

Representational similarity analysis (RSA)

Marieke Mur
CBU, march 2014

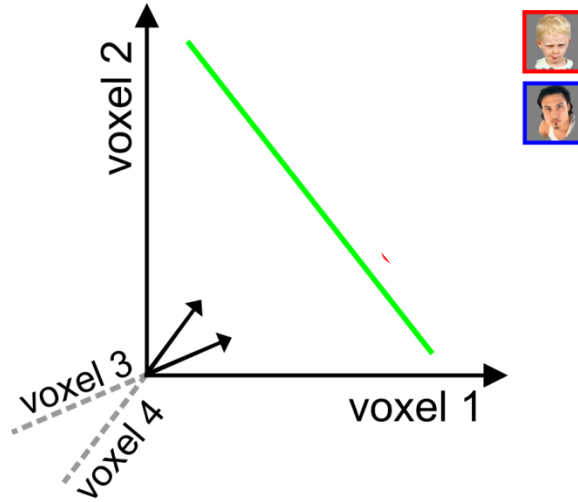
Overview

- Representational similarity analysis: why and how?
- Example: 96-image experiment
 - descriptive visualisations
 - statistical inference
- RSA applications in other areas of neuroscience
- Toolbox
- Literature

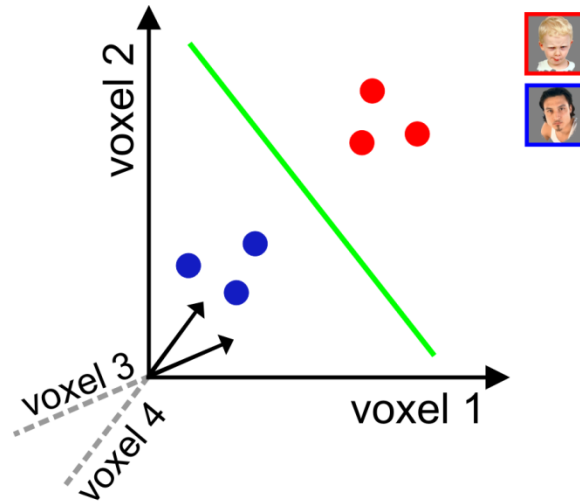
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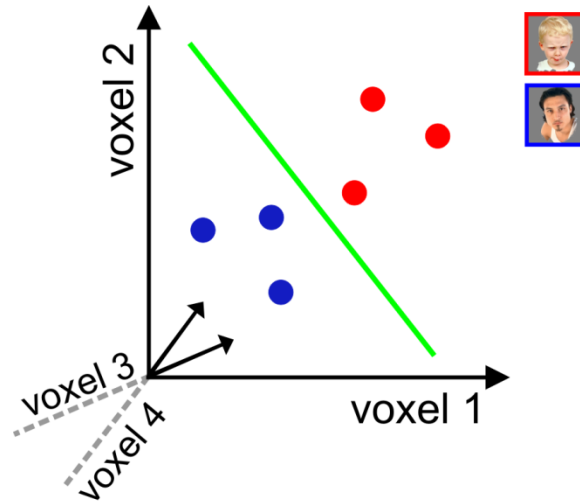
Linear classification: anything missing?



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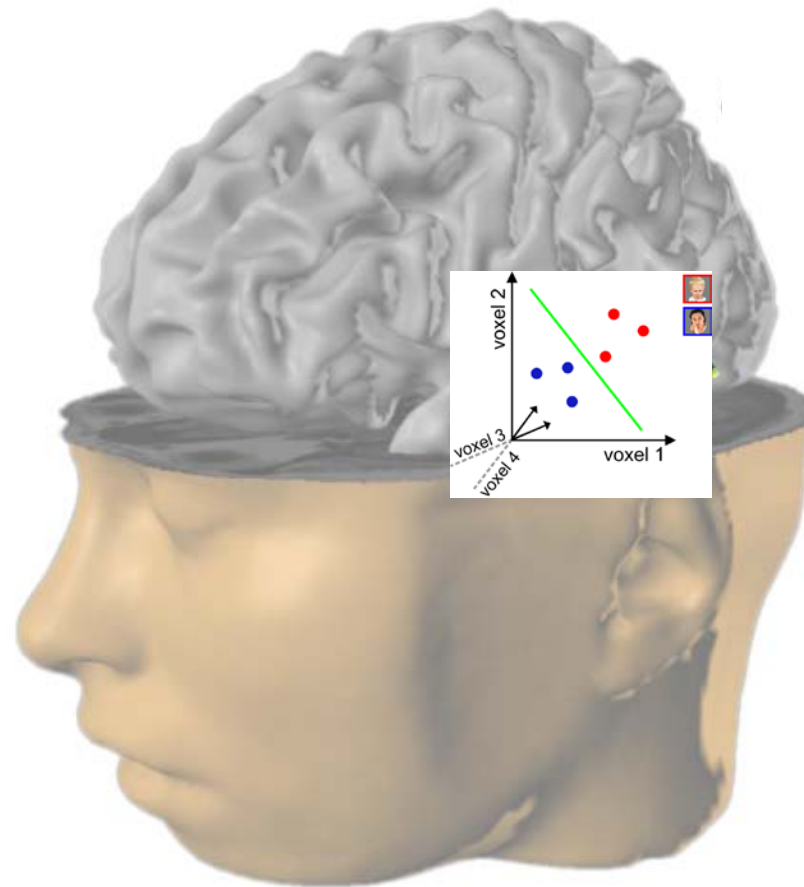


Linear classification: anything missing?

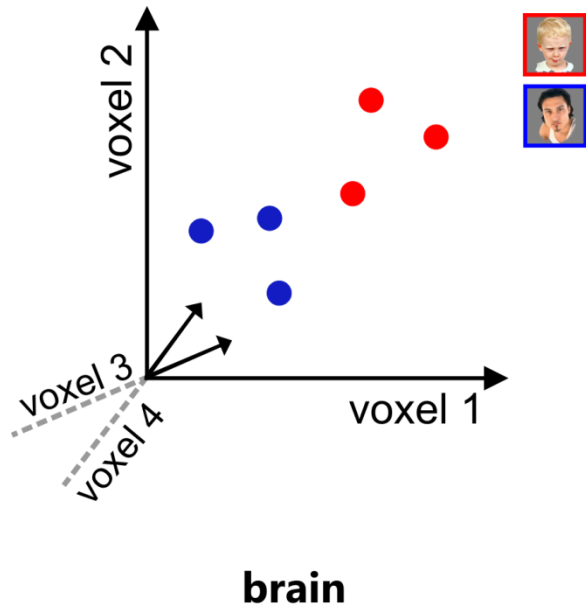


Need a richer characterisation of the stimulus representations.

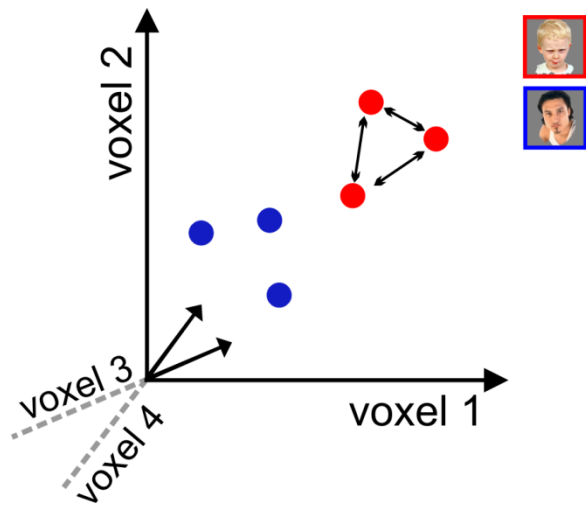
One step further: how to relate brain representations to subjective experience?



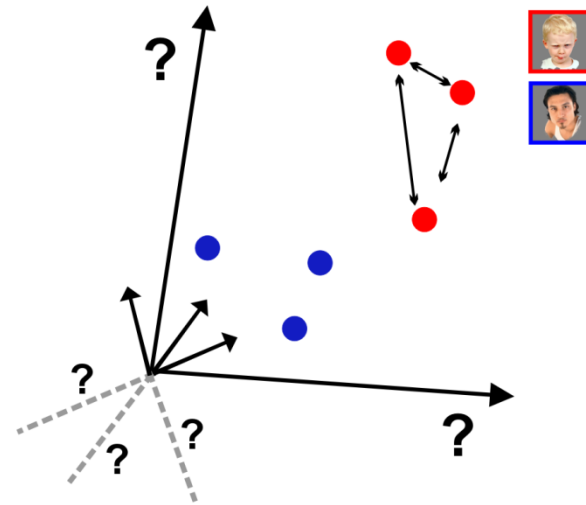
Relate brain and subjective experience



Relate brain and subjective experience

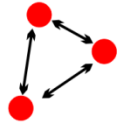


brain



subjective
experience

Relate brain and subjective experience

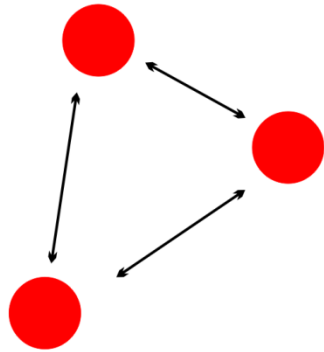


brain

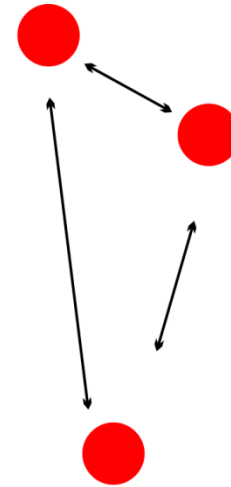


**subjective
experience**

Relate brain and subjective experience

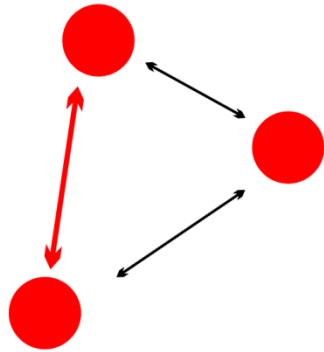


brain

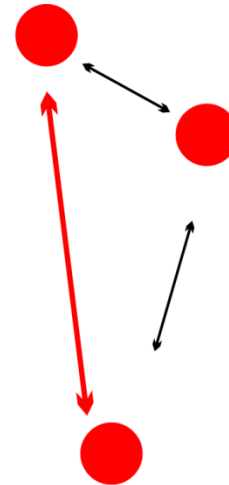


**subjective
experience**

Relate brain and subjective experience

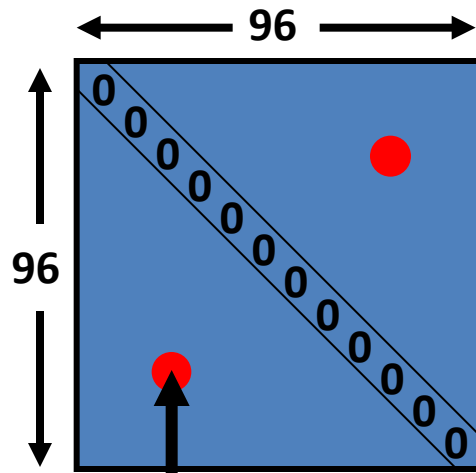


brain



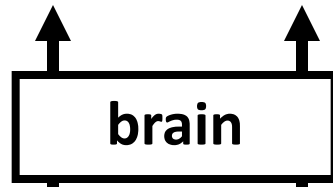
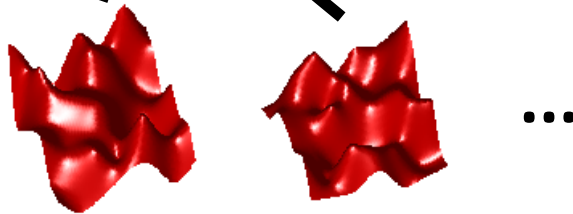
**subjective
experience**

**representational
dissimilarity
matrix (RDM)**



compute dissimilarity (1-correlation across space)

