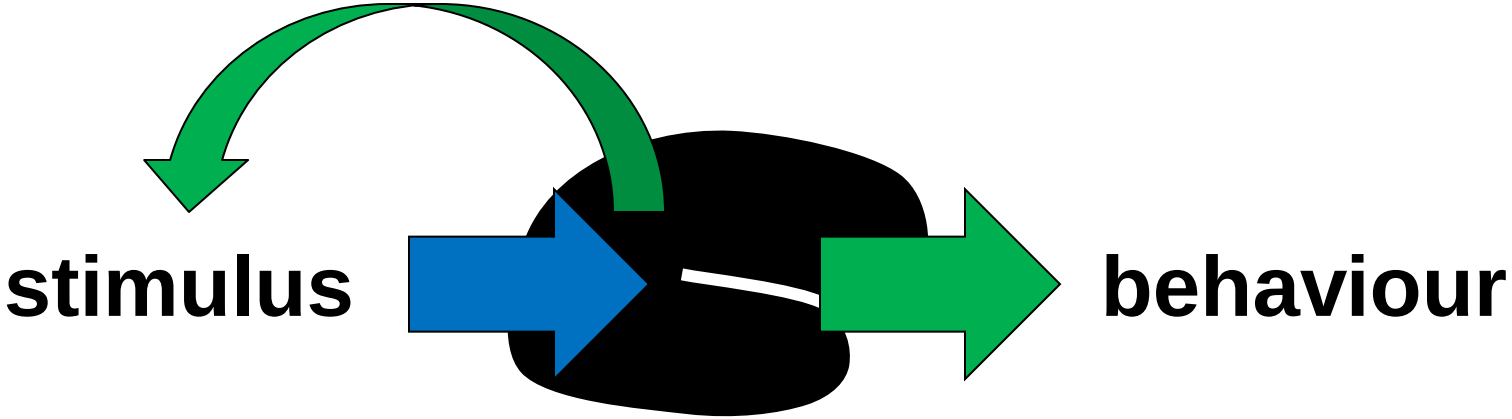
Model direction has no neuroscientific implications

Model direction has no neuroscientific implications



4 Why test encoding models with fMRI?

decoding encoding

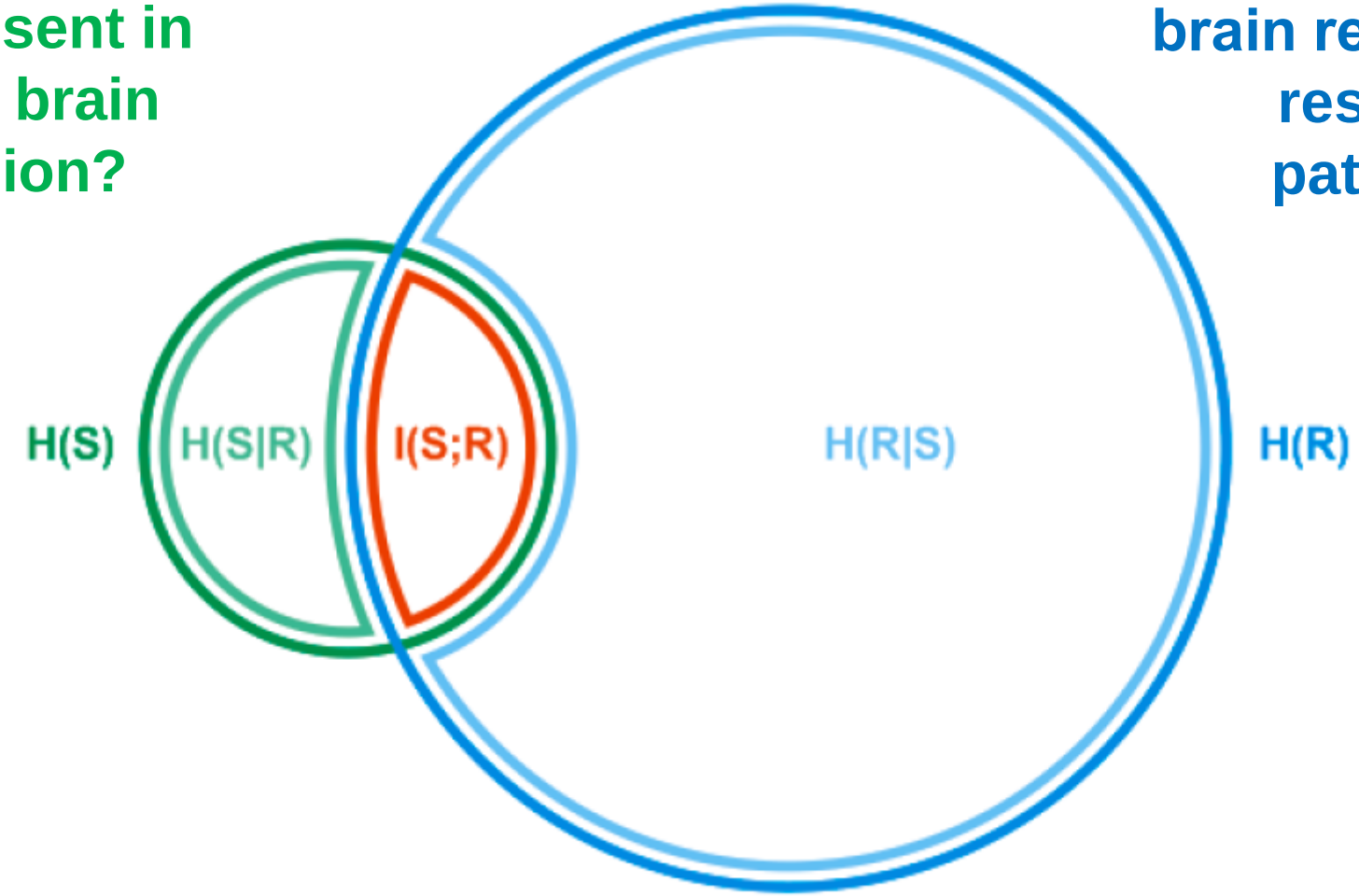


decoding

How much stimulus information is present in the brain region?

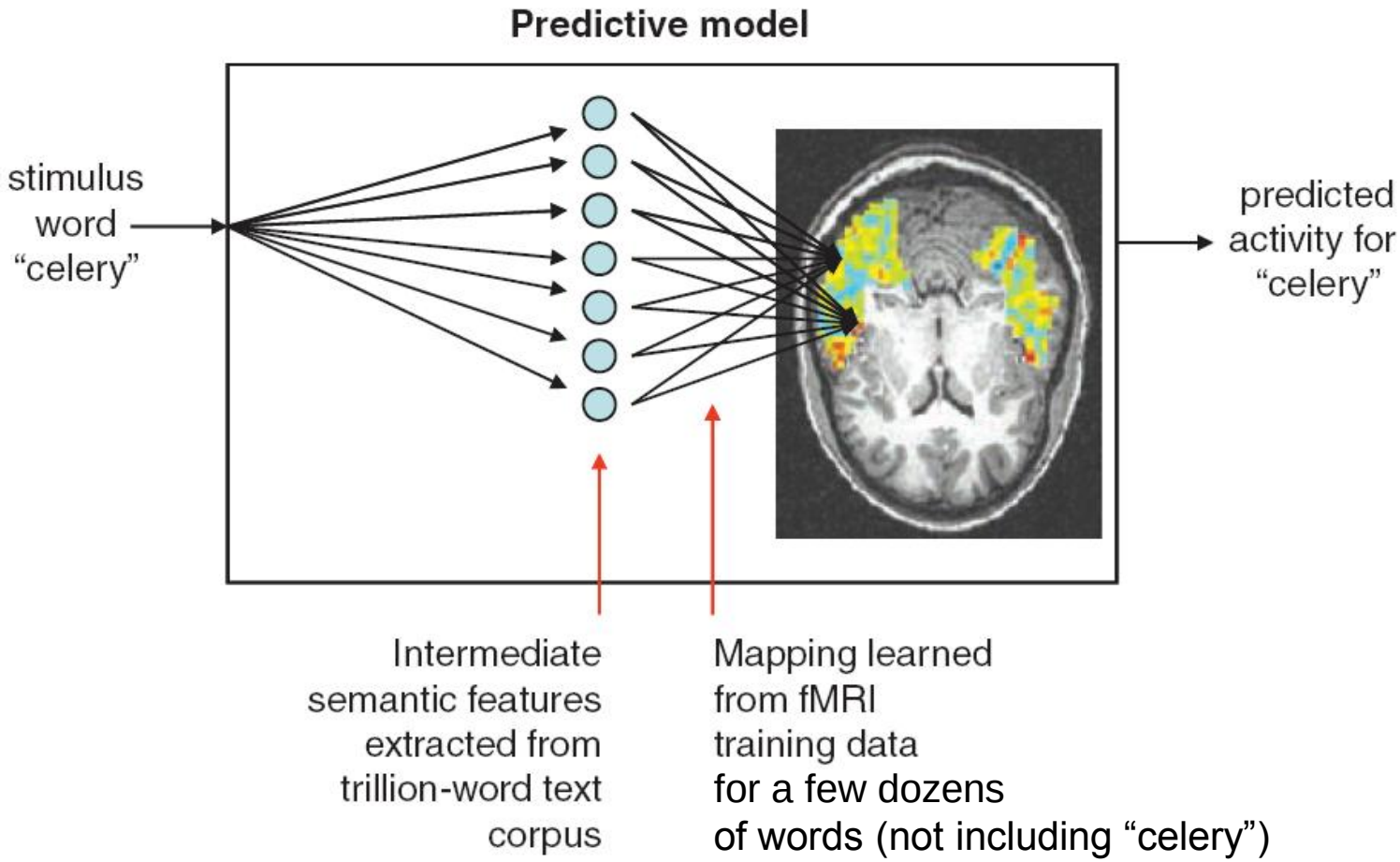
encoding

How well does our model explain the brain region's response patterns?



