Multivariate Pattern Analysis in Brain Imaging

Turku PET Centre Brain Imaging Course 2026

Maya Rassouli, Turku PET Centre

Resources

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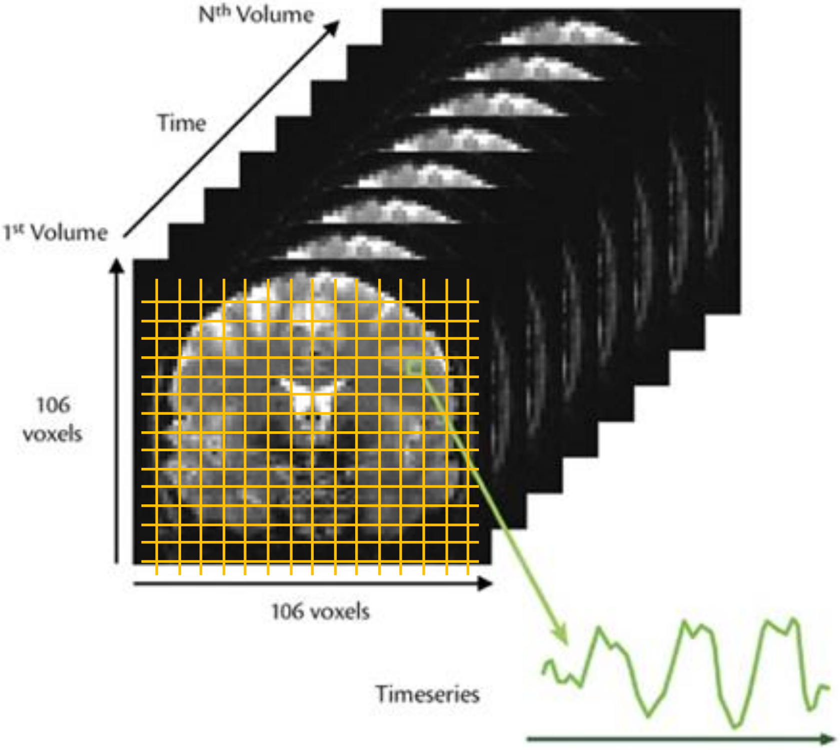
Outline

1. Univariate vs. Multivariate Pattern Analysis (MVPA)
2. Multivariate Pattern Classification Analysis: Decoding
3. Representational Similarity Analysis: Encoding

Univariate vs. Multivariate Pattern Analysis

Mass Univariate Analysis: General Linear Model



$$
\begin{aligned}
y_1 &= x_1\beta + \varepsilon_1 \\
y_2 &= x_2\beta + \varepsilon_2 \\
y_3 &= x_3\beta + \varepsilon_3 \\
&\vdots \\
y_n &= x_n\beta + \varepsilon_n
\end{aligned}
\quad \longrightarrow \quad
\begin{bmatrix} y_1 \\ y_2 \\ y_3 \\ \vdots \\ y_n \end{bmatrix}
=
\begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ \vdots \\ x_n \end{bmatrix}
[\beta] +
\begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \\ \vdots \\ \varepsilon_n \end{bmatrix}
$$

Mass Univariate Analysis

➔ limited information

Associating brain regions with functions

➔ Which task/stimulus activates a region globally ?

➔ **Activity**: general involvement of a brain region in a function (music listening vs silence)

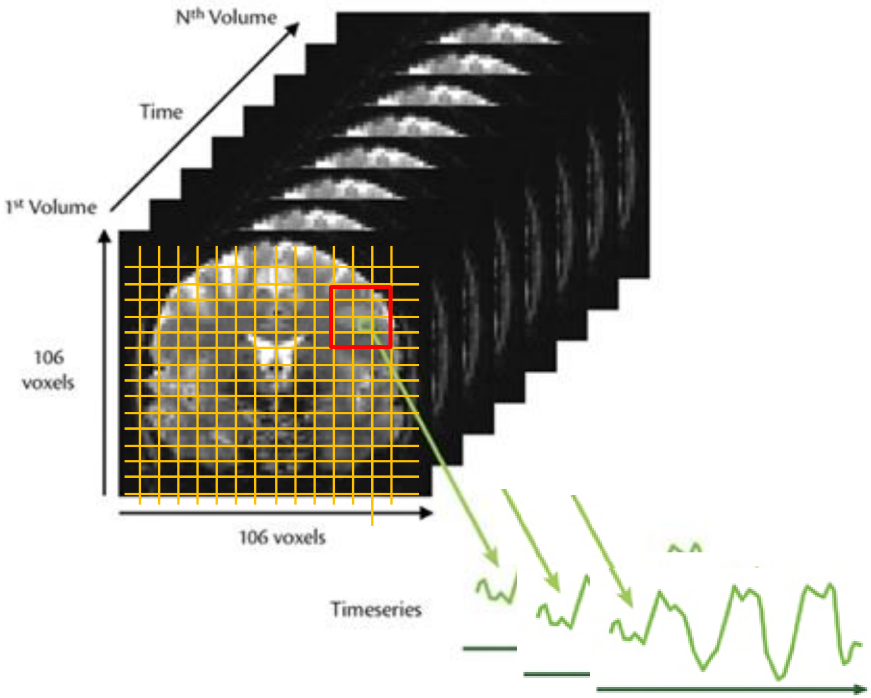
vs.

