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Introduction to Representational Similarity Analysis



By: Hamza Abdelhedi



Objectives

- Understanding Representational Similarity Analysis (RSA) and Representational Dissimilarity Matrices (RDMs)
- Time resolved RSA
- Challenges and Limitations, and Mitigation Strategies.
- Steps to perform RSA
- Hands On Tutorial

History...

History...

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ORIGINAL RESEARCH article

Front. Syst. Neurosci., 23 November 2008

Volume 2 - 2008 | <https://doi.org/10.3389/neuro.06.004.2008>

Representational similarity analysis – connecting the branches of systems neuroscience

Nikolaus Kriegeskorte^{1,*}, Marieke Mur^{1,2} and Peter Bandettini¹¹ Section on Functional Imaging Methods, Laboratory of Brain and Cognition, National Institute of Mental Health, National Institutes of Health, Bethesda, MD, USA² Department of Cognitive Neuroscience, Faculty of Psychology, Maastricht University, Maastricht, The Netherlands

A fundamental challenge for systems neuroscience is to quantitatively relate its three major branches of research: brain-activity measurement, behavioral measurement, and computational modeling. Using measured brain-activity patterns to evaluate computational network models is complicated by the need to define the correspondence between the units of the model and the channels of the brain-activity data, e.g., single-cell recordings or voxels from functional magnetic resonance imaging (fMRI). Similar correspondence problems complicate relating activity patterns between different modalities of brain-activity measurement (e.g., fMRI and invasive or scalp electrophysiology), and between subjects and species. In order to bridge these divides, we suggest abstracting from the activity patterns themselves and computing representational dissimilarity matrices (RDMs), which characterize the information carried by a

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Volume 2 - 2008 | https://doi.org/10.3389/neuro.06.004.2008

Representational similarity analysis – connecting the branches of systems neuroscience

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RESEARCH ARTICLE

A Toolbox for Representational Similarity Analysis

Hamed Nili, Cai Wingfield, Alexander Walther, Li Su, William Marslen-Wilson, Niklaus Kriegeskorte

Published: April 17, 2014 • https://doi.org/10.1371/journal.pcbi.1003553

Article	Authors	Metrics	Comments	Media Coverage
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Abstract

Introduction

Results

Additional Analysis

Options

Discussion

Abstract

Neuronal population codes are increasingly being investigated with multivariate pattern-information analyses. A key challenge is to use measured brain-activity patterns to test computational models of brain information processing. One approach to this problem is representational similarity analysis (RSA), which characterizes a representation in a brain or computational model by the distance matrix of the response patterns elicited by a set of stimuli. The representational distance matrix encapsulates what distinctions between stimuli are emphasized and what distinctions are de-emphasized in the representation. A model is tested

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RESEARCH ARTICLE

Representational models: A common framework for understanding encoding, pattern-component, and representational-similarity analysis

Jörn Diedrichsen, Niklaus Kriegeskorte

Version 2



Published: April 24, 2017 • https://doi.org/10.1371/journal.pcbi.1005508

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Abstract

Author summary
Introduction
Materials and methods
Results
Discussions

Abstract

Representational models specify how activity patterns in populations of neurons (or, more generally, in multivariate brain-activity measurements) relate to sensory stimuli, motor responses, or cognitive processes. In an experimental context, representational models can be defined as hypotheses about the distribution of activity profiles across experimental conditions. Currently, three different methods are being used to test such hypotheses: encoding analysis, pattern component modeling (PCM), and representational similarity analysis (RSA). Here we

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The topology and geometry of neural representations

Baihan Lin and Niklaus Kriegeskorte

Edited by Terrence Sejnowski, Salk Institute for Biological Studies, La Jolla, CA; received October 13, 2023; accepted July 24, 2024

October 7, 2024 | 121 (42) e2317881121 | https://doi.org/10.1073/pnas.2317881121

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Bell Book

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Significance

Characterizing the representations encoded in patterns of neural activity is key to understanding brain computation. Representational similarity analysis uses the geometry of neural population response patterns to compare representations between brains and models. We propose topological representational similarity analysis (tRSA) to also

Time-resolved RSA

Time-resolved RSA

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Volume 158, September 2017, Pages 441-454



Multivariate pattern analysis of MEG and EEG: A comparison of representational structure in time and space

Radoslaw Martin Cichy ^a  , Dimitrios Pantazis ^b

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RESEARCH ARTICLE | BIOLOGICAL SCIENCES | 



Recurrence is required to capture the representational dynamics of the human visual system

Tim C. Kietzmann , Courtney J. Spoerer, Lynn K. A. Sørensen,  +2, and Nikolaus Kriegeskorte [Authors Info & Affiliations](#)

Edited by Terrence J. Sejnowski, Salk Institute for Biological Studies, La Jolla, CA, and approved September 17, 2019 (received for review April 8, 2019)

October 7, 2019 | 116 (43) 21854-21863 | <https://doi.org/10.1073/pnas.1905544116>

 24,350 | 186



Before we start:

Before we start:

What is ...
Representation?

Before we start:

What is ...

Representation?

Representational space?

Before we start:

What is ...

Representation?

Representational space?

Representational geometry ?

Representation...

Representation...

PERSPECTIVES / DEFINING REPRESENTATIONS

What are we talking about? Clarifying the fuzzy concept of representation in neuroscience and beyond

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The physics of representation

Interdisciplinary Perspectives on Locating Representations in Brain | [Open access](#) | Published

Volume 199, pages 1307–1325, (2021) [Cite this article](#)

To foster discourse, scientists need to account for all the different ways they use the term “representation.”

BY FRANCIS T. FALLON, TOMÁS J. RYAN, JOHN W. KRAKAUER, THE RPPF GROUP

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Representation...

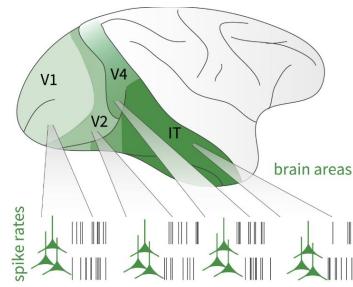
Representation...

... patterns of activity that bear a systematic relationship to the structure of the external world and play a causal role in behavior ...

Russ Poldrack

Representation...

... patterns of activity that bear a systematic relationship to the structure of the external world and play a causal role in behavior ...

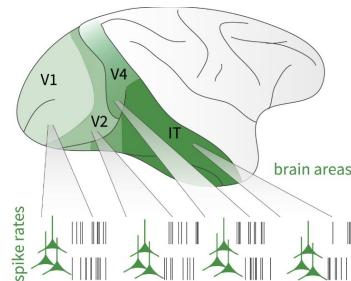
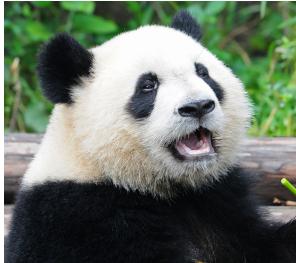


Russ Poldrack

Behavior:
Panda
Animal

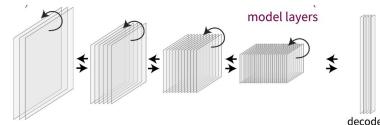
Representation...

... patterns of activity that bear a systematic relationship to the structure of the external world and play a causal role in behavior ...



Russ Poldrack

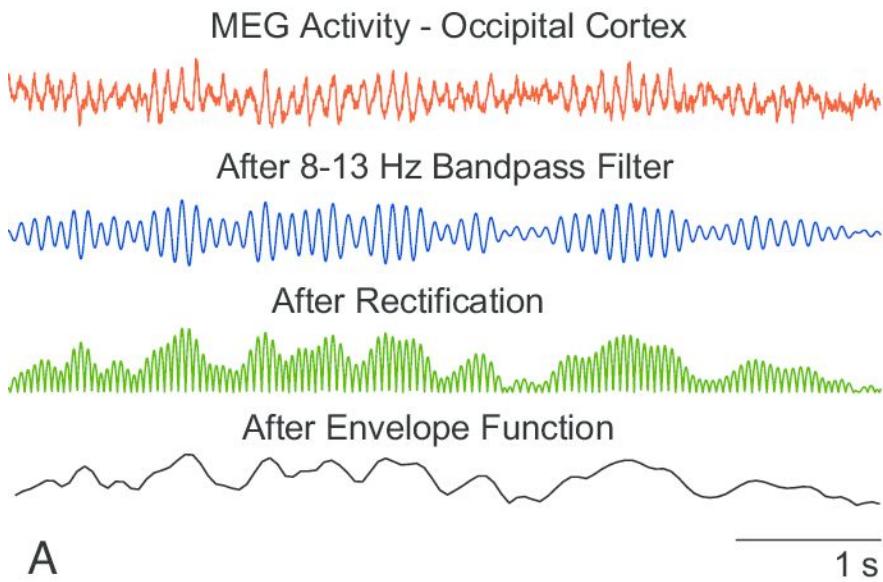
Behavior:
Panda
Animal



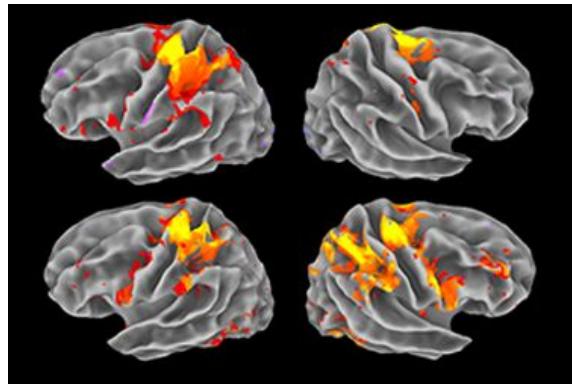
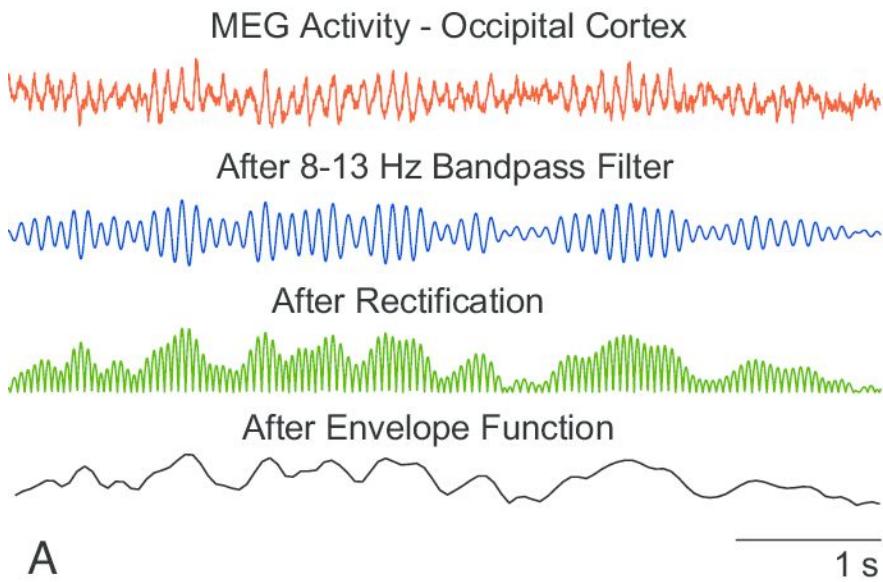
Behavior:
Panda
Animal

Representation...