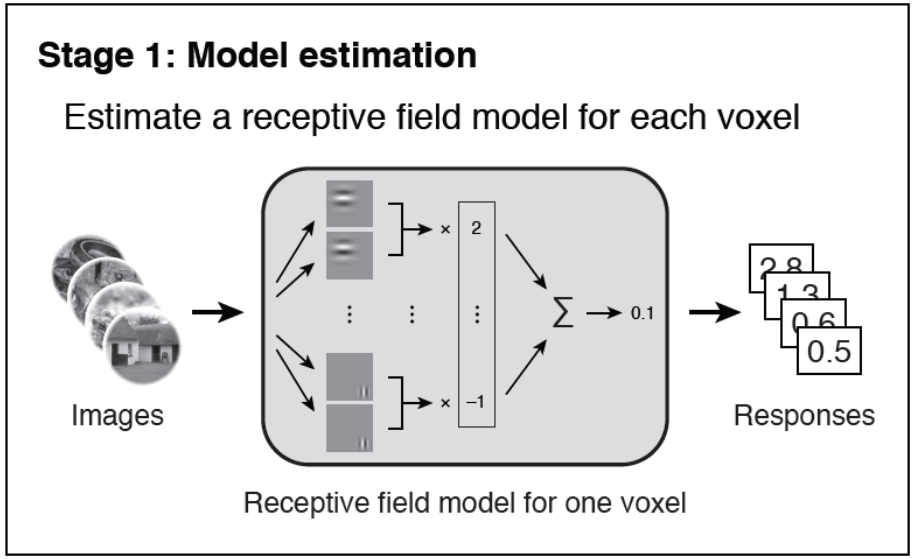
Kriegeskorte (2011)

Predicting brain responses for *novel* stimuli



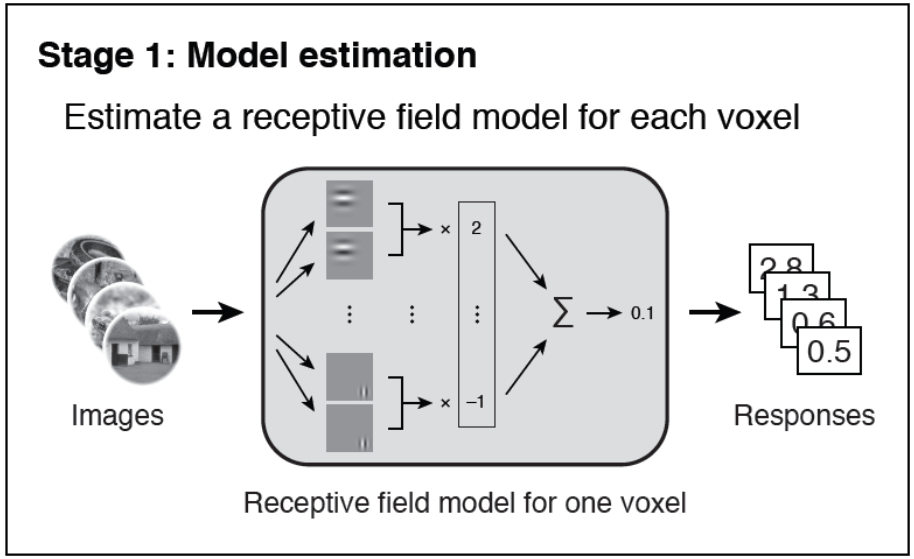
Mitchell et al. (2008)

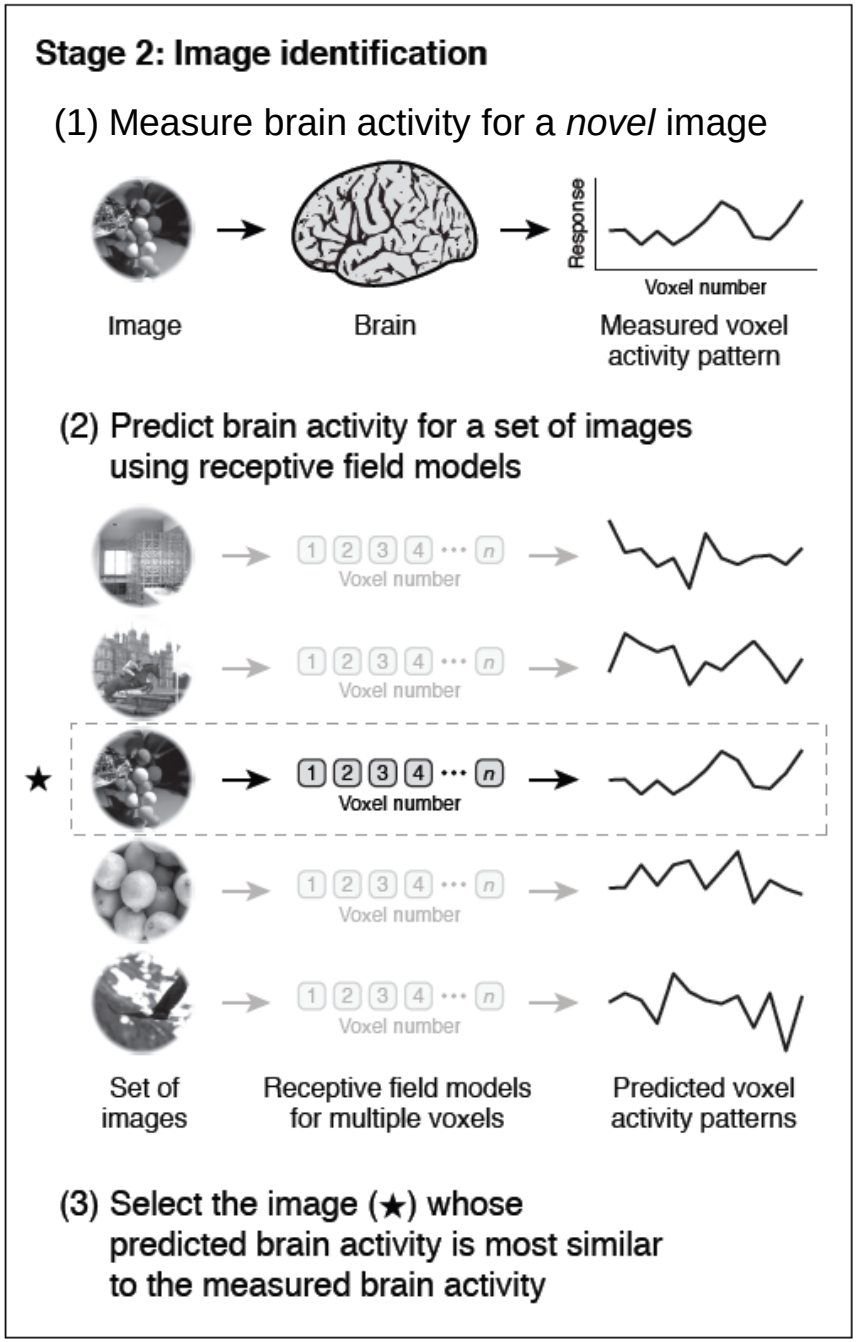
“Predicting” *novel* stimuli from brain responses



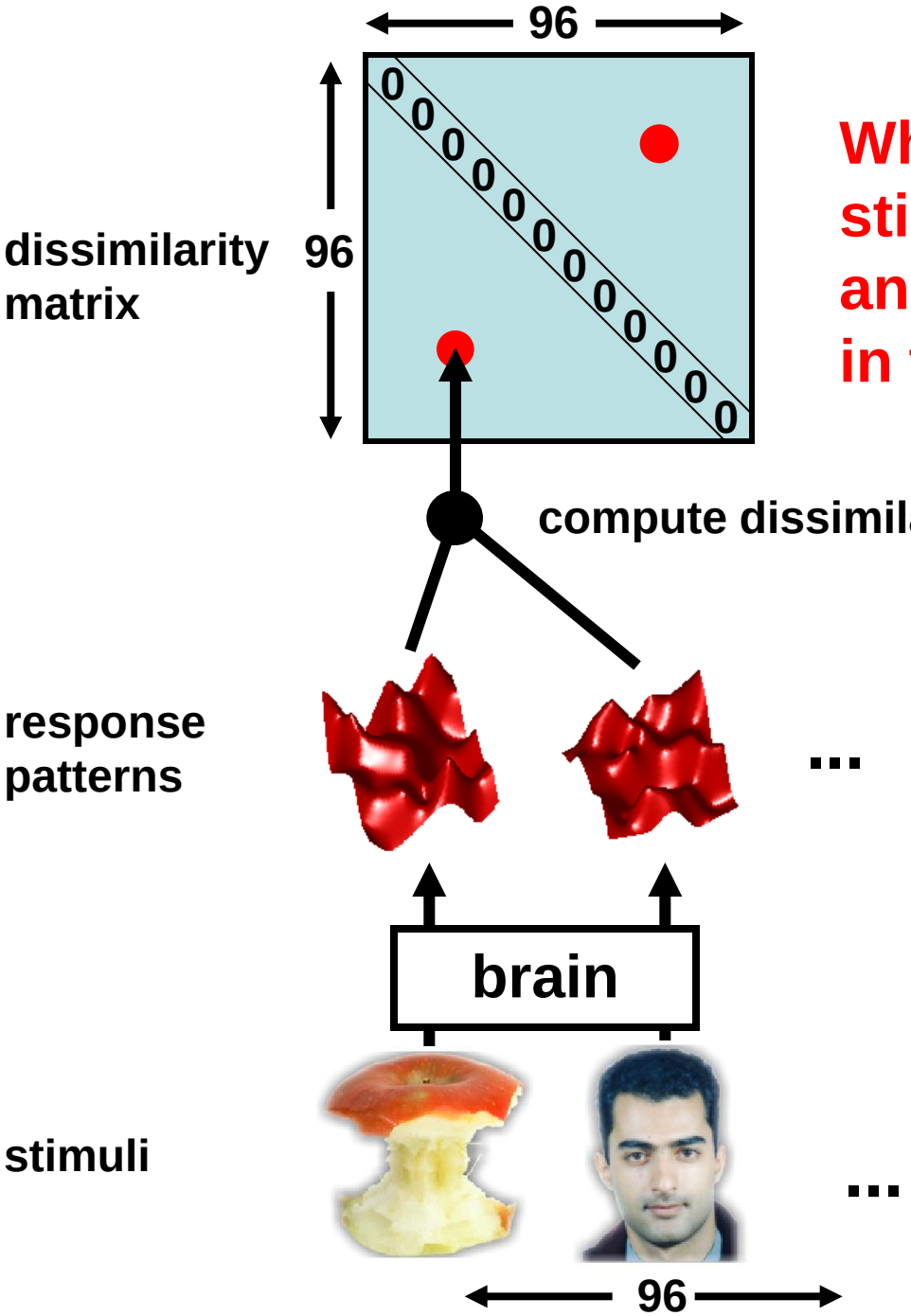
Kay et al. (2008)