Mass Univariate Analysis

→ limited information

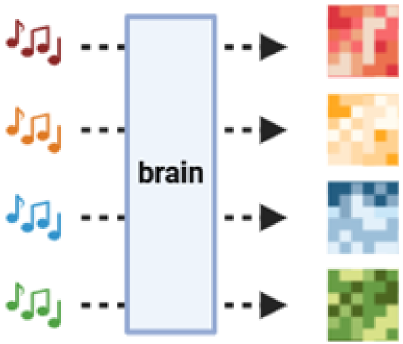
Multivariate Pattern Analysis (MVPA)

“combined use of multiple variables measuring the brain (BOLD signal in multiple voxels) to predict/characterize states of the brain”



Multivariate Pattern Analysis (MVPA)

➔ What information is represented in a region ?
➔ How is that information encoded and organized ?



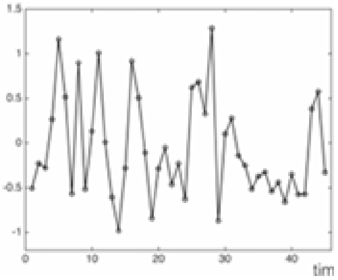
➔ higher sensitivity
➔ greater functional significance

➔ **Information**: representational content in the brain region (music stimuli A vs. music stimuli B)

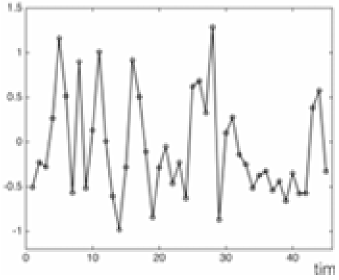
Encoding vs. Decoding

Encoding: explainable variable → measured data

stimulus, task BOLD signal



Decoding: measured data → explainable variable



Encoding vs. Decoding

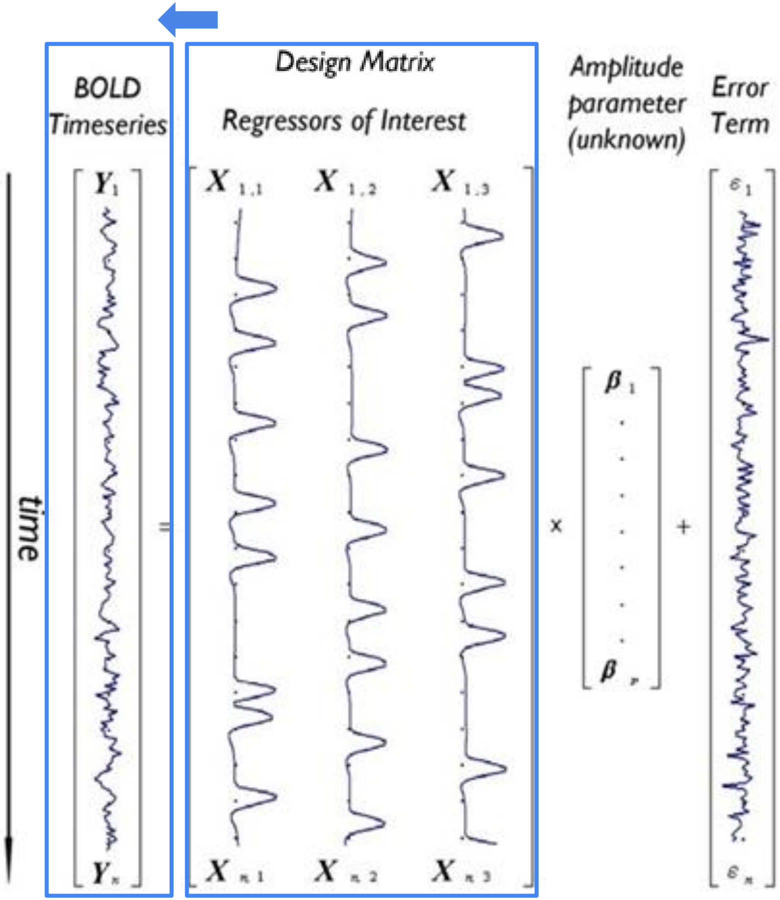
	Encoding	Decoding
Univariate	General Linear Model	Simple Classification
Multivariate	Similarity Analysis	Classification Analysis

