Characterizing information processing in human (and animal) brains through analyses of representational geometry

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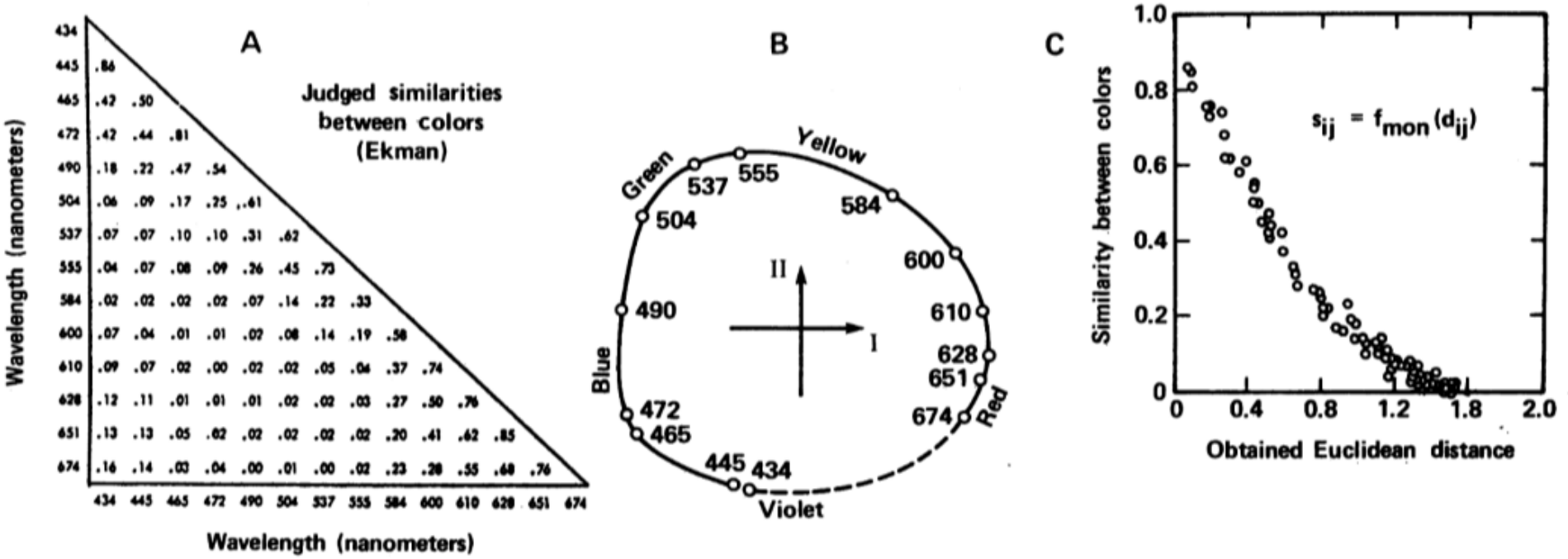
Representational geometry: Where it started

Roger Shepard

It is argued that, while there is no structural resemblance between an individual internal representation and its corresponding external object, an approximate parallelism should nevertheless hold between the relations among different internal representations and the relations among their corresponding external objects. In support of this “second-order” type of isomorphism, …