“Predicting” *novel* stimuli from brain responses





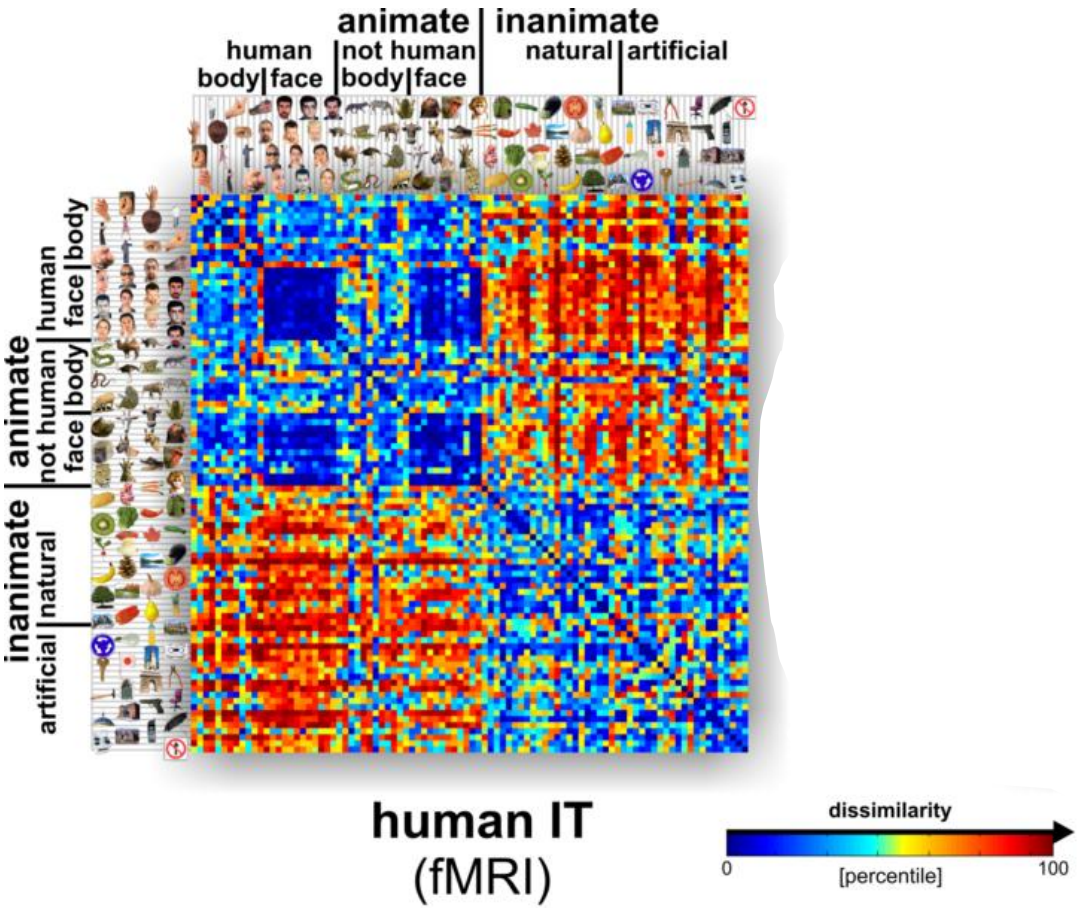
Kay et al. (2008)



Which distinctions between stimuli are reflected and which are lost in the population code?

