Brain presentation

Representational similarity analysis

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Agenda

- Introduction
  - Perception of the World
  - The Experiment
  - How to Analyze and Compare the Data?
- Representational Similarity Analysis
  - What Is It
  - How It Works
  - Representational Dissimilarities Matrix
- Usefulness of RSA
  - Results of the Experiment
  - Importance

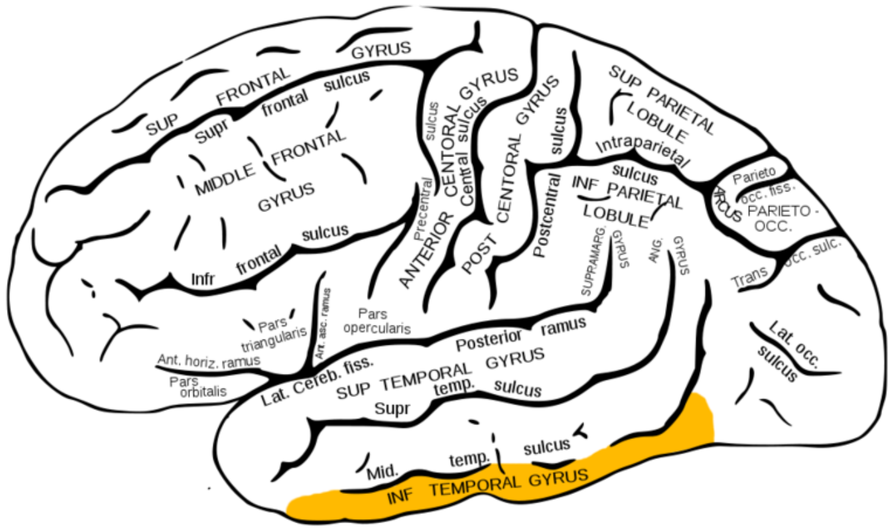
Introduction: Perception of the World

- According to the current theory, Inferior Temporal (IT) has a role in the categorization of objects, but this is not well understood yet

- “Do monkeys and humans see the world similarly? Do monkeys categorize objects as humans do?” [1]

- Experiment in 2008 to study the IT and try to answer the question

- Their goal was to “investigate what extent monkey and human-IT represent the same object information” [2]



[3]

[1], [2] Kriegeskorte, Nikolaus., Mur, M., Ruff, D. A., Kiani, R., Bodurka, J., Esteky, H., Tanaka, K., & Bandettini, P. A. (2008). Matching categorical object representations in inferior temporal cortex of man and monkey. Neuron, 60(6), 1126–1141. https://doi.org/10.1016/j.neuron.2008.10.043
[3] https://nl.wikipedia.org/wiki/Bestand:Gray726_inferior_temporal_gyrus.png

Introduction: The Experiment

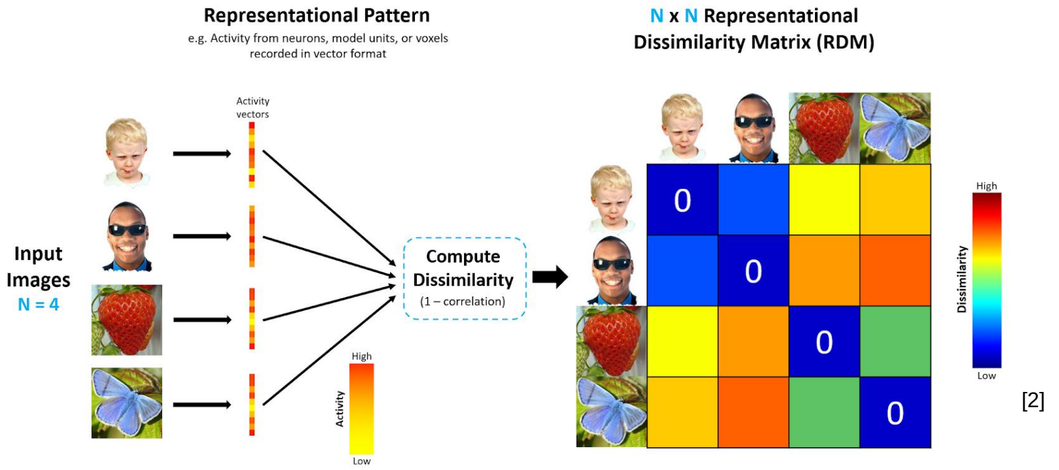
- For measuring the brain activity in Inferior Temporal (IT) they used electrode single-cell recording (674 neurons in total) in monkeys and functional Magnetic Resonance Imaging (fMRI) in humans
- Then they presented the same 92 images of real-world objects to both species
- For each stimulus, they estimated the IT response pattern
- And then they did an analysis to interpret the data and compare the result between the species

[1]

[1] https://www.unr.edu/neuroscience/research/center/core-facilities/neuroimaging-core

Introduction: How to Analyze & Compare the Data?