Multivariate Pattern Classification Analysis

Decoding

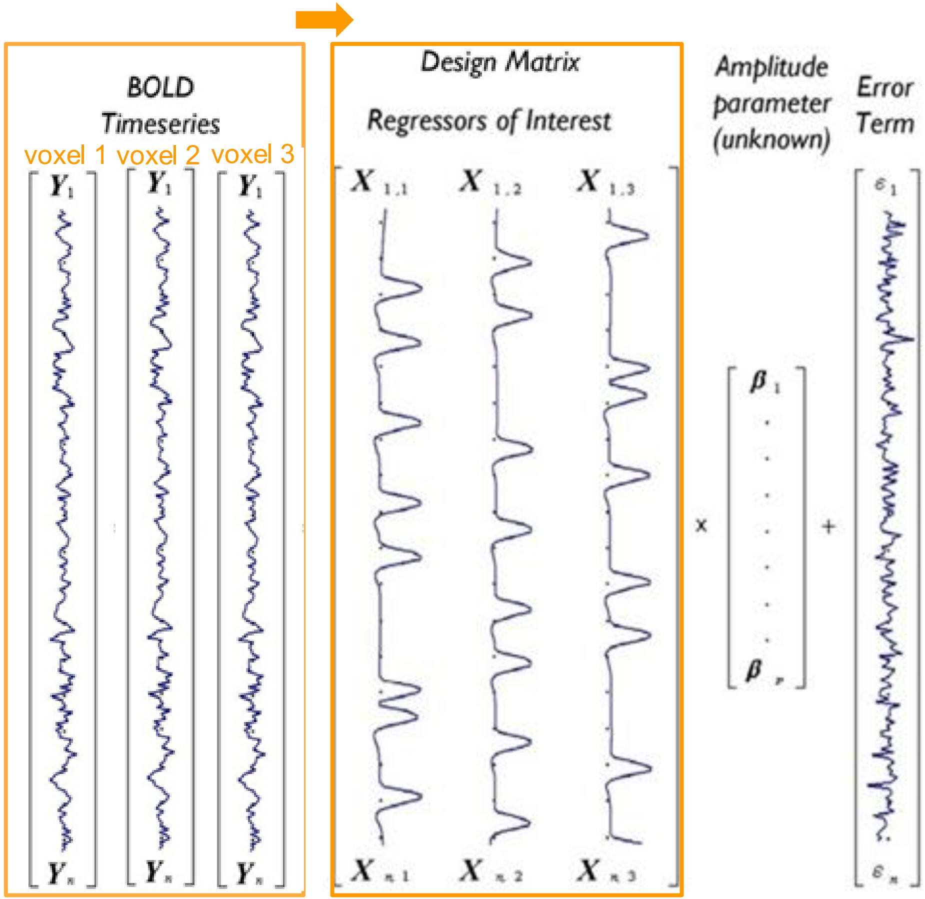
Multivariate Pattern Classification Analysis