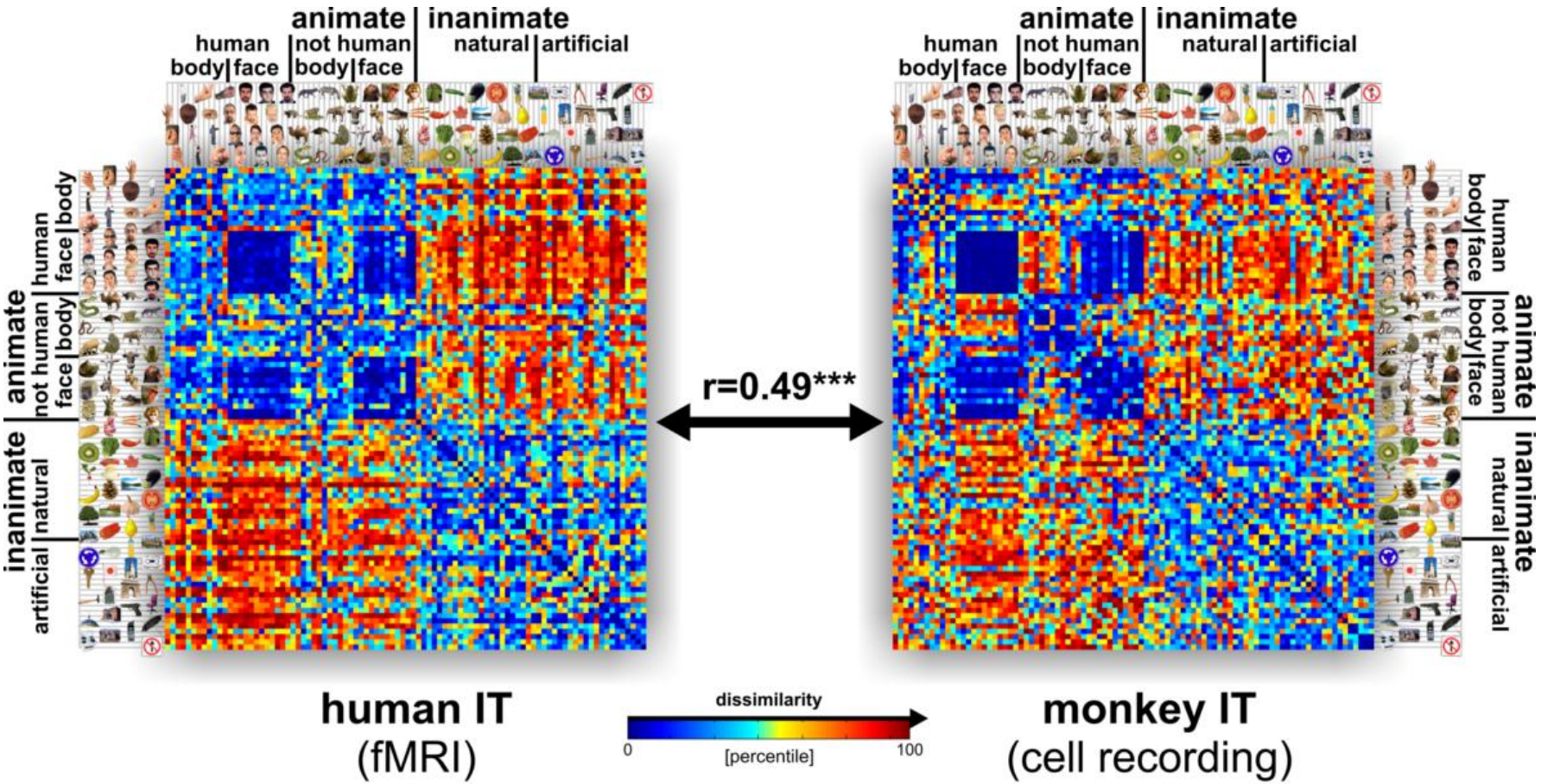
Kriegeskorte et al. 2008

Inferior temporal (IT) representational space



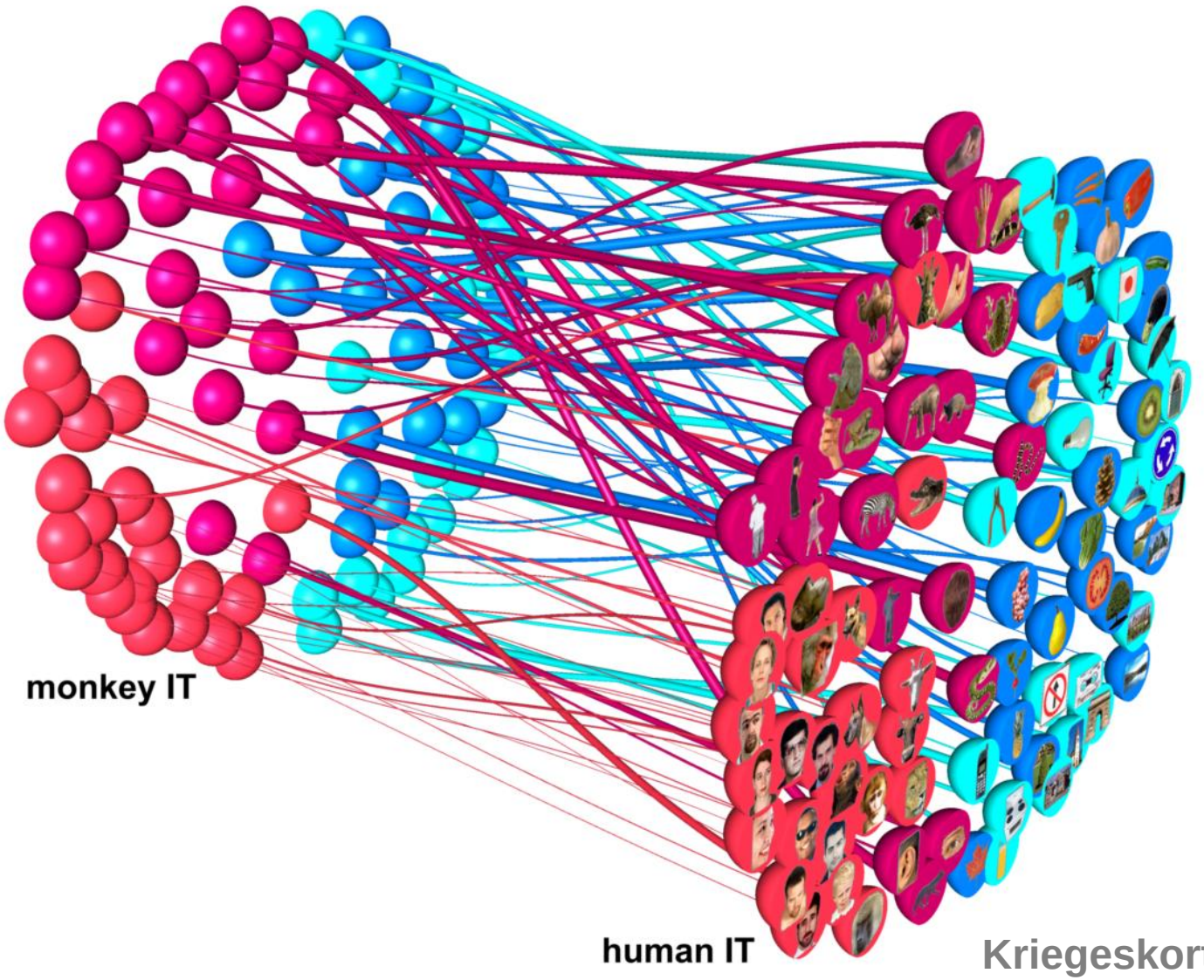
Kriegeskorte et al. 2008

Inferior temporal (IT) representational space



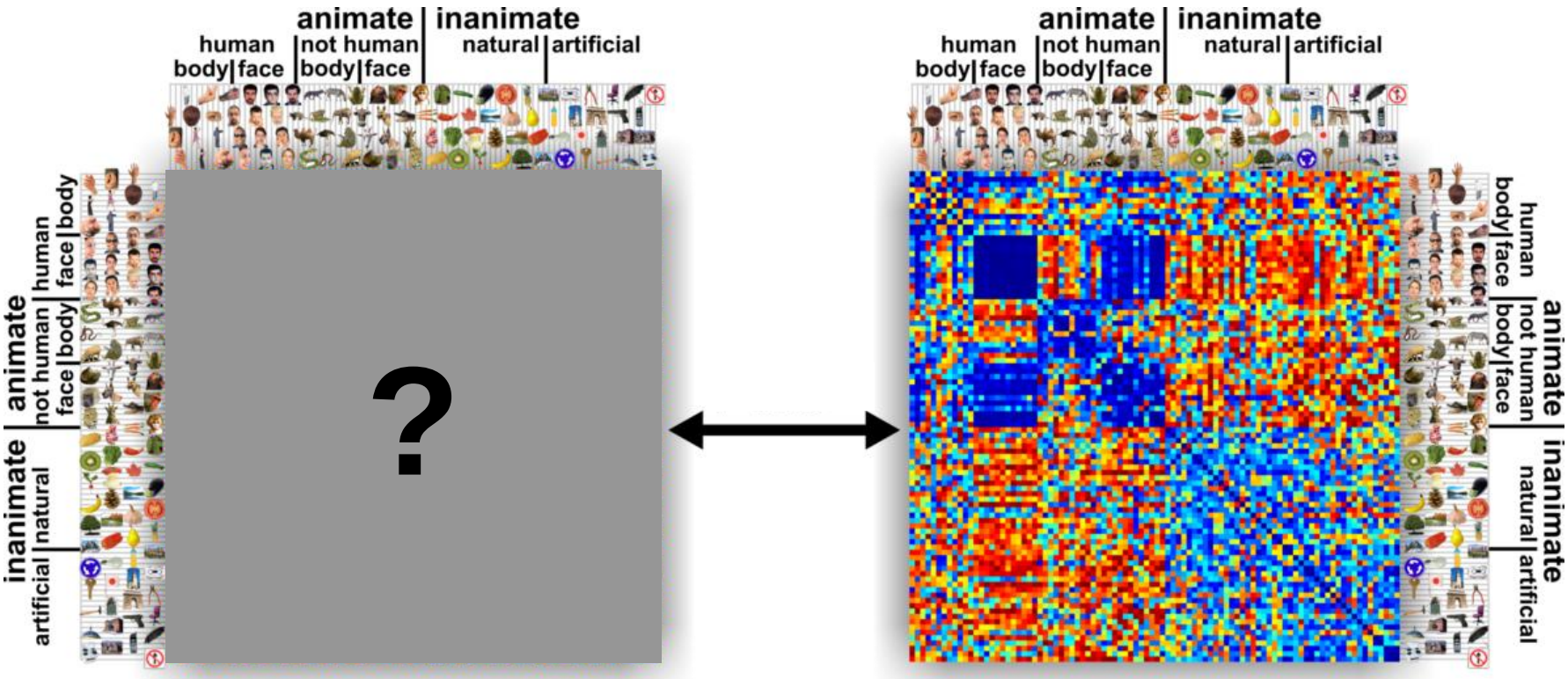
Kriegeskorte et al. 2008

Inferior temporal (IT) representational space



Kriegeskorte et al. 2008

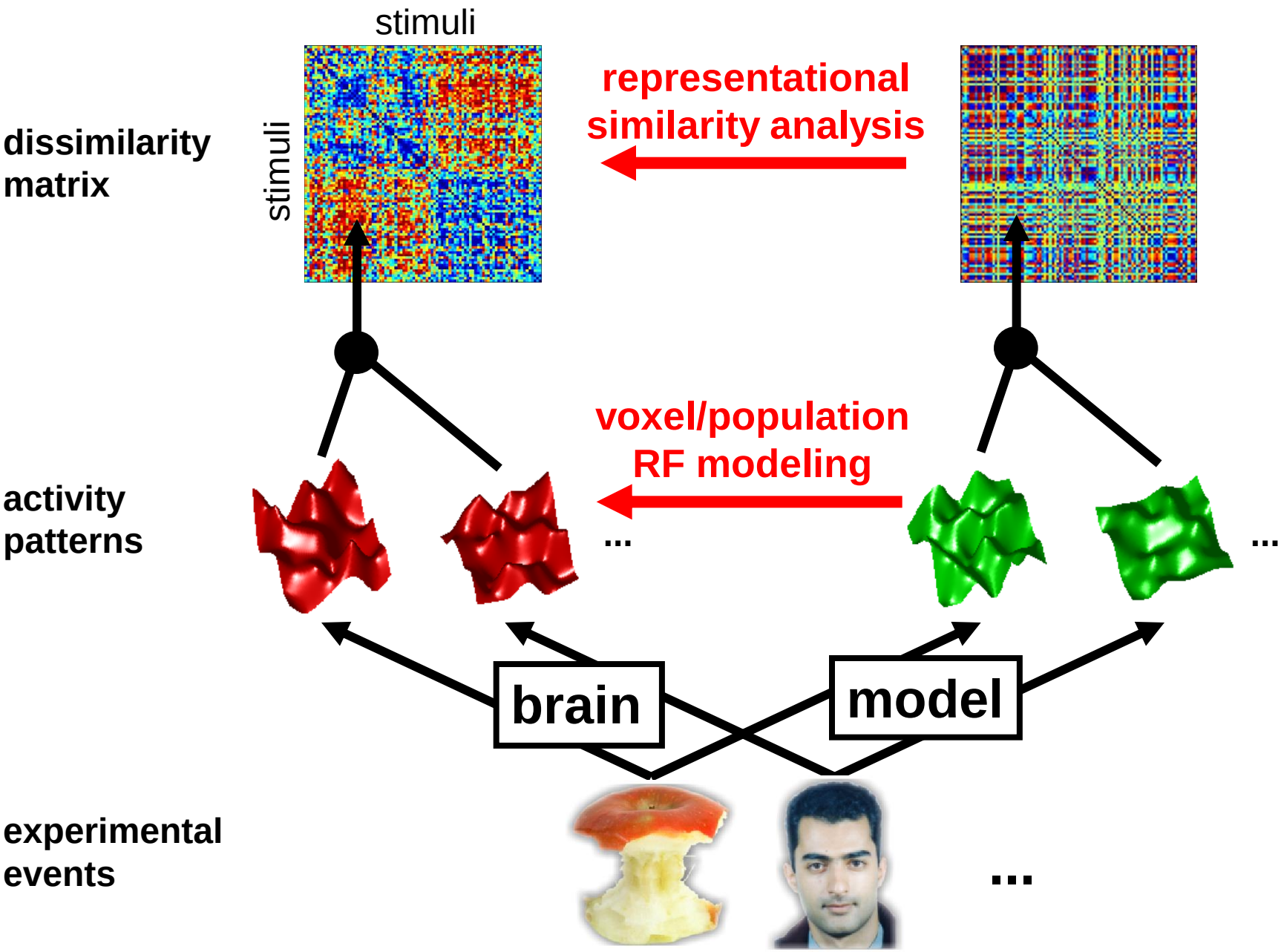
Comparing brain and model representations



computational model
(dissimilarity matrix of internal response patterns)

monkey IT
(cell recording)