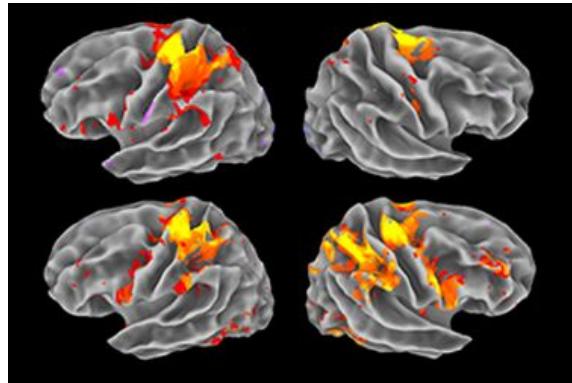
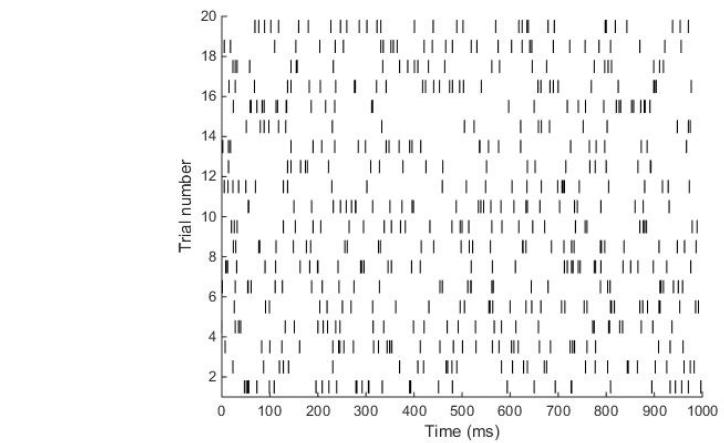
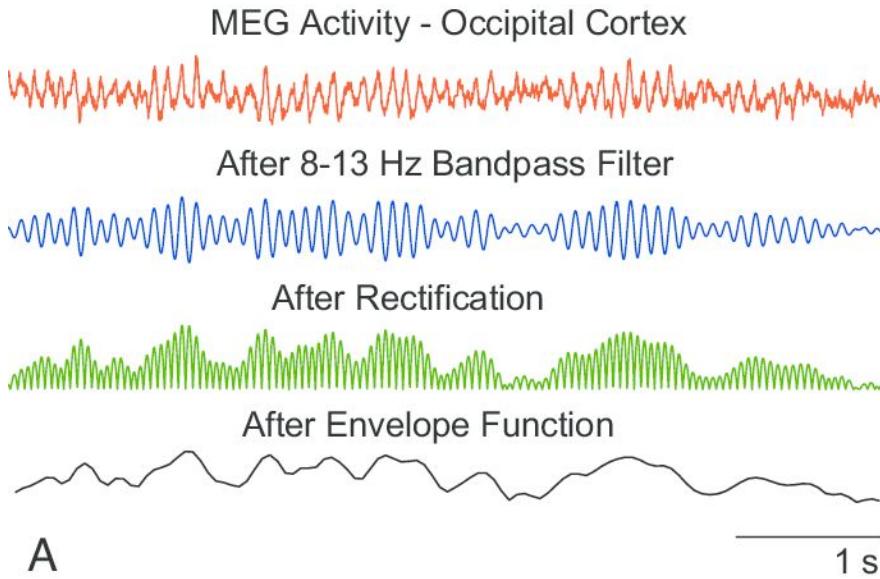
Representation...



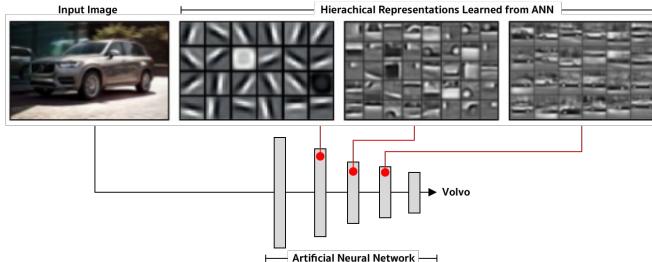
Representation...



Representation...



Representation...



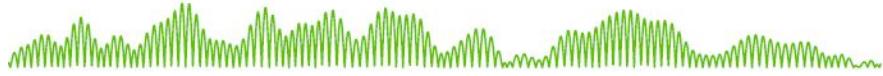
MEG Activity - Occipital Cortex



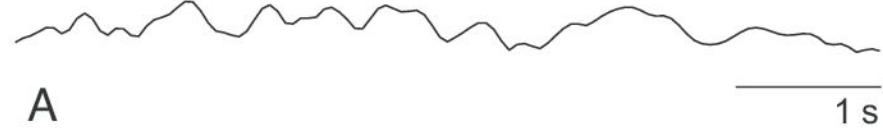
After 8-13 Hz Bandpass Filter



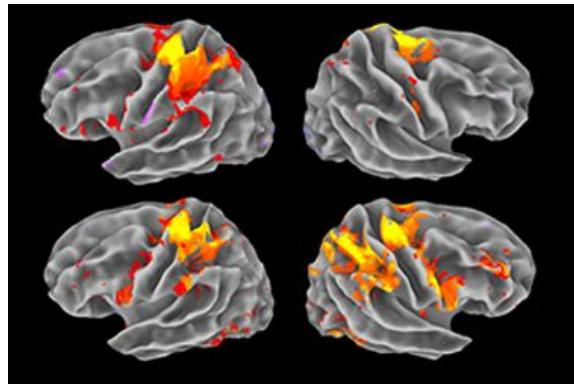
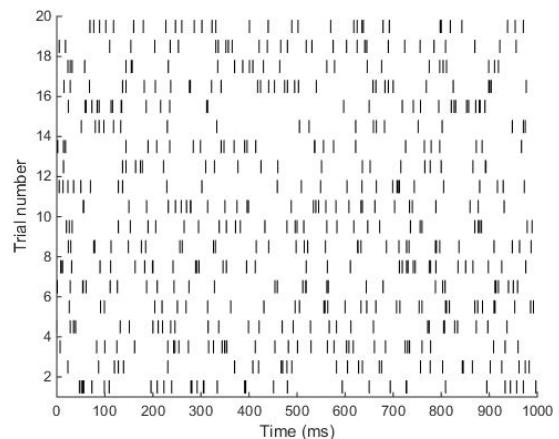
After Rectification



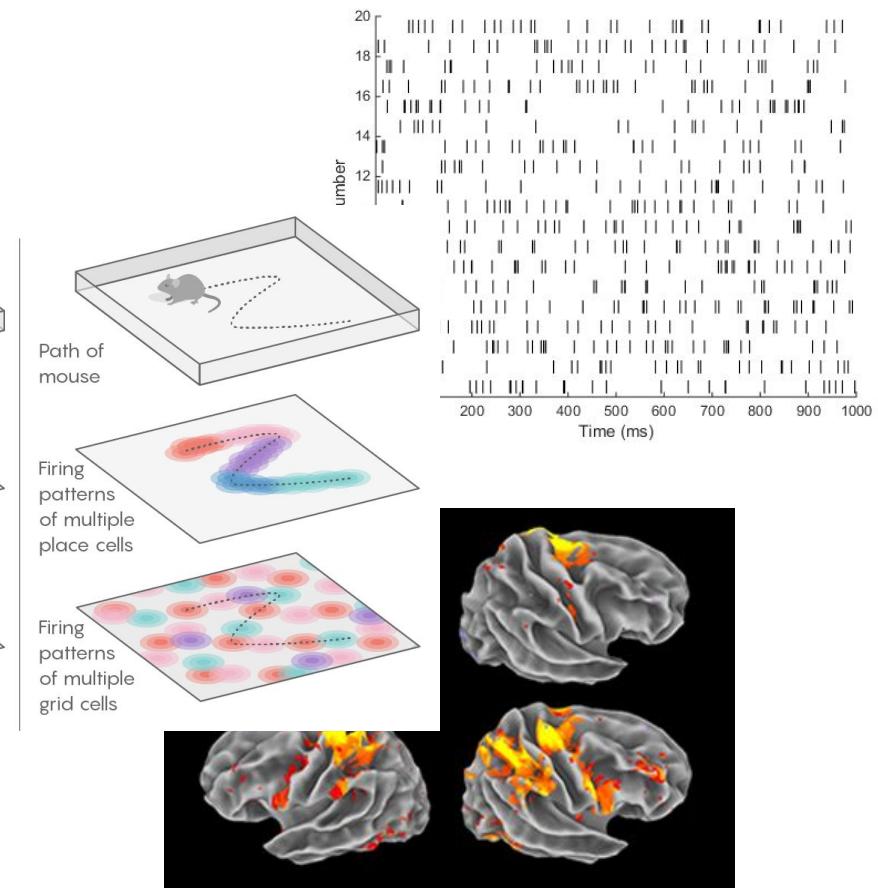
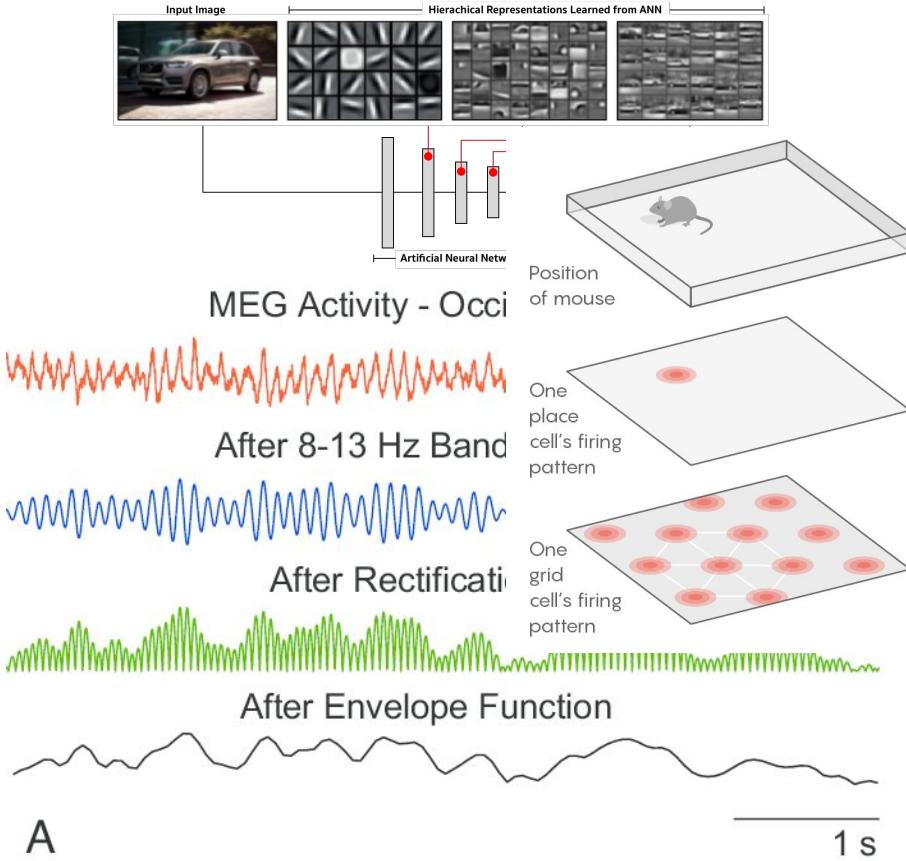
After Envelope Function



A



Representation...