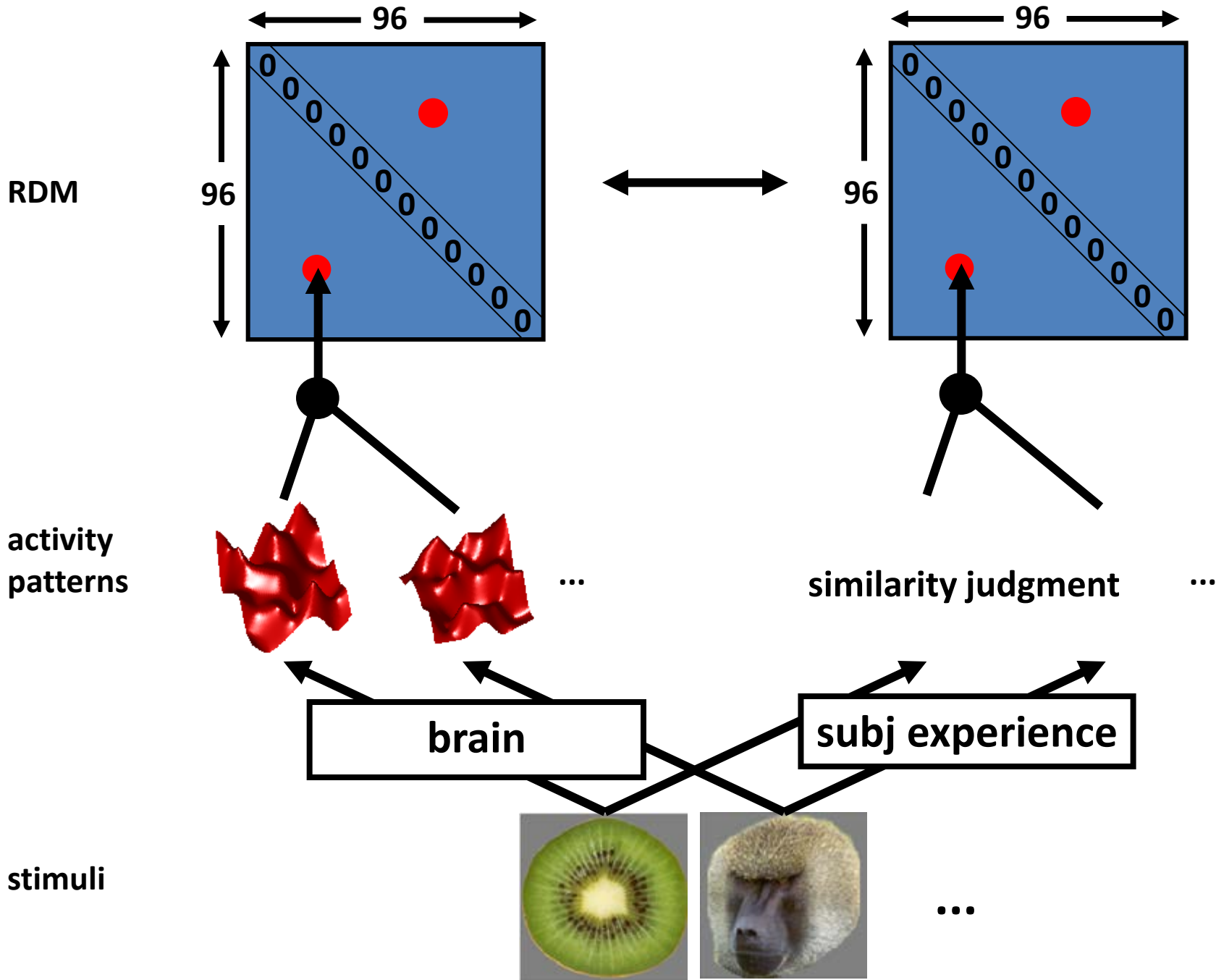
**activity
patterns**

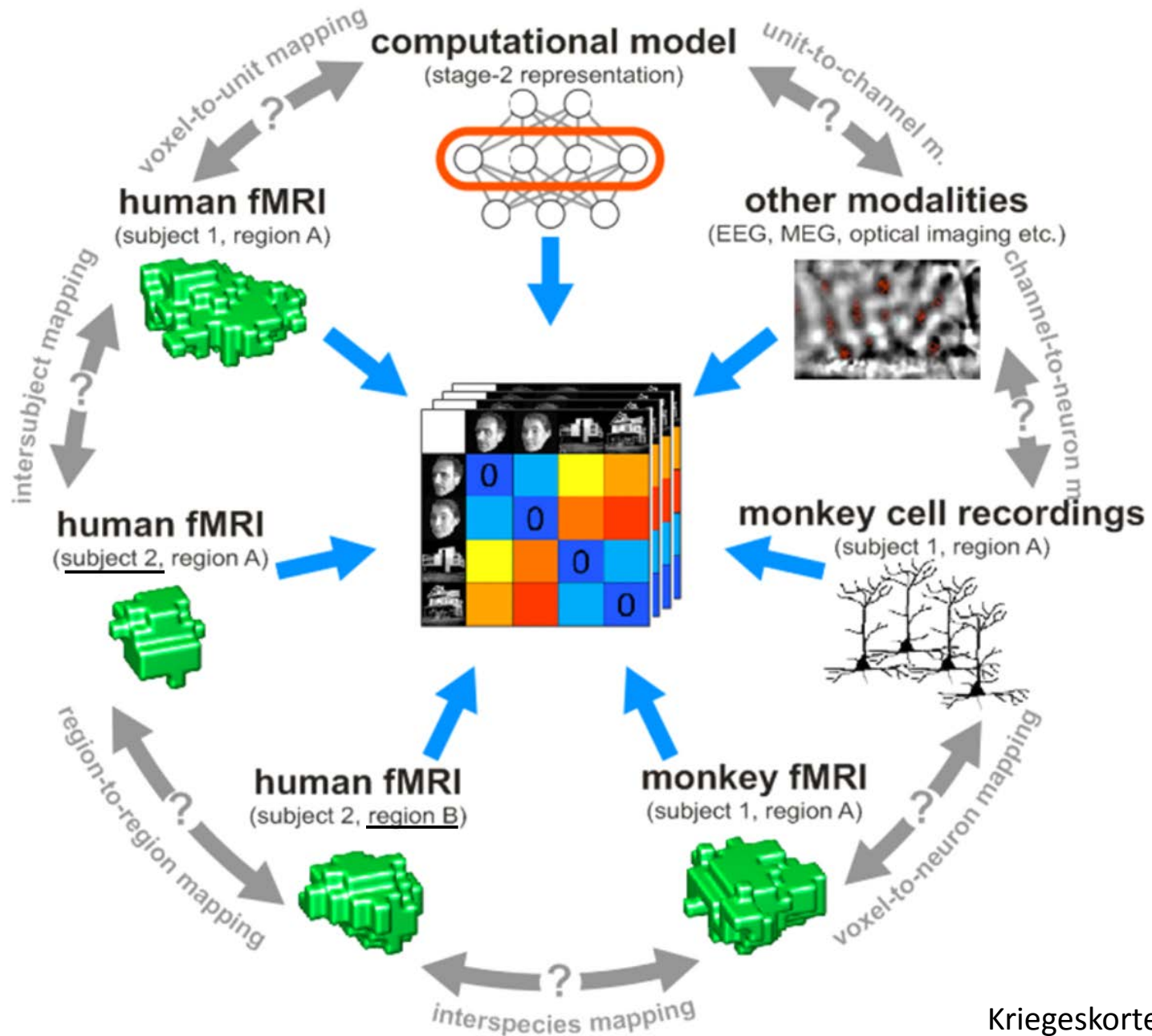


stimuli



96





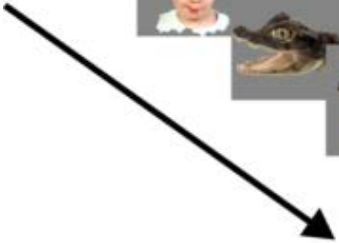
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96 object images



Stimuli from Kiani et al. 2007, Kriegeskorte et al. 2008

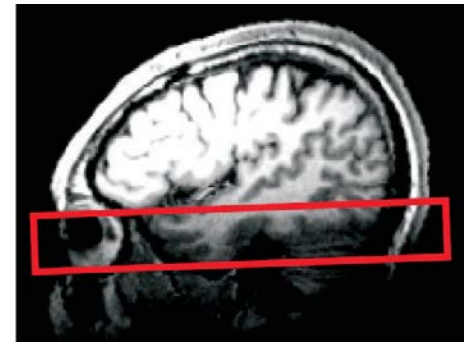


96-object-image fMRI experiment

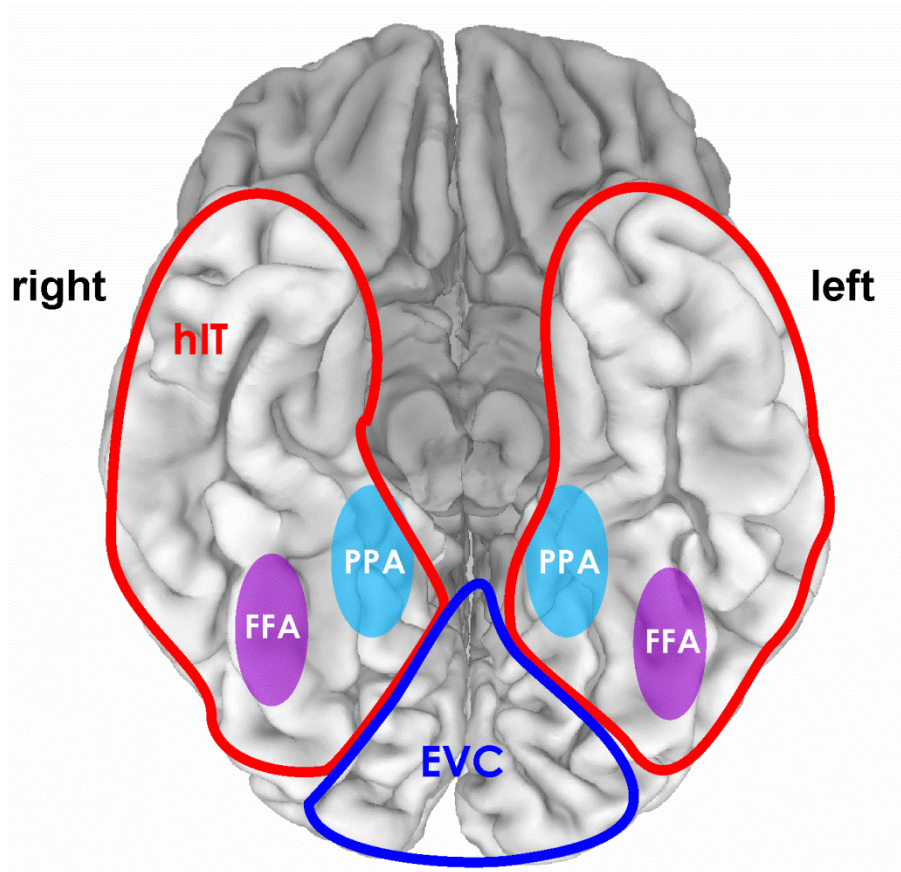
- 4 healthy human subjects
- rapid event-related design (minimum SOA: 4 s)
- stimulus duration: 300 ms
- object images spanned a visual angle of 2.9°
- fixation-cross color-discrimination task
- 12 runs/subject, each object image presented once per run

96-object-image fMRI experiment

- 25 axial slices covering ventral occipital and inferior temporal cortex (no gap)
- voxel size: $1.95 \times 1.95 \times 2 \text{ mm}^3$
- TR: 2 s