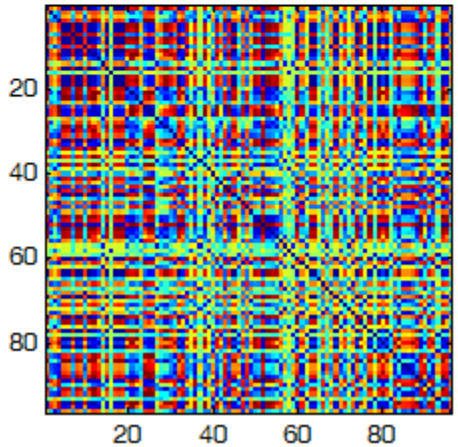
Kriegeskorte et al. 2008


stimuli
stimuli
dissimilarity matrix
representational similarity analysis
voxel/population RF modeling
activity patterns
...
...
brain
model
experimental events
...

Model dissimilarity matrices

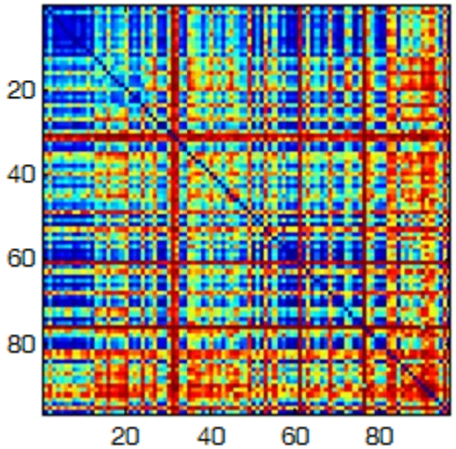
Model dissimilarity matrices

HMAX model