Challenges in studying representations...

Challenges in studying representations...

..different to compare representations from different systems or models

Representational space...

Representational space...

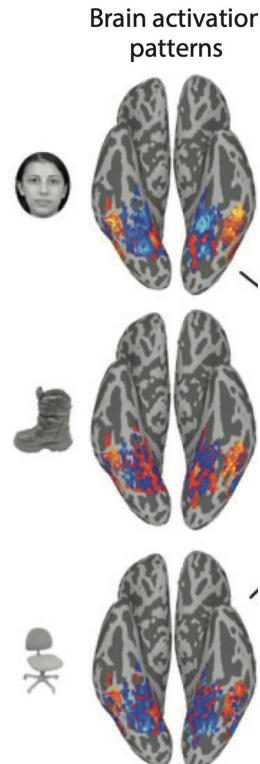
REPRESENTATIONAL SPACE

Representational space is a high-dimensional space in which each neural response or stimulus is expressed as a vector with different values for each dimension. In a neural representational space, each pattern feature is a measure of local activity, such as a voxel or a single neuron. In a stimulus representational space, each feature is a stimulus attribute, such as a physical attribute or semantic label.

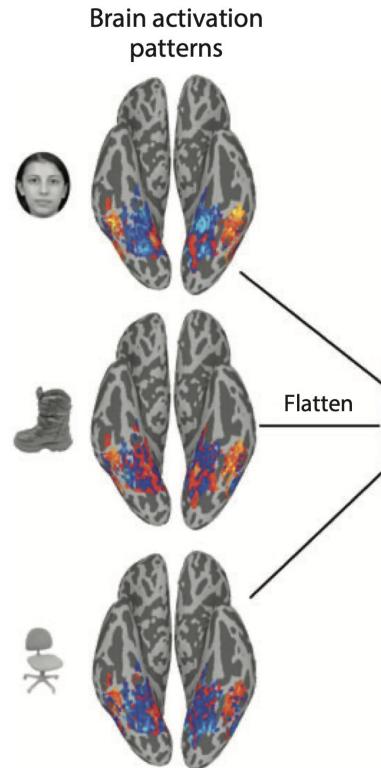
Representational space...



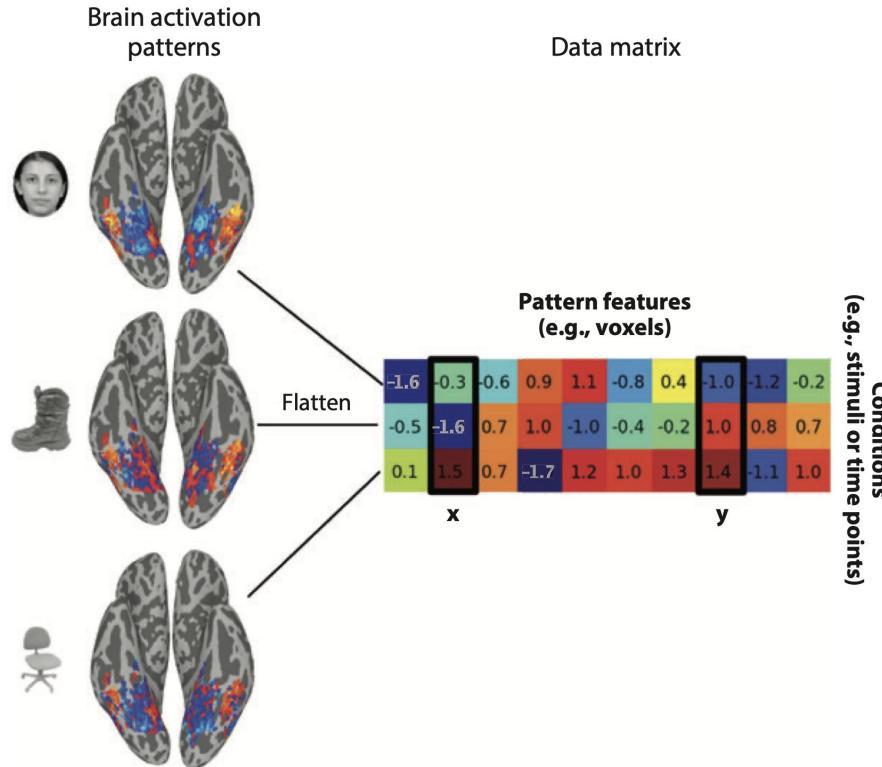
Representational space...



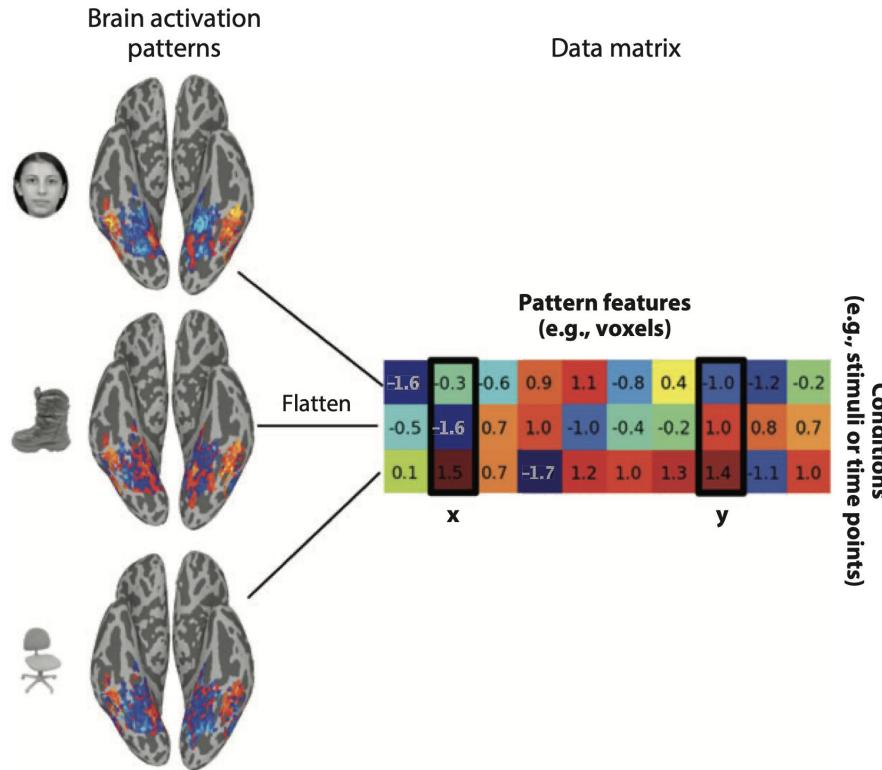
Representational space...



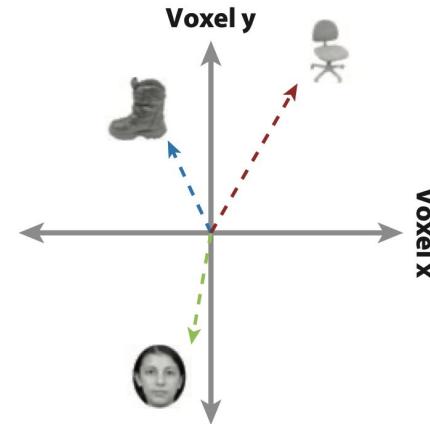
Representational space...



Representational space...

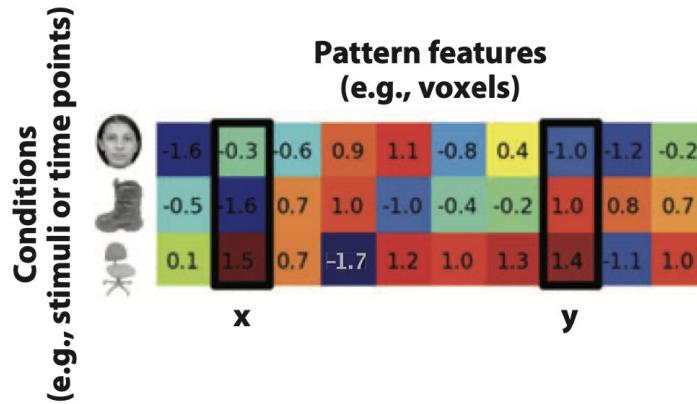


Representational space of 2-voxel brain

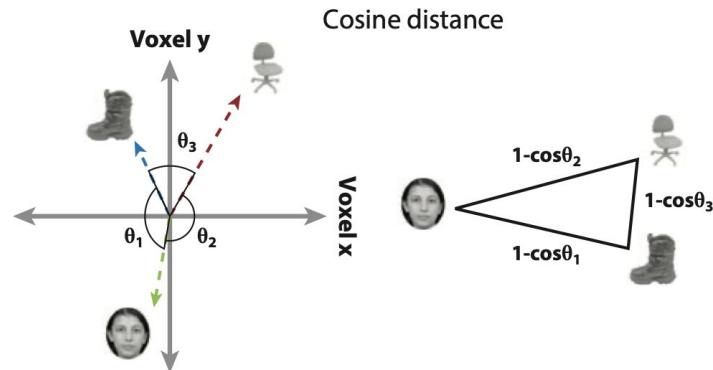
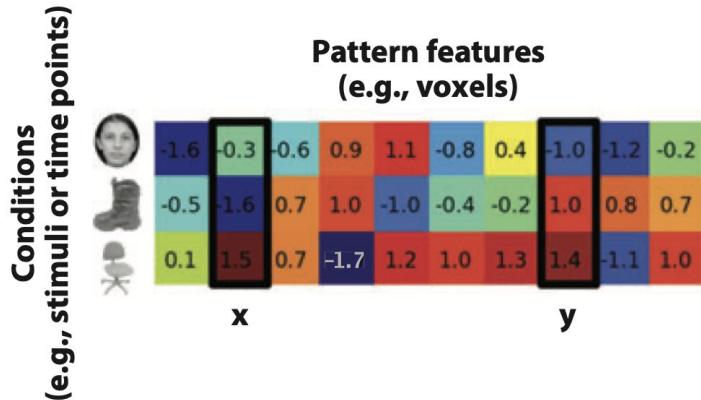


Representational geometry...