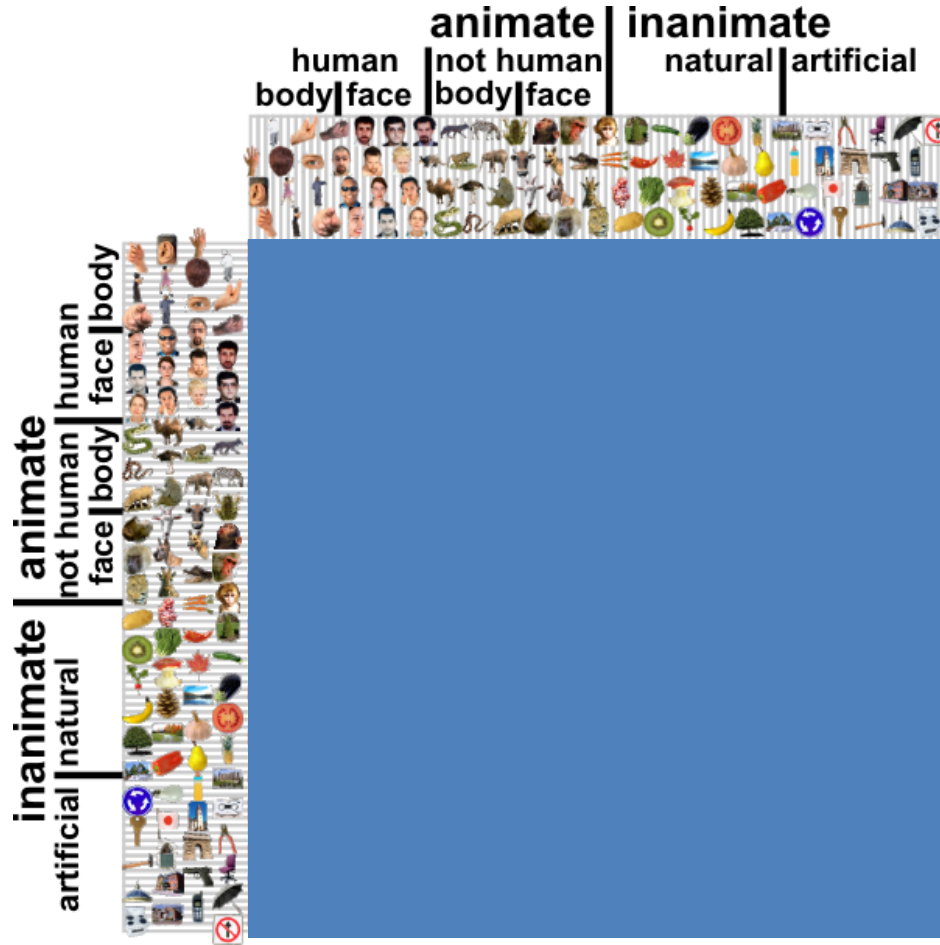


Region of interest: **hIT**

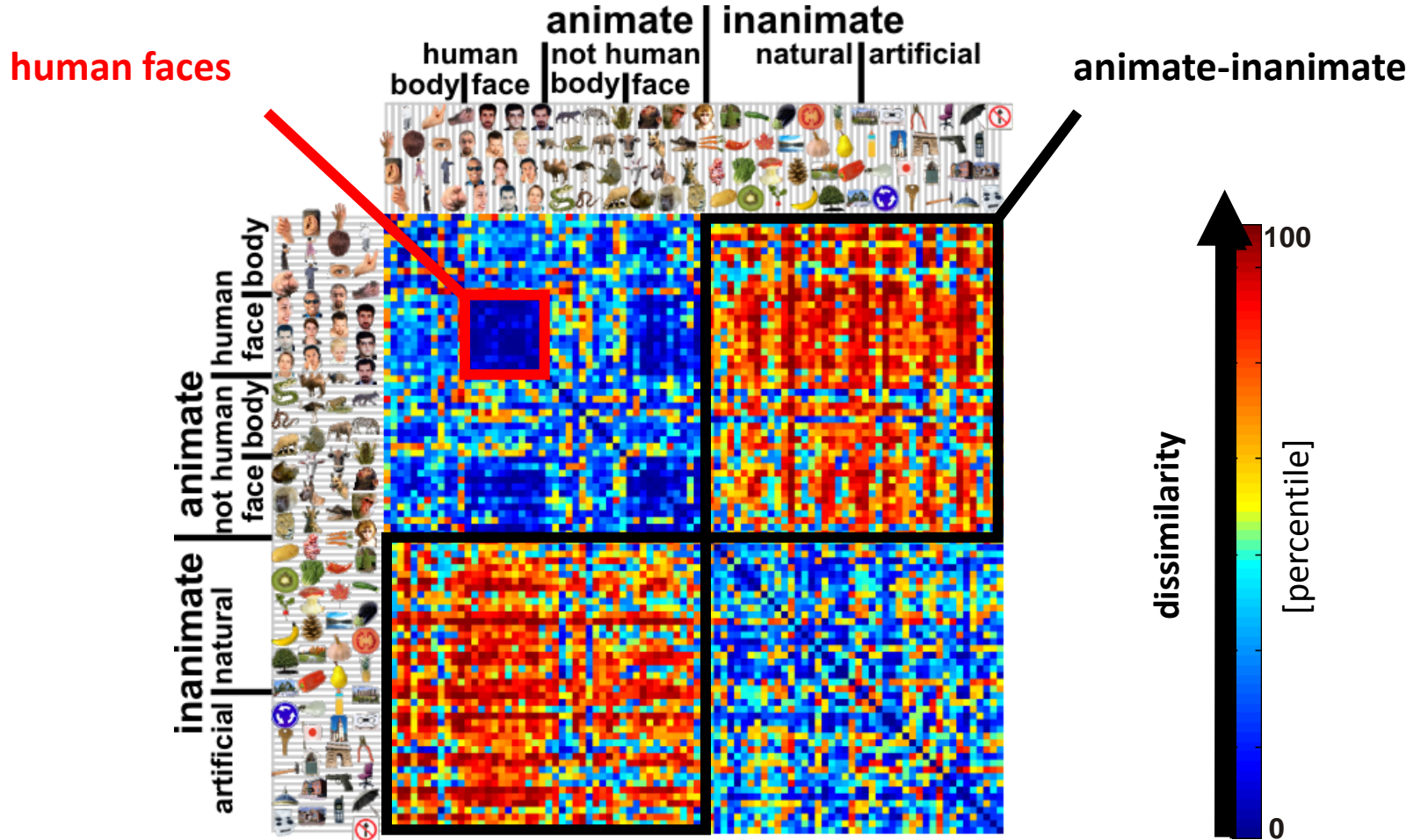


- independent data
- bilateral
- most visually-responsive voxels within “red” region
- results same if FFA and PPA excluded from hIT

RDM of IT activity patterns

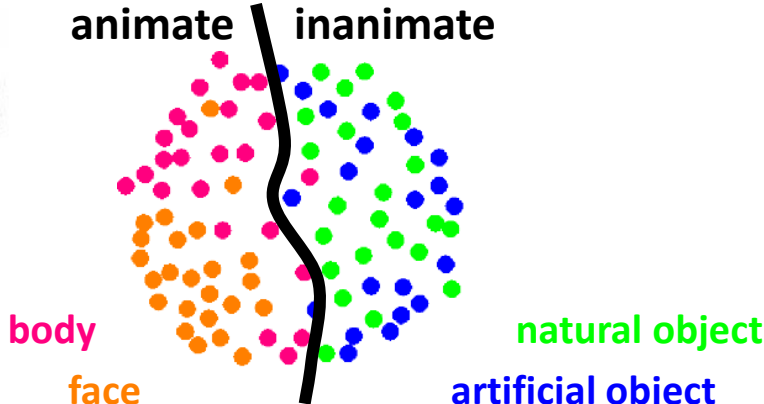


RDM of IT activity patterns



4 subjects' average

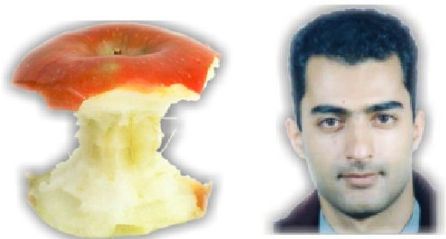
Multidimensional scaling of IT dissimilarities





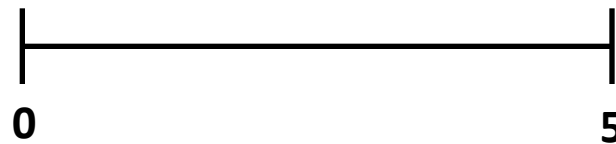
Conventional method: Pairwise similarity ratings

How similar are these objects?



very similar

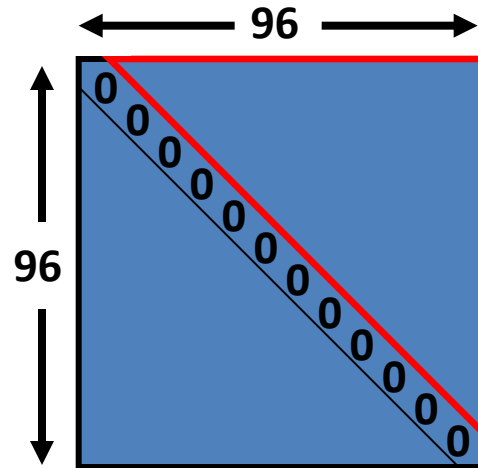
very dissimilar



Many pairwise dissimilarities

$$96 \times 95 / 2 = 4560 \text{ pairs}$$

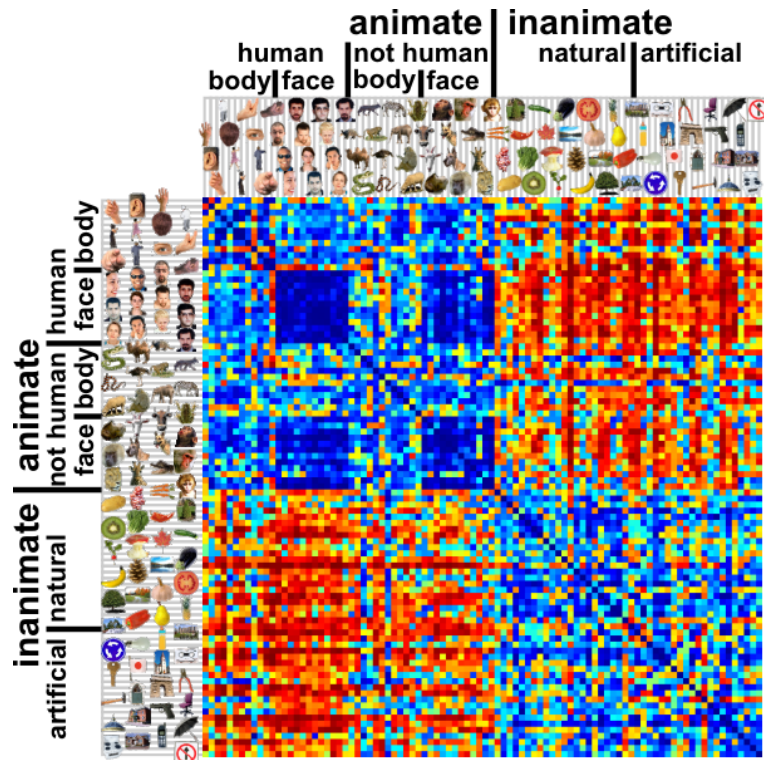
$$4560 * 4 \text{ s} = 5 \text{ hours per subject}$$