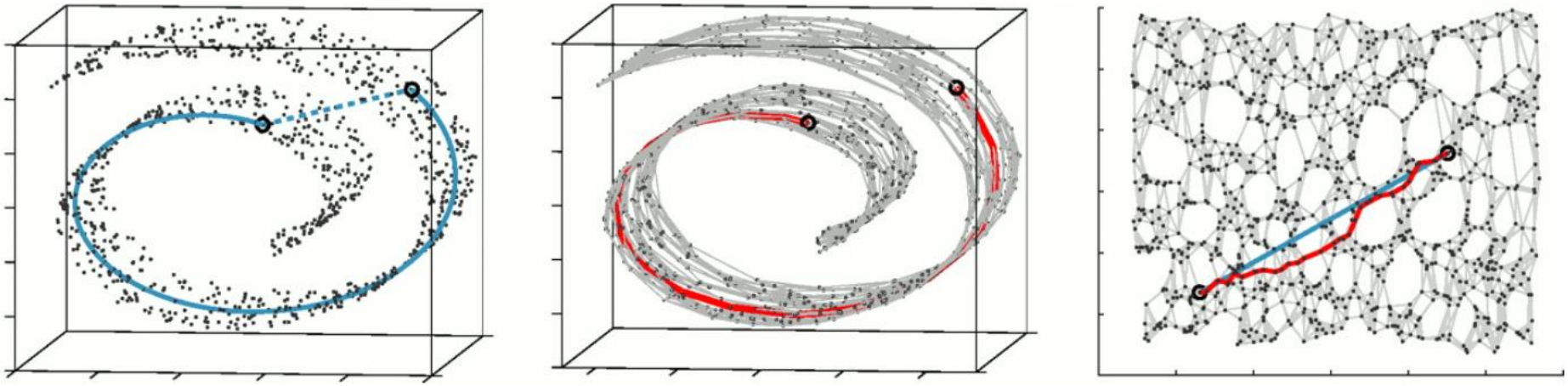
Quote from Shepard & Chipma, 1970

Representational geometry: An early example



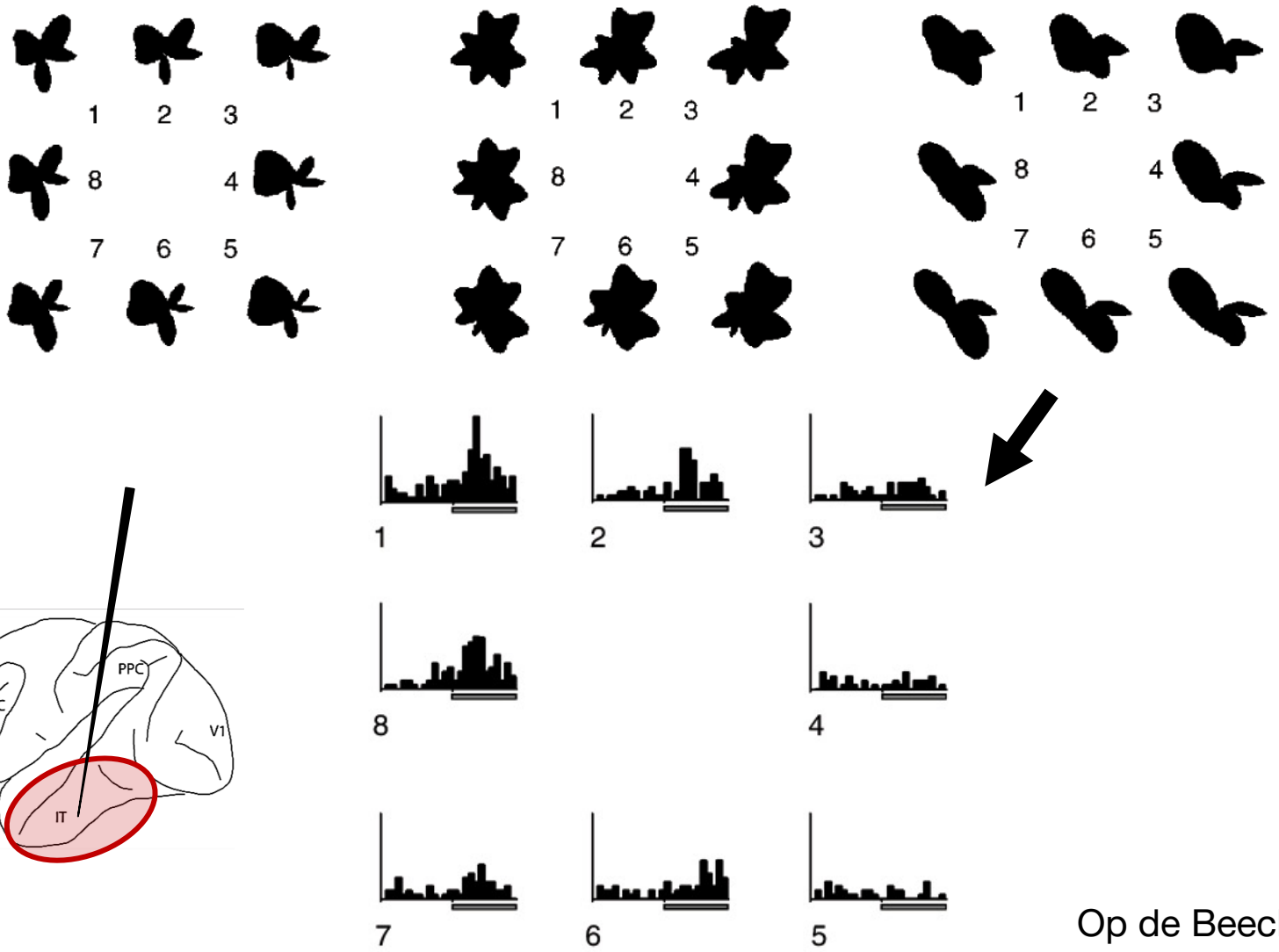
Shepard, 1962, 1980

Representational geometry: More fancy stuff



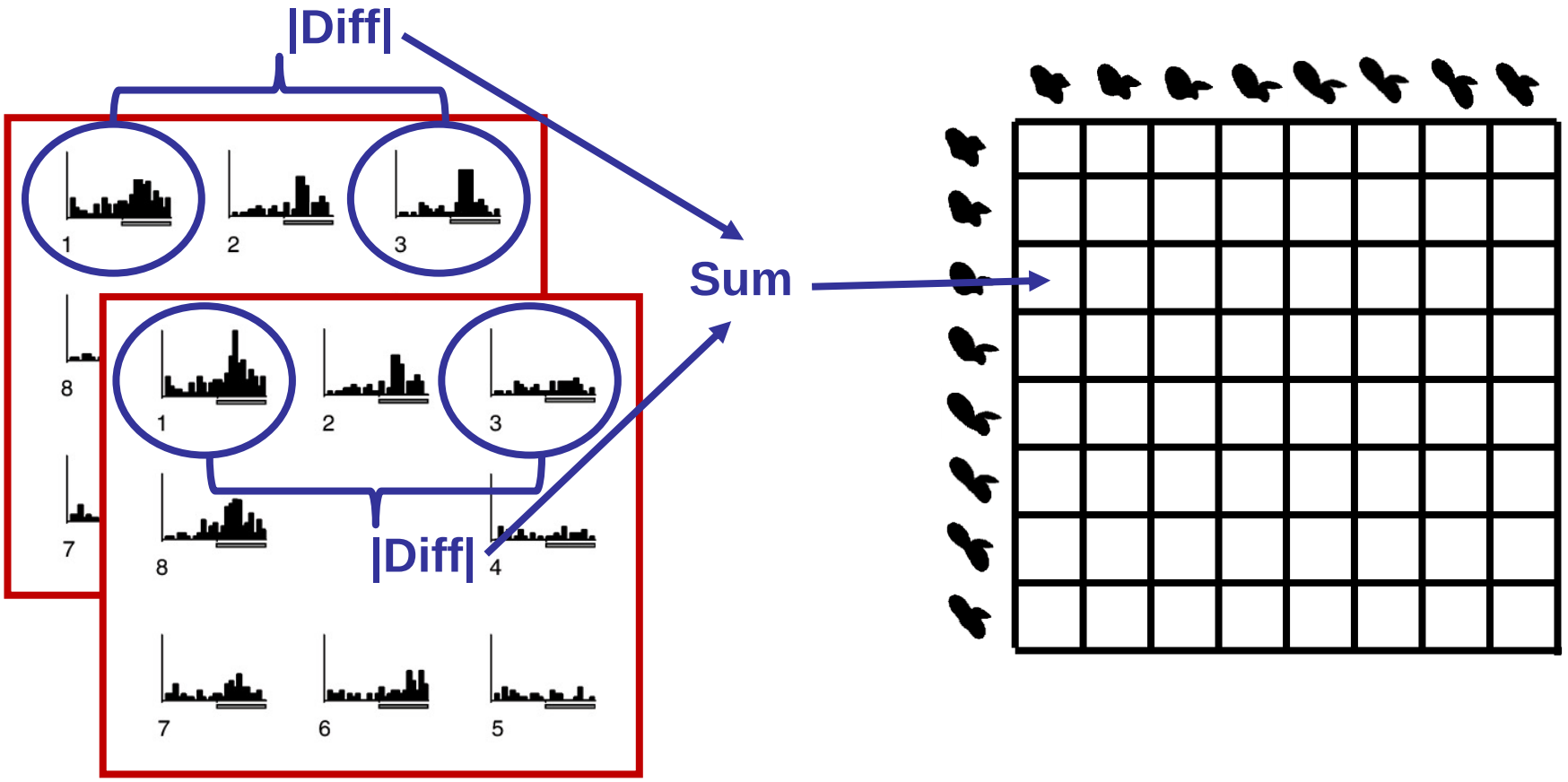
Tenenbaum et al., 2000

Representational geometry: Early example from neuroscience



Op de Beeck et al., 2001

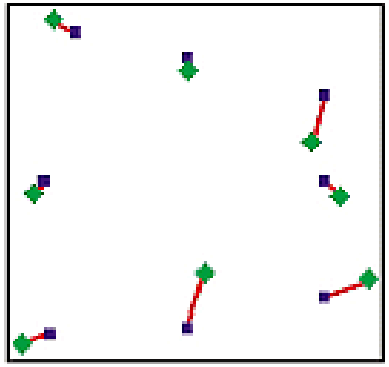
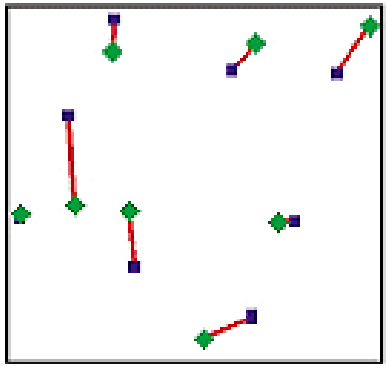
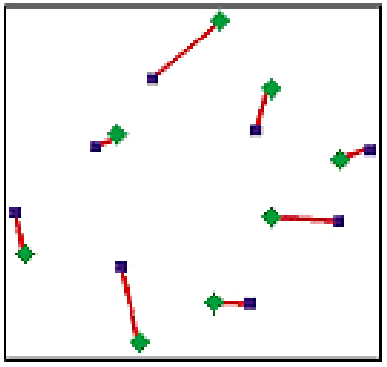
Representational geometry: From raw data to matrix



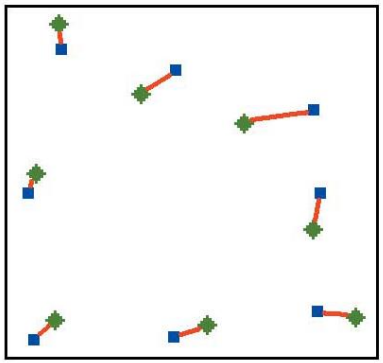
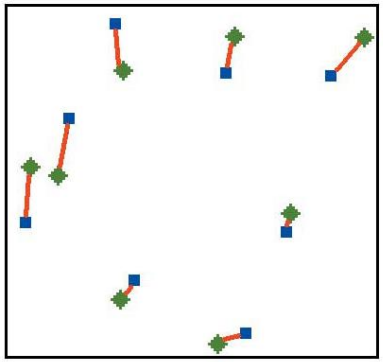
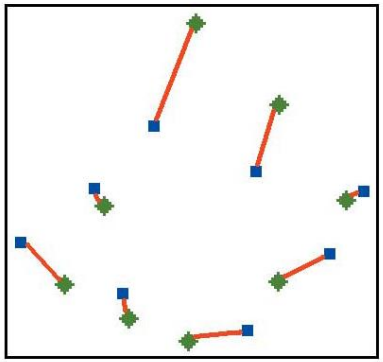
Op de Beeck et al., 2001

Representational geometry: From matrix to space

Neural space:

Behavioral space:

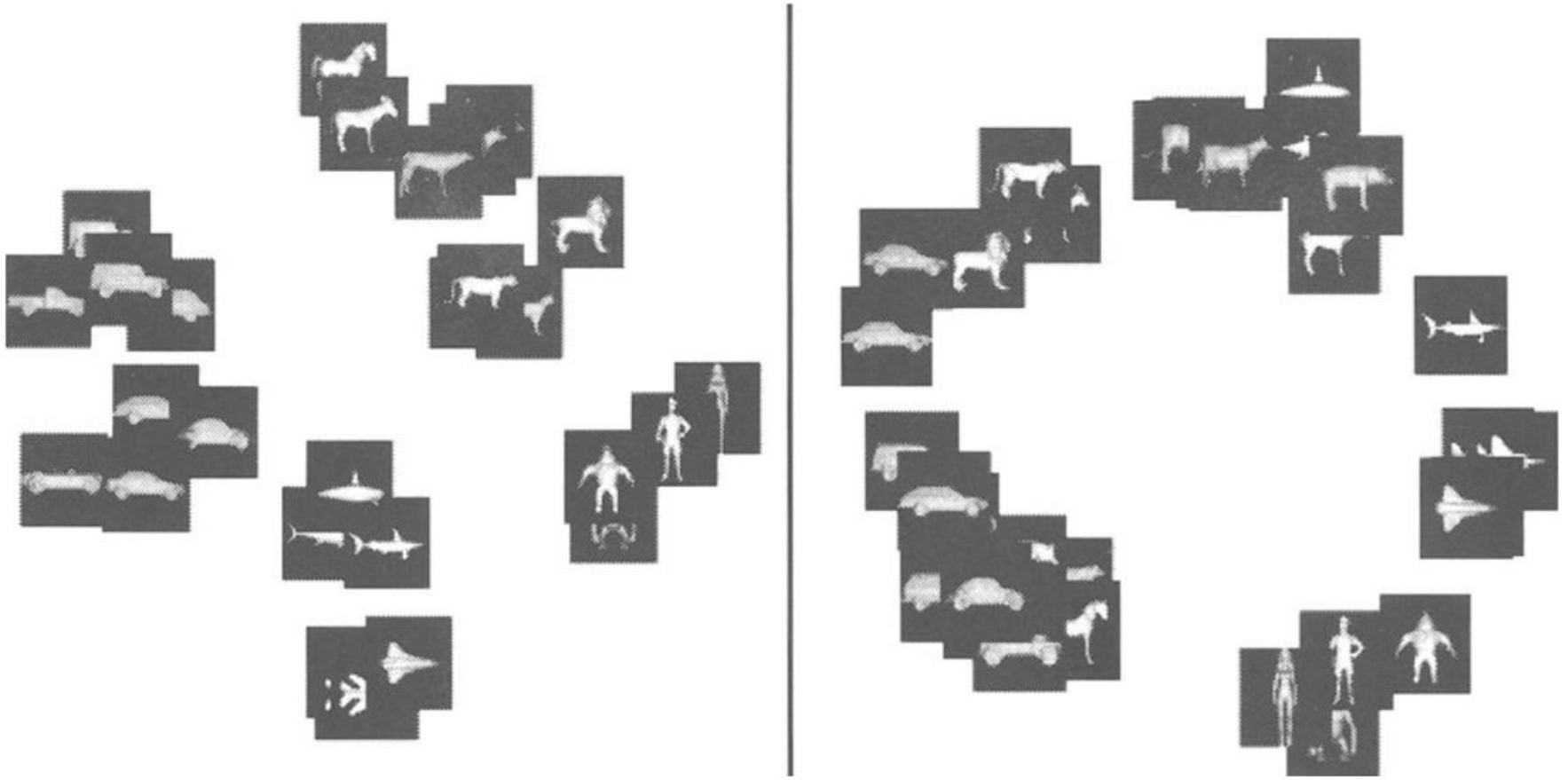




Op de Beeck et al., 2001

Representational geometry: Where it started for fMRI

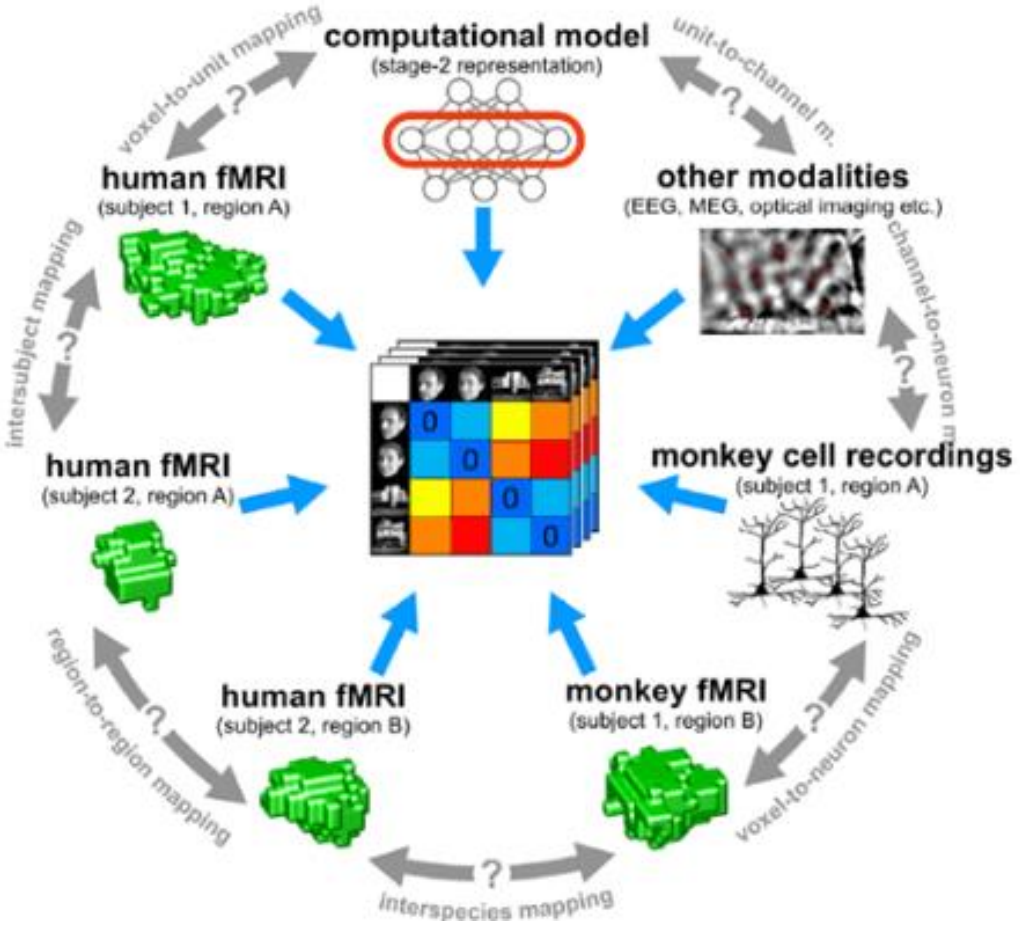
Behavioral space:

Neural space:



Edelman, Grill-Spector, et al., 1998

Representational geometry and its potential



Kriegeskorte et al., 2008

Representational geometry and information processing

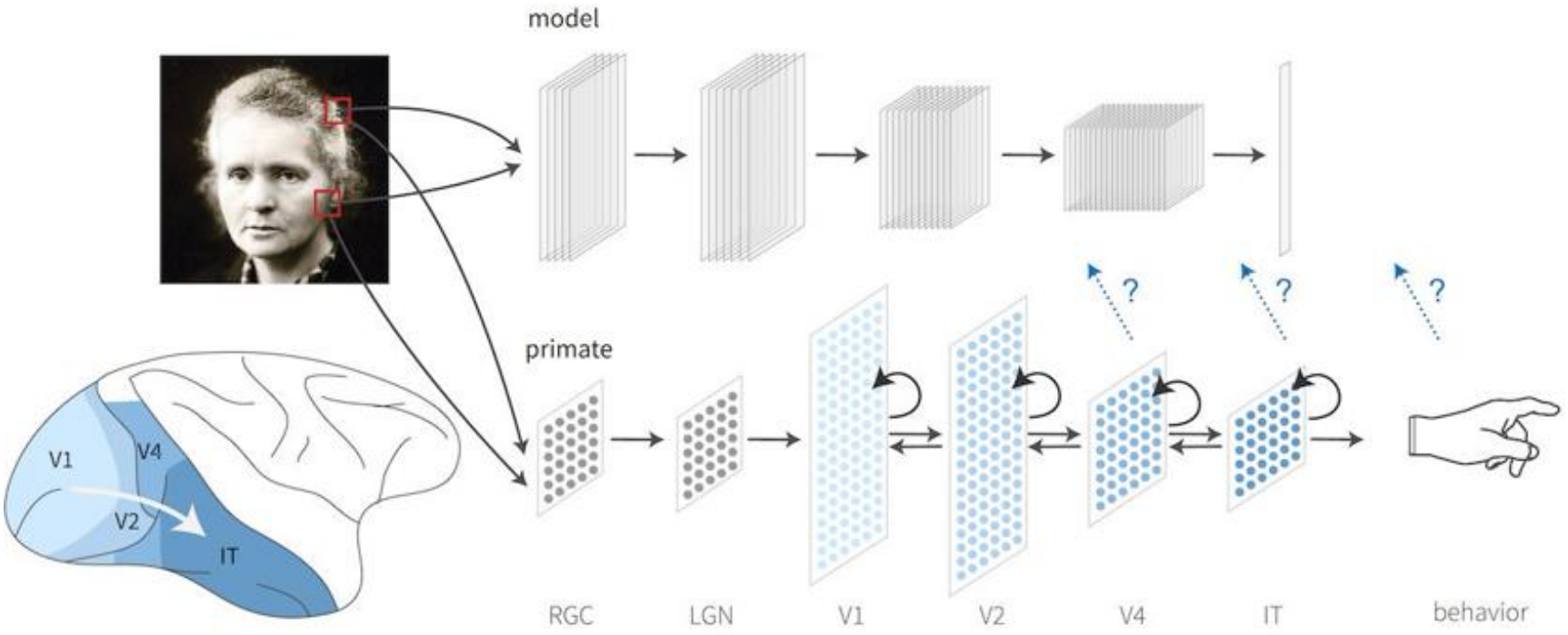
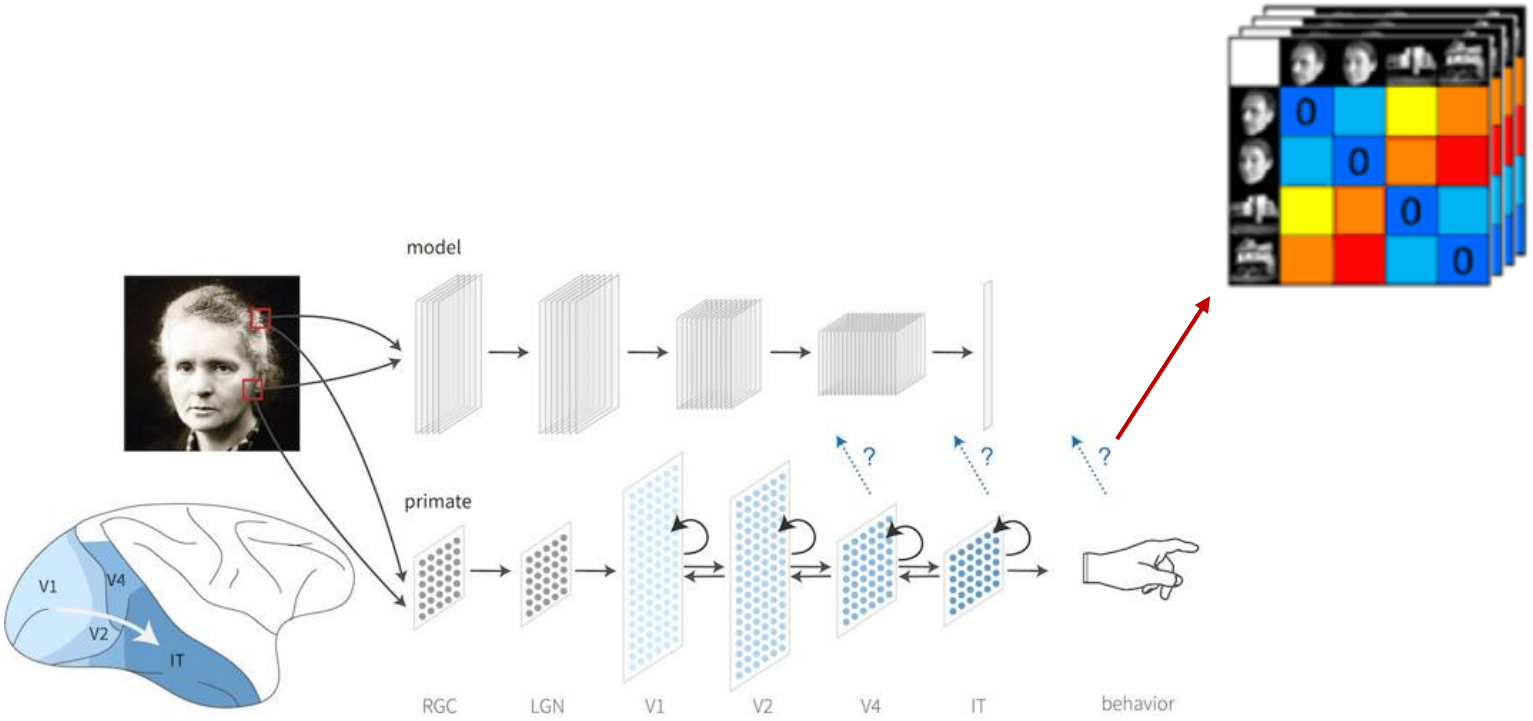


Figure by Kubilius et al.

Representational geometry and information processing



Useful models to characterize information processing?

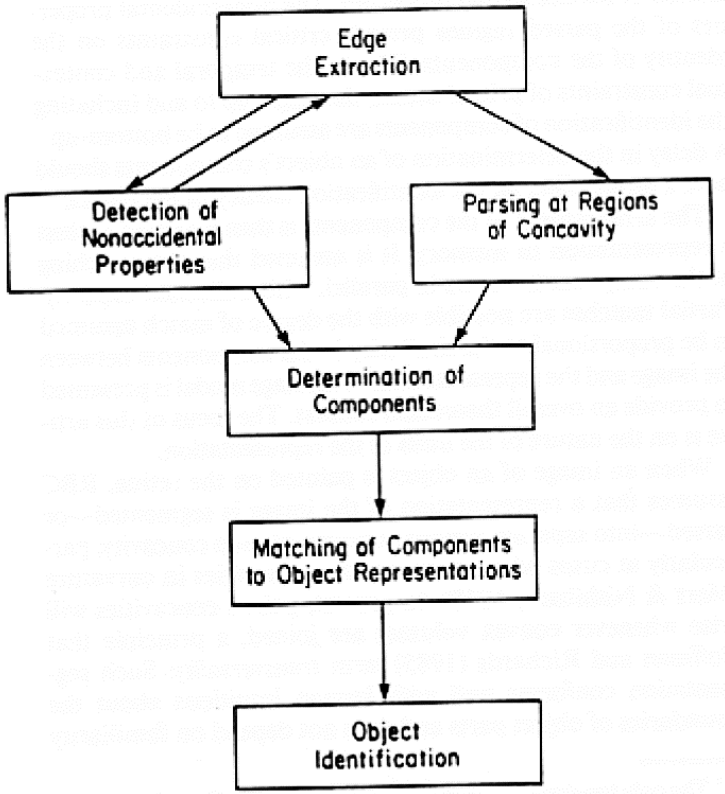
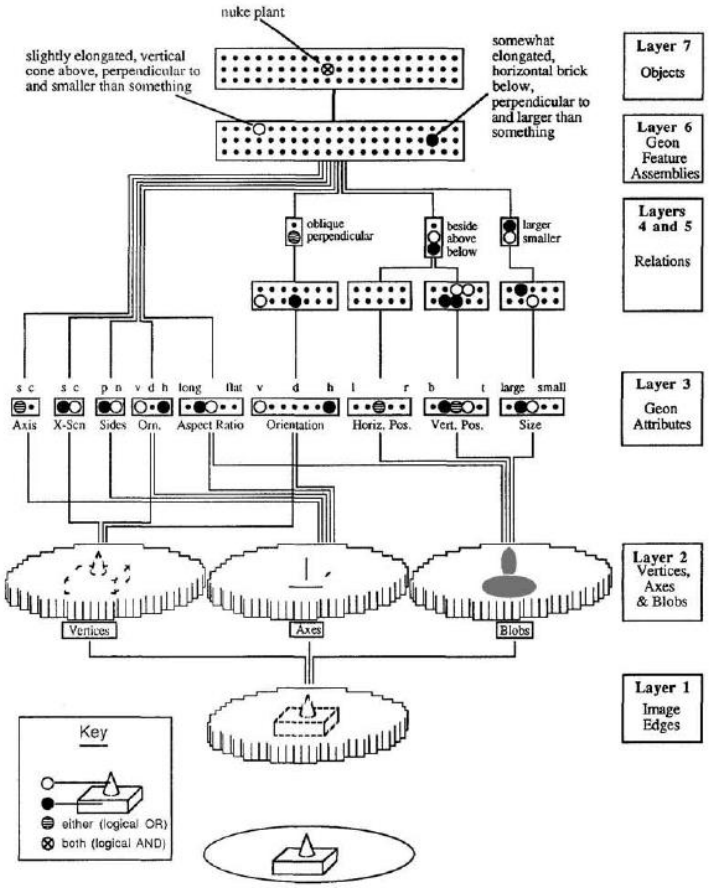


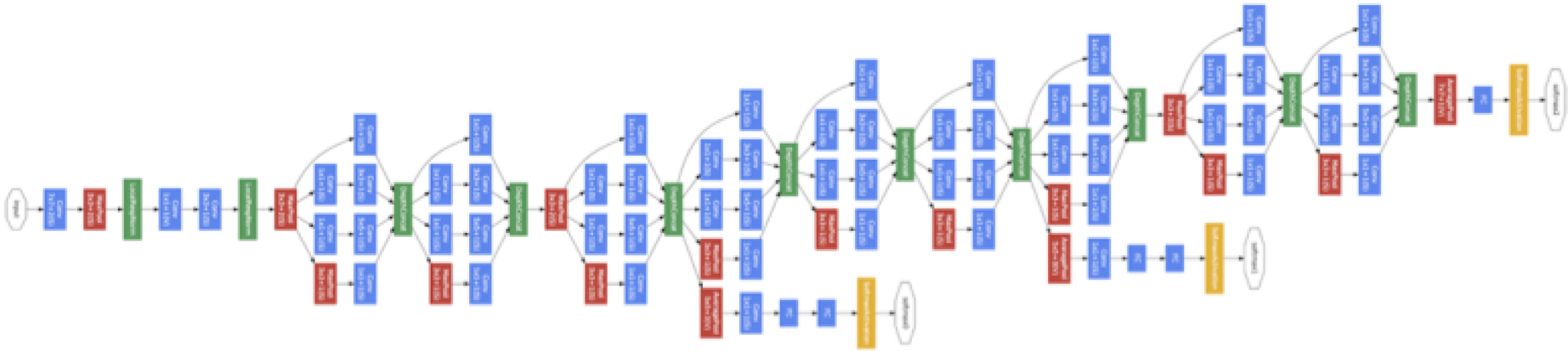
Figure 2. Presumed processing stages in object recognition.