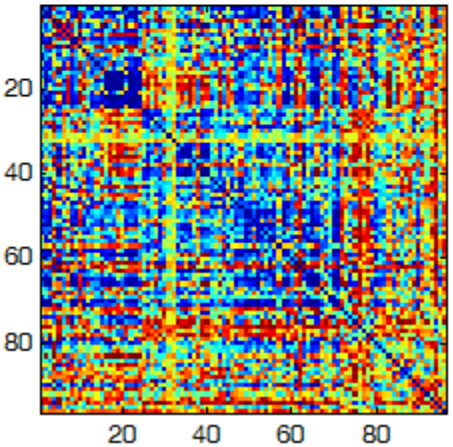


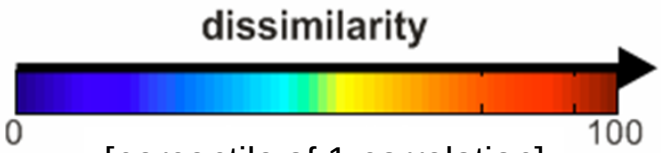
Riesenhuber & Poggio 2002

V1 model



stimulus image

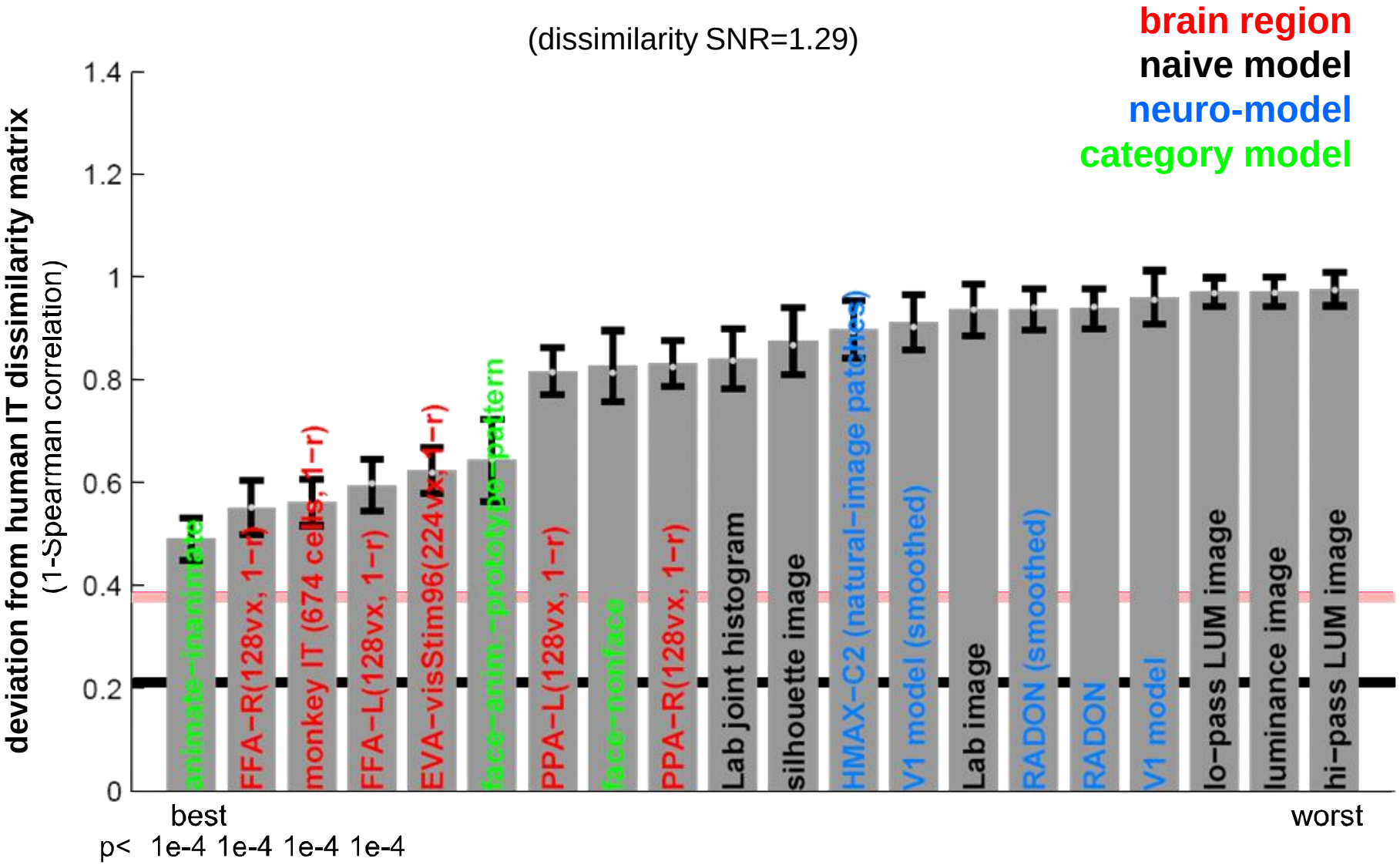


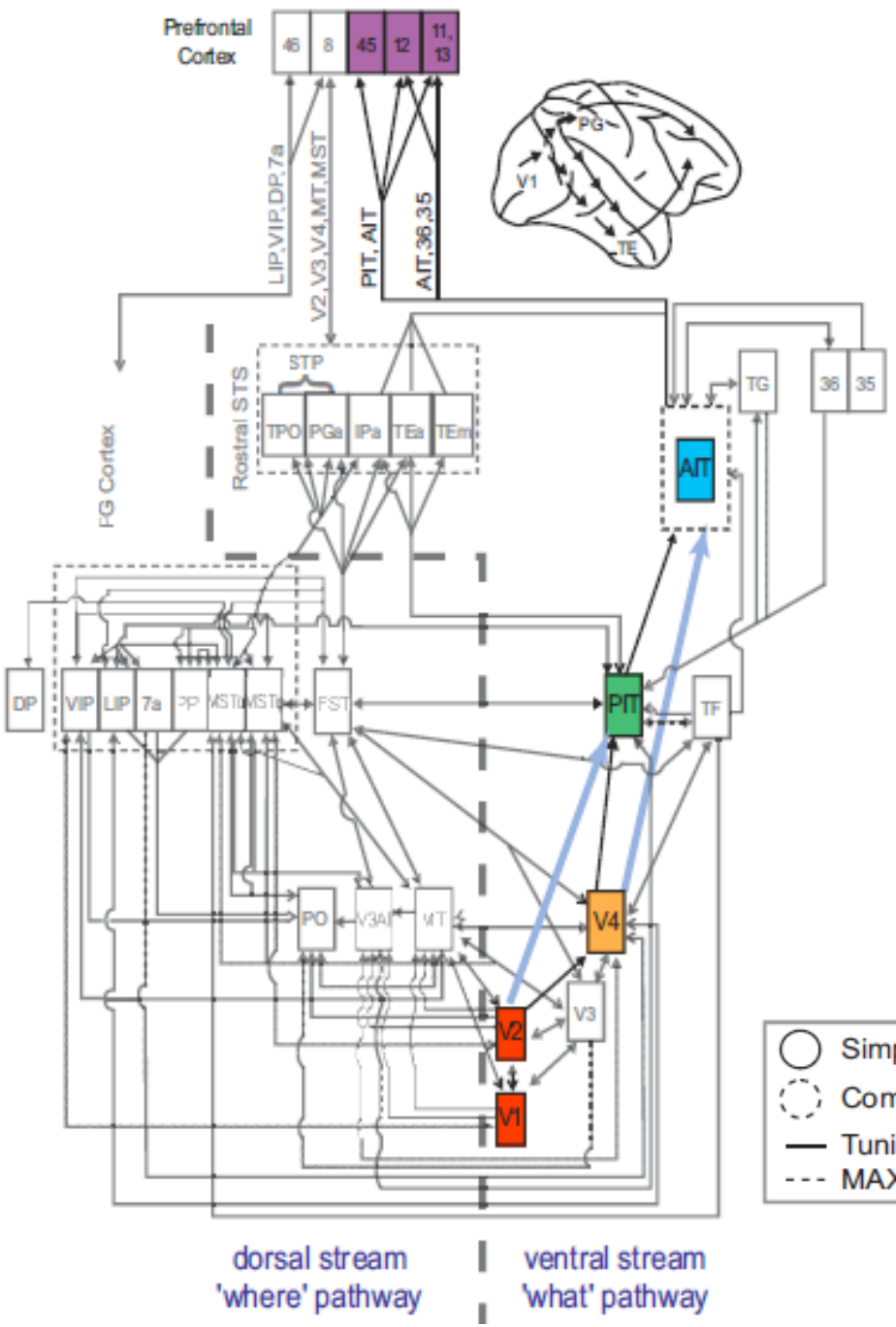


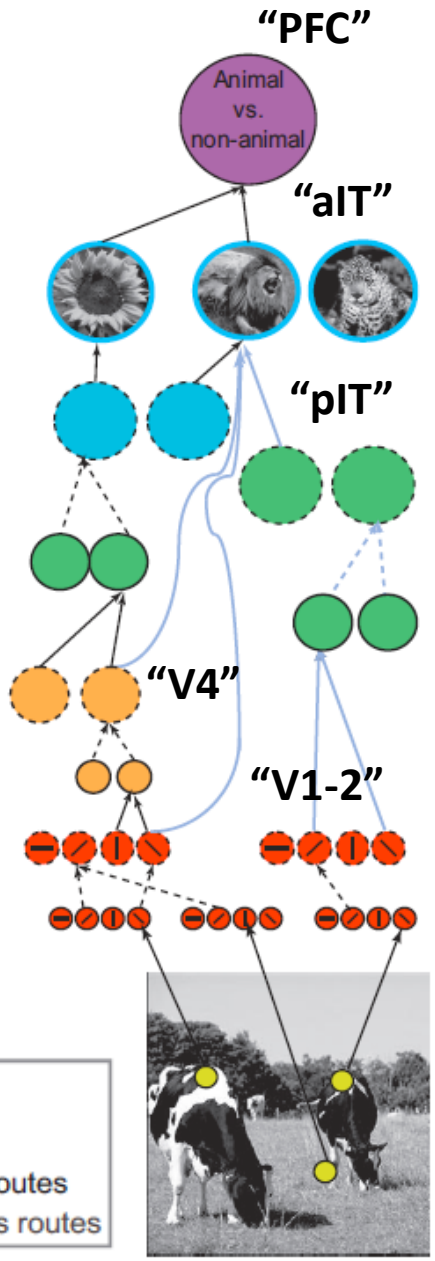
[percentile of 1-correlation]

Human IT

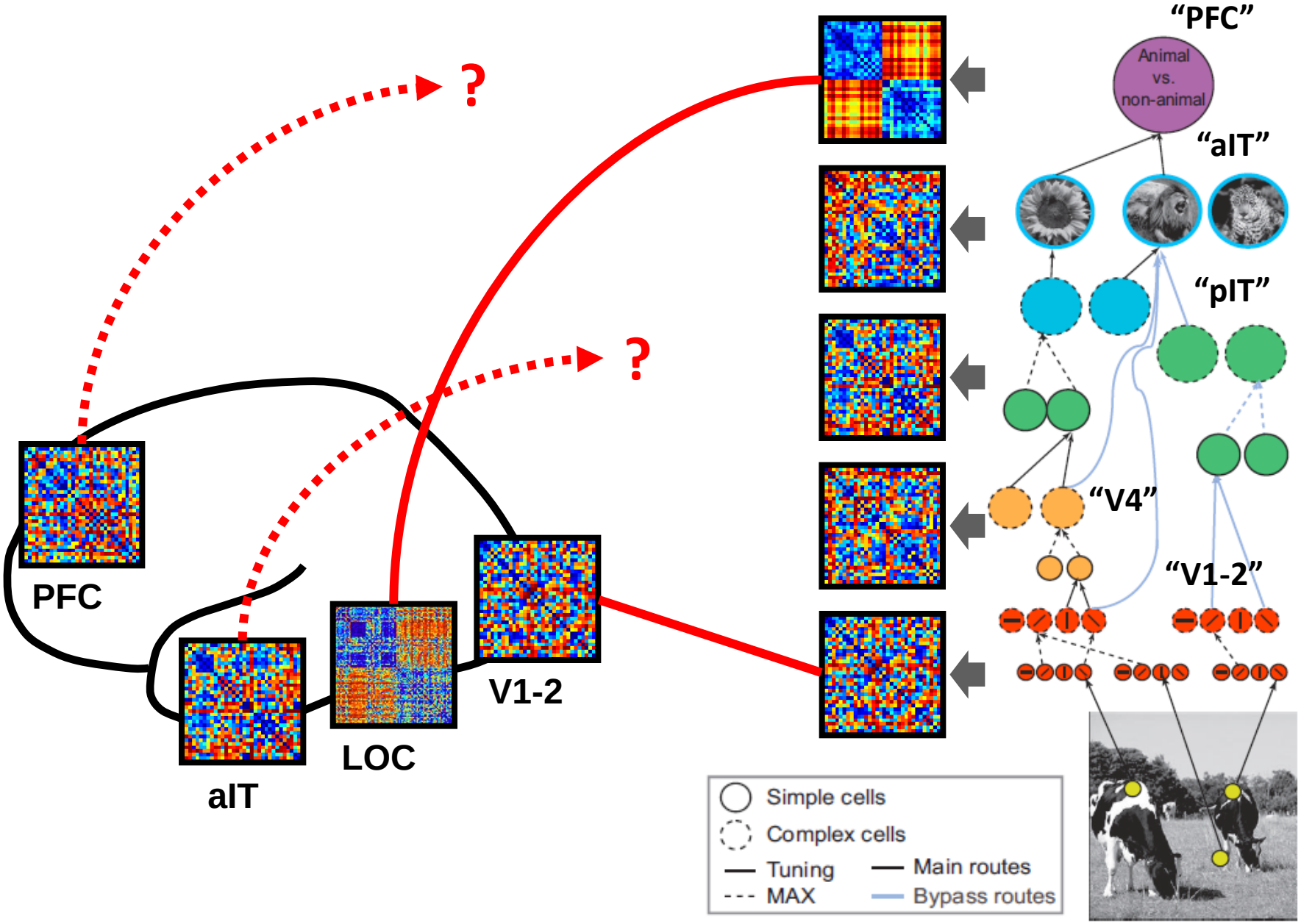
(dissimilarity SNR=1.29)