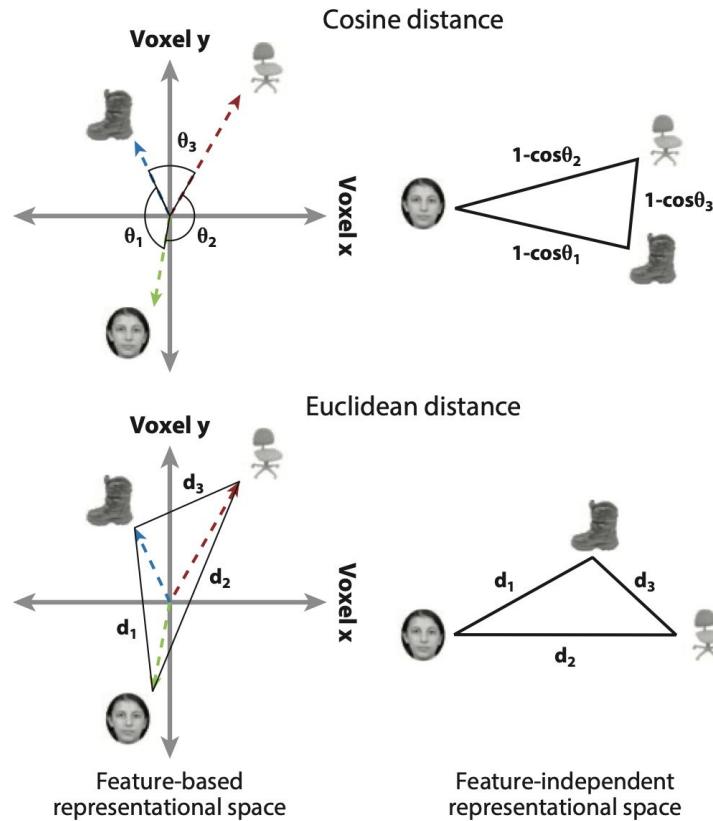
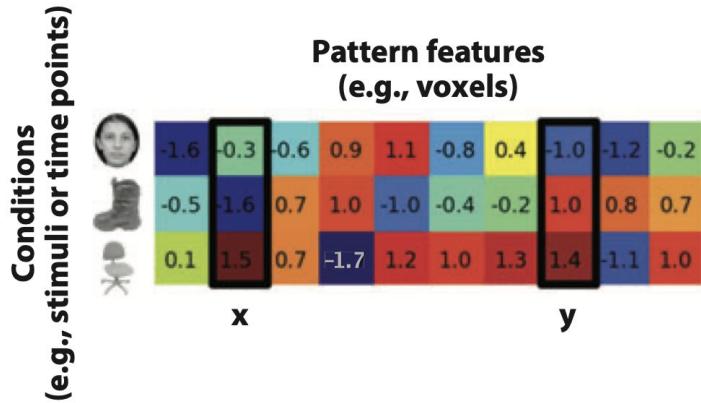
Representational geometry...



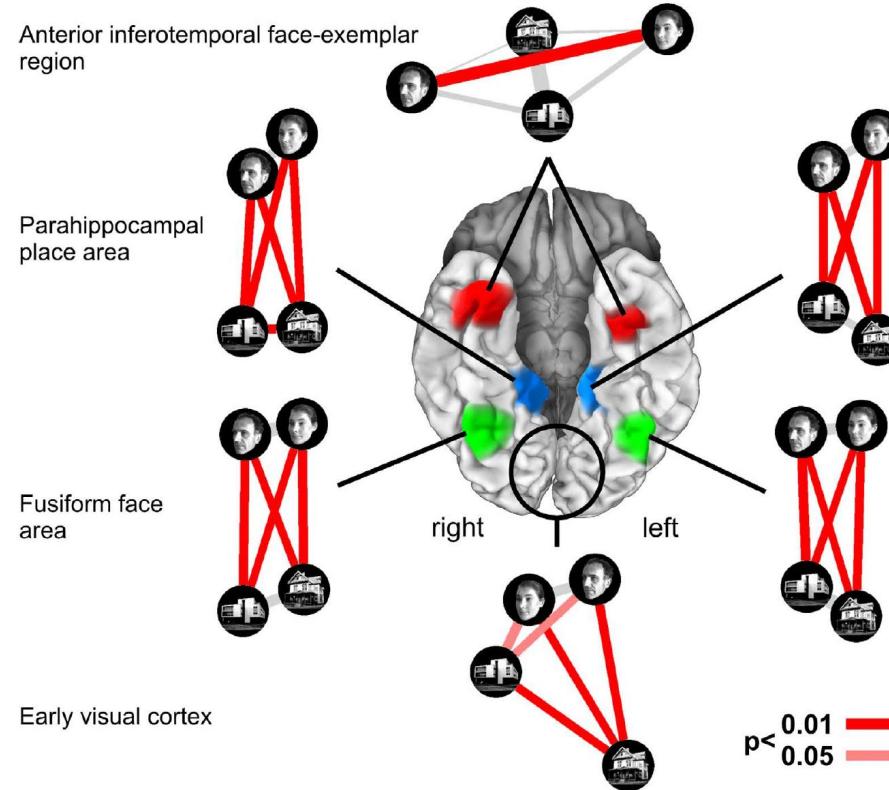
Representational geometry...



Representational geometry...



Representational geometry...



Representational dissimilarity matrices...

Representational dissimilarity matrices...

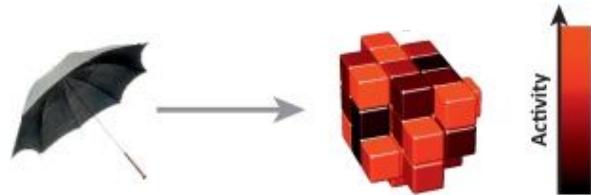
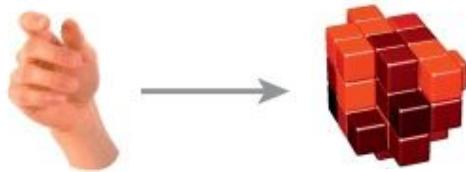
(A) **Stimulus**
(e.g. images, sounds, other
experimental conditions)



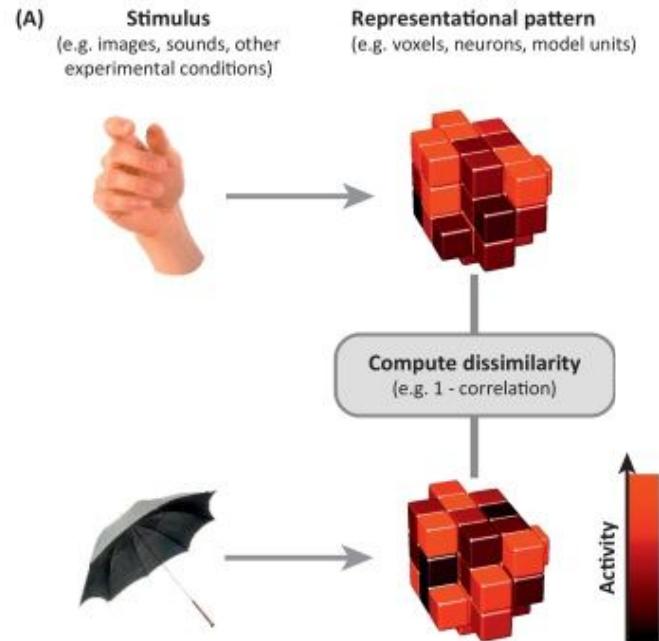
Representational dissimilarity matrices...

(A) **Stimulus**
(e.g. images, sounds, other experimental conditions)

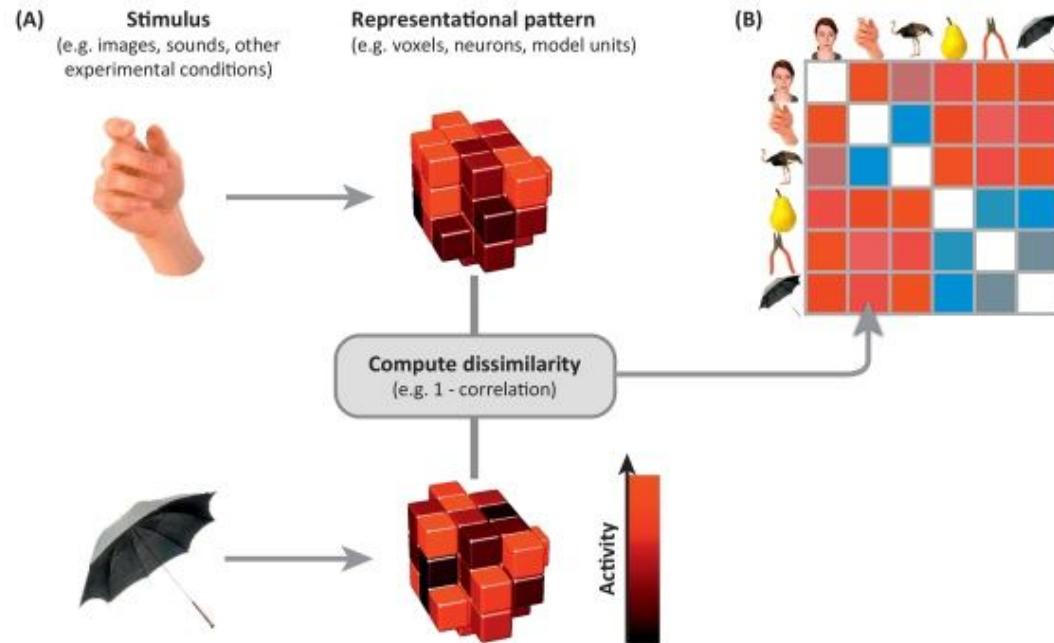
Representational pattern
(e.g. voxels, neurons, model units)