GLM



Multivariate Pattern Classification Analysis

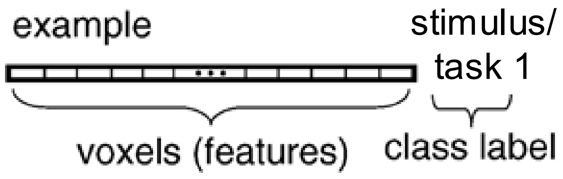
MVP
Classification

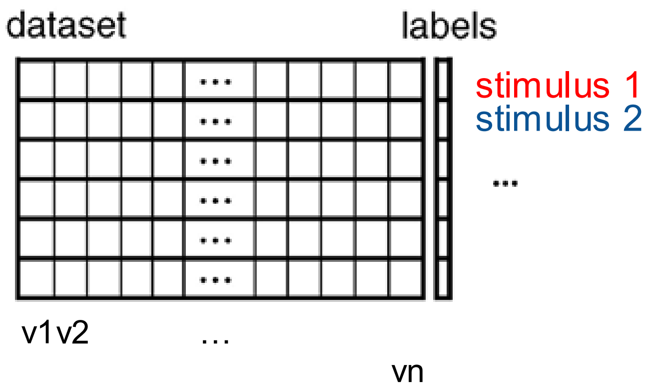


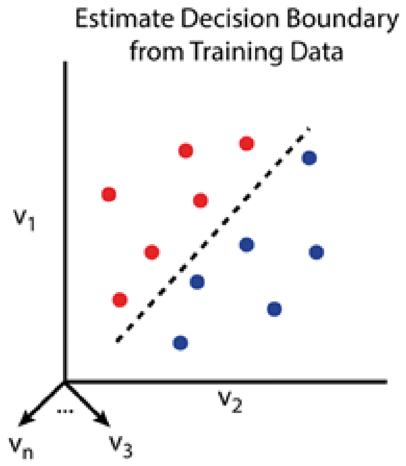
Classifiers

Function f(x) = y

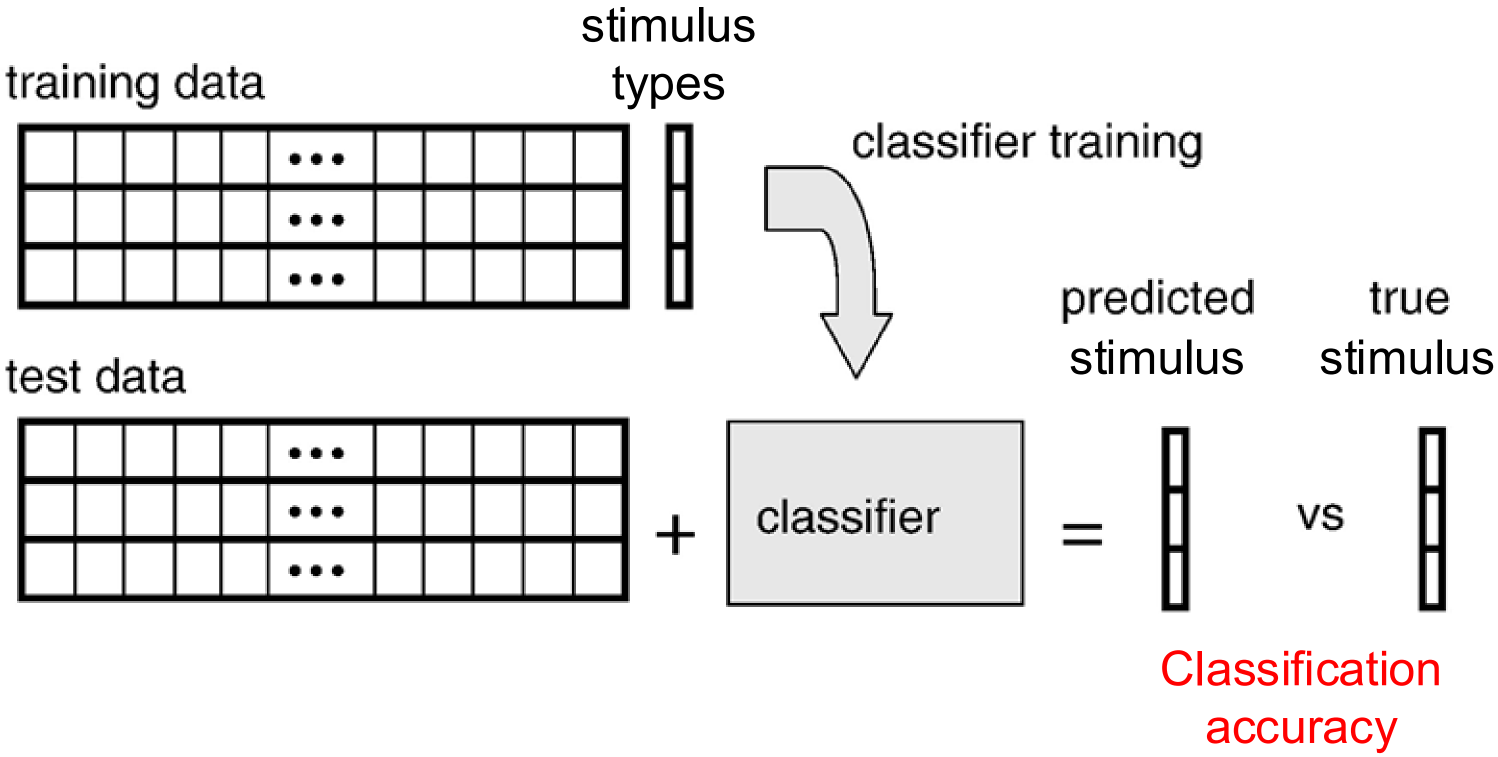
- x = features — voxels
- y = class — type of stimulus/task







Classifiers



Linear Classifiers

value for voxel 1

value for voxel v

for an example ***x***

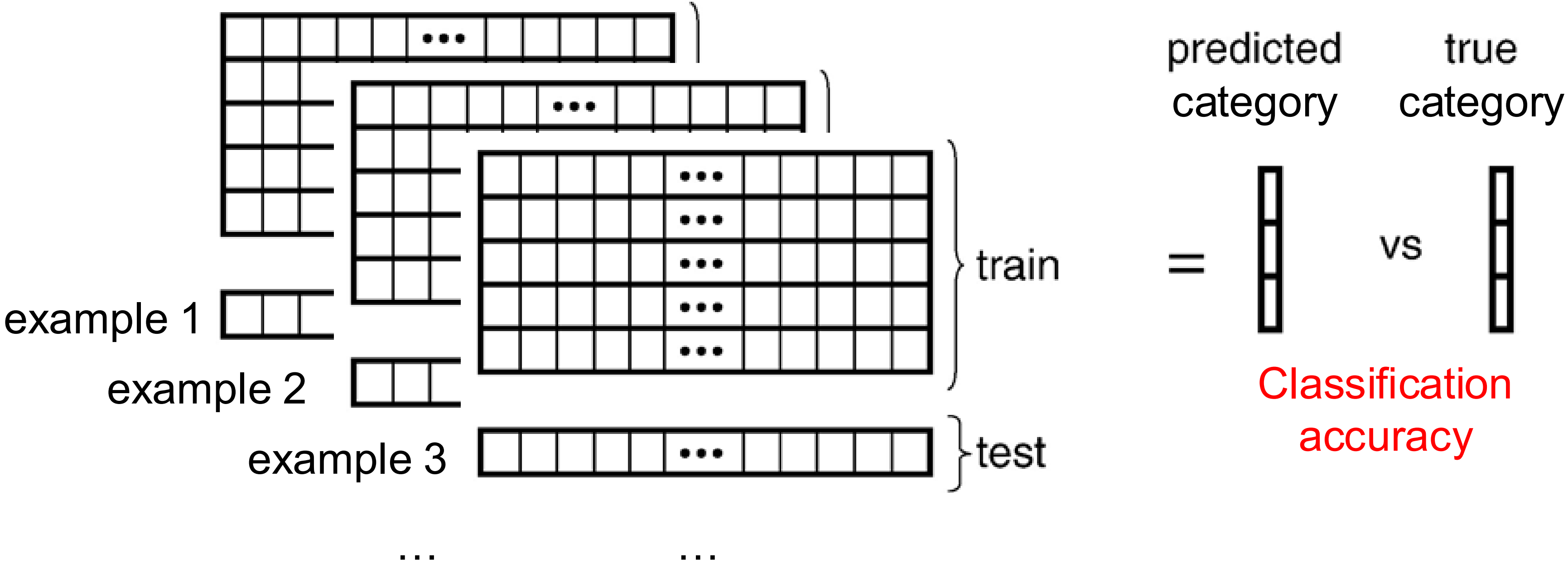
$$xw = x_1 w_1 + \; \dots \; + x_V w_V$$