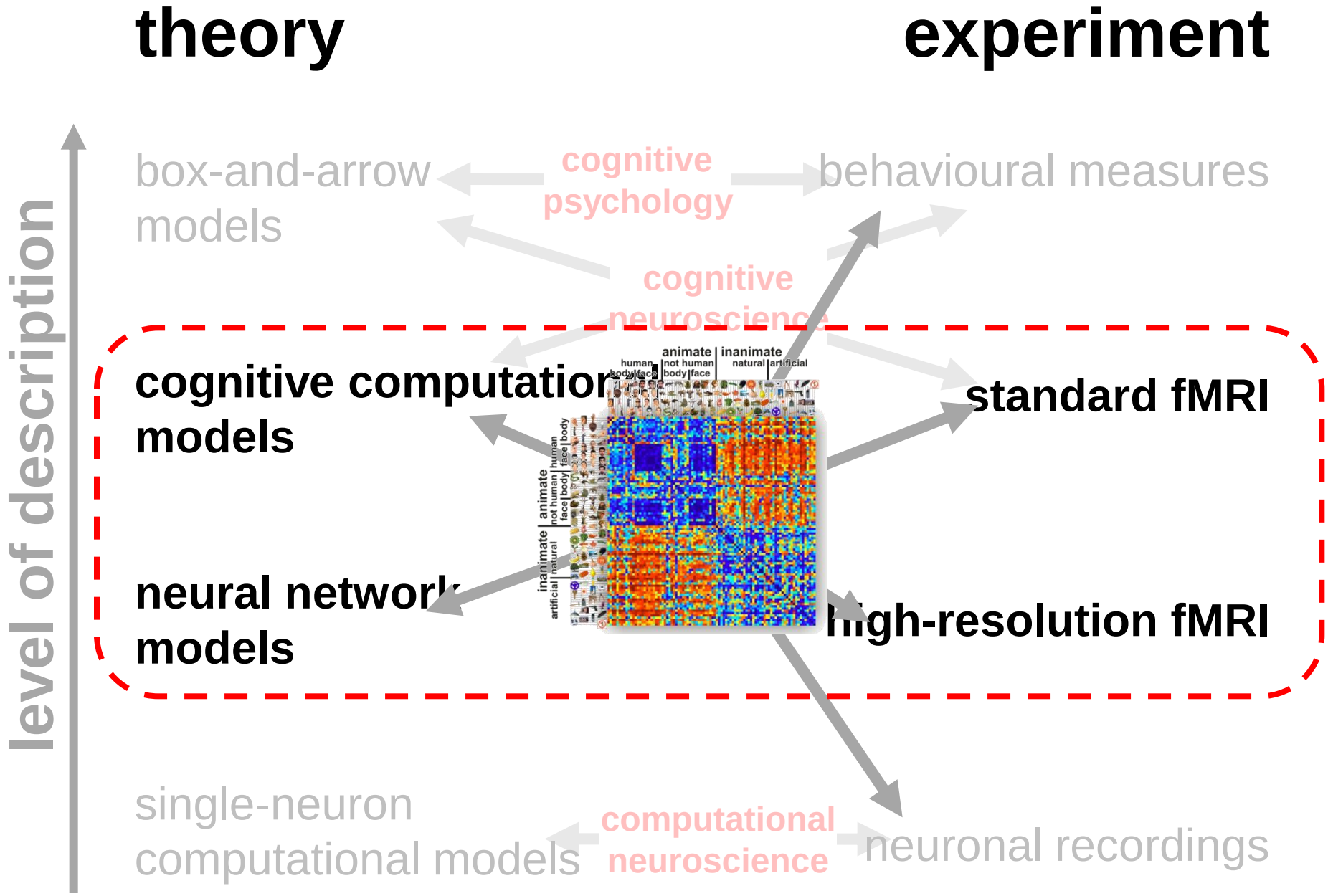




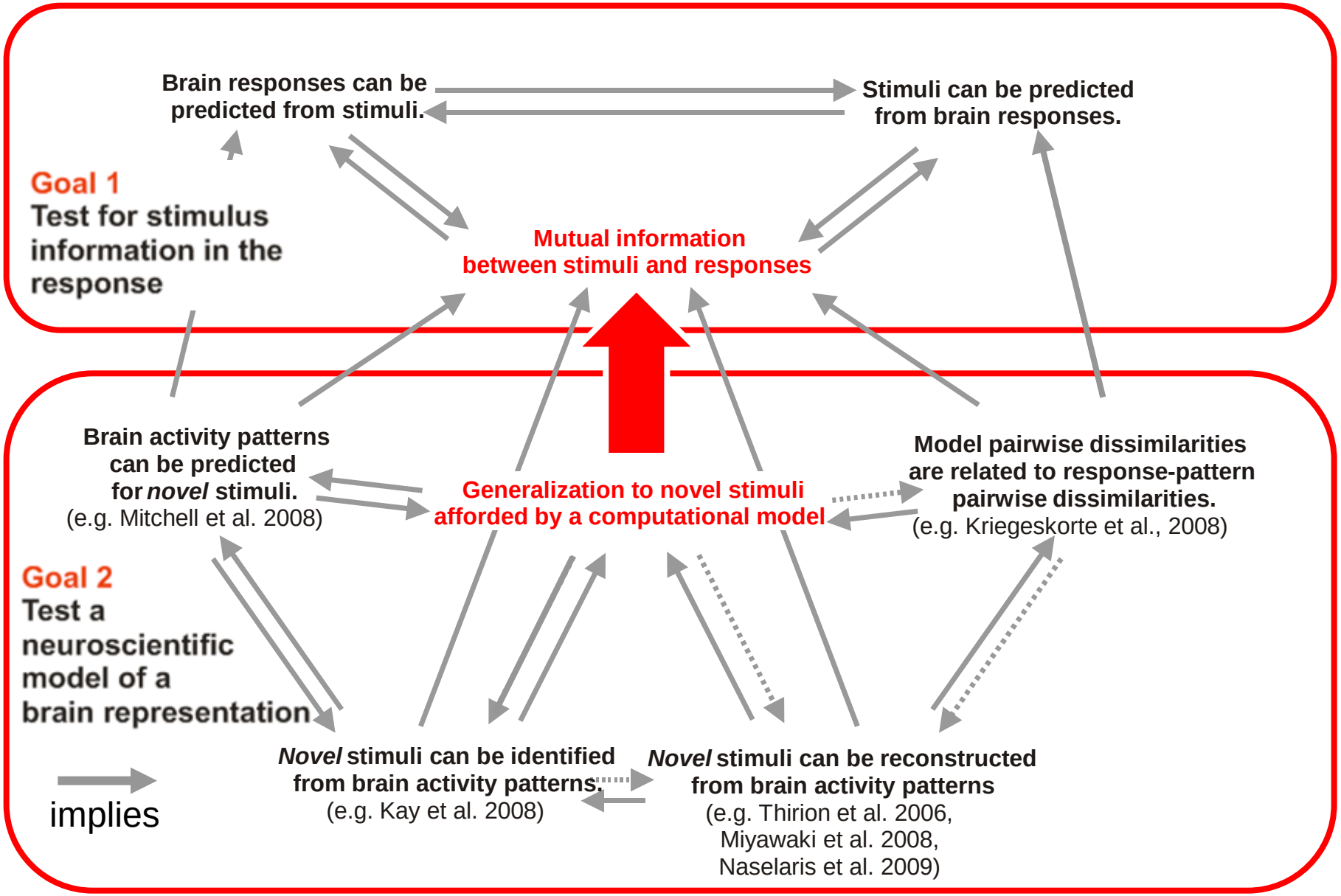
Serre, Oliva & Poggio (2007)
PNAS



Serre, Oliva & Poggio (2007)
PNAS

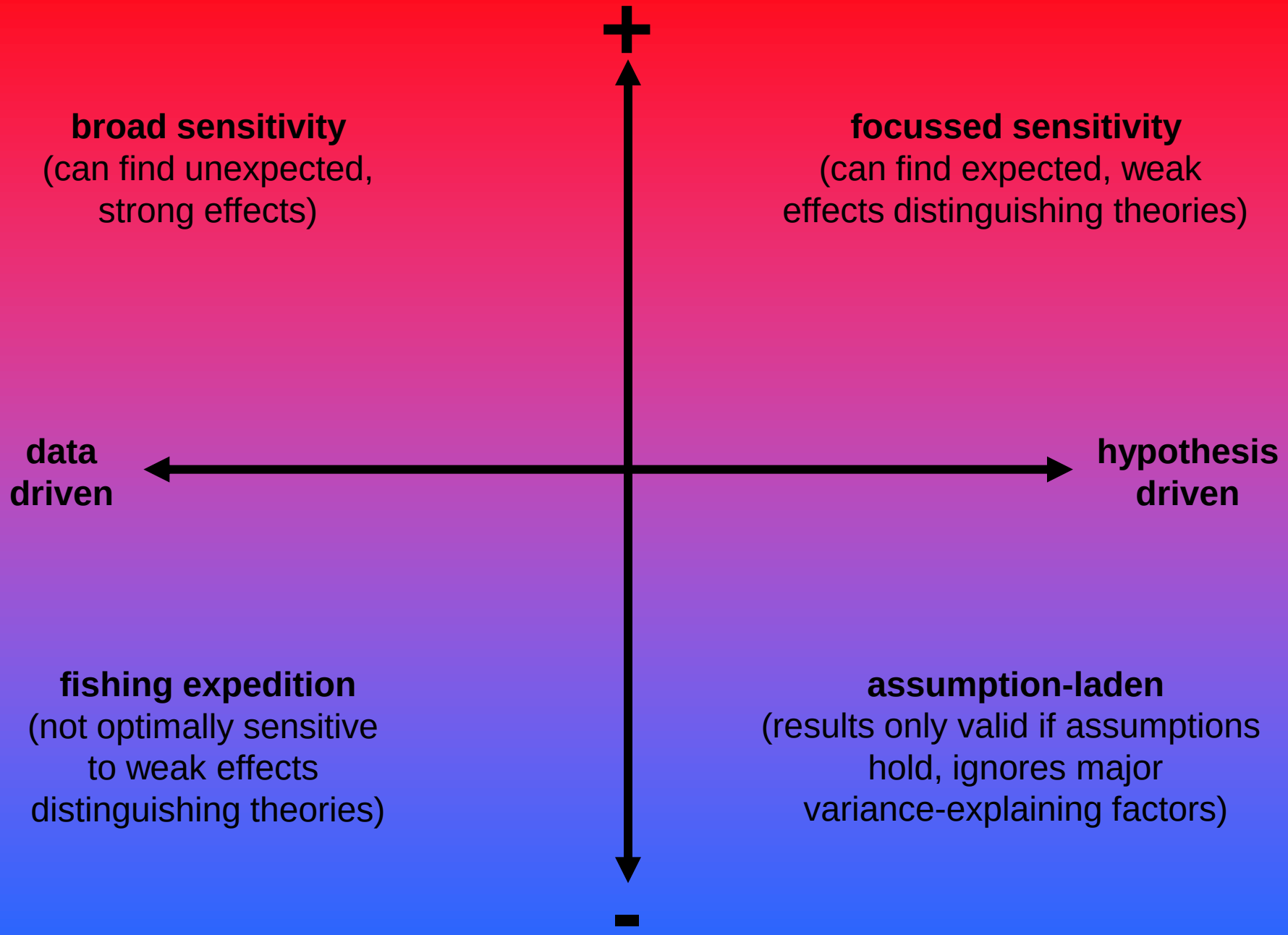

theory
experiment
level of description
box-and-arrow models
cognitive psychology
behavioural measures
cognitive neuroscience
cognitive computational models
standard fMRI
neural network models
high-resolution fMRI
single-neuron computational models
computational neuroscience
neuronal recordings
animate
inanimate
not human
human
body
face
natural
artificial

What neuroscientific implications do these different types of pattern-information result have?