Biederman, 1987, Psych. Rev.



Hummel & Biederman, 1992, Psych. Rev.

Deep nets as a useful, quantitative benchmark

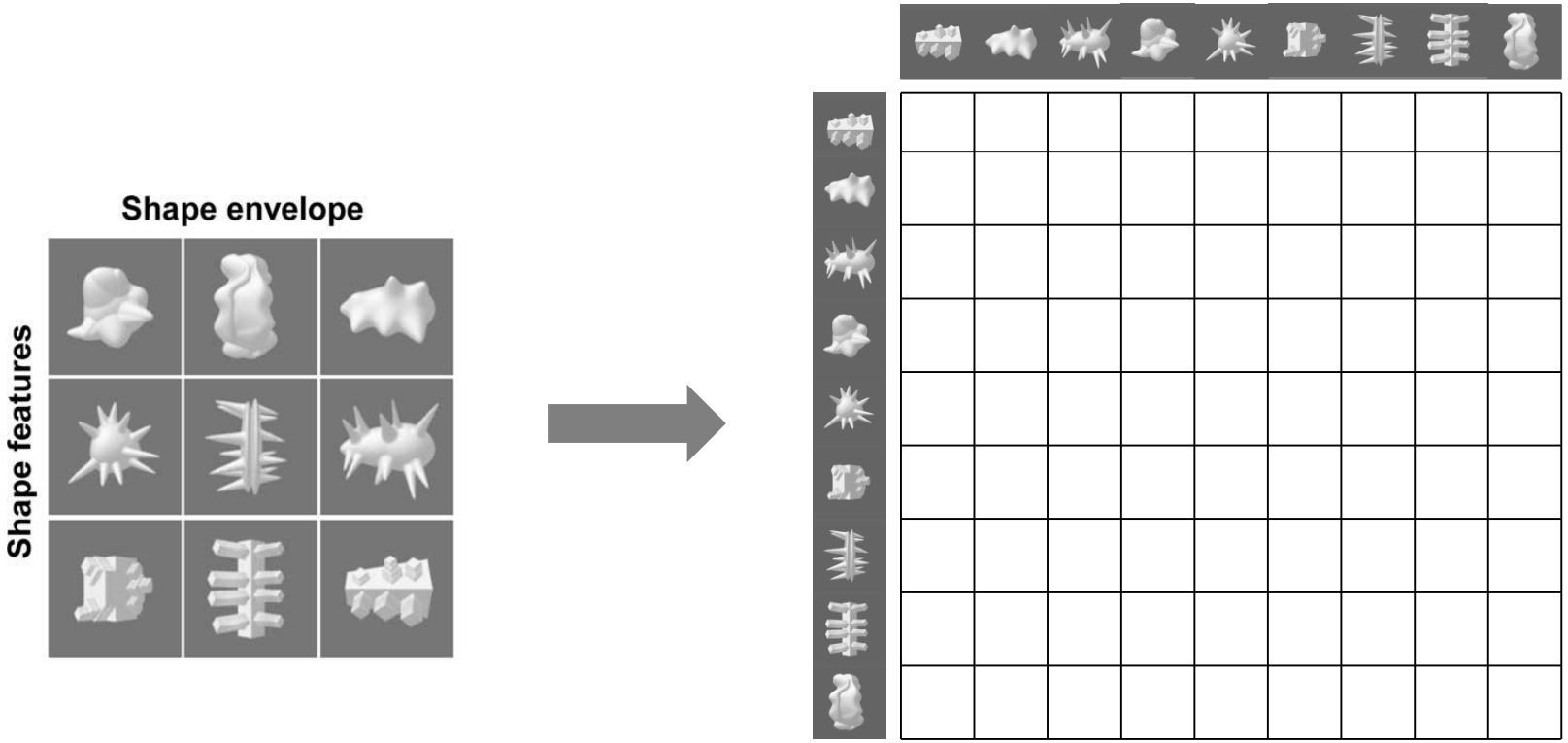


Convolution
Pooling
Softmax
Other

Many architectures & applications:

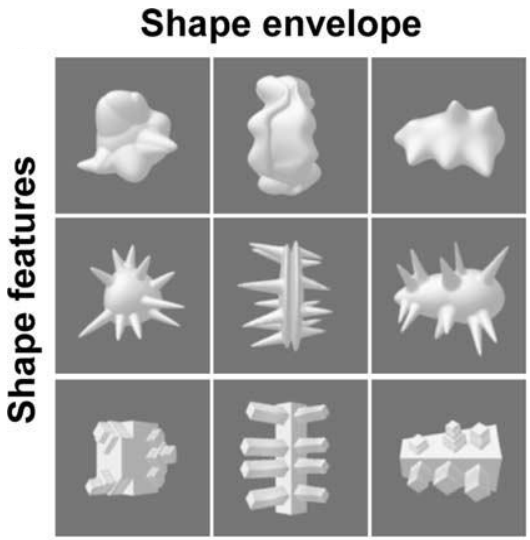
CaffeNet, AlexNet, **GoogLeNet**, FaceNet, ResNet, CORnet, …