- They used a method called Representational Similarity Analysis (RSA)
- RSA relates different brain regions, different species and different sources by making a quantitative comparison in their representational dissimilarities matrices (RDM)
- The RDM is computed by comparing the response patterns of brain activity
- In summary, their findings “suggest that primate IT across species may host a common code, which combines a categorical and a continuous representation of objects” [1]

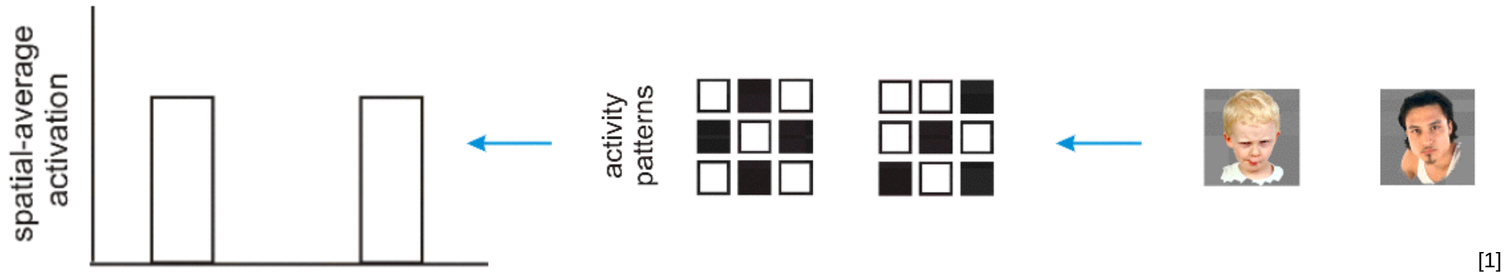


[2]

[1] Kriegeskorte, N., Mur, M., Ruff, D. A., Kiani, R., Bodurka, J., Esteky, H., Tanaka, K., & Bandettini, P. A. (2008). Matching categorical object representations in inferior temporal cortex of man and monkey. Neuron, 60(6), 1126–1141. https://doi.org/10.1016/j.neuron.2008.10.043
[2] http://algonauts.csail.mit.edu/rsa.html

RSA: Patterns are important

- Technique looking at patterns rather than at mean activity
- Spatial-average activation can be the same, but patterns can be very distinct



[1]