similarity-judgment RDM

RDM

2D arrangement by dissimilarity



multidimensional
scaling

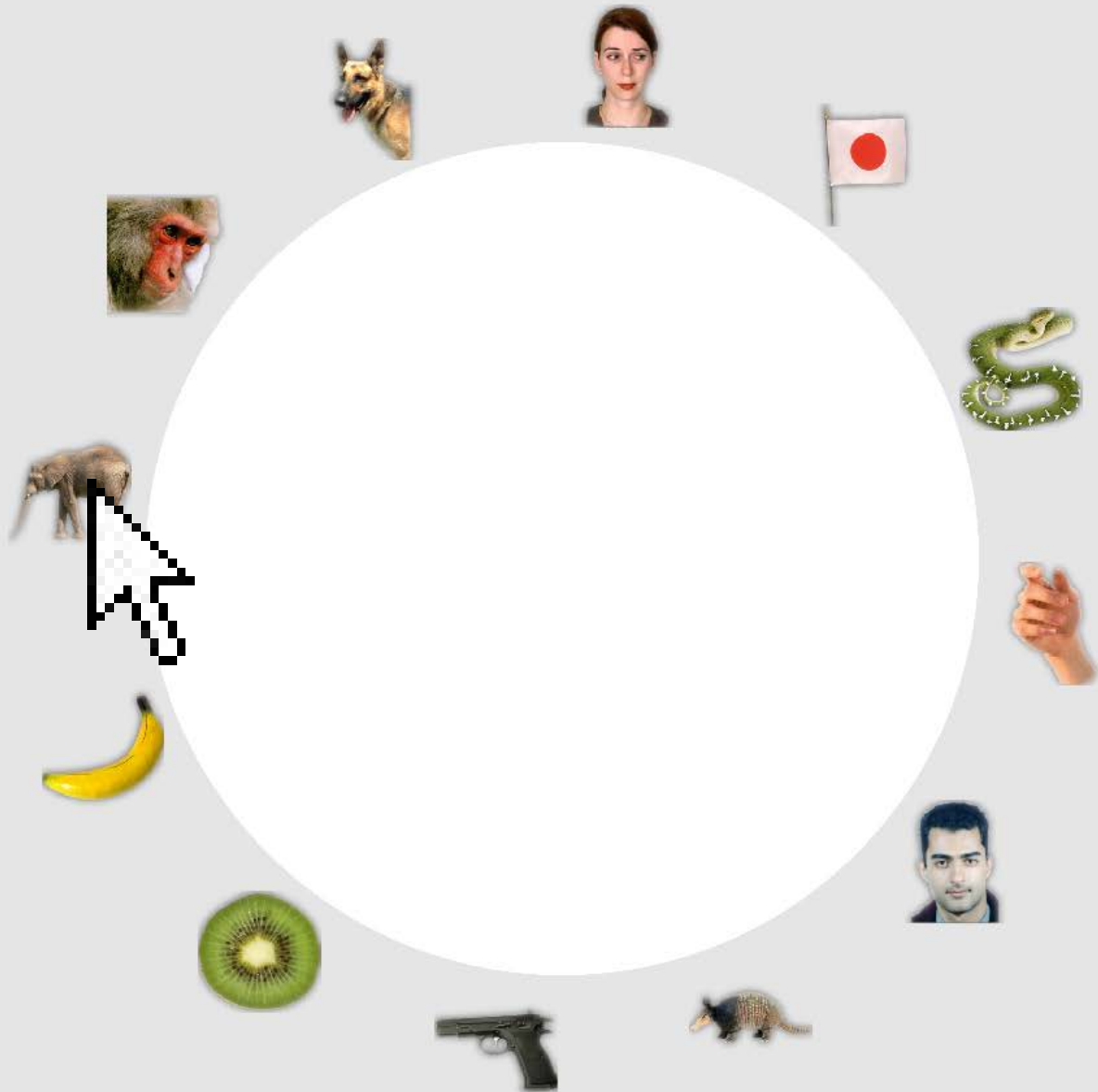


inverse
multidimensional
scaling

Multi-object arrangement (MA) method

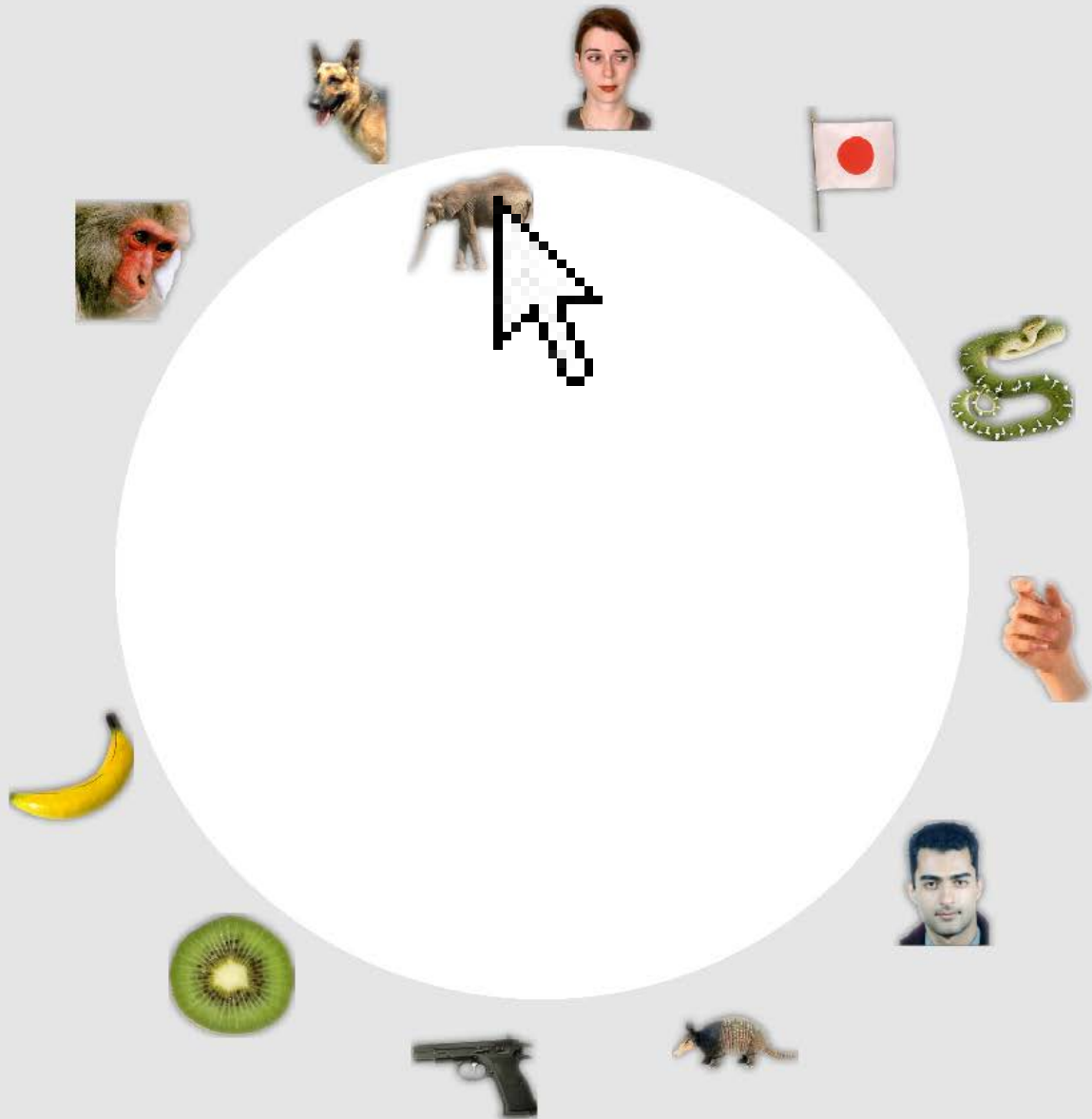
- Subjects arrange objects in 2D by mouse drag-and-drop.
- More efficient than pairwise similarity ratings.
- Subjects arrange objects in the context of the other objects in the set.