learned weight for voxel 1

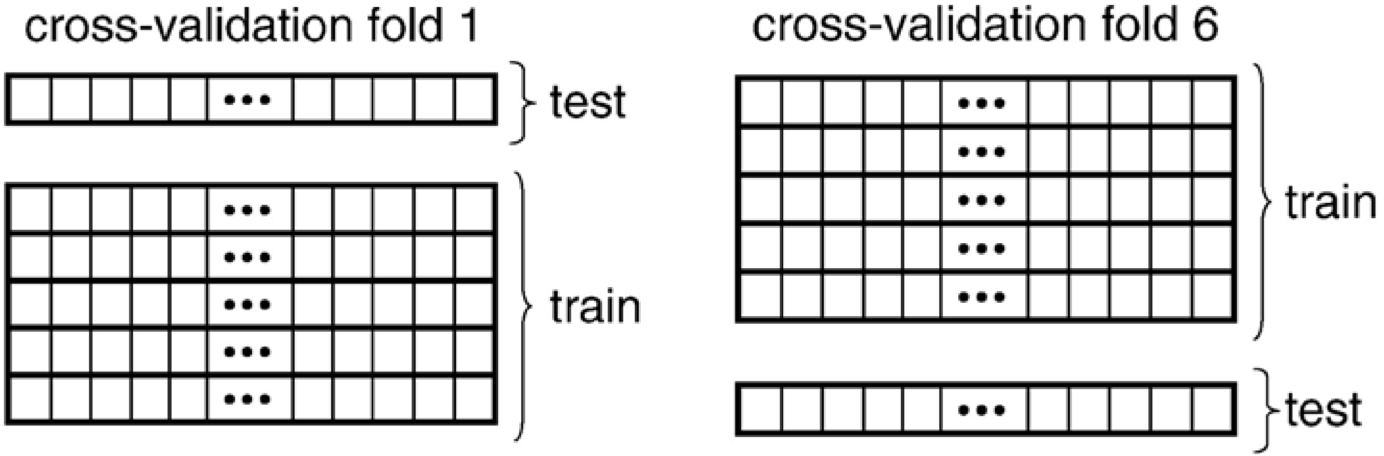
xw > 0 stimulus 1

xw < 0 stimulus 2

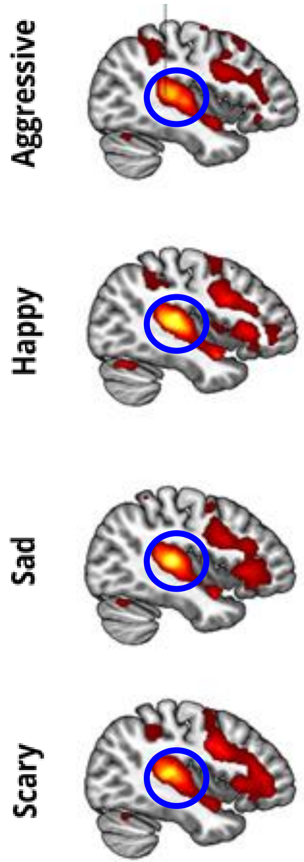
Leave-One-Out Cross-validation (LOO-CV)