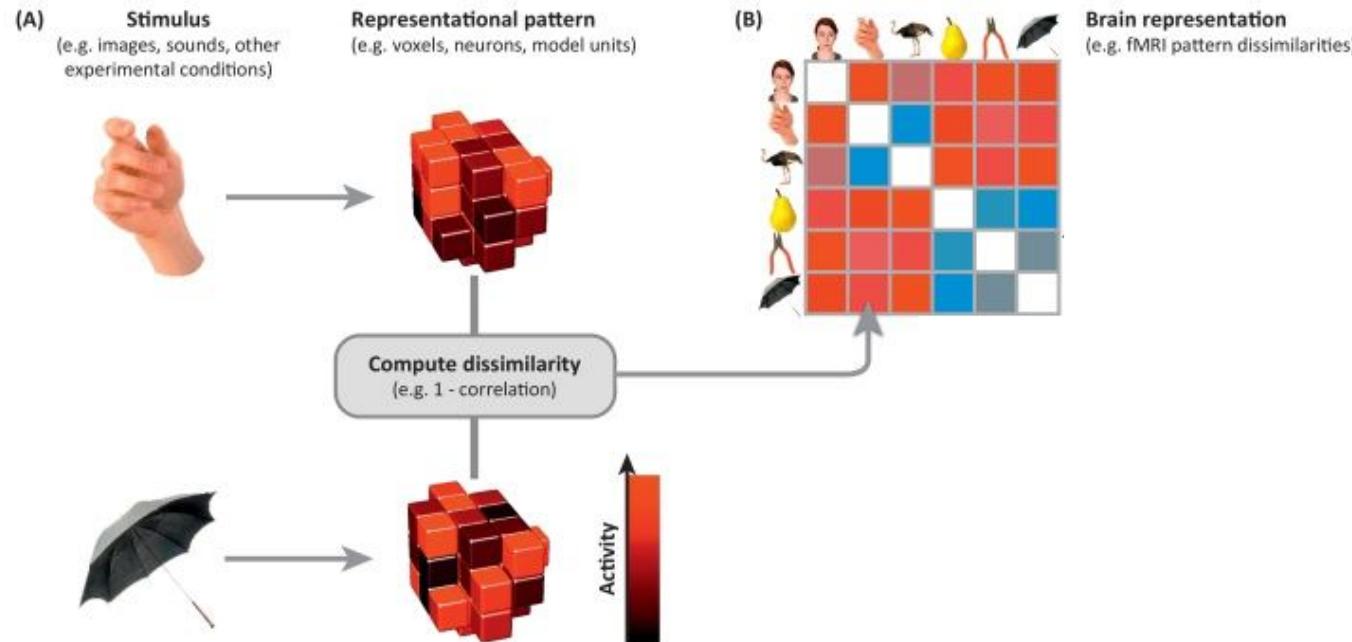
Representational dissimilarity matrices...



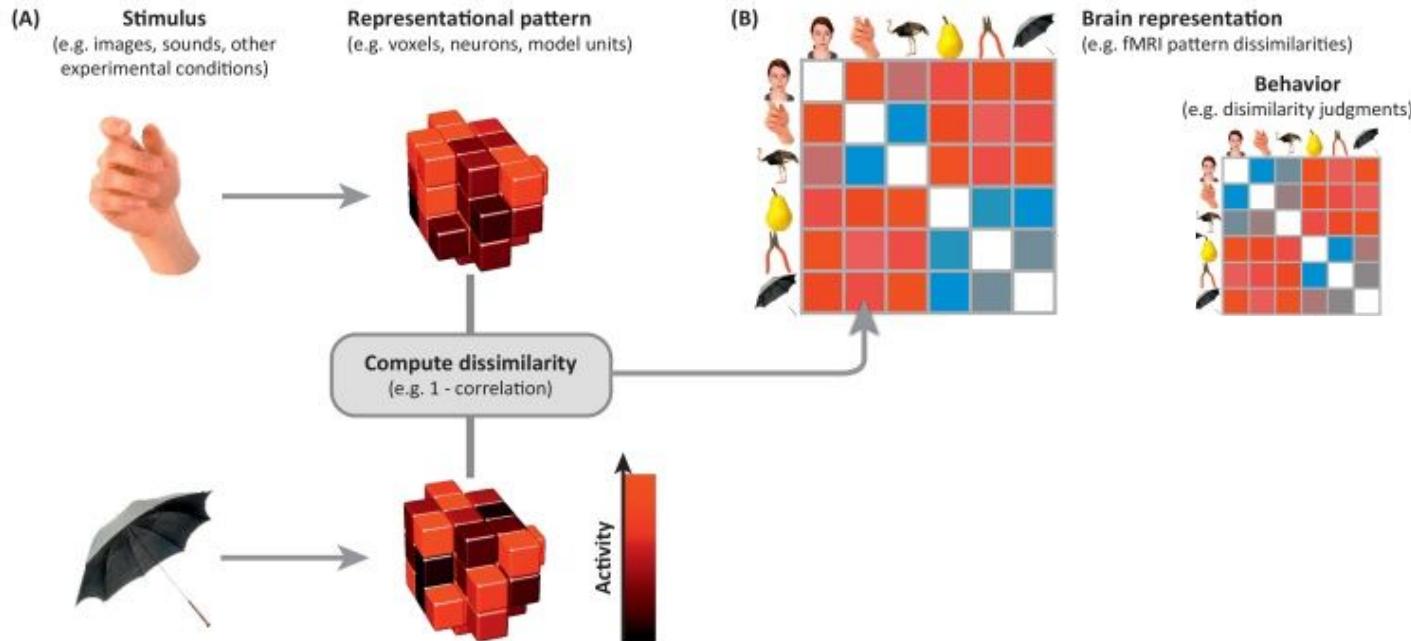
Representational dissimilarity matrices...



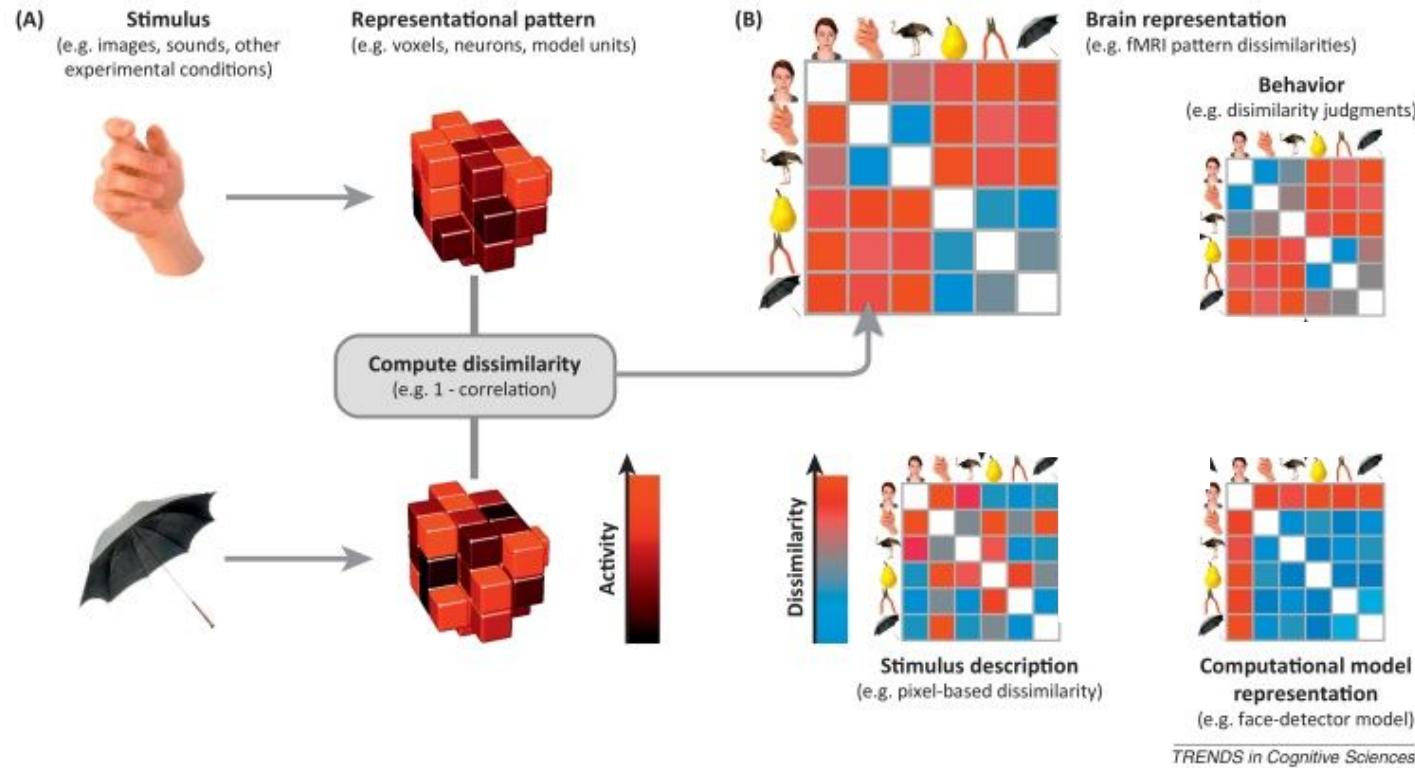
Representational dissimilarity matrices...



Representational dissimilarity matrices...

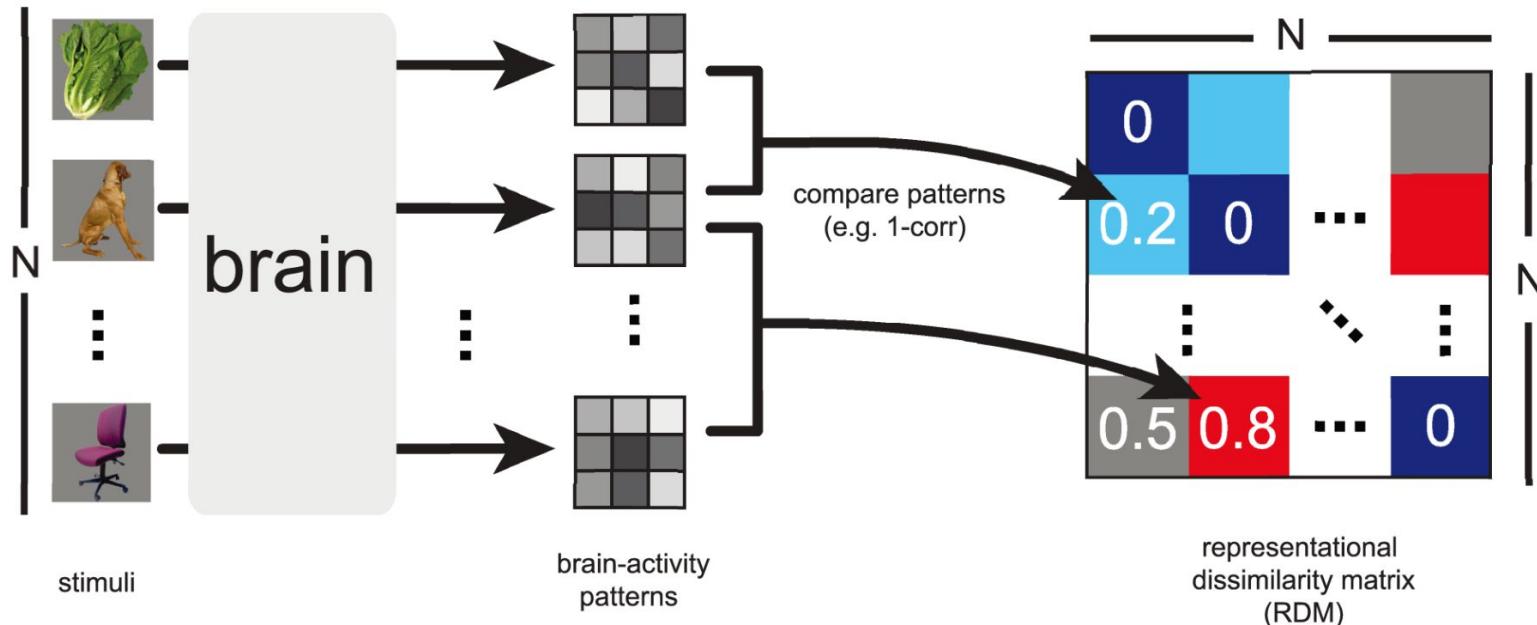


Representational dissimilarity matrices...