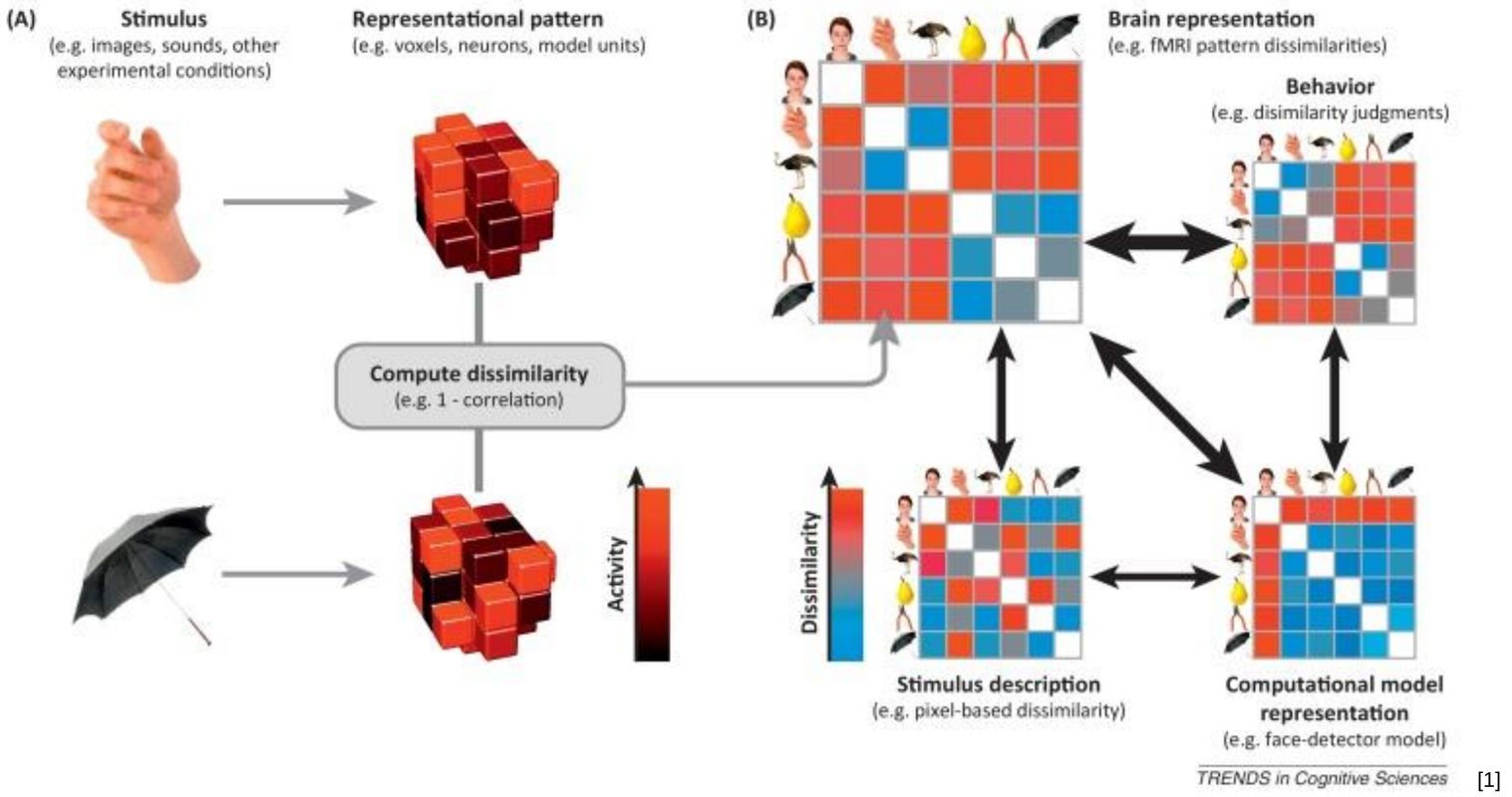
➢ Possible to compare response patterns

Classical approach that was used before revealed regions involved in the processing of particular stimulus classes.

However, it could not reveal how those regions represent particular stimuli. [2]

[1] Kietzman, Tim (2020). Brain lecture 2 – Neural measurement and analysis techniques. Slide 39.
[2] Kriegeskorte, Nikolaus., Mur, M., Ruff, D. A., Kiani, R., Bodurka, J., Esteky, H., Tanaka, K., & Bandettini, P. A. (2008). Matching categorical object representations in inferior temporal cortex of man and monkey. Neuron, 60(6), 1126–1141. https://doi.org/10.1016/j.neuron.2008.10.043