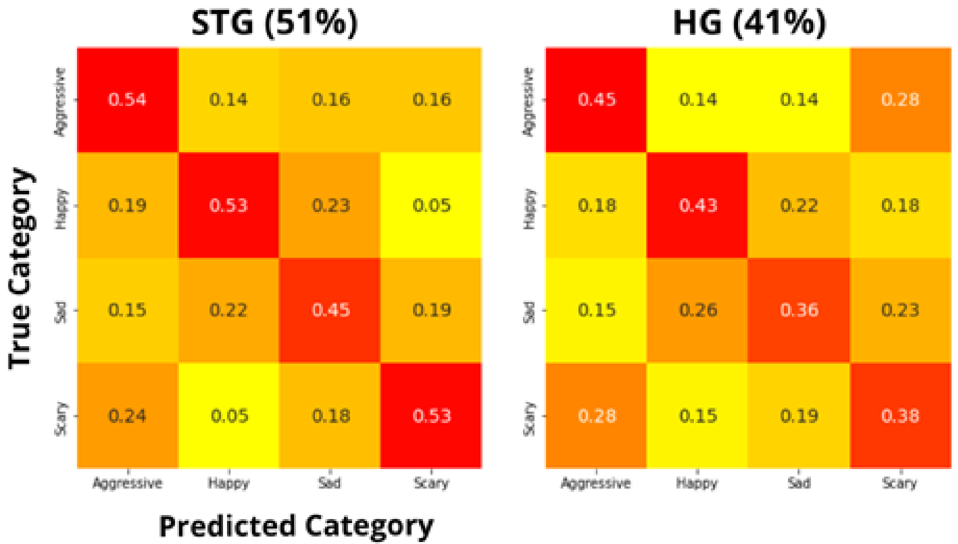
k-fold Cross-validation



Case Study



Linear Classifier
LOO-CV



Representational Similarity Analysis

Encoding

Encoding vs. Decoding

	Encoding	Decoding
Univariate	General Linear Model	Simple Classification
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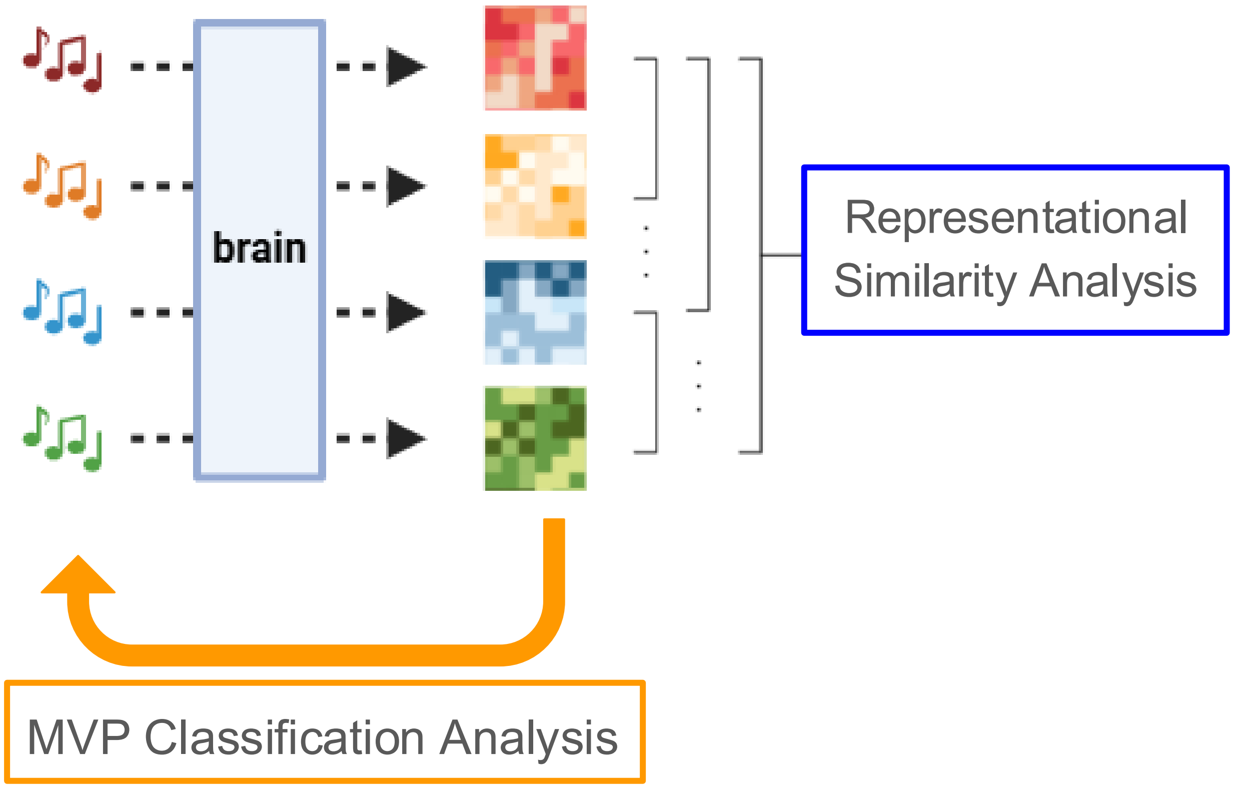
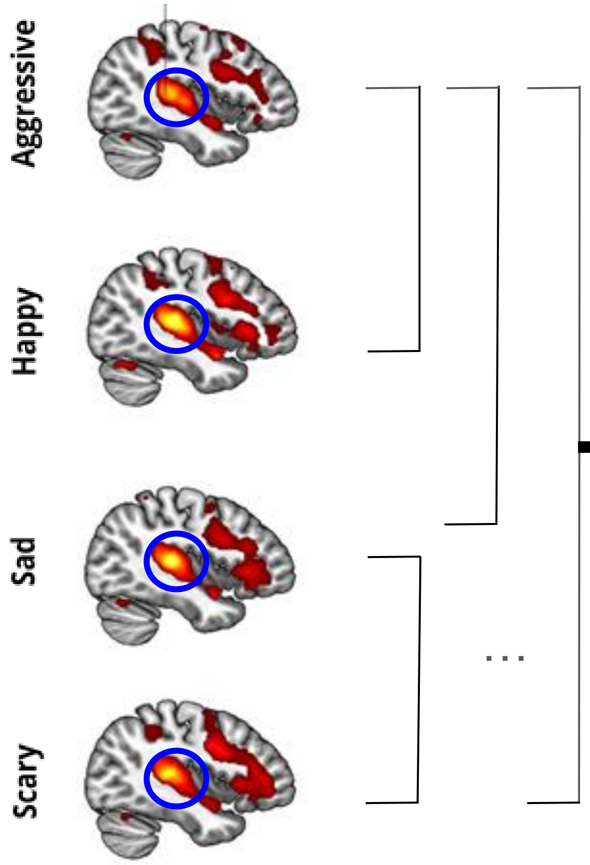
Representational Similarity Analysis (RSA)