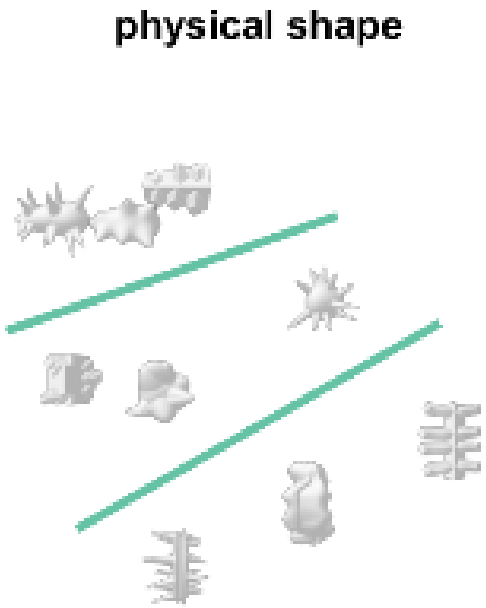
Example 1: Shape processing

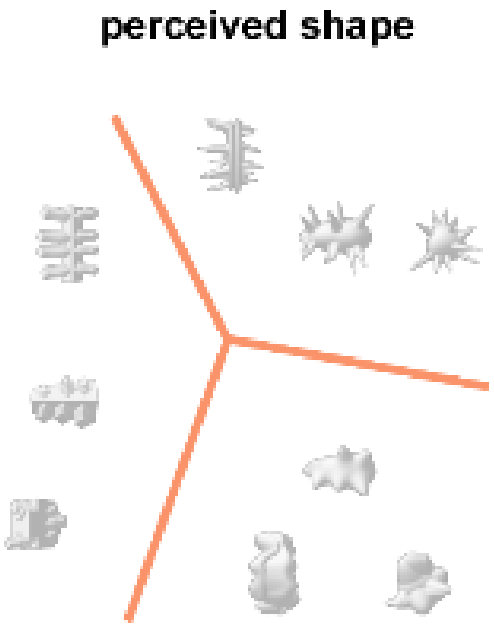


Op de Beeck et al., 2008

Example 1: Different stages of shape processing



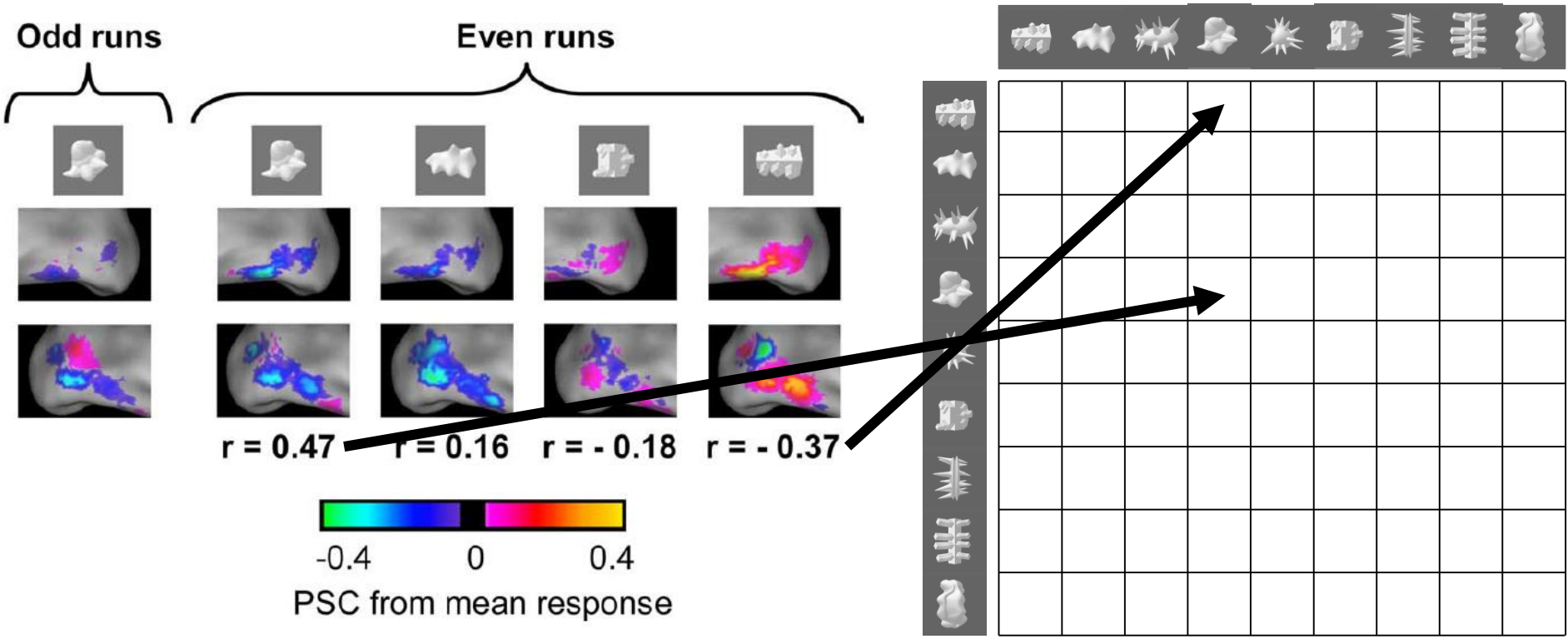




Also see: Biederman

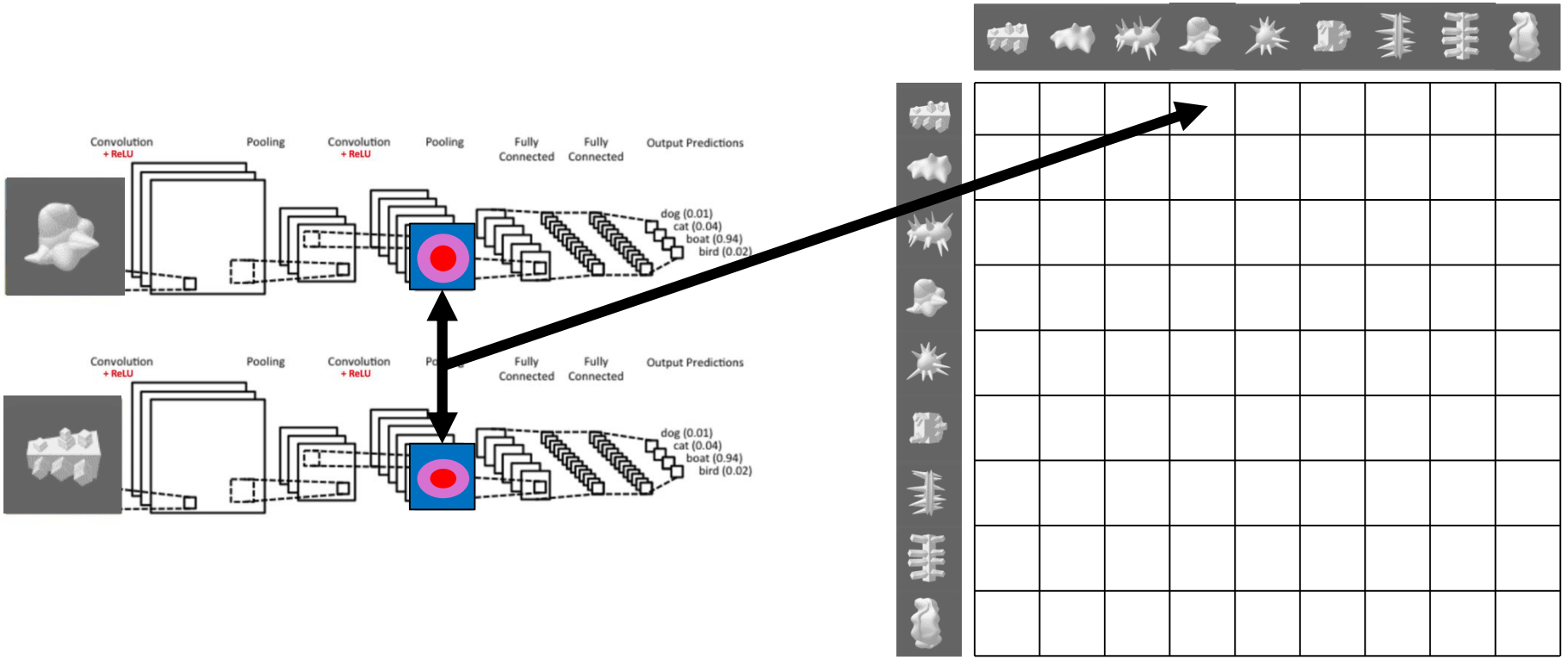
Op de Beeck et al., 2008

Example 1: Shape processing in visual cortex



Op de Beeck et al., 2008

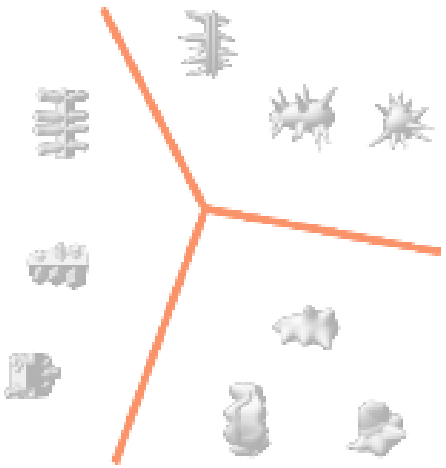
Example 1: Shape processing in DNNs



Kubilius et al., 2016

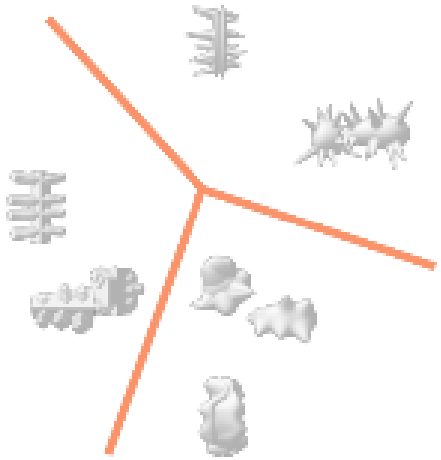
Example 1: Comparing shape representations

Perceived shape



Neural shape (LOC)

Deep shape
(last layer of GoogLeNet)



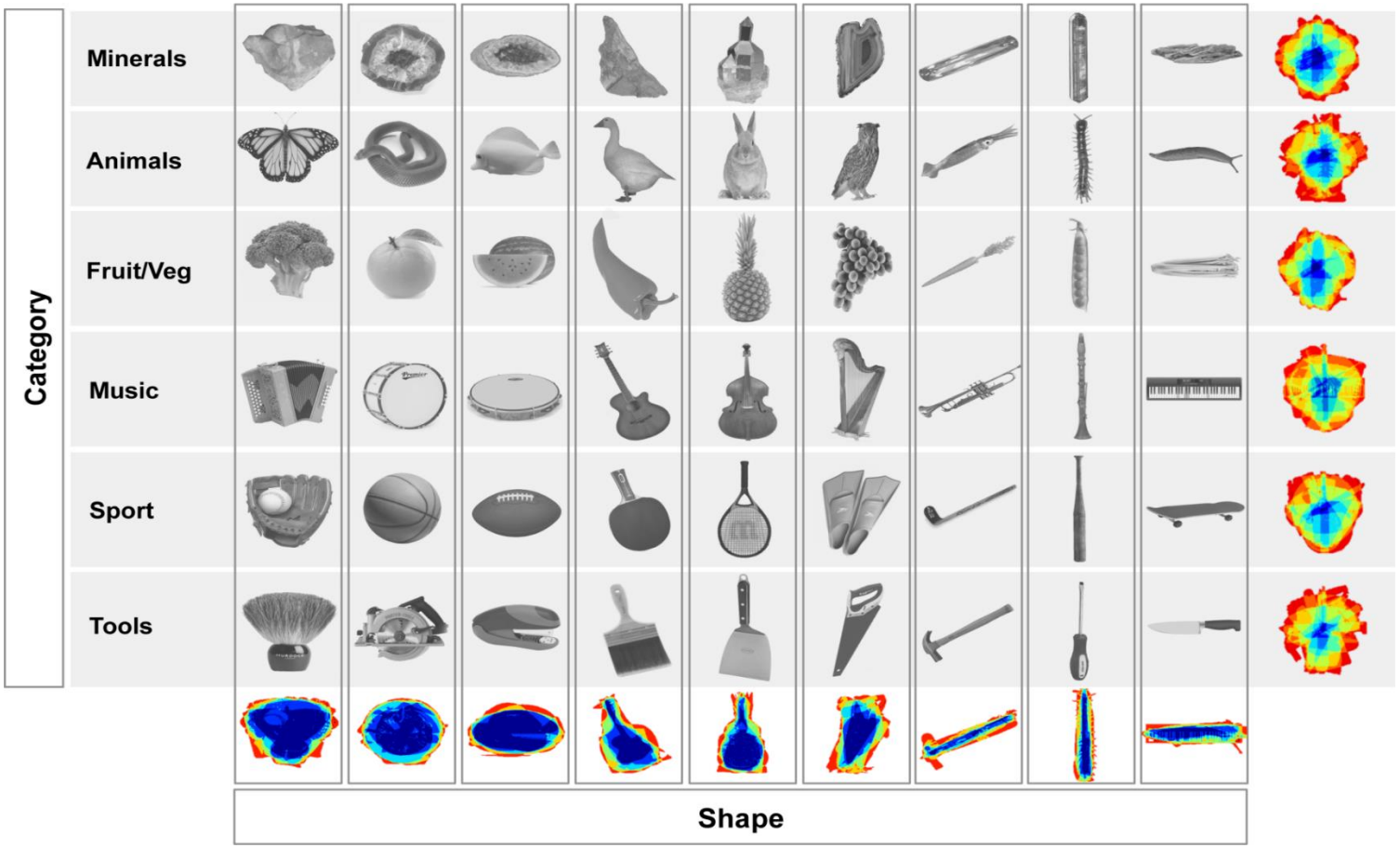
Example 2: Dissociating shape from category

Multiple object properties are typically correlated/confounded:

Kriegeskorte et al., 2008

➡ Clever stimulus designs to dissociate these factors!