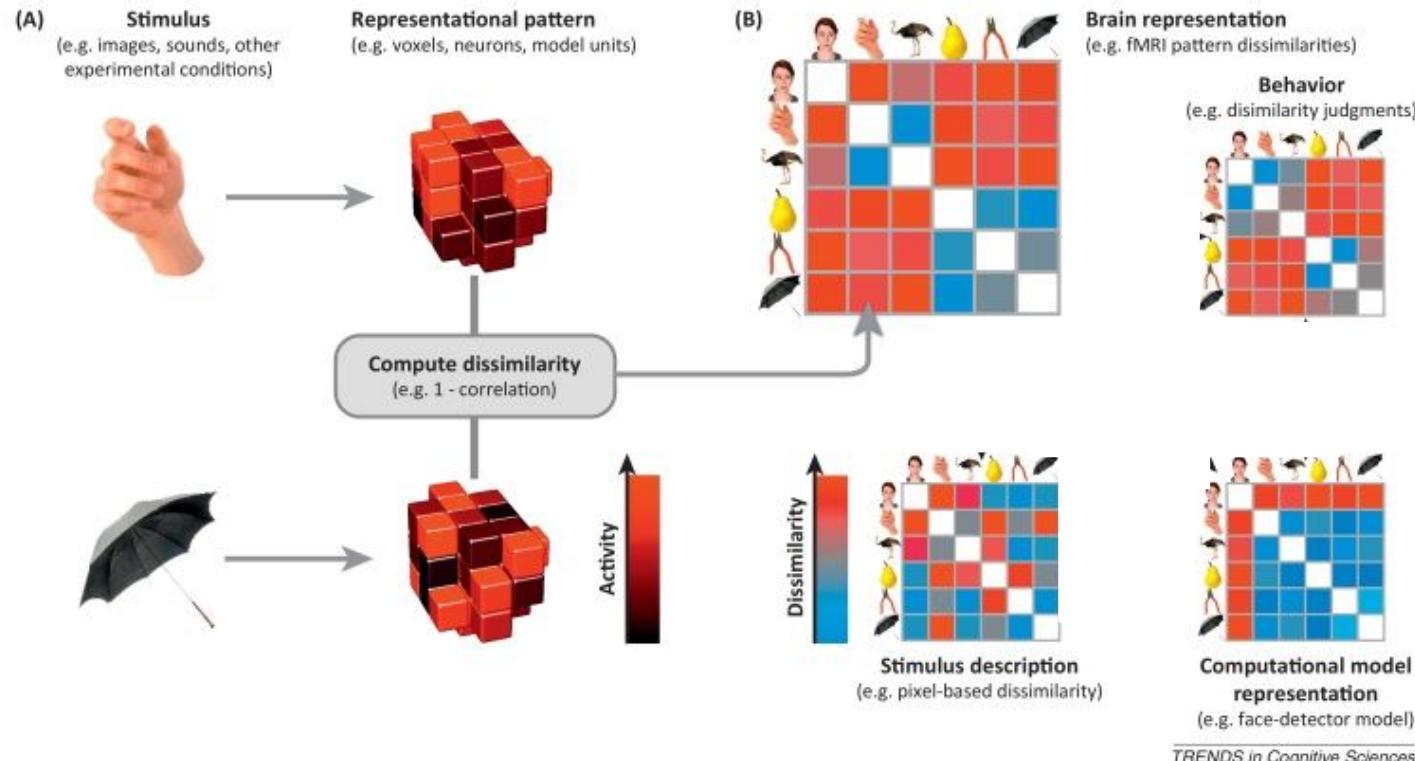
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Representational dissimilarity matrices... (more details)



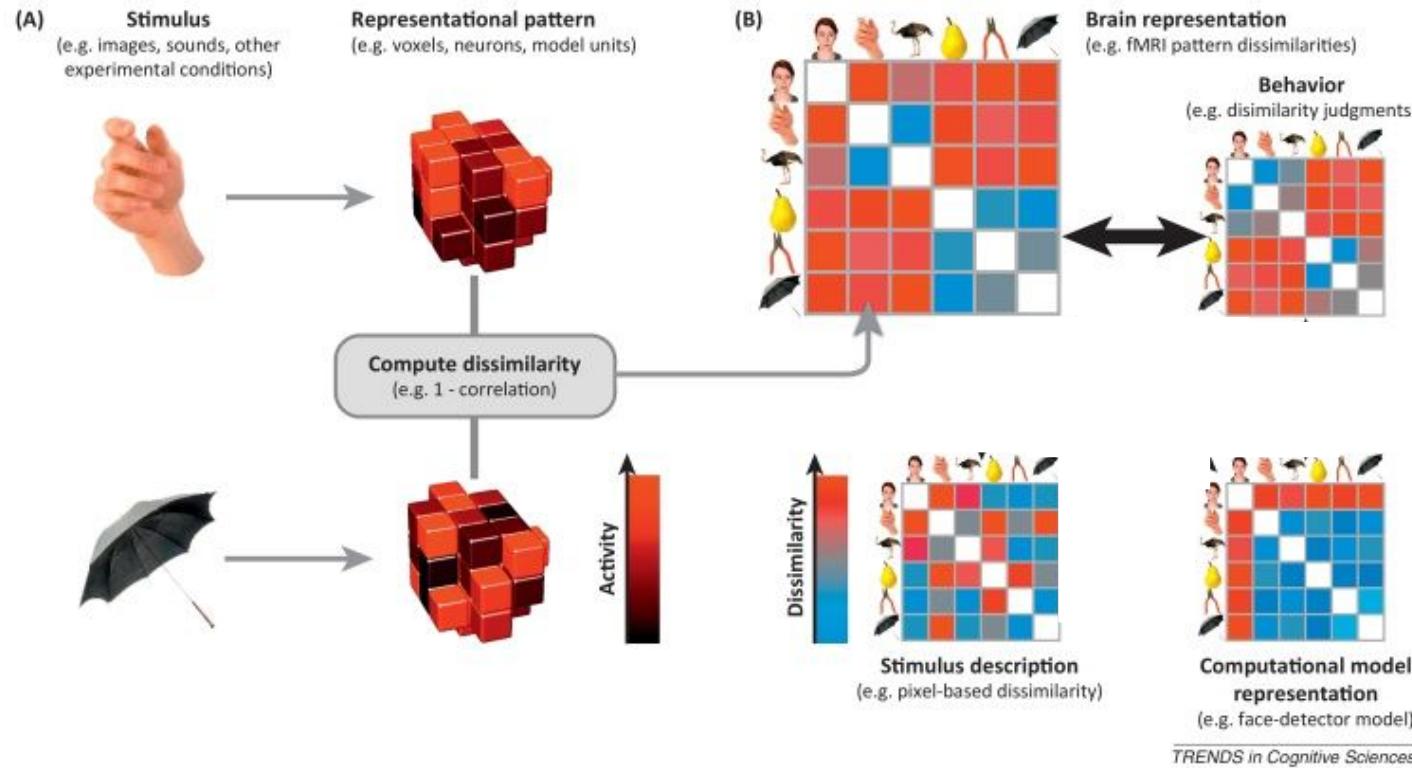
Representational Similarity Analysis...

Representational Similarity Analysis...



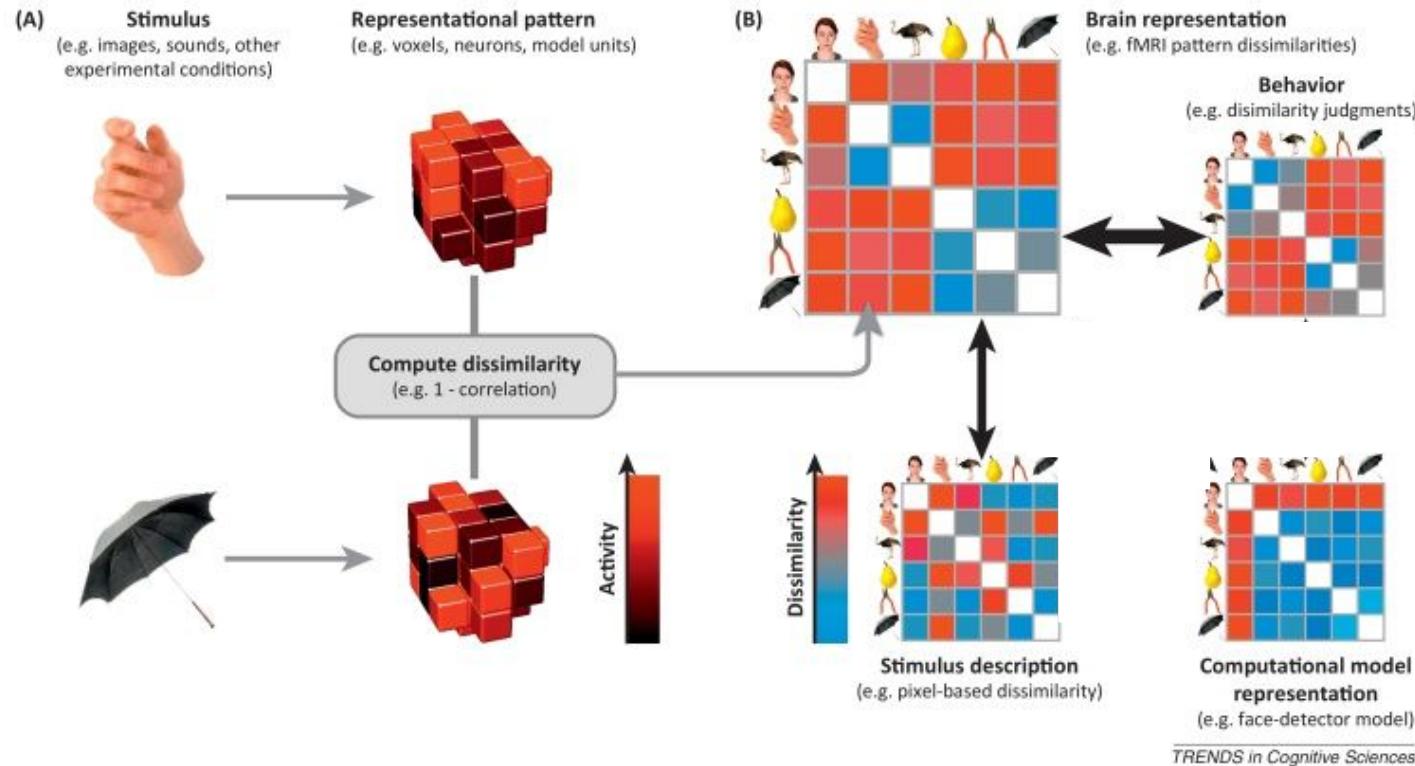
TRENDS in Cognitive Sciences

Representational Similarity Analysis...