RSA: How it Works

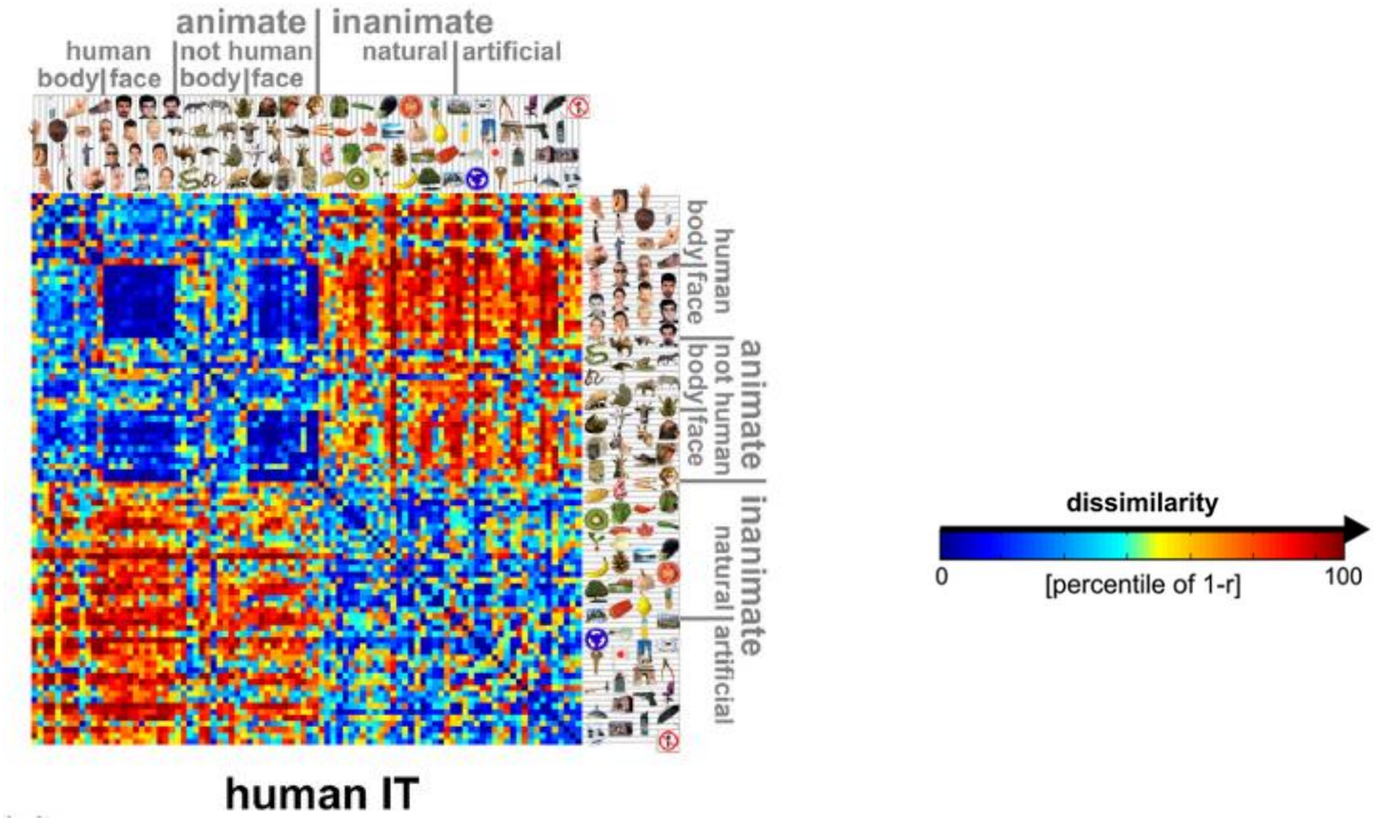


[1]

Representational dissimilarity matrix (RDM) shows which distinctions between stimuli are emphasized and which are deemphasized in the representation. [2]

[1] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3730178/figure/fig0015/
[2] Kriegeskorte, Nikolaus., Mur, M., Ruff, D. A., Kiani, R., Bodurka, J., Esteky, H., Tanaka, K., & Bandettini, P. A. (2008). Matching categorical object representations in inferior temporal cortex of man and monkey. Neuron, 60(6), 1126–1141. https://doi.org/10.1016/j.neuron.2008.10.043

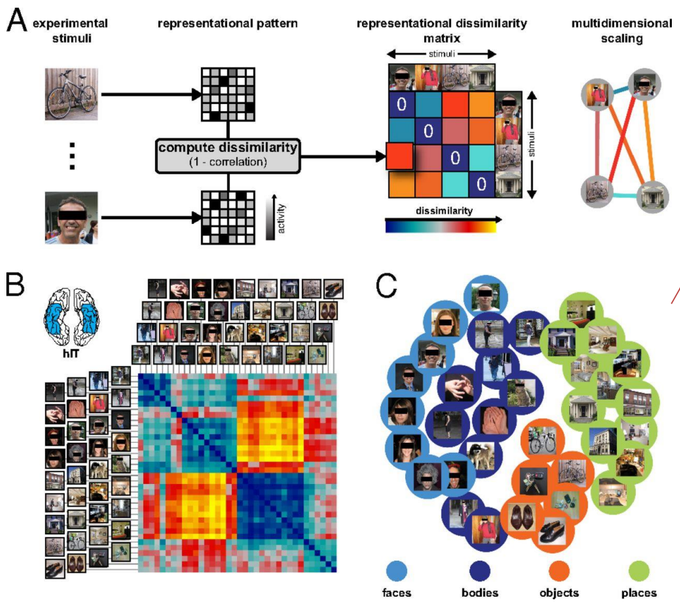
RSA: Human RDM example [1]



For each pair of stimuli, each RDM color codes the dissimilarity of the two response patterns elicited by the stimuli in IT.

[1] All sources from Kriegeskorte, Nikolaus., Mur, M., Ruff, D. A., Kiani, R., Bodurka, J., Esteky, H., Tanaka, K., & Bandettini, P. A. (2008). Matching categorical object representations in inferior temporal cortex of man and monkey. Neuron, 60(6), 1126–1141. https://doi.org/10.1016/j.neuron.2008.10.043