Please arrange these objects according to their similarity



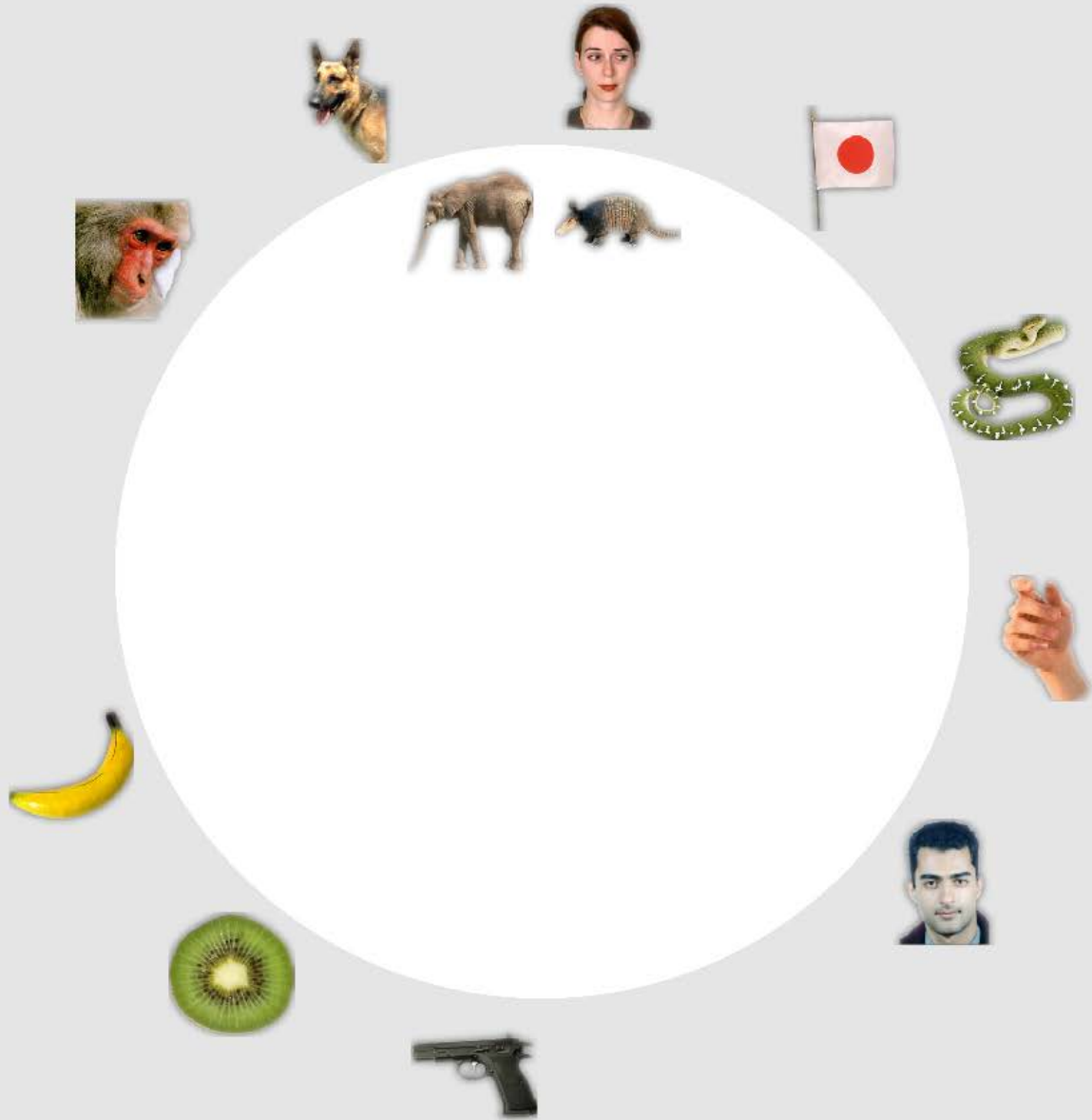
Done

Please arrange these objects according to their similarity



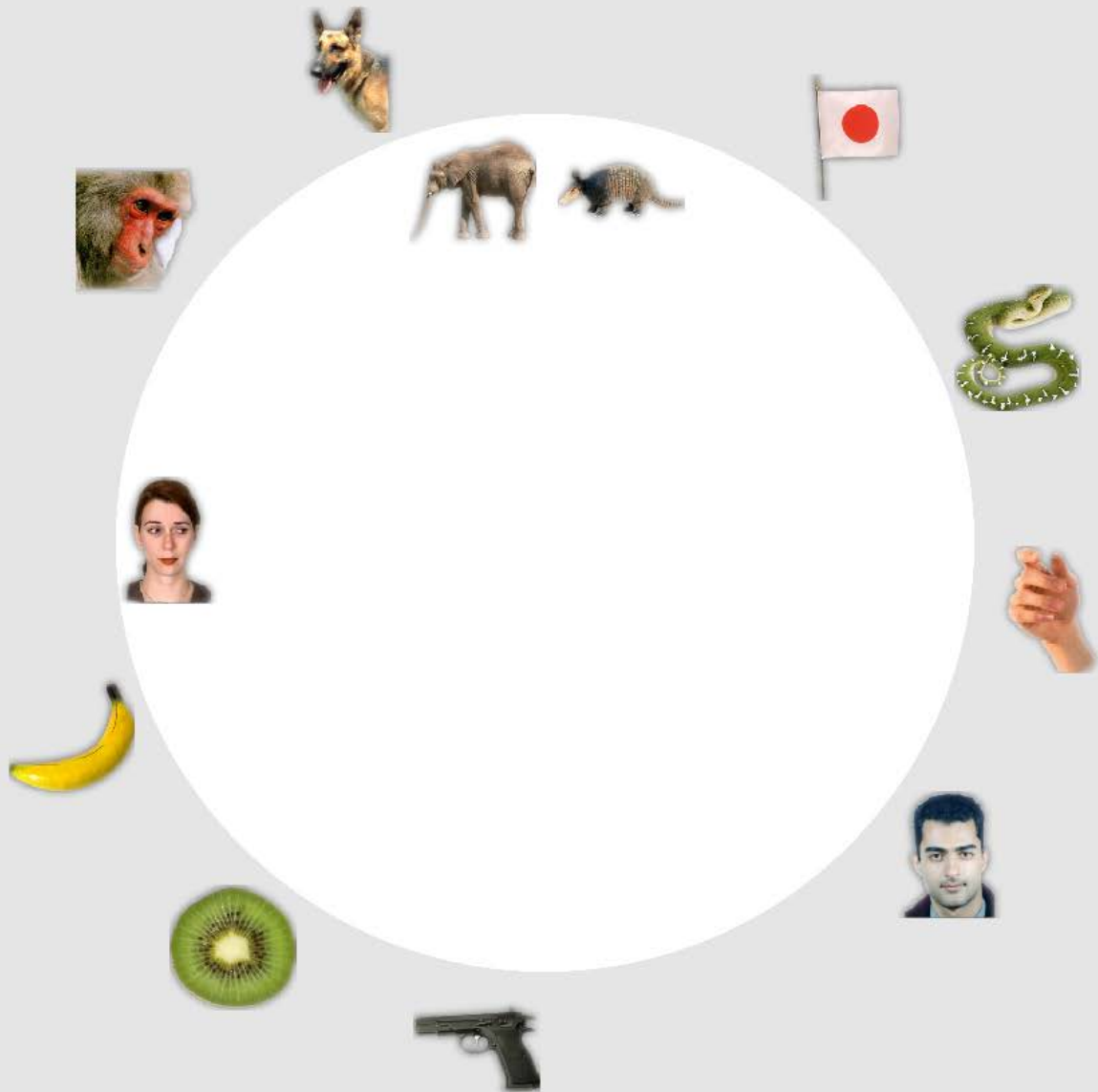
Done

Please arrange these objects according to their similarity



Done

Please arrange these objects according to their similarity



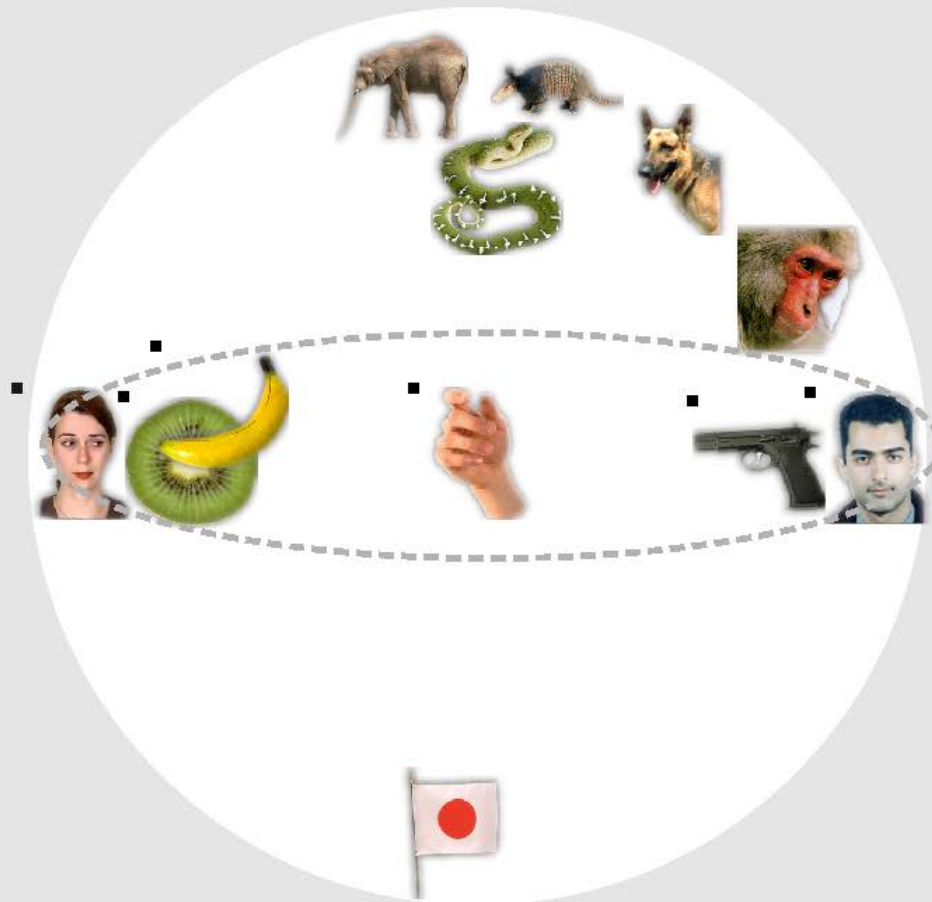
Done

Please arrange these objects according to their similarity



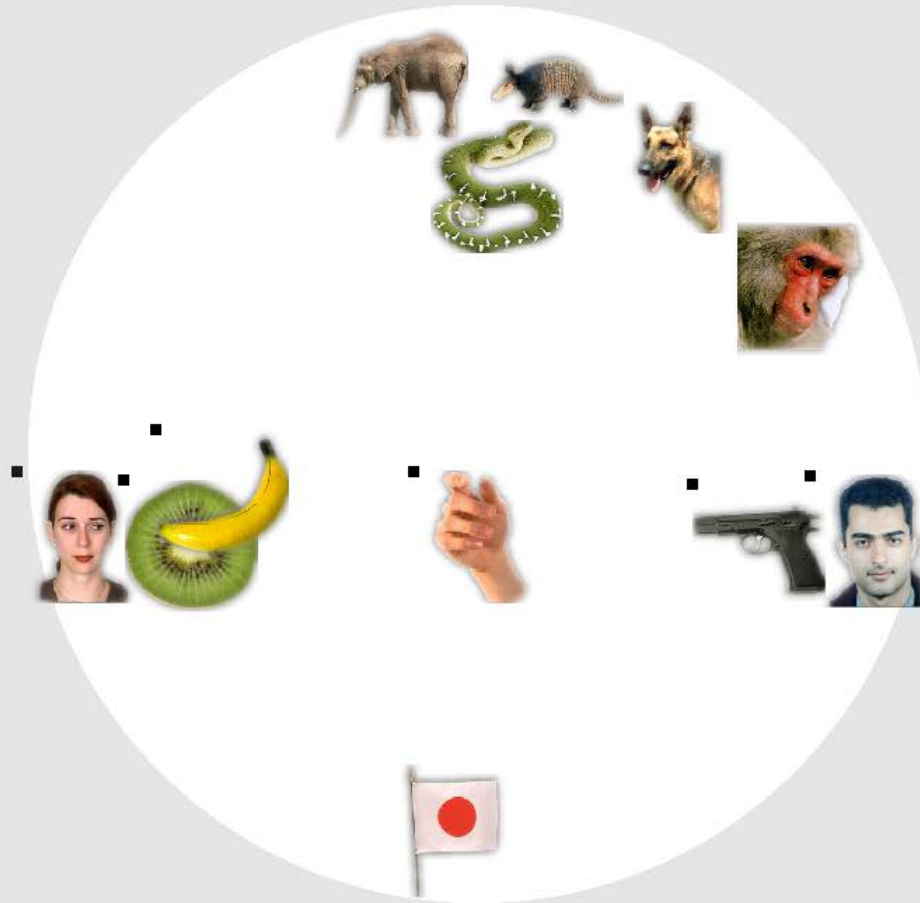
Done

Please arrange these objects according to their similarity



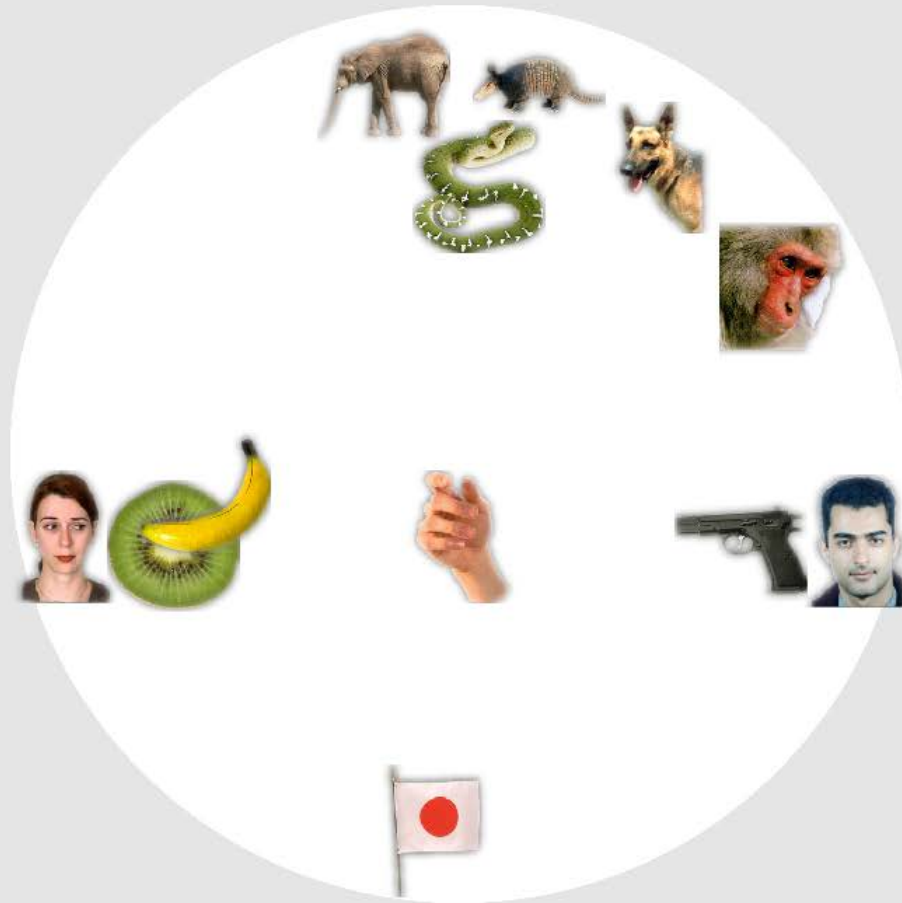
Done

Please arrange these objects according to their similarity



Done

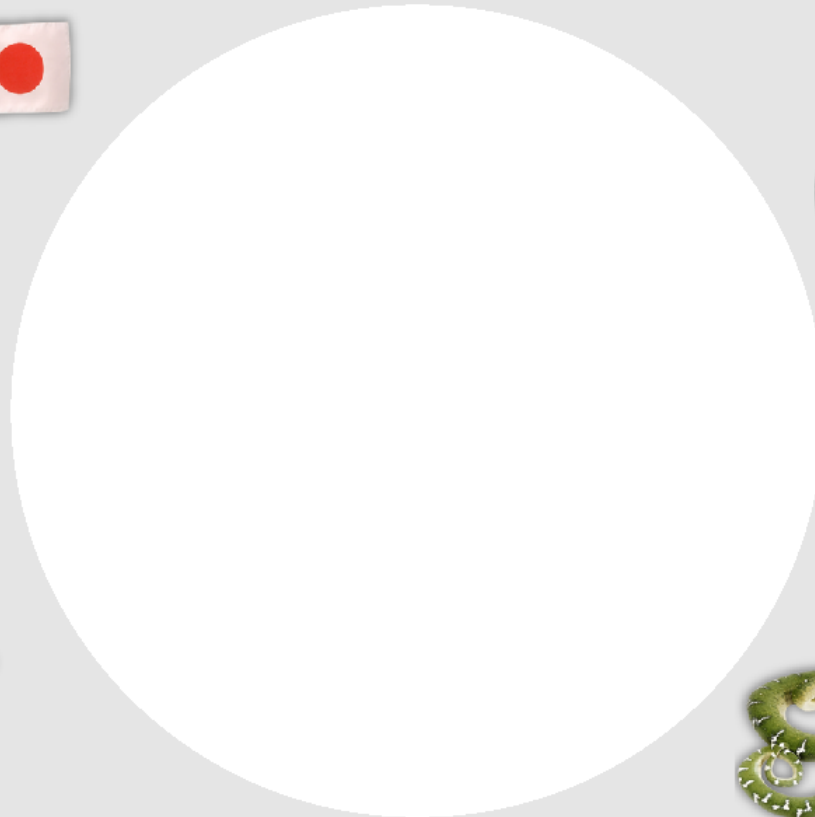
Please arrange these objects according to their similarity