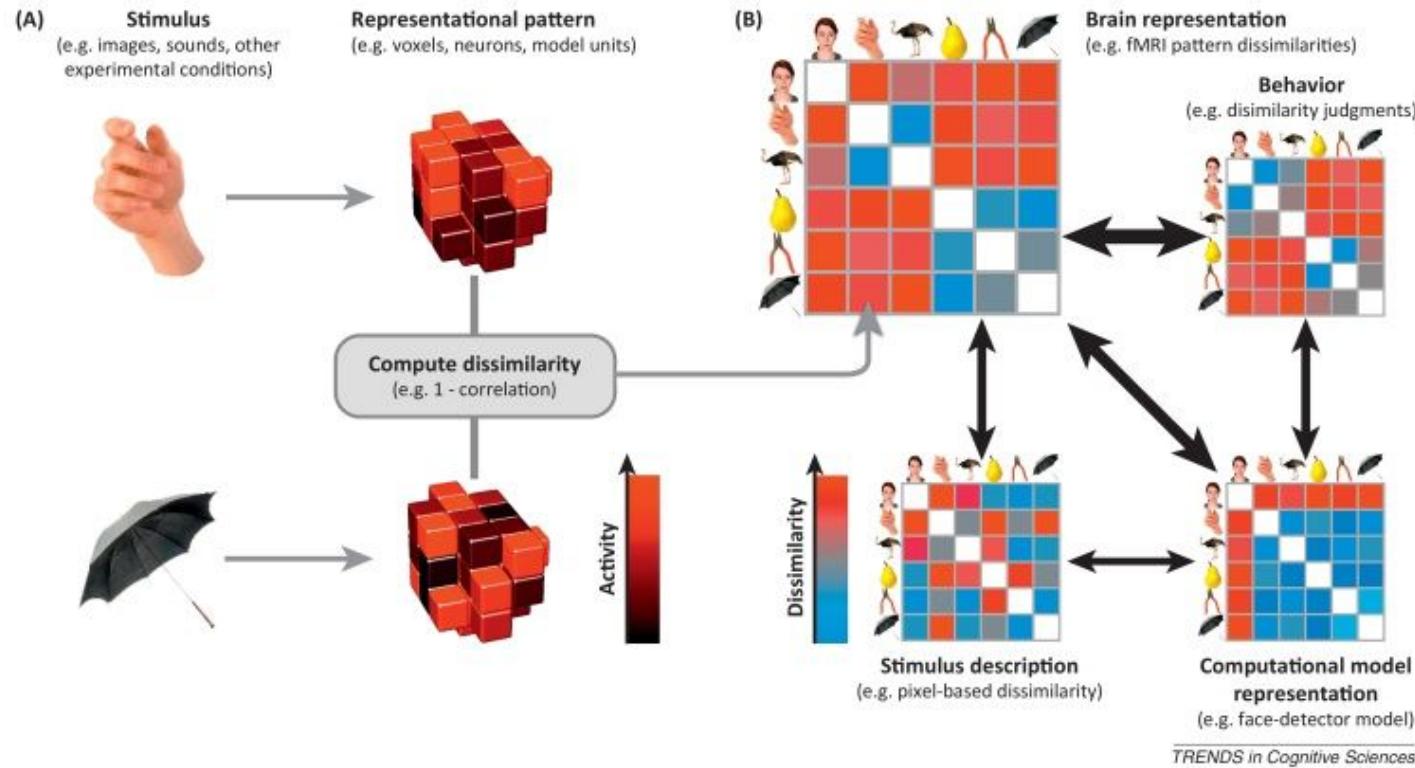
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Representational Similarity Analysis...



TRENDS in Cognitive Sciences

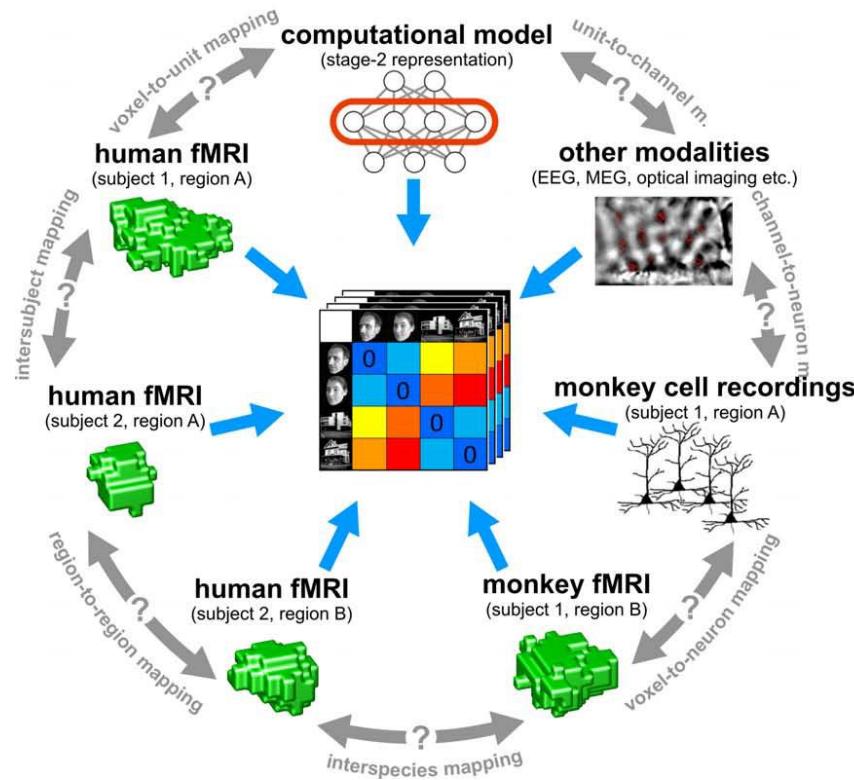
Representational Similarity Analysis...



TRENDS in Cognitive Sciences

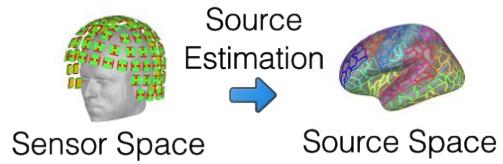
Representational Similarity Analysis...

Representational Similarity Analysis...

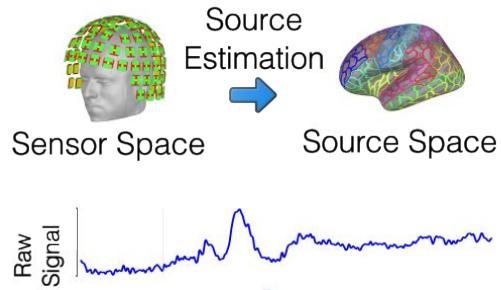


Time resolved RDMs...

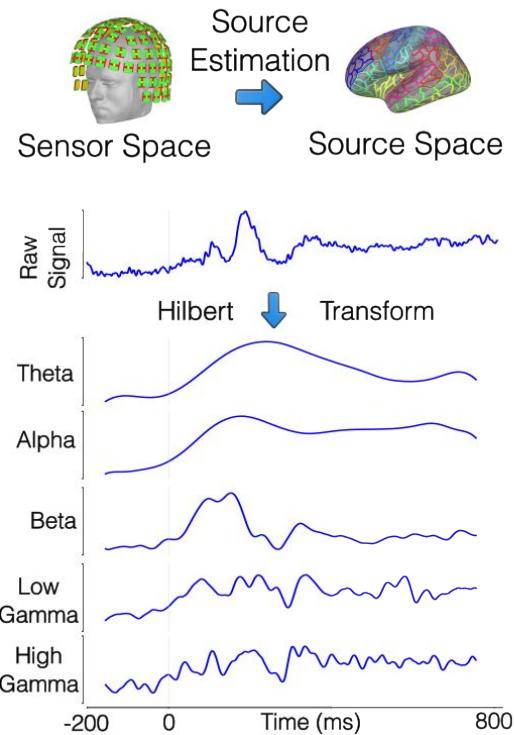
Time resolved RDMs...



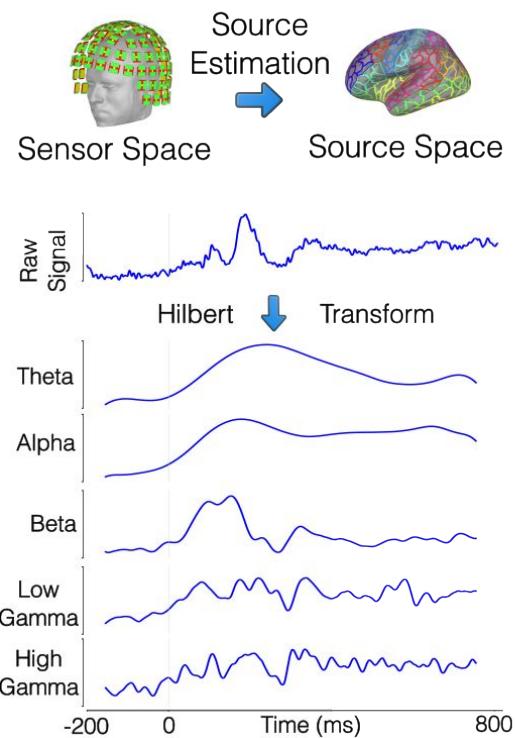
Time resolved RDMs...



Time resolved RDMs...

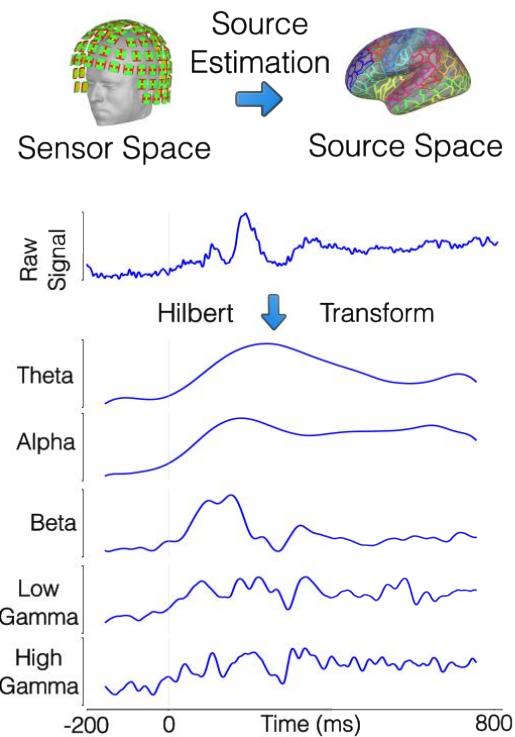


Time resolved RDMs...