Example 2: Dissociating shape from category

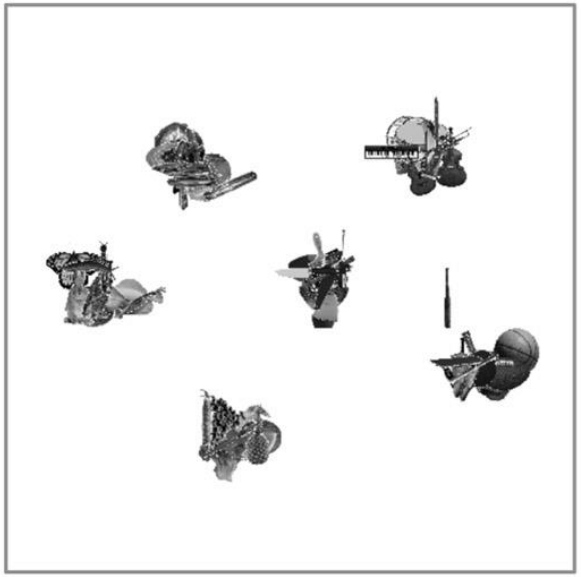


Bracci et al., 2016

Example 2: Dissociating shape from category

silhouette similarity

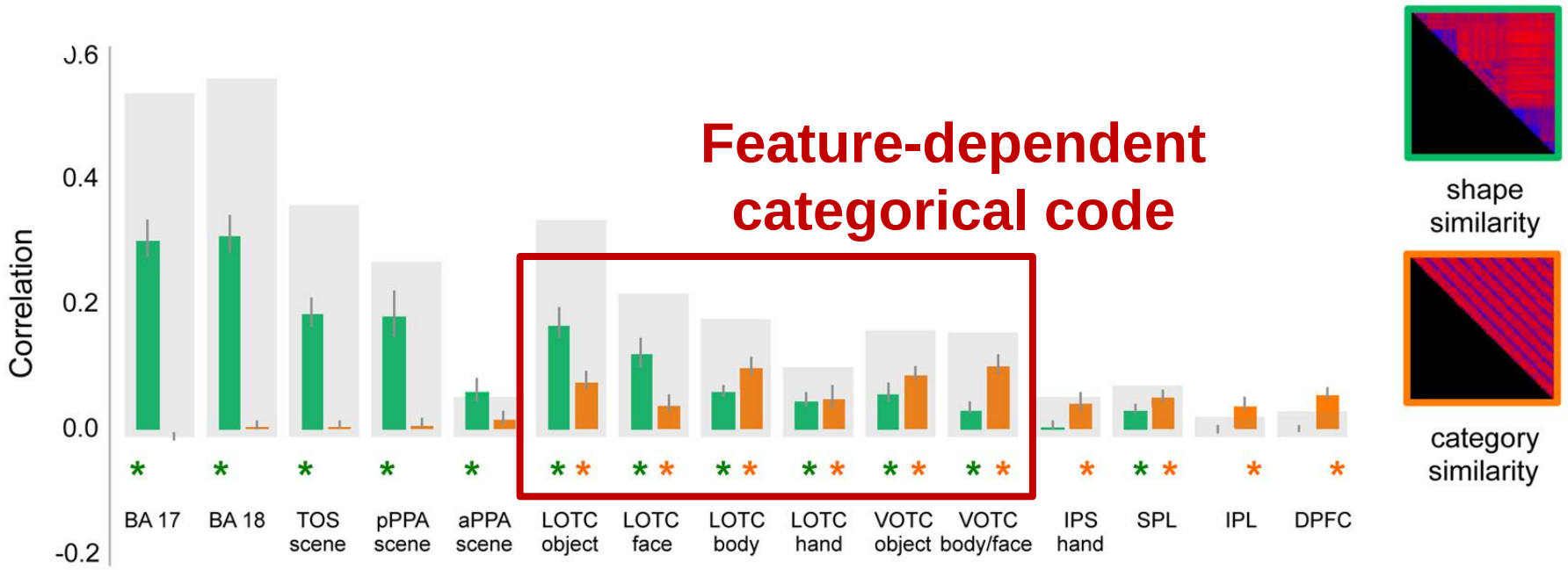
shape similarity



category similarity

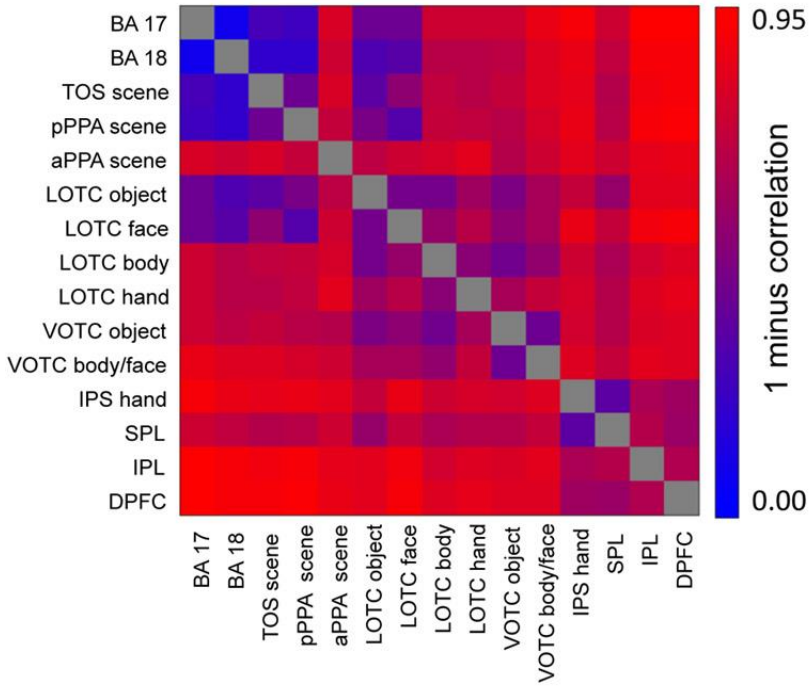
Bracci et al., 2016

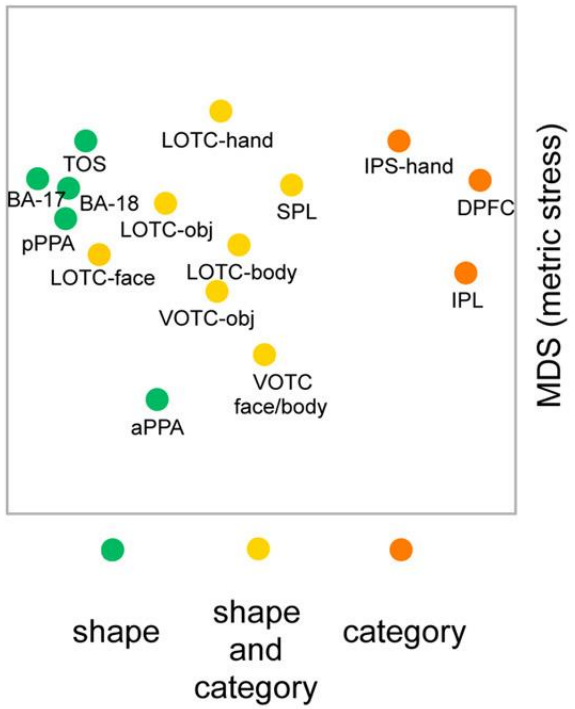
Example 2: Dissociating shape from category

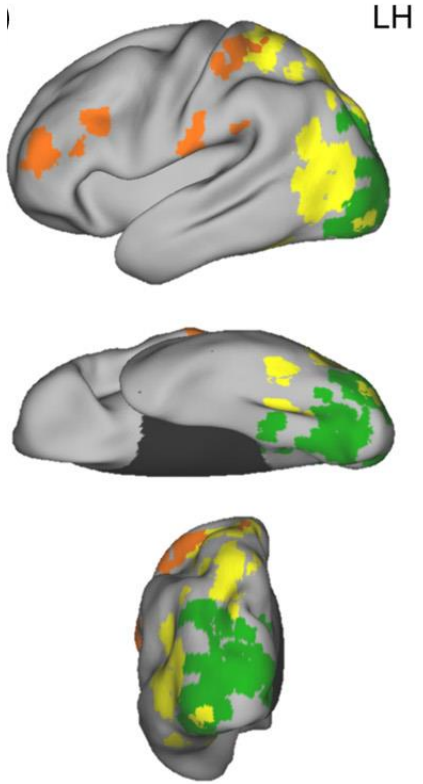


Bracci et al., 2016

Example 2: Representational hierarchies



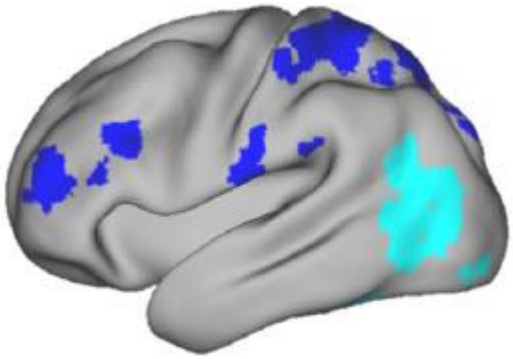


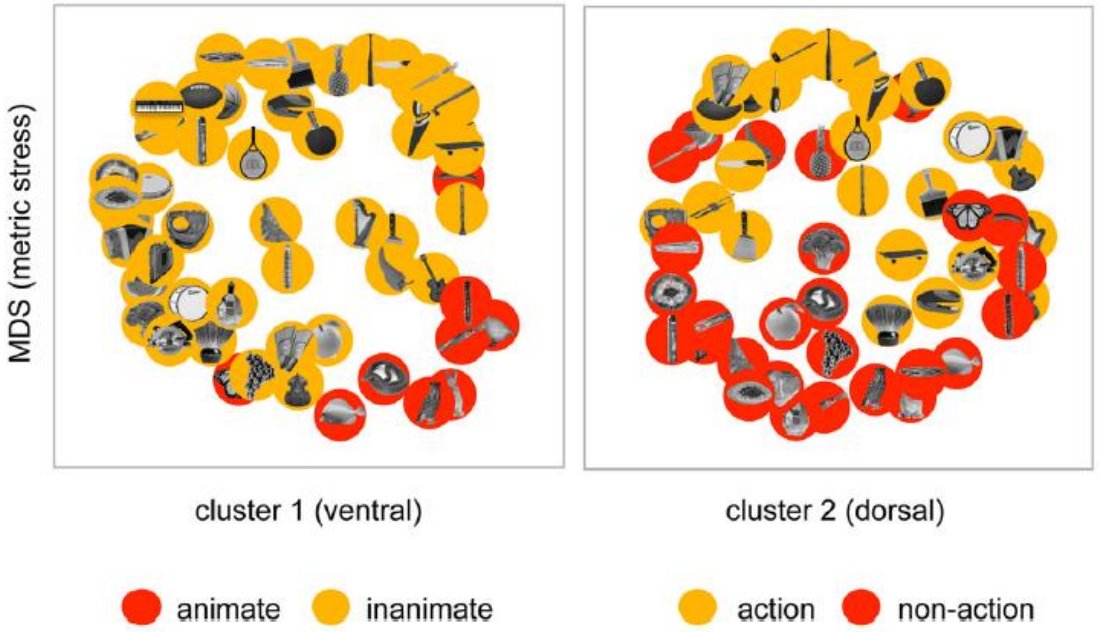


Bracci et al., 2016

Example 2: Representational pathways

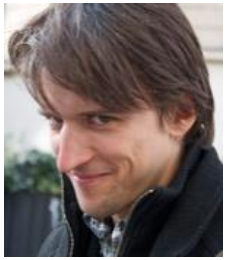
Multiple category representations:

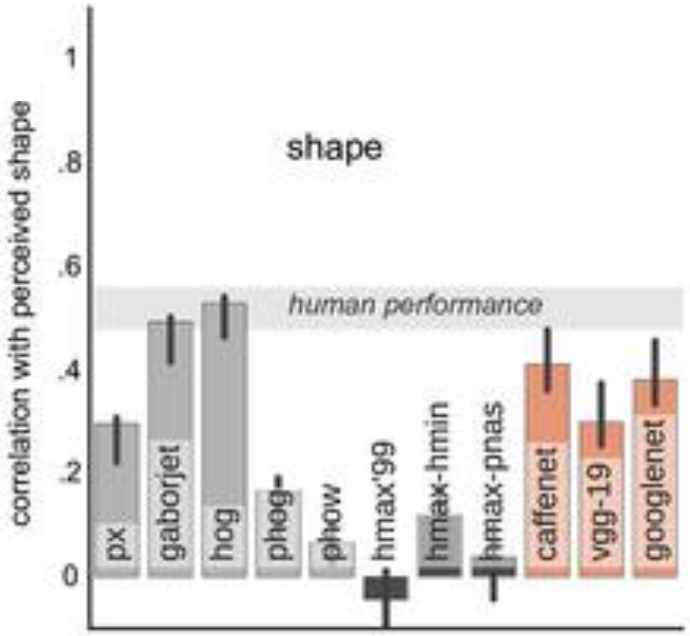


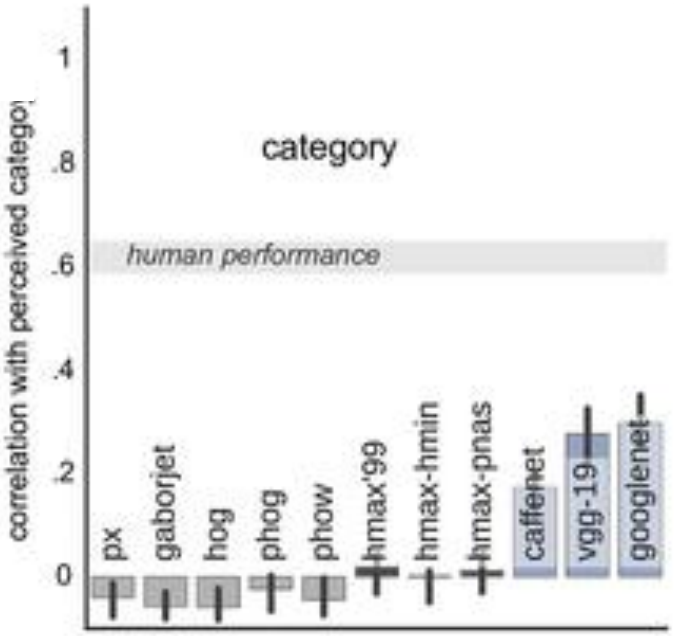


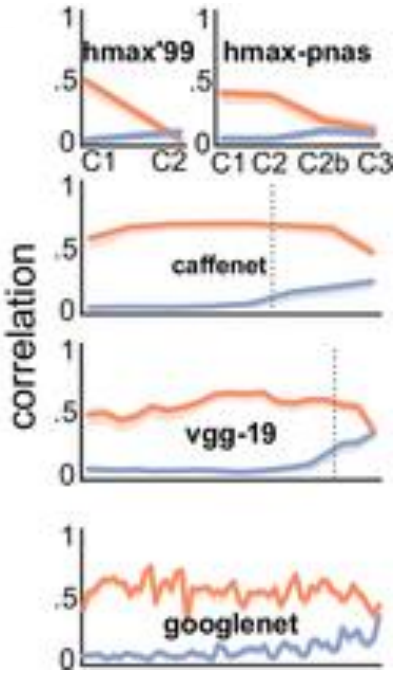
Bracci et al., 2016

Example 2: Feature dissociations in DNNs







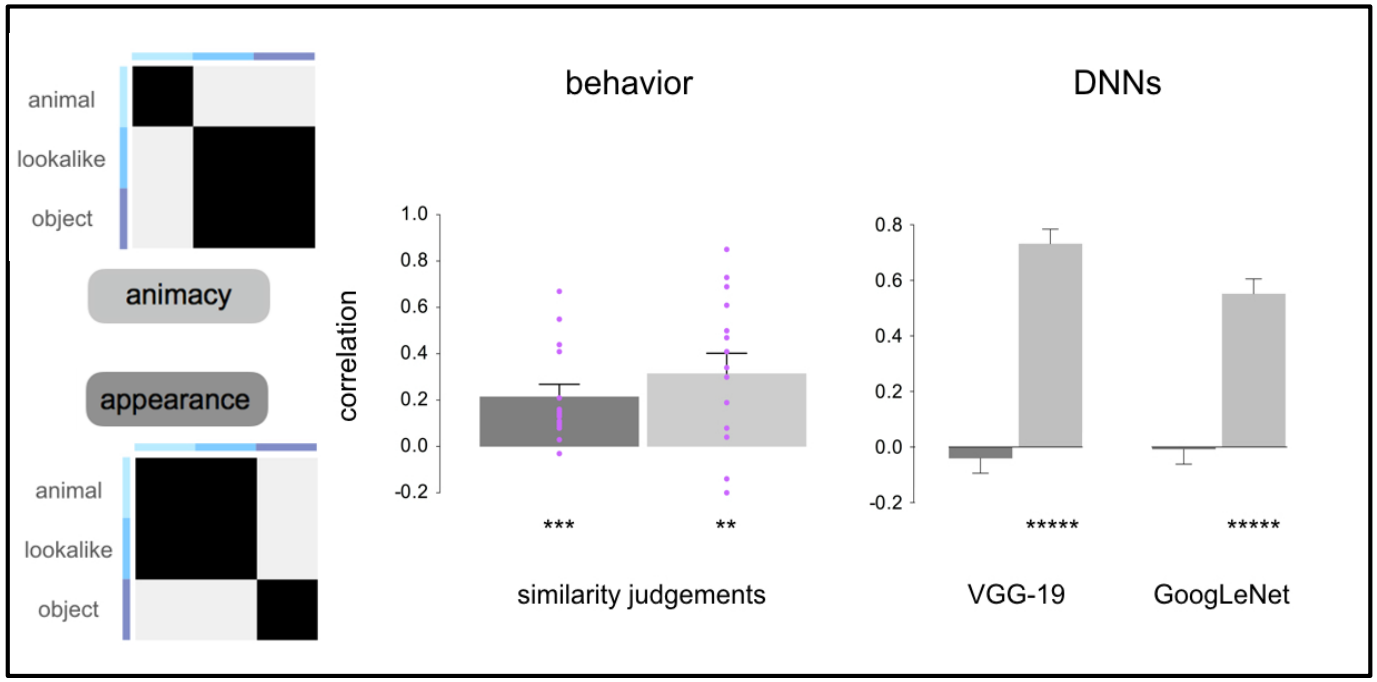


Kubilius et al., 2016

Example 3: Animacy representations in ‘visual’ cortex?

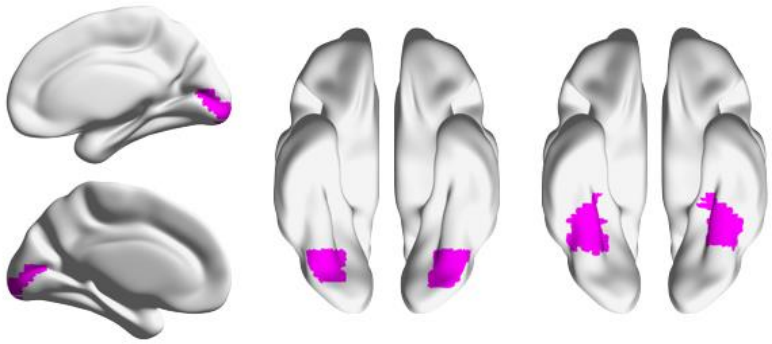
Bracci et al., 2019

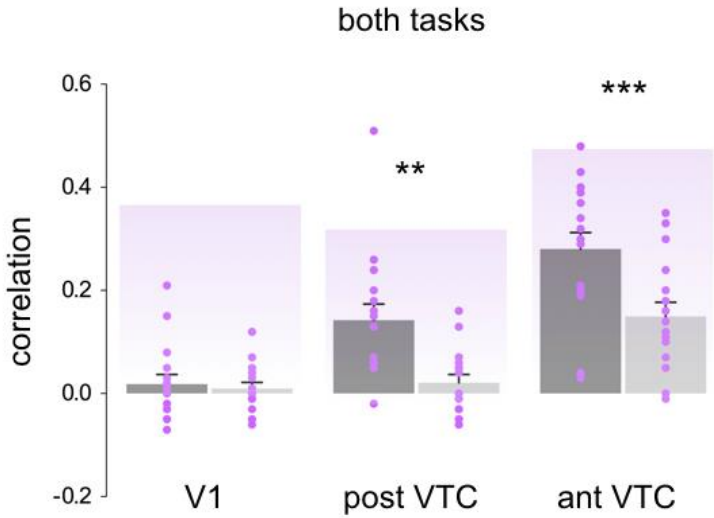
Example 3: Animacy representations in DNNs & behavior



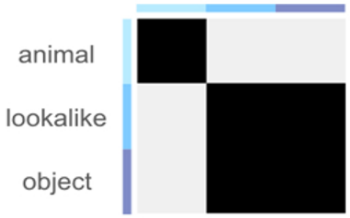
Bracci et al., 2019

Example 3: Animacy representations in visual cortex?





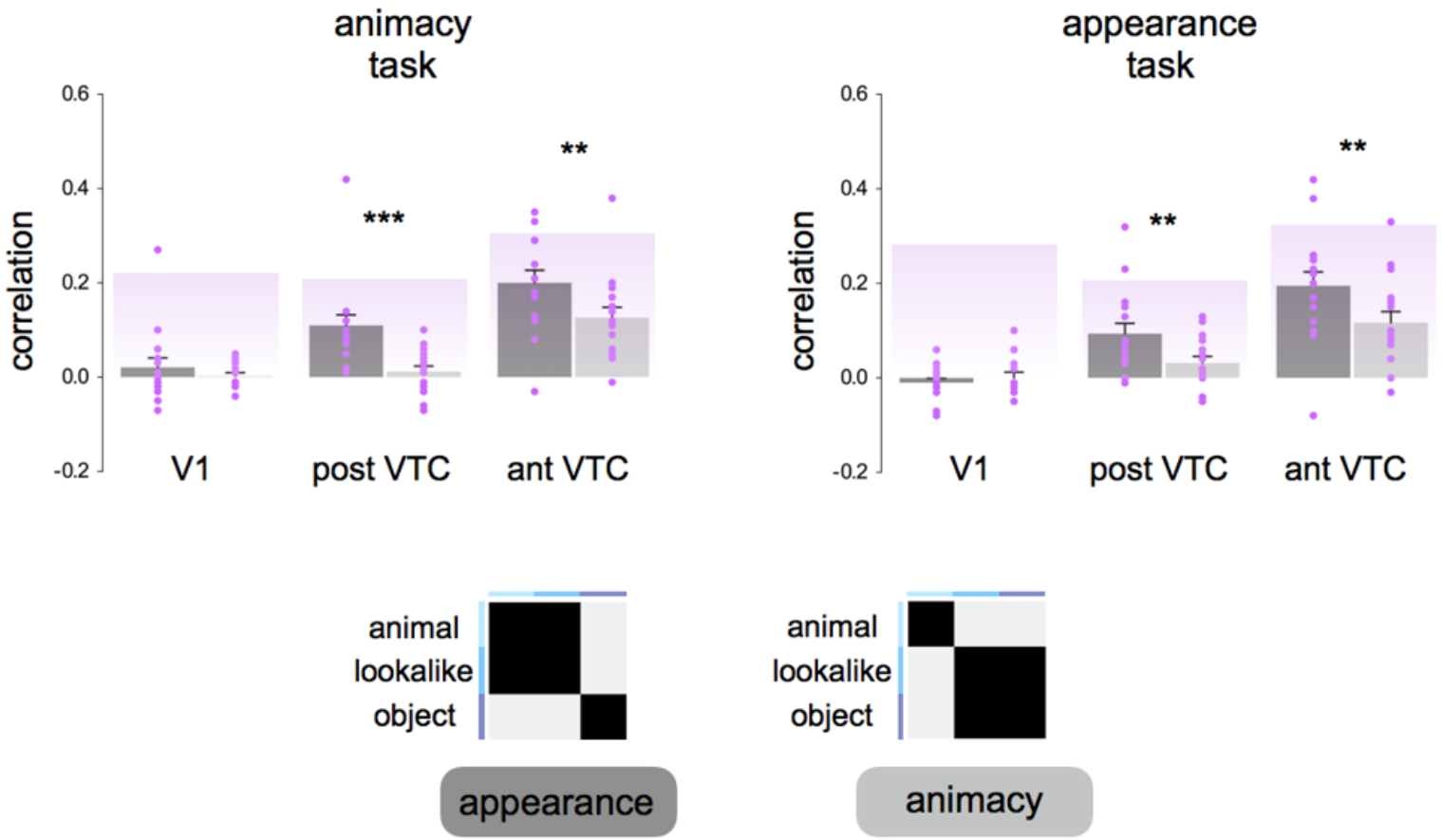
appearance



animacy

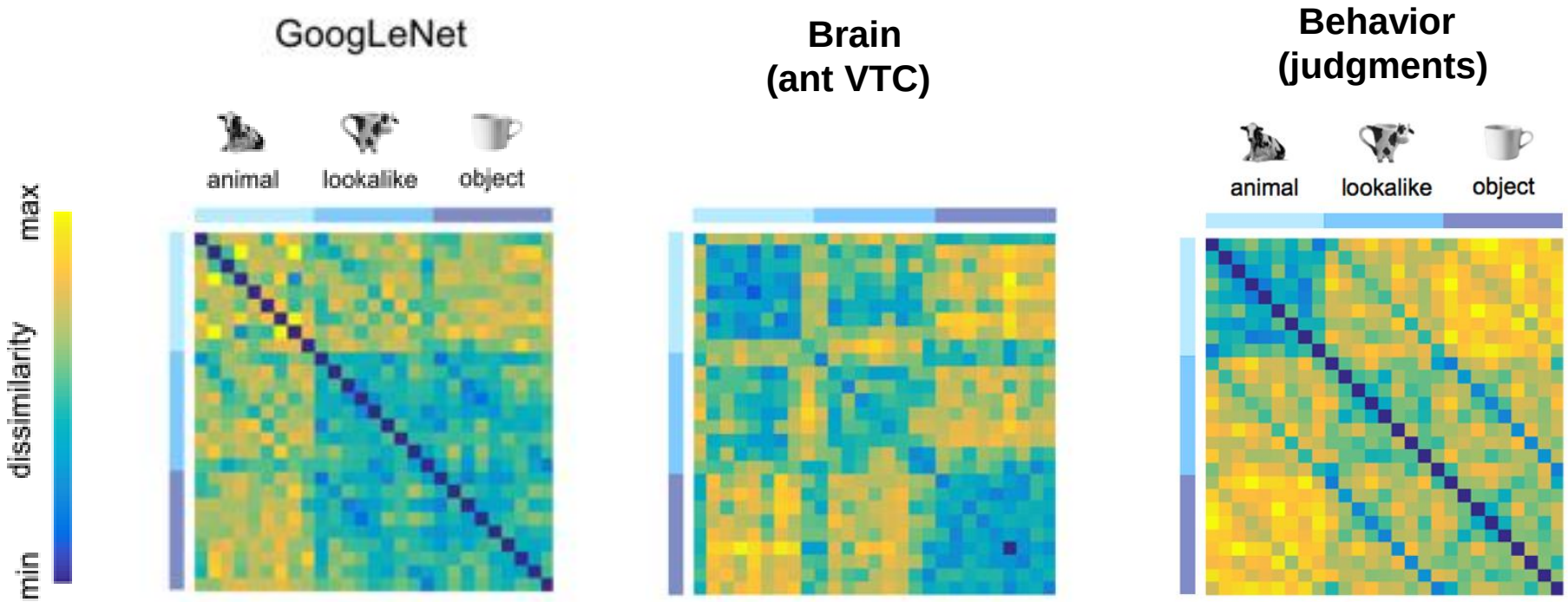
Bracci et al., 2019

Example 3: Task does not matter!