Done

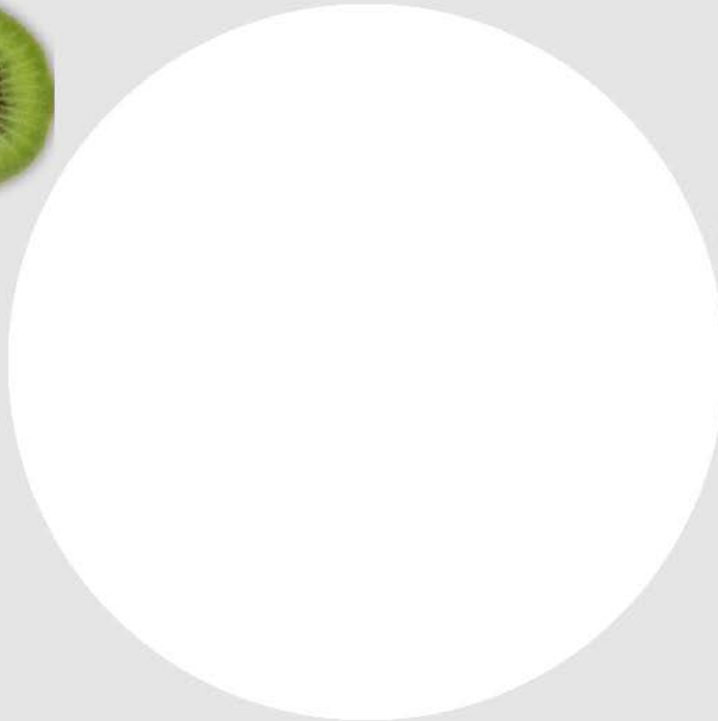


Please arrange these objects according to their similarity



Done

Please arrange these objects according to their similarity



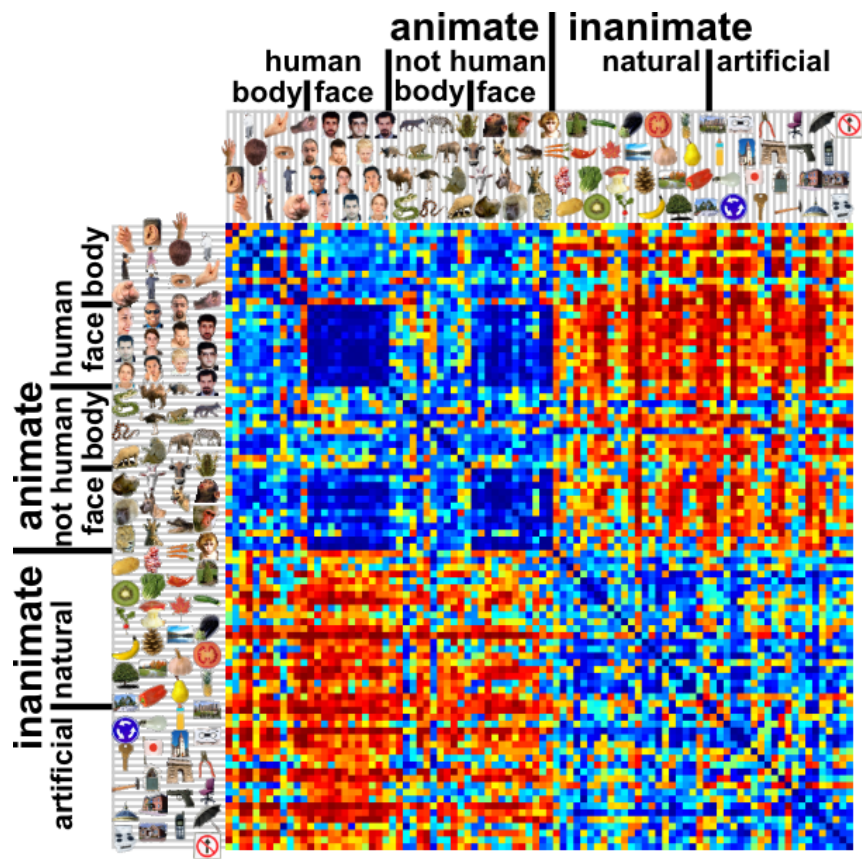
Done

Multi-object arrangement (MA) method

- Multiple arrangements (subsets) to let the subjects convey $>2D$ similarity structure.
- Subsets designed by algorithm to optimize the dissimilarity estimates.
- Validated by comparison to conventional methods.

96-object-image MA experiment

- 16 healthy human subjects
- each subject performed one 1-hour session (outside the scanner)