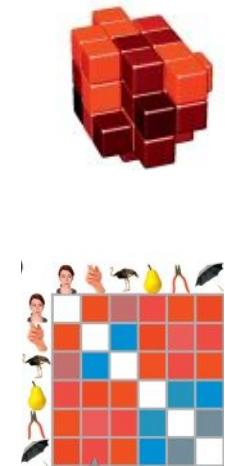
Representational pattern
(ROI, Group of sensors, ...)

Time resolved RDMs...

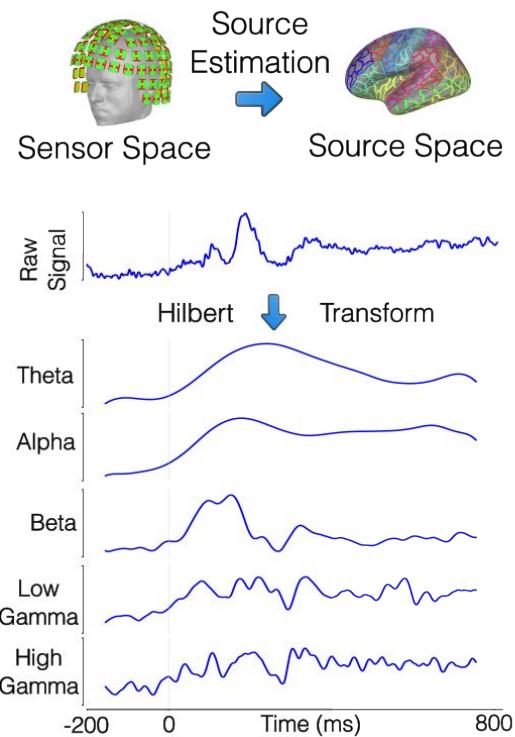


Representational pattern
(ROI, Group of sensors, ...)

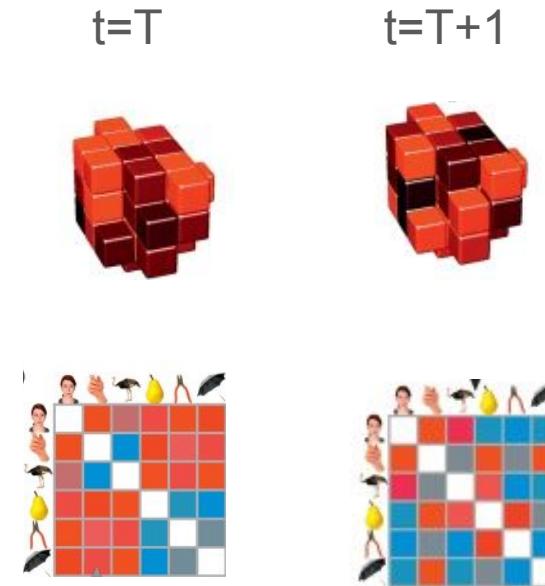
$t=T$



Time resolved RDMs...

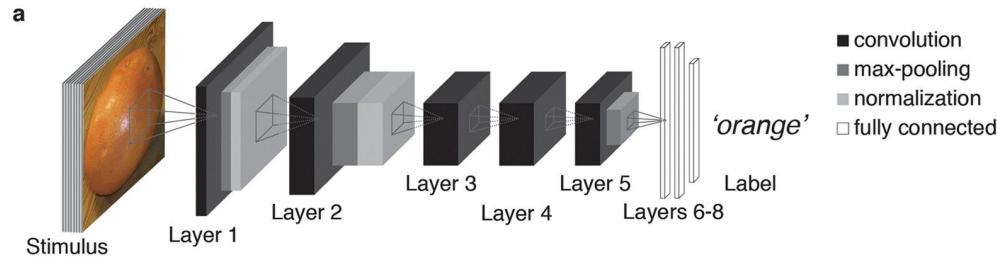


Representational pattern
(ROI, Group of sensors, ...)

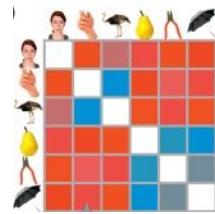
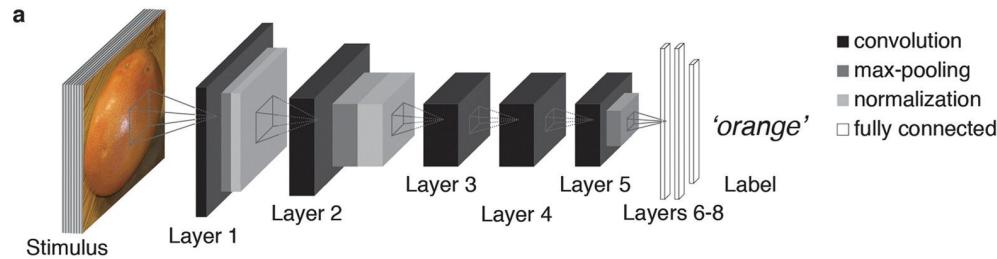


Artificial Neural Networks RDMs...

Artificial Neural Networks RDMs...

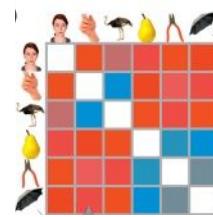
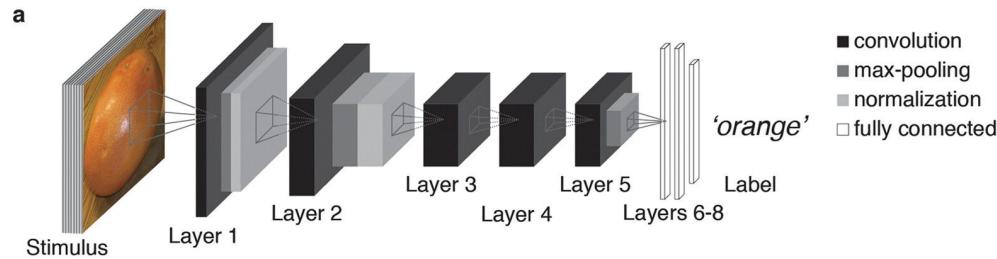


Artificial Neural Networks RDMs...

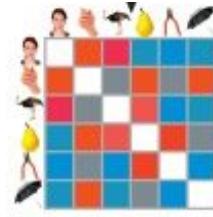


Layer 1 RDM

Artificial Neural Networks RDMs...



Layer 1 RDM



Layer N RDM

Challenges and Limitations, and Mitigation Strategies.

Challenges and Limitations, and Mitigation Strategies.

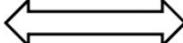
- Dealing with the diagonal

Challenges and Limitations, and Mitigation Strategies.

- Dealing with the diagonal

	Face_Left	Face_Center	Face_Right	Hand_Left	Hand_Center	Hand_Right
Face_Left	1.00	0.00	0.00	0.00	0.00	0.00
Face_Center	0.00	1.00	0.00	0.00	0.00	0.00
Face_Right	0.00	0.00	1.00	0.00	0.00	0.00
Hand_Left	0.00	0.00	0.00	1.00	0.00	0.00
Hand_Center	0.00	0.00	0.00	0.00	1.00	0.00
Hand_Right	0.00	0.00	0.00	0.00	0.00	1.00

Spearman r
 (ρ)
= .44



	Face_Left	Face_Center	Face_Right	Hand_Left	Hand_Center	Hand_Right
Face_Left	1.00	1.00	1.00	0.00	0.00	0.00
Face_Center	1.00	1.00	1.00	0.00	0.00	0.00
Face_Right	1.00	1.00	1.00	0.00	0.00	0.00
Hand_Left	0.00	0.00	0.00	1.00	1.00	1.00
Hand_Center	0.00	0.00	0.00	1.00	1.00	1.00
Hand_Right	0.00	0.00	0.00	1.00	1.00	1.00

Challenges and Limitations, and Mitigation Strategies.

- Dealing with the diagonal

	Face_Left	Face_Center	Face_Right	Hand_Left	Hand_Center	Hand_Right
Face_Left	1.00	0.00	0.00	0.00	0.00	0.00

Unsplit Data RSM with null effects

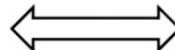
	Face_Left	Face_Center	Face_Right	Hand_Left	Hand_Center	Hand_Right
Face_Left	1.00	0.00	0.00	0.00	0.00	0.00
Face_Center	0.00	1.00	0.00	0.00	0.00	0.00
Face_Right	0.00	0.00	1.00	0.00	0.00	0.00
Hand_Left	0.00	0.00	0.00	1.00	0.00	0.00
Hand_Center	0.00	0.00	0.00	0.00	1.00	0.00
Hand_Right	0.00	0.00	0.00	0.00	0.00	1.00

$$\text{Spearman r} \\ (\rho) =$$

$$\text{Spearman r}$$

$$(\rho)$$

$$= 0$$



	Face_Left	Face_Center	Face_Right	Hand_Left	Hand_Center	Hand_Right
Face_Left	1.00	1.00	1.00	0.00	0.00	0.00

Face-Hand Model with diagonal excluded

	Face_Left	Face_Center	Face_Right	Hand_Left	Hand_Center	Hand_Right
Face_Left		1.00	1.00	0.00	0.00	0.00
Face_Center	1.00		1.00	0.00	0.00	0.00
Face_Right	1.00	1.00		0.00	0.00	0.00
Hand_Left	0.00	0.00	0.00		1.00	1.00
Hand_Center	0.00	0.00	0.00	1.00		1.00
Hand_Right	0.00	0.00	0.00	1.00	1.00	

Challenges and Limitations, and Mitigation Strategies.

- Dealing with the diagonal

Challenges and Limitations, and Mitigation Strategies.

- Dealing with the diagonal
- Fisher Transforming r Values

Challenges and Limitations, and Mitigation Strategies.

- Dealing with the diagonal
- Fisher Transforming r Values
- Noise Ceiling

Challenges and Limitations, and Mitigation Strategies.

- Dealing with the diagonal
- Fisher Transforming r Values
- Noise Ceiling
- Random models

Challenges and Limitations, and Mitigation Strategies.

- Dealing with the diagonal
- Fisher Transforming r Values
- Noise Ceiling
- Random models
- Scrambled stimuli

Steps to perform RSA.

Steps to perform RSA.

- Get your neural activity ready

Steps to perform RSA.

- Get your neural activity ready
- Compute and visualize RDMs

Steps to perform RSA.

- Get your neural activity ready
- Compute and visualize RDMs
- Compute Similarity scores and visualize them

Steps to perform RSA.

- Get your neural activity ready
- Compute and visualize RDMs
- Compute Similarity scores and visualize them
- Benchmark and interpret your results

Now to the tutorial!