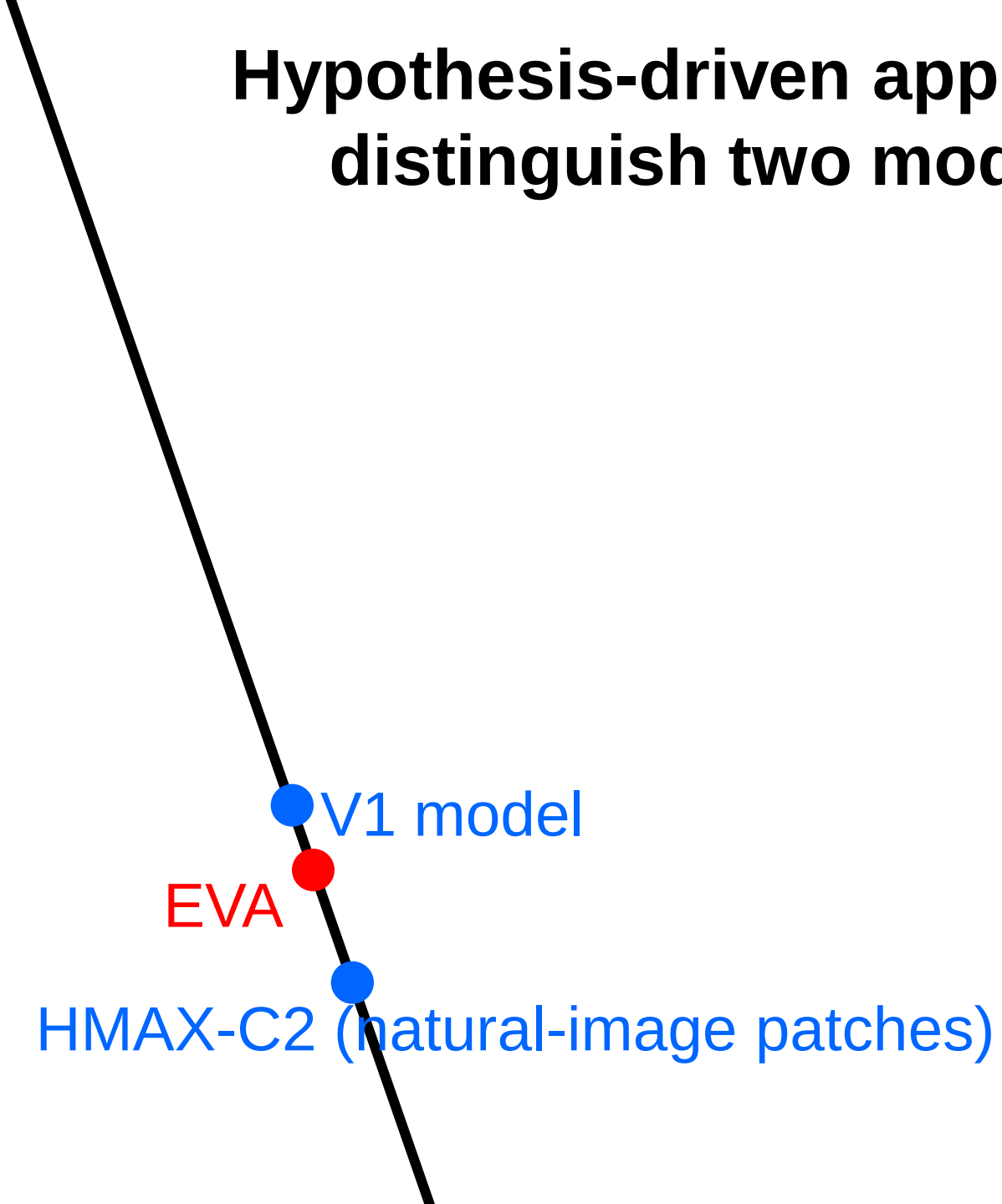


Kriegeskorte (2011)

5 Why should your analysis be at once data- and hypothesis-driven?


+
broad sensitivity
(can find unexpected, strong effects)
focussed sensitivity
(can find expected, weak effects distinguishing theories)
data driven
hypothesis driven
fishing expedition
(not optimally sensitive to weak effects distinguishing theories)
assumption-laden
(results only valid if assumptions hold, ignores major variance-explaining factors)
-

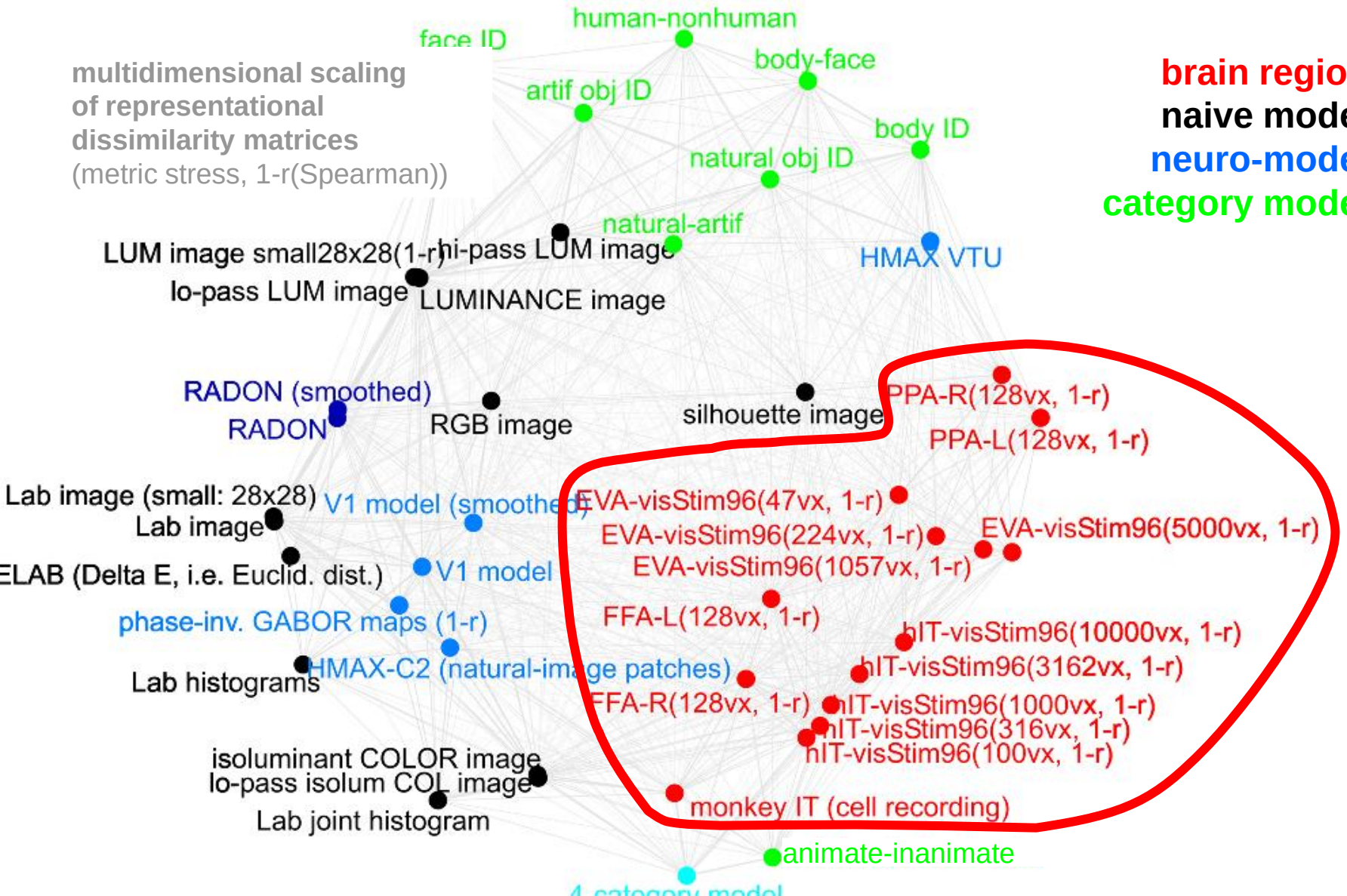
Hypothesis-driven approach: distinguish two models



Data- *and* hypothesis-driven approach!

multidimensional scaling of representational dissimilarity matrices
(metric stress, 1-r(Spearman))

brain region
naive model
neuro-model
category model



Quiz

1 **Why fMRI?**
- many channels, whole-brain coverage
- noninvasive use in humans

2 **Why pattern-information fMRI?**
- The brain is multivariate.
- need population summary

3 **Why decode fMRI?**
- to test for information that might be read out from a region

4 **Why test encoding models with fMRI?**
- to test computational models of visual processing

5 **Why should your analysis be at once data and hypothesis-driven?**
- need reasonable prior assumptions to stabilise our estimates
- avoid untenable assumptions and learn from rich data