human IT

2D arrangements by dissimilarity

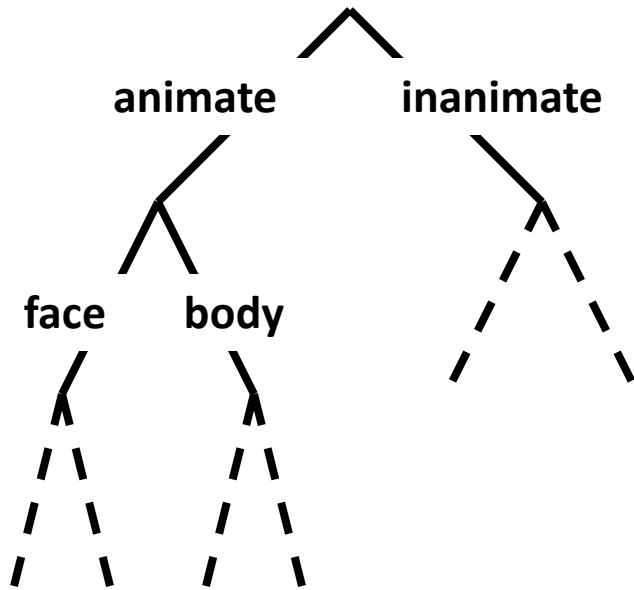


human IT

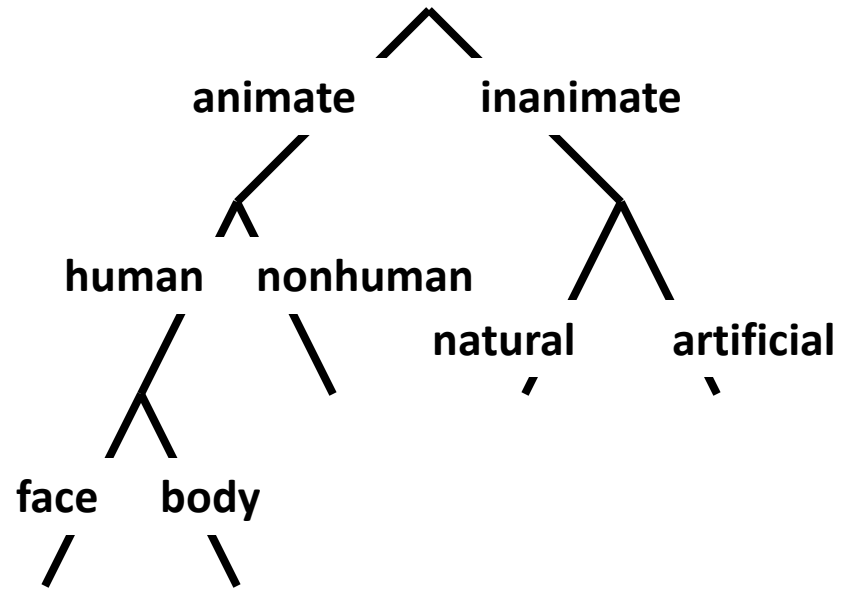


similarity judgments

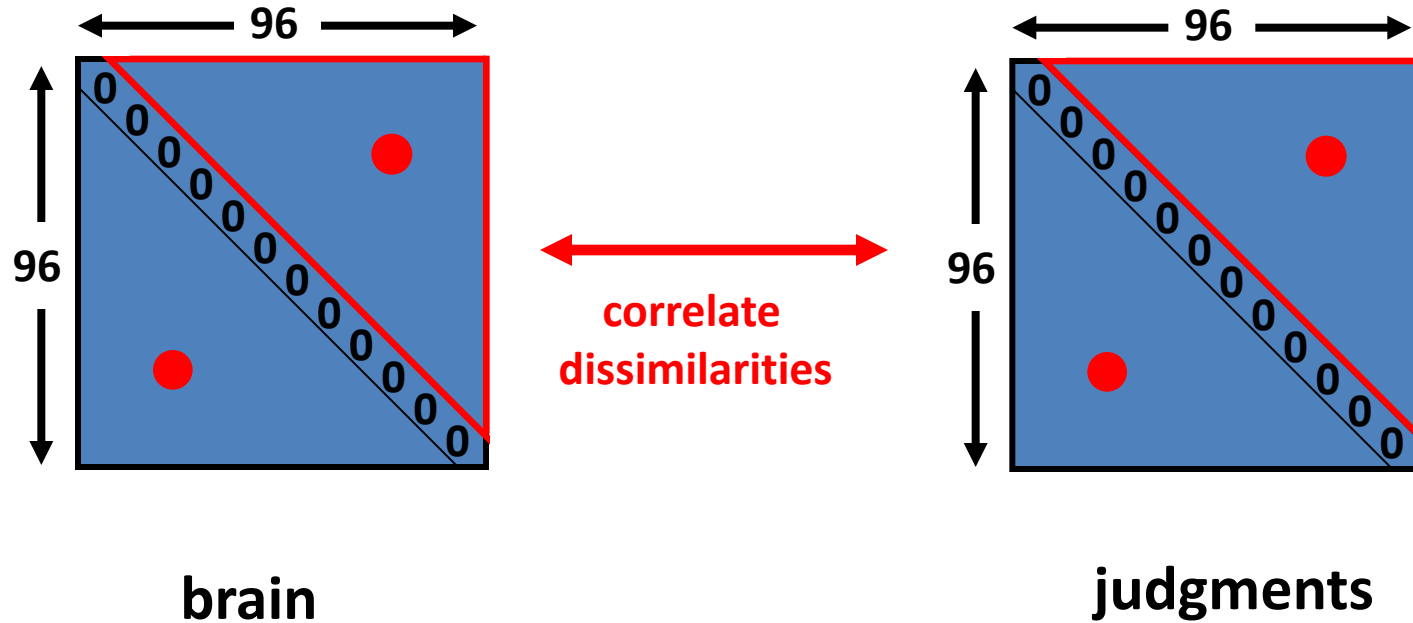
human IT



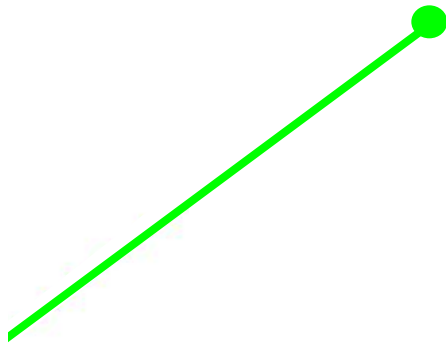
similarity judgments



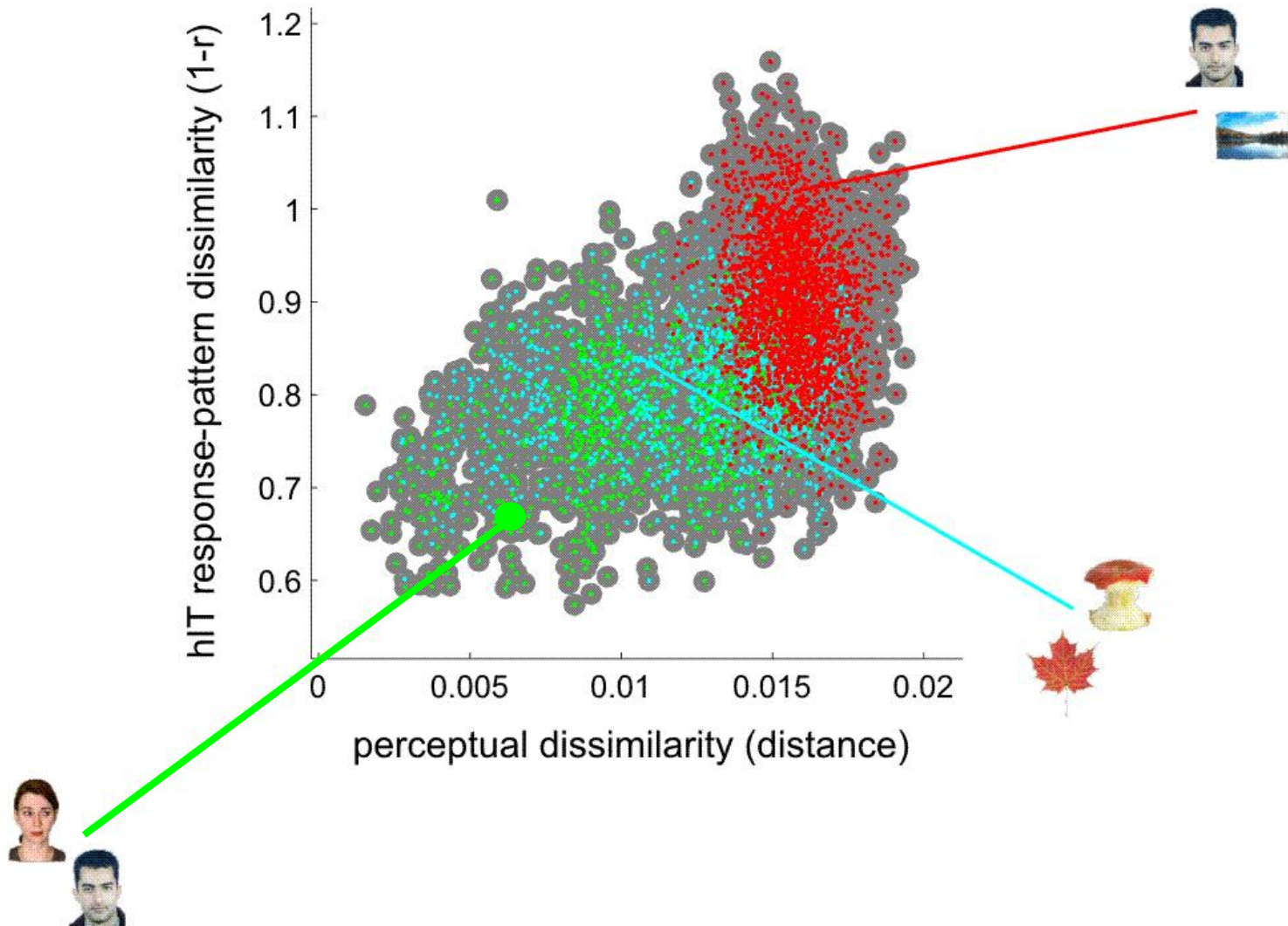
Statistical inference



**Are hIT and perceptual dissimilarities
correlated?**



Are hIT and perceptual dissimilarities correlated?



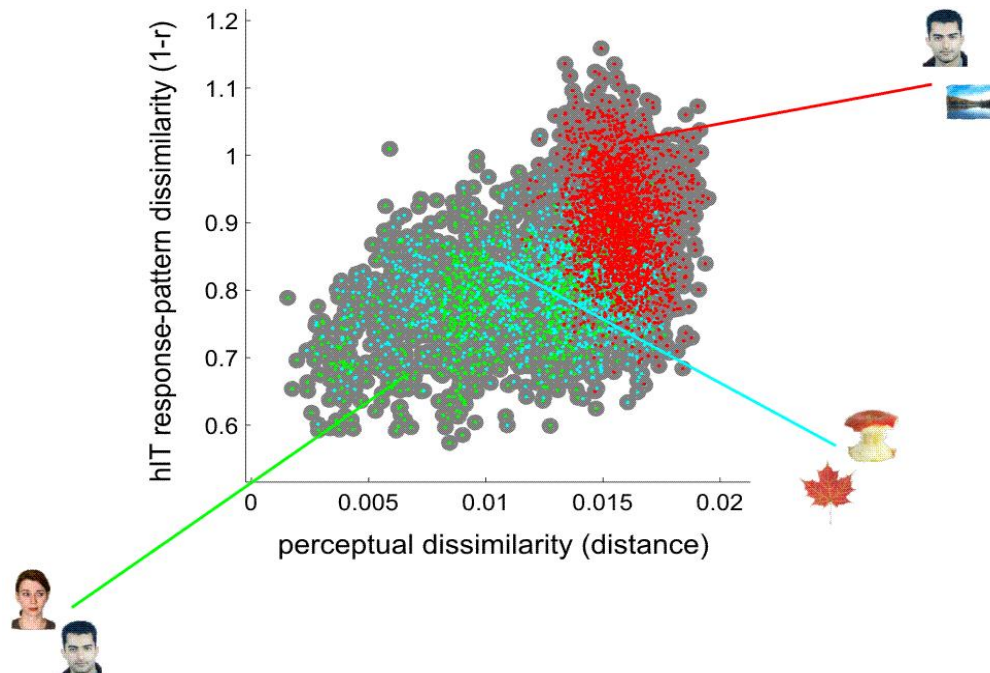
Are hIT and perceptual dissimilarities correlated?

within all images: $r=0.39$, $p<0.0001$ ***

within animates: $r=0.34$, $p<0.0001$ ***

within inanimates: $r=0.19$, $p<0.0001$ ***

between animates and inanimates: $r=-0.16$, ns



Are hIT and perceptual dissimilarities correlated?

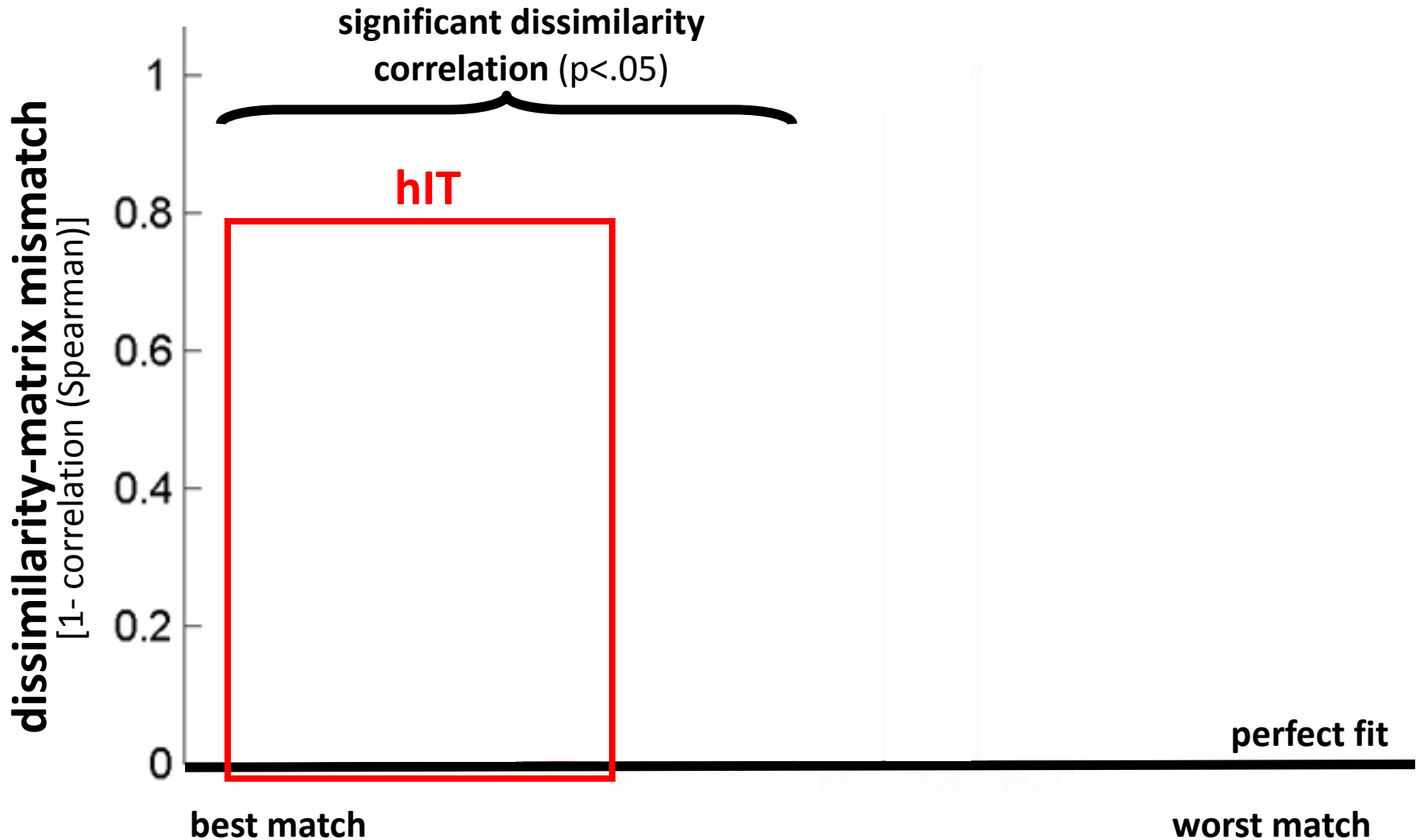
also significant for

- faces
- body parts
- humans
- nonhuman animates
- natural objects
- artificial objects

not significant for

- human faces

Judgments' match to brain representations



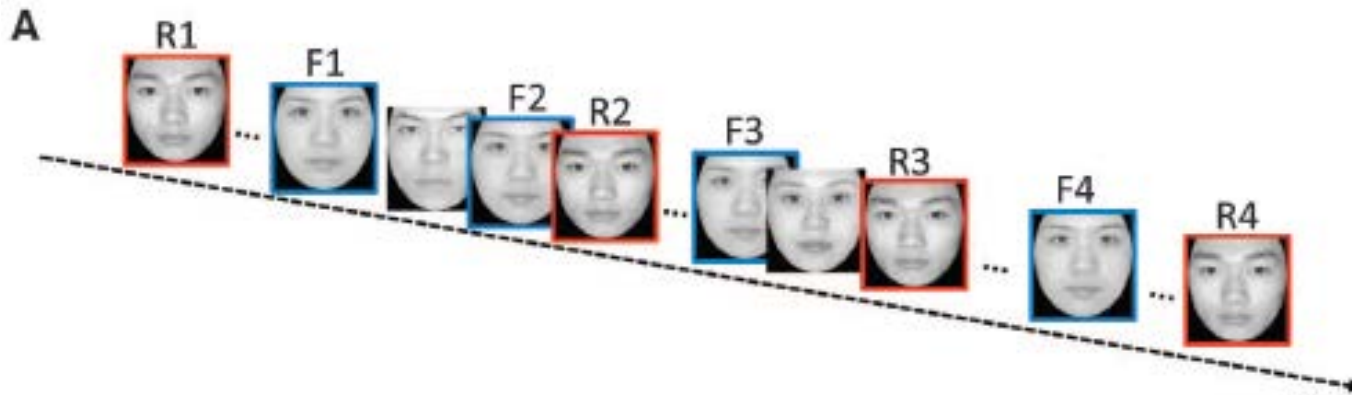
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Applications: memory