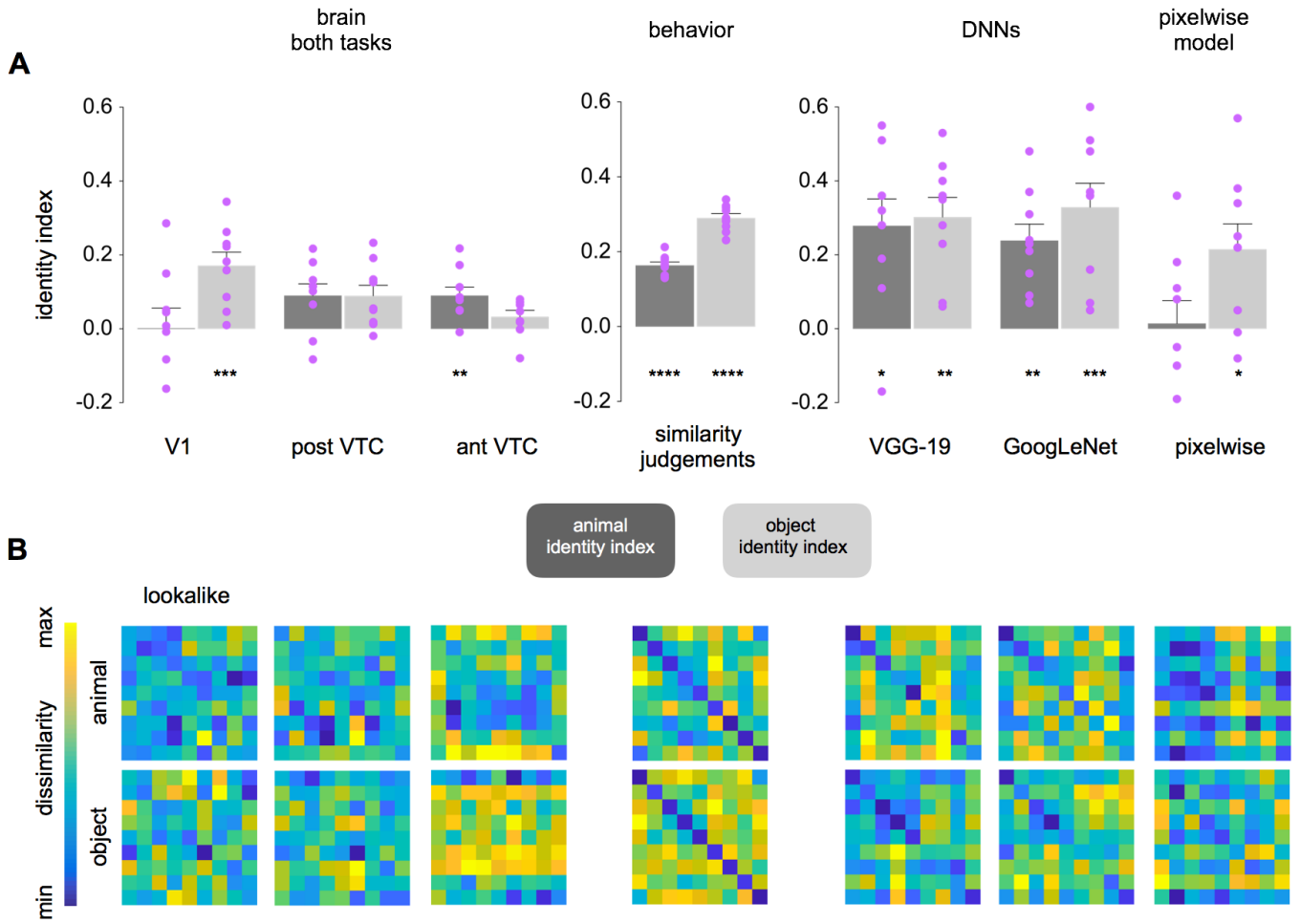
Bracci et al., 2019

Example 3: Comparison DNNs, brain, behavior



Bracci et al., 2019

Example 3: Failure of human cortex in object recognition



Bracci et al., 2019

Example 4: Information processing and autism

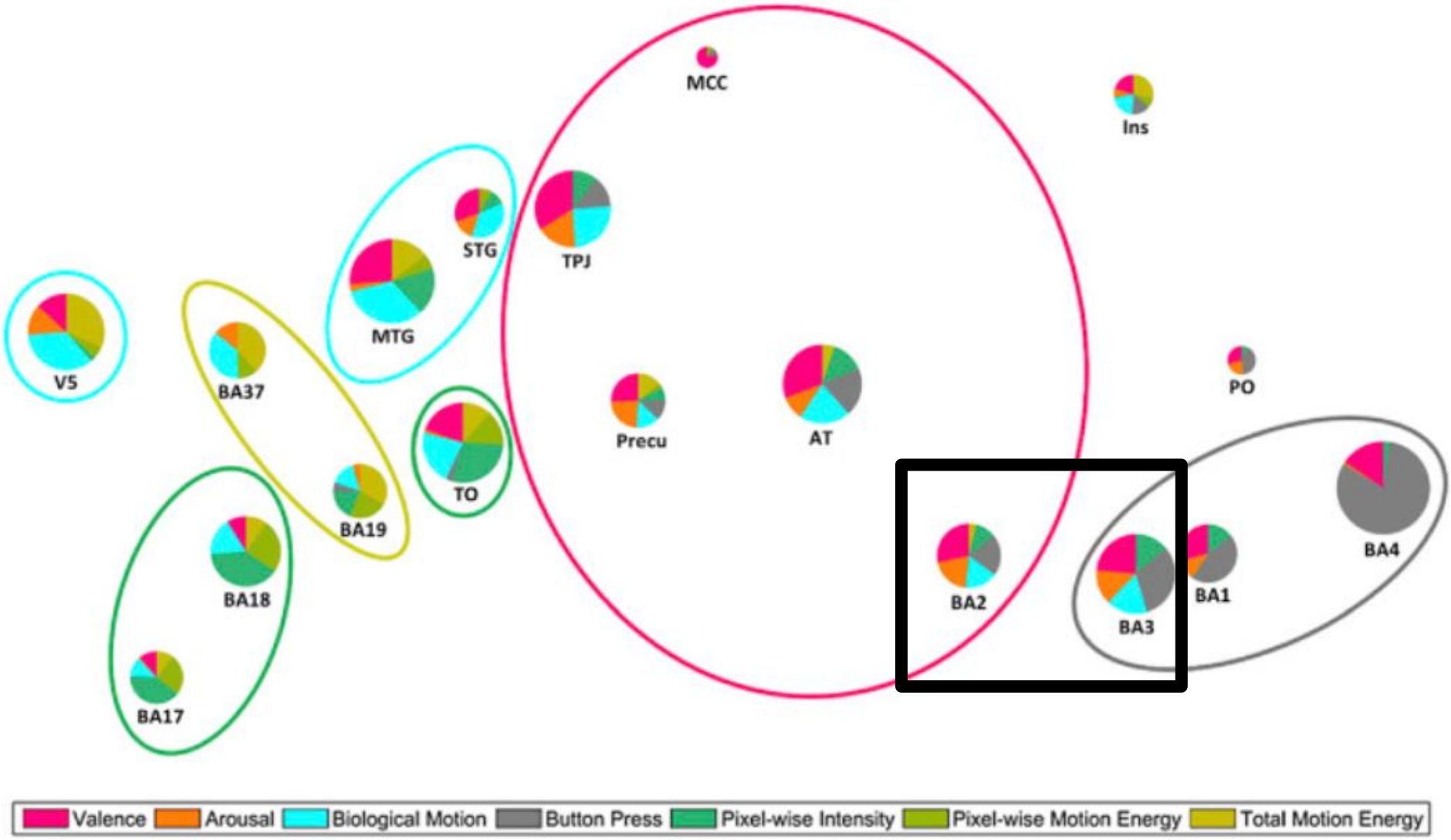
Positive Social Touch Stimuli

Negative Social Touch Stimuli

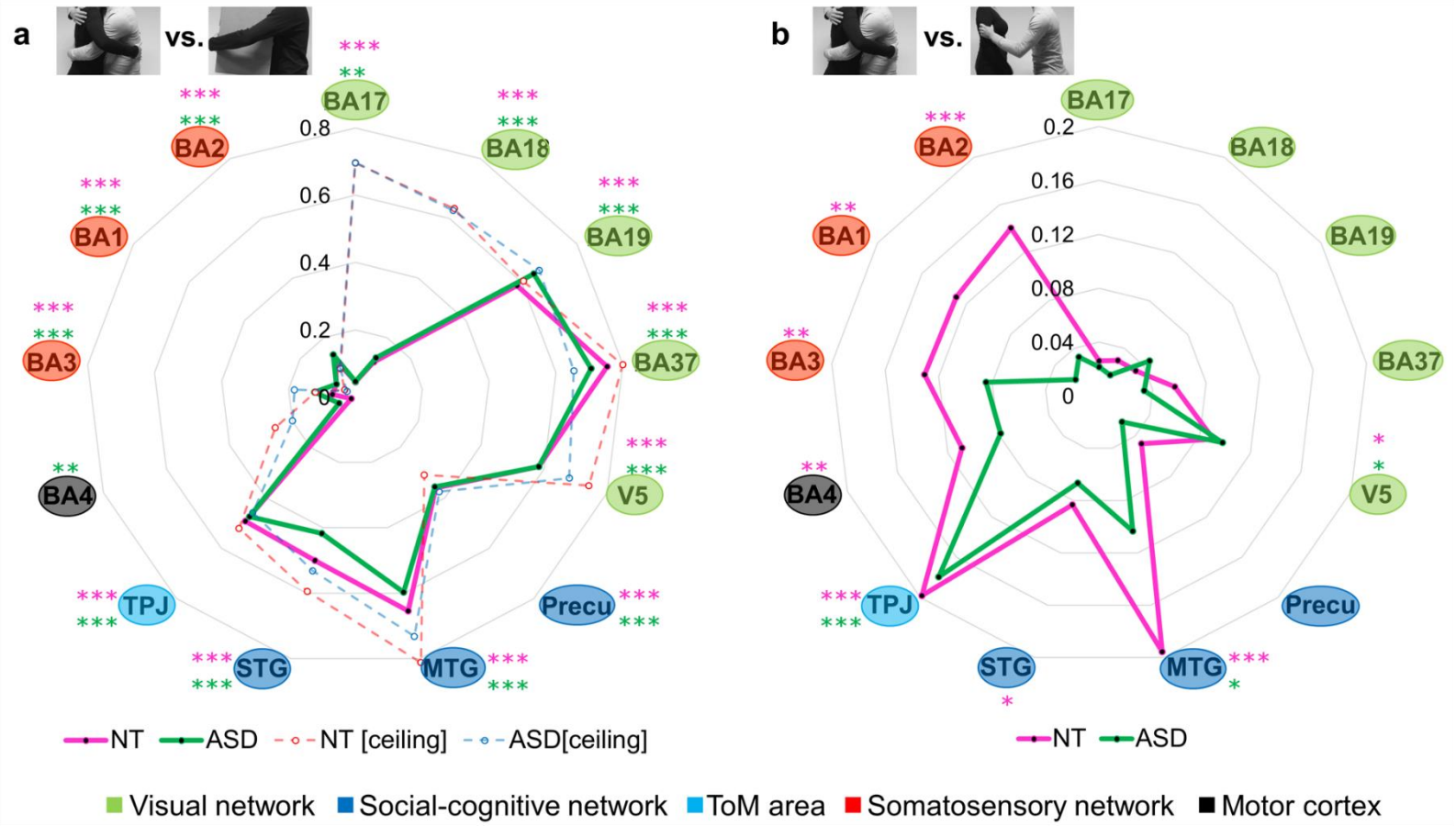
Neutral non-Social Touch Stimuli

Lee-Masson et al., 2018, in press

Example 4: Visualizing information processing



Autism: Similar perceptual & cognitive processing, but lower resonance



Lee-Masson et al., in press

Value of representational geometry to understand the brain and its disorders?

Acknowledgements

Thanks to the lab!

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