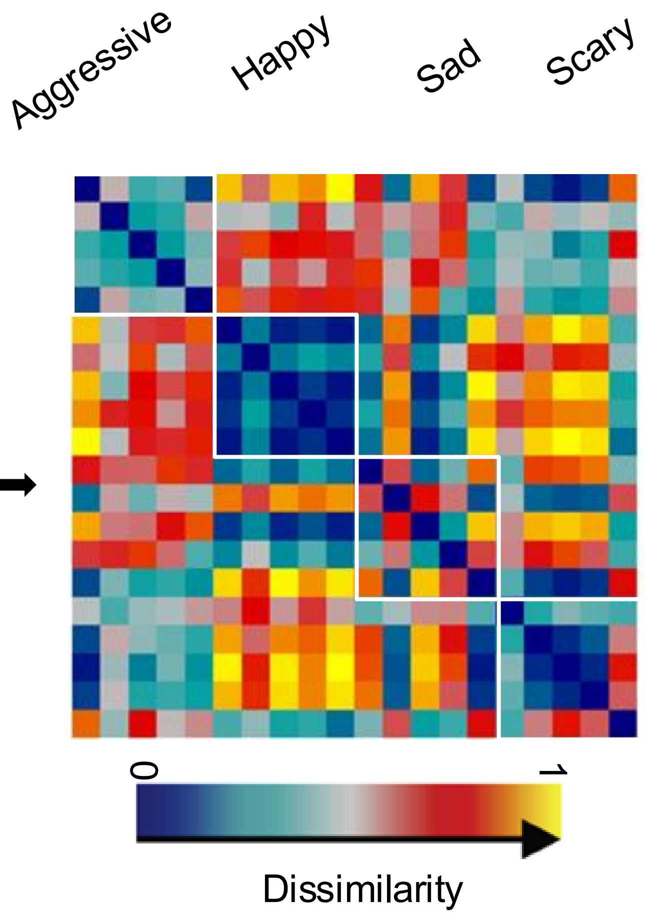


Construct Neural Representational Dissimilarity Matrix (RDM)