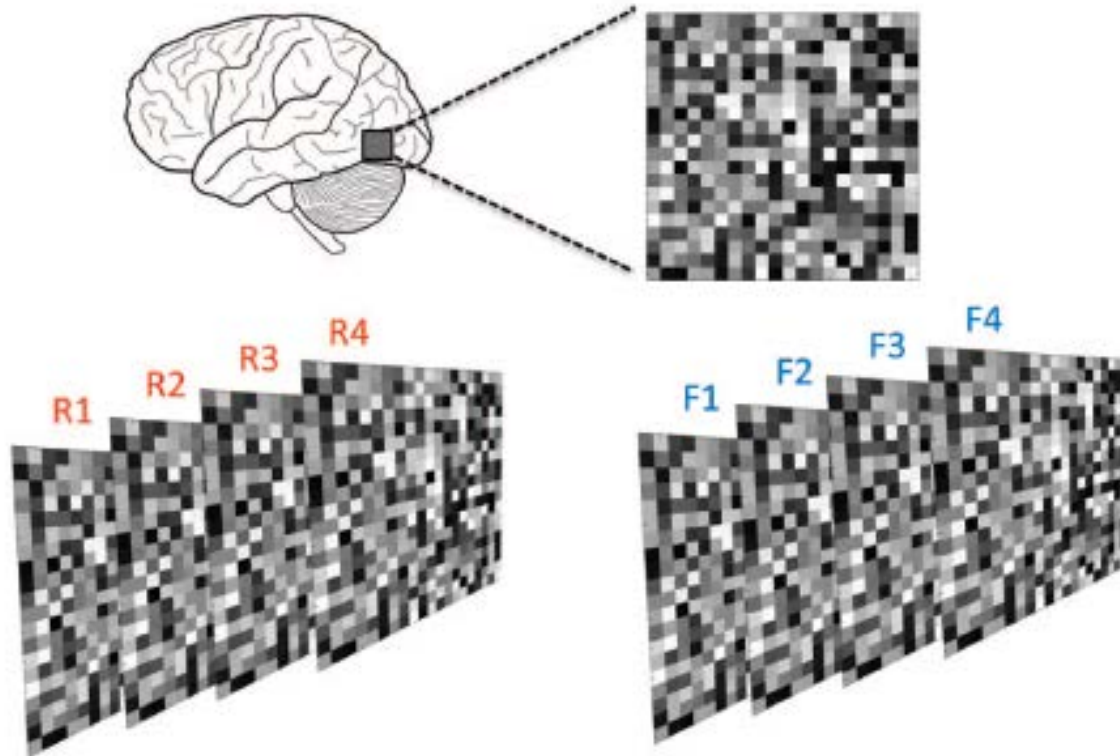
Greater Neural Pattern Similarity Across Repetitions Is Associated with Better Memory

Gui Xue,^{1,2} Qi Dong,^{1*} Chuansheng Chen,³ Zhonglin Lu,² Jeanette A. Mumford,⁴ Russell A. Poldrack^{5,4,6*}



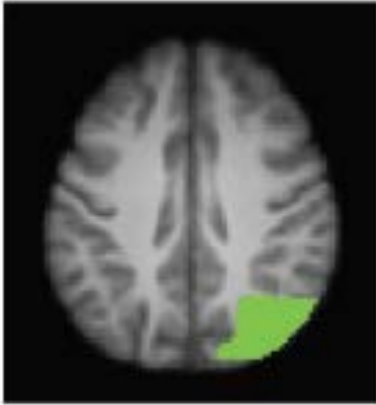
Applications: memory

B



Applications: memory

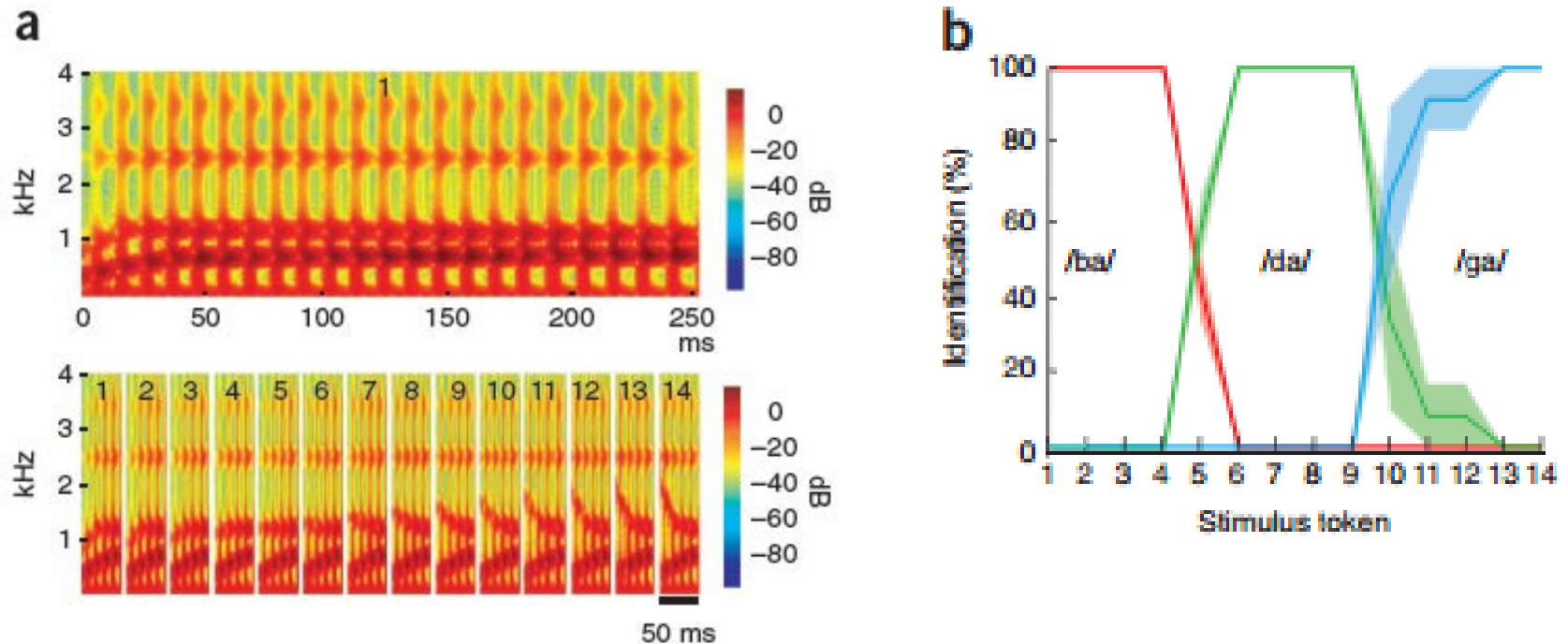
A



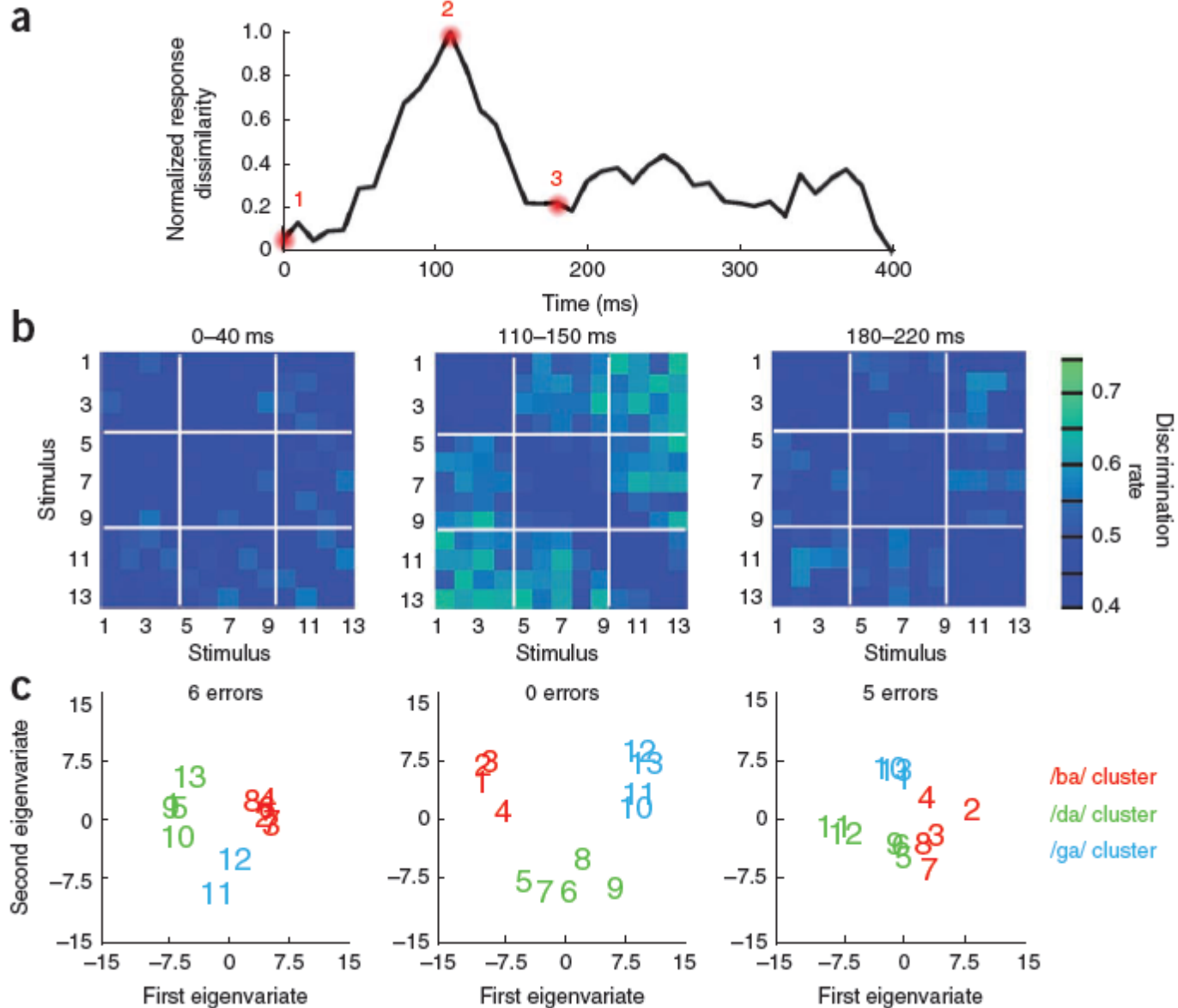
Applications: speech

Categorical speech representation in human superior temporal gyrus

Edward F Chang^{1,2,6}, Jochem W Rieger^{2,3,6}, Keith Johnson⁴, Mitchel S Berger¹, Nicholas M Barbaro¹ & Robert T Knight^{1,2,5}



Applications: speech



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Toolbox

The RSA toolbox can be downloaded here:

<http://www.mrc-cbu.cam.ac.uk/methods-and-resources/toolboxes/>

The toolbox runs in Matlab and does not have a GUI, but contains good documentation and multiple demos to familiarise you with the analyses. You can use the demo scripts as a starting point for your own analyses.

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- **Literature**

Literature

RSA

Kriegeskorte N et al. (2008) *Front Syst Neurosci* 2(4): 1-28. [original methods paper]

Kriegeskorte N, Kievit R (2013) *Trends Cogn Sci* 17(8): 401-412. [recent review]

RSA applications in neuroscience

Kriegeskorte N et al. (2008) *Neuron* 60: 1126-1141. [object vision: human - monkey]

Mur M et al. (2013) *Front Psychol* 4(128): 1-22. [object vision: brain - behaviour]

Xue G et al. (2010) *Science* 330: 97-101. [memory: forgotten vs remembered items]

Ward EJ et al. (2013) *J Neurosci* 33(37): 14749-14757. [memory: implicit vs explicit]

Ritchey M et al. (2013) *Cereb Cortex* doi:10.1093/cercor/bhs258. [memory]

RSA toolbox

Nili et al. 2014 (in press) *PLoS Comput Biol*