RSA: Clusters

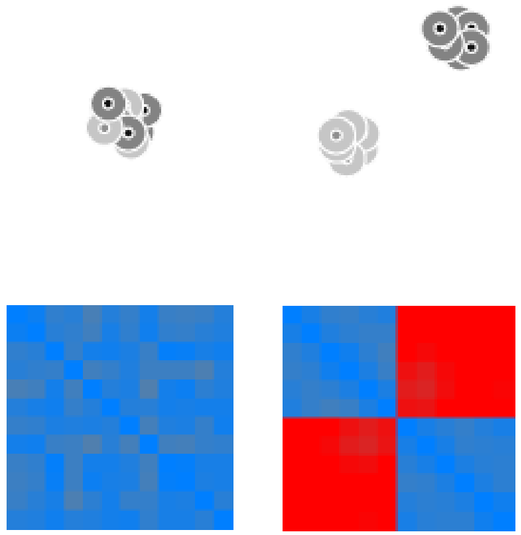


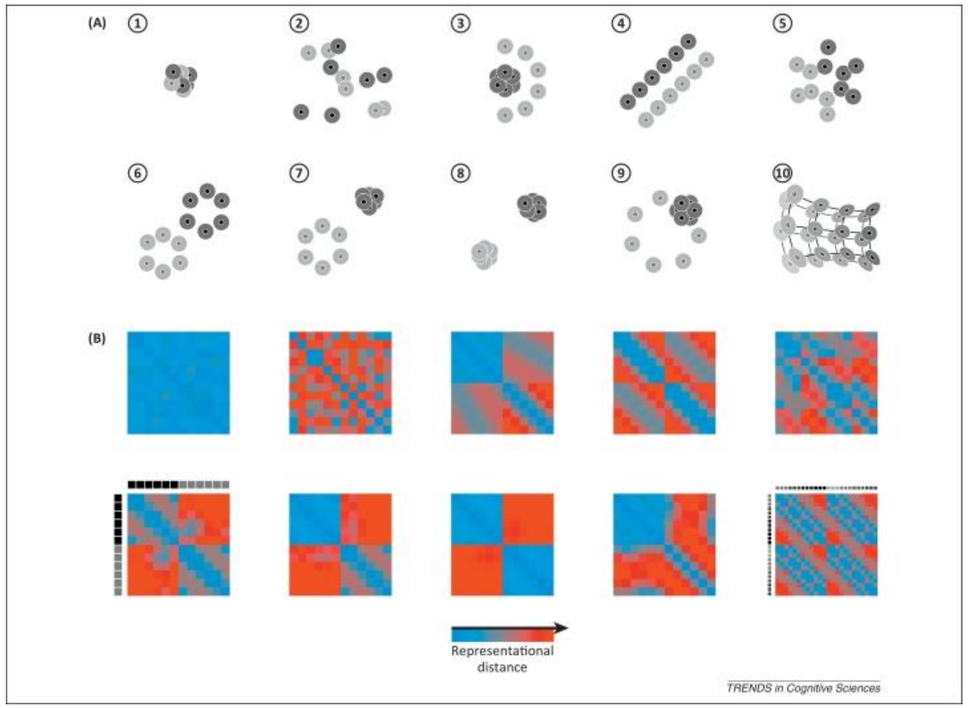
[1]

Not only we can observe single pairs of different stimuli, but also clusters of different stimuli and see how they group by.

[1] https://www.pnas.org/content/111/40/14565

RSA: Representational geometries and their reflection in distance matrices





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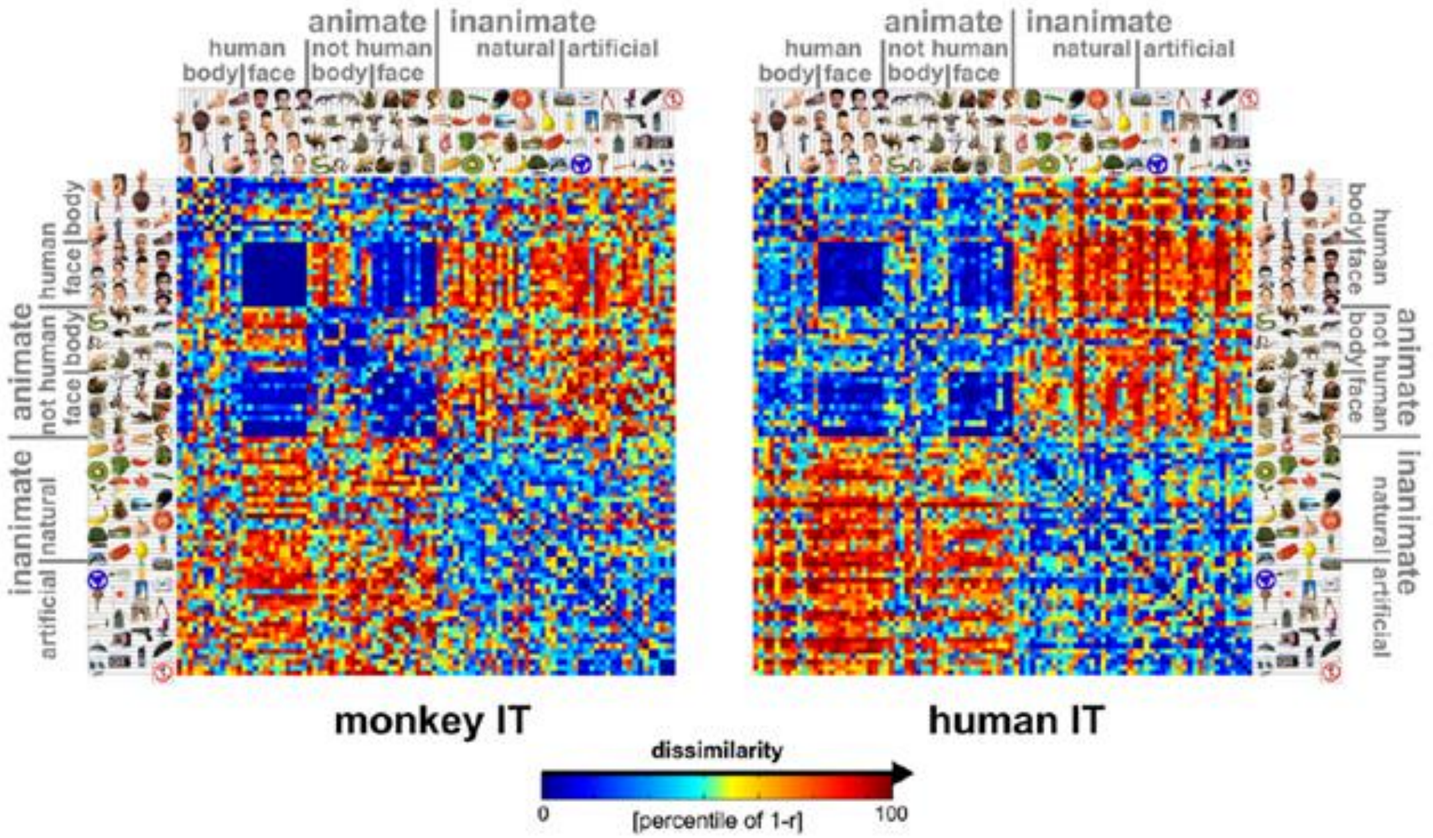
Not only we can observe single pairs of different stimuli, but also clusters of different stimuli and see how they group by.

[1] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3730178/figure/fig0005/

Results: Usefulness of RSA



- RDMs allow us to compare the representations between the species
- A striking match
- Two stimuli (object images) tend to be dissimilar to the same extent in the human and monkey IT representations

[1] Kriegeskorte, Nikolaus., Mur, M., Ruff, D. A., Kiani, R., Bodurka, J., Esteky, H., Tanaka, K., & Bandettini, P. A. (2008). Matching categorical object representations in inferior temporal cortex of man and monkey. Neuron, 60(6), 1126–1141. https://doi.org/10.1016/j.neuron.2008.10.043

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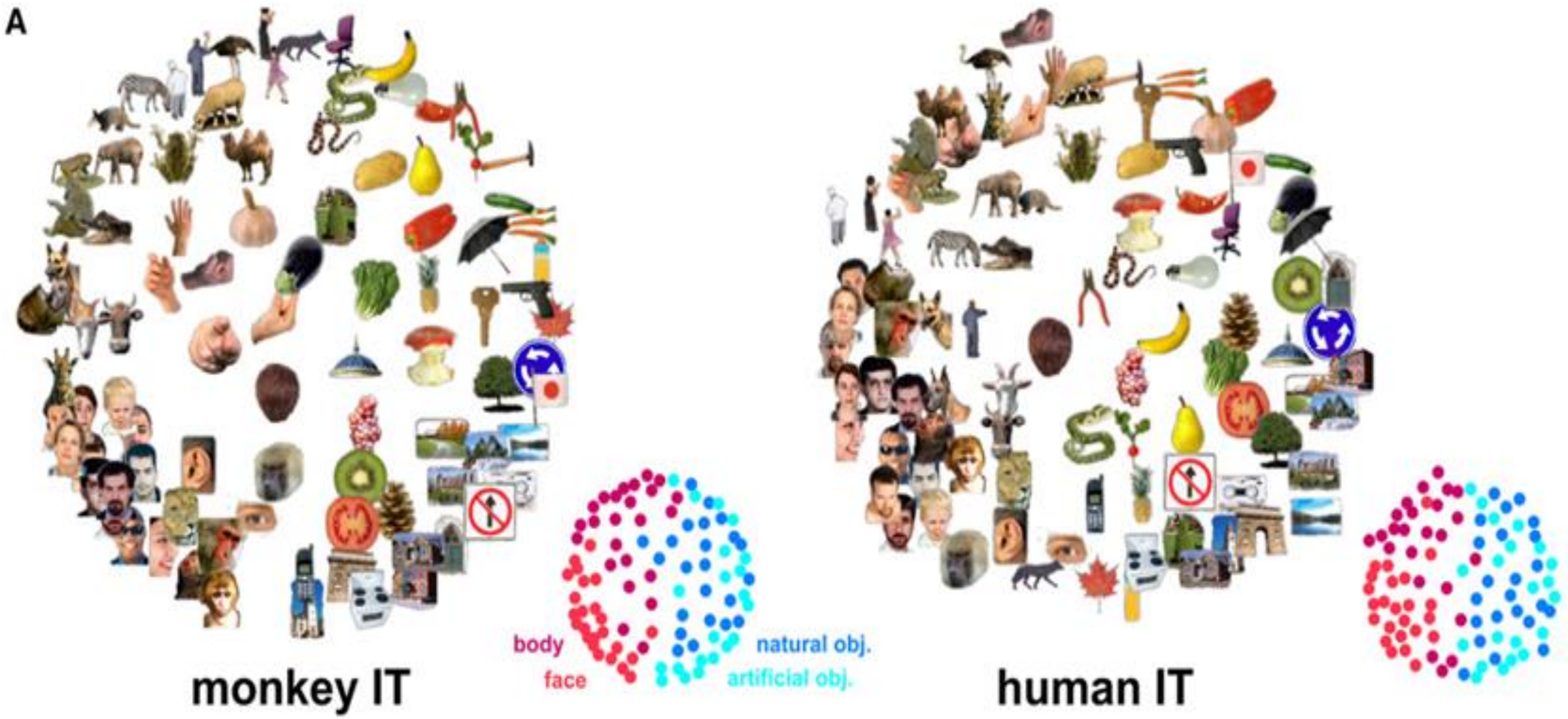

[1]

- Visualisation
- Categorical distinctions

animates ←→ inanimates

faces ←→ bodies
(among the animates)

[1] Kriegeskorte, Nikolaus., Mur, M., Ruff, D. A., Kiani, R., Bodurka, J., Esteky, H., Tanaka, K., & Bandettini, P. A. (2008). Matching categorical object representations in inferior temporal cortex of man and monkey. Neuron, 60(6), 1126–1141. https://doi.org/10.1016/j.neuron.2008.10.043

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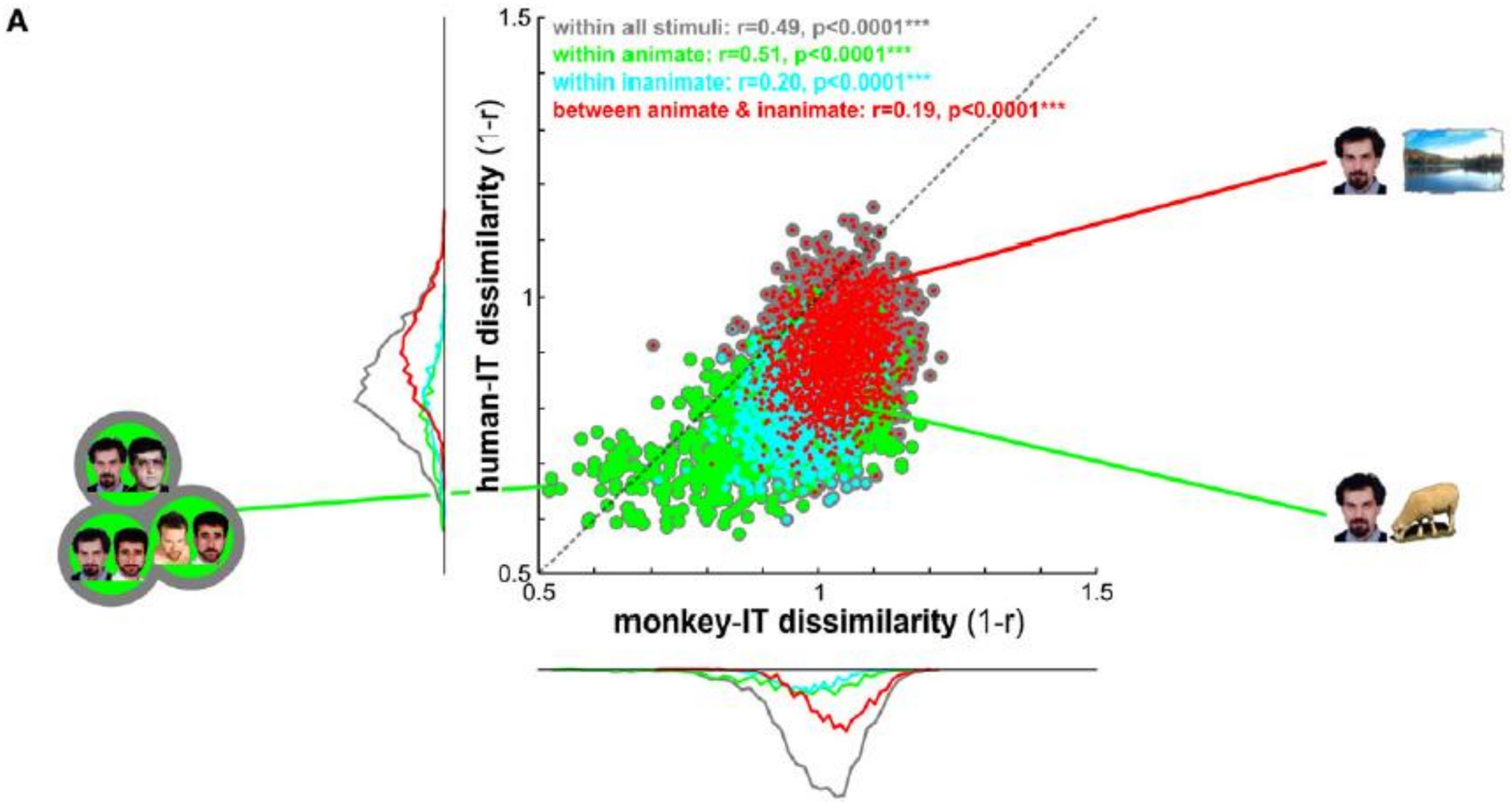
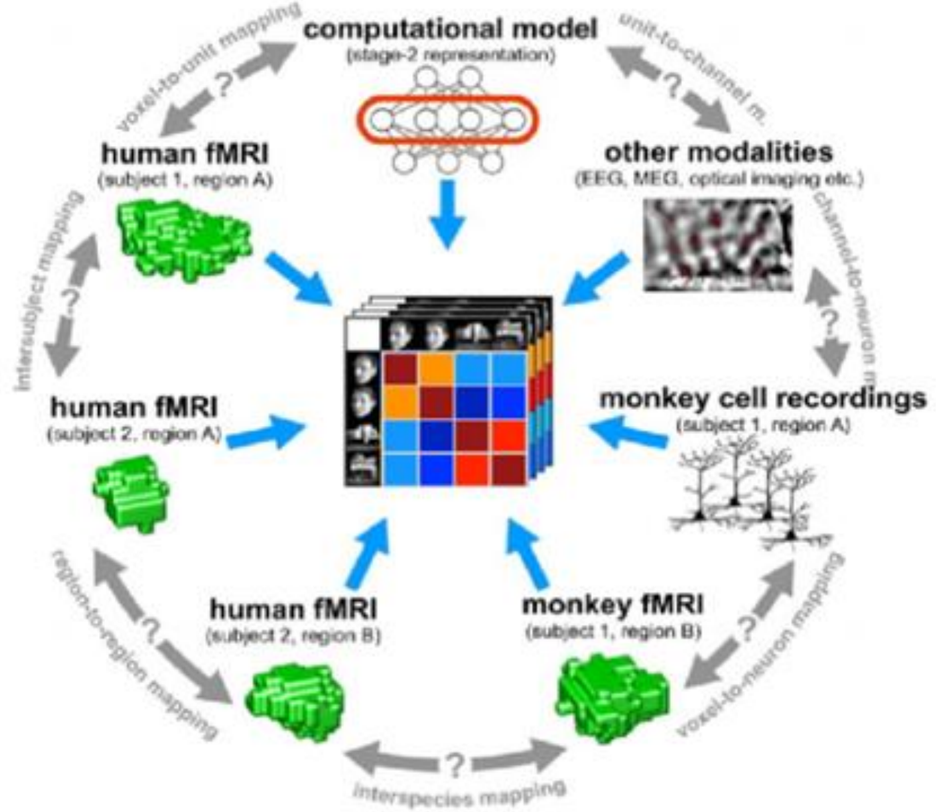


- Quantification of the results
- Smaller dissimilarities within categories
- Largest dissimilarity
  → animate-inanimate
- Smallest dissimilarity
  → between faces

[1] Kriegeskorte, Nikolaus., Mur, M., Ruff, D. A., Kiani, R., Bodurka, J., Esteky, H., Tanaka, K., & Bandettini, P. A. (2008). Matching categorical object representations in inferior temporal cortex of man and monkey. Neuron, 60(6), 1126–1141. https://doi.org/10.1016/j.neuron.2008.10.043

Usefulness of RSA



Representational similarity analysis allows us to make comparisons between

- species (human-monkey)
- measurement modalities (fMRI – cell recordings)
- brain regions
- biological brains and computational models

[1] Kriegeskorte, Nikolaus., Mur, M., Ruff, D. A., Kiani, R., Bodurka, J., Esteky, H., Tanaka, K., & Bandettini, P. A. (2008). Matching categorical object representations in inferior temporal cortex of man and monkey. Neuron, 60(6), 1126–1141. https://doi.org/10.1016/j.neuron.2008.10.043

Discussion

- Are there bigger dissimilarities in the human representation of human faces than in the monkey representation of human faces or vice versa?

- Can RSA be used to compare other species' (apart from humans and monkeys) stimuli representations?