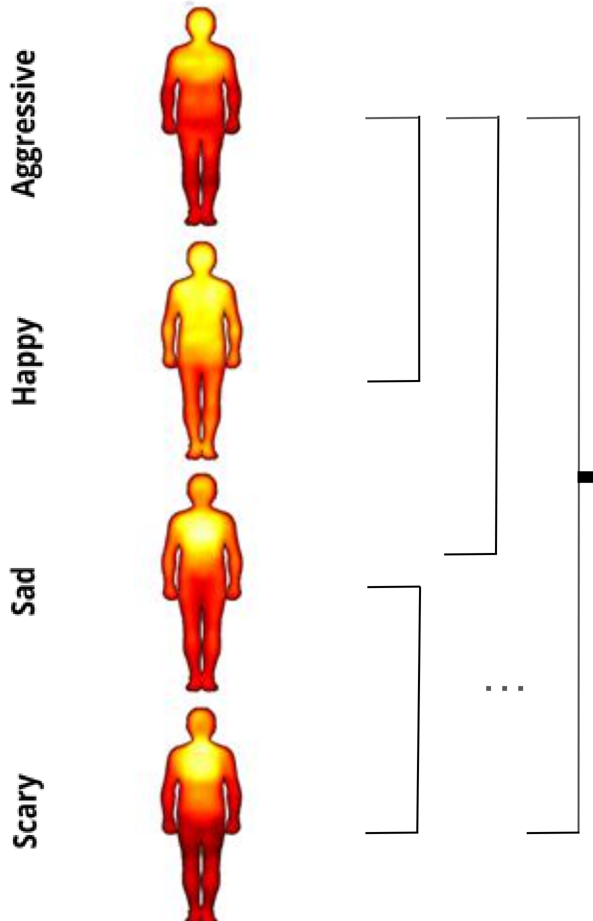


Similarity / Dissimilarity
r / 1- r

- Pearson correlation r
- Spearman correlation r

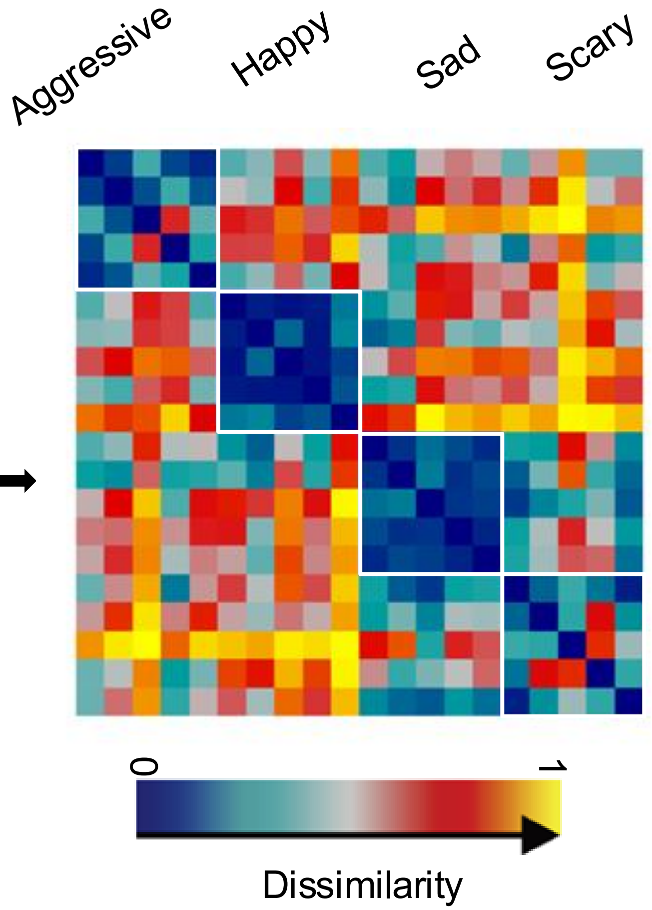


Construct Model RDMs

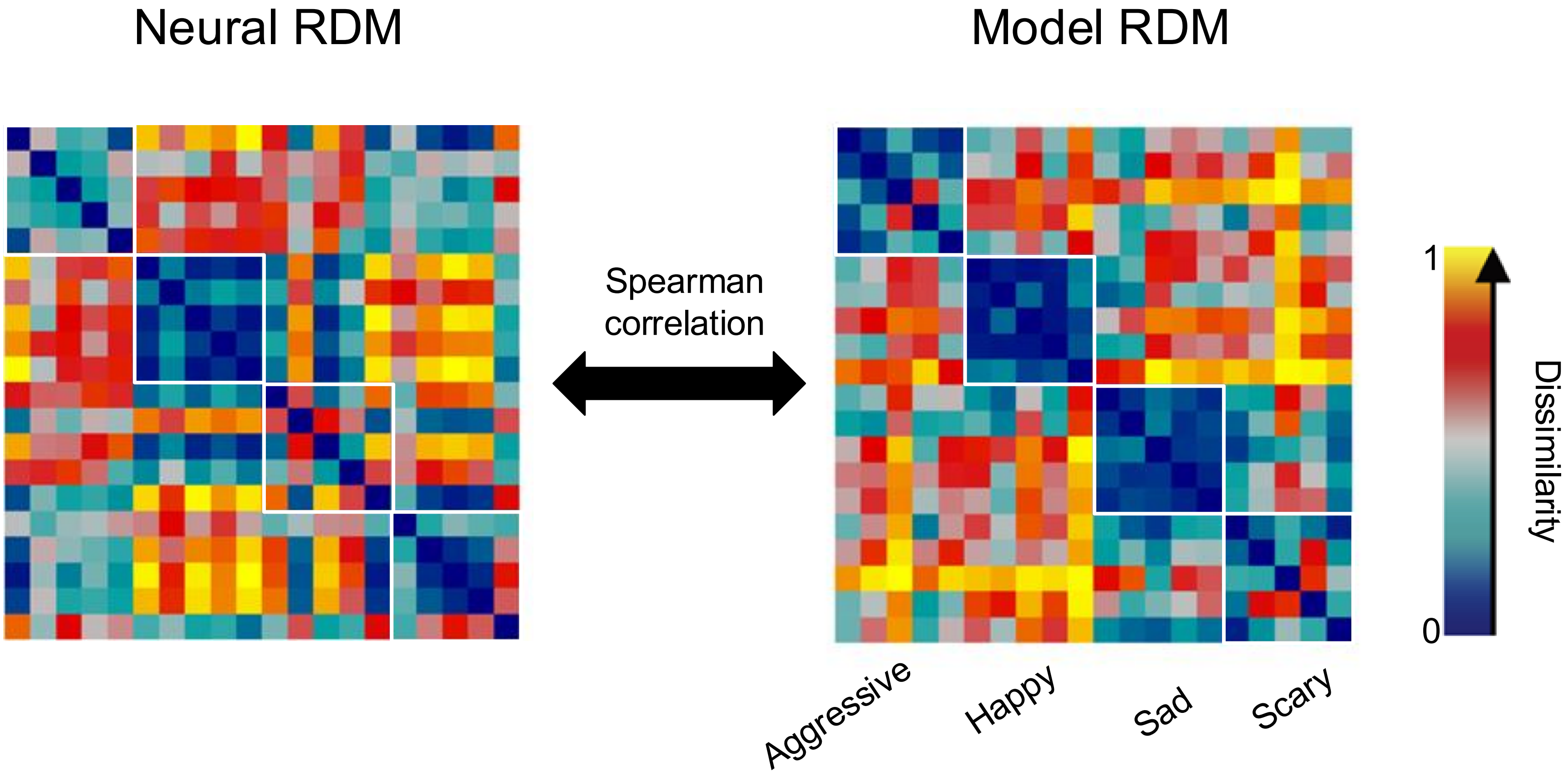


Similarity / Dissimilarity
r / 1- r

- Pearson correlation r
- Spearman correlation r



Compare RDMs



Take-Home Messages

MVPA provides **information** about representational content by combining the use of **multiple voxels**' BOLD signal to predict/characterize brain states.

- **MVP Classification** demonstrates reliable **distinctions** among brain states.
- **RSA** analyzes the **geometry of representational (dis)similarities** among brain states.

Thank you for your